Economic Study for Ocean Energy Development in Ireland

A report to the Sustainable Energy Authority of Ireland and Invest Northern Ireland

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Report prepared on behalf of

SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Invest Northern Ireland
Building Locally
Competing Globally

SQWenergy

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1: Executive Summary

Rationale and economic modelling

1.1 It is clear that there is much interest and activity in the Ocean Energy[1] (OE) sector for the island of Ireland (Republic of Ireland and Northern Ireland), premised on the scale of its marine renewable resource, and which if successfully developed, could make a major contribution towards economic growth and renewable energy targets – both locally (including exports) and globally.

1.2 Ireland already has world-leading OE companies, utilities, ocean engineering and marine research capabilities, although the ability to capture the future opportunities is presently difficult to quantify in such a nascent industry.

1.3 Developing the emerging OE technologies is extremely challenging and the costs at this stage of early development are therefore comparatively high. This has placed limitations on OE technology developers to prove the capability of their devices, and their effective operation. There are however a small number of promising technologies (wave and tidal), some of which have a couple of years of in-sea operational experience.

1.4 The OE economic modelling evaluated 9 possible scenarios based on a combination of the following main scenarios:

- Technology development and deployment scenarios: **Optimistic, Central, Pessimistic.**
- Potential island of Ireland market share scenarios (local and global): **Whale, Shark, Minnow**.

Projected economic value of OE to the Island of Ireland

1.5 In terms of the objectives of an intervention in OE, it is clear that carbon savings, increased security of supply and additional employment are achieved by an island of Ireland OE sector, however the cost of doing so against the counterfactual or indeed competing technologies is better measured or compared by means of Benefit-Cost Ratios (BCRs). Table 1-1 summarises the BCRs realised in 2025 for both wave and tidal technologies under the central scenarios. These are noted to be highly dependent on the extent of the export market captured (the main difference between the Whale, Shark and Minnow scenarios): the Whale scenarios providing an attractive rate of return in comparison to similar investments in comparable sectors, and the Shark scenario reporting reasonable levels of return.

[1] *Ocean Energy refers to wave energy and tidal stream energy in this instance.*

Table 1-1 BCRs in 2025 for OE under Whale, Shark and Minnow central scenarios

Scenario	Wave	Tidal
Whale	11.2	10.6
Shark	8.1	7.5
Minnow	6.1	5.6

Source: SQW Energy

1.6 There is currently sound quantitative evidence that by 2030 a fully developed island of Ireland OE sector providing a home market and feeding a global market for RE could produce a total Net Present Value (NPV) of around €9 billion and many thousands of jobs to the Republic of Ireland and Northern Irish economies.

1.7 It is possible that an island of Ireland wave energy industry meeting the 500MW 2020 target could produce at least 1,431 additional FTE jobs and an NPV of €0.25bn, increasing to 17,000-52,000 FTE jobs and an NPV of between €4-10bn by 2030. This is dependent upon achieving sufficient technology learning rates - most likely encouraged and maintained initially through a form of capital and/or operational subsidy.

1.8 Similarly a tidal industry providing 200MW of capacity by 2020 may deliver around 600 FTE jobs and an NPV of €111m, increasing to 8,500-17,000 FTE jobs and an NPV of between €1.5-2.75bn by 2030.

1.9 Although the optimistic scenarios may seem just that (optimistic), it is worth noting that many of the factors and variables chosen are similar to those witnessed for the onshore wind industry over the past 20 years. It is apparent that even since the onshore wind experience, governmental priorities have further shifted and are increasingly focussed on low carbon RE capacity. This is motivated by the legally binding emissions targets, an imperative for increased security of supply and an opportunity to use home advantage not only to deliver these, but also to gain economic benefit through capture of both local and export opportunities.

Early actions required:

Initial incentives and subsidy

1.10 The current levels of subsidy are unlikely to be sufficient to aid and retain local OE development for the island of Ireland. The monies currently available to OE under the REFIT although greater per MWh than those of the RO have a much shorter duration of 15 years. This has been proven by developers, academics and this study to be unlikely to sufficiently incentivise OE development and deployment in the Republic of Ireland. Indeed, most developers have shown that the levels of funding under the RO are also currently insufficient to provide a significant incentive to gain matching investment; at least for the more expensive production prototypes that are currently being deployed.

1.11 There is good evidence that a 'production based' credit system (such as the REFIT or NIRO) is of limited use in delivering a new technology as there is a gap in funding between R&D and full commercial production. This gap exists most notably for pre-commercial demonstrators – which may have lower load-factors due to variability, testing, or reliability issues; and at this stage will most likely not benefit from the economies of scaled production. It is therefore suggested that a form of capital grant should be implemented to allow full development and deployment of OE in Ireland.

1.12 It is likely that the need for subsidy will rapidly decrease should the predicted learning rates and cost reductions emerge.

Promoting local capacity growth rates

1.13 In addition to technical and economic factors, barriers to capacity growth rates such as the ability of the electricity grid to transport the OE power to demand centres; regulatory and environmental delays or barriers; and supply chain availability have the greatest long term affect on economic viability. The efficient working or removal of these barriers is of utmost importance and will allow competitive advantage for foreign investment in OE over those regions that lag. If these critical enablers (many of which are within the Government's power) are put in place in a timely fashion the OE opportunity can be exploited and the associated benefits flow.

Promoting learning for cost reduction

1.14 The major impact on economic viability is the rate at which learning develops leading to greater productivity and lower costs. The wide range of devices and concepts confirms that there is still much to learn, and the local capacity of research organisations (academic and industrial) will be critical to creating Intellectual Property and maintaining the relevance of the island of Ireland's knowledge base. This in itself has been, and will be, central to both developing the local supply chain and attracting international finance or companies.

1.15 Beyond the direct OE technical or device requirements there is a great deal more in the value chain which will require development and collaboration. Many aspects of the value chain are all-Ireland specific (e.g. electricity grid, ports, skills, research, etc.) and are generic in terms of which technologies become dominant. The generic support and learning in such areas will be applicable across the global OE industry.

Promoting OE exports

1.16 Although a home market is likely to be the initial driver for island of Ireland companies to engage with the OE sector, the analysis within this report demonstrates that gaining a good share of the global OE market through exports (products and services) allows maximum leverage of local capabilities and significantly increases net Gross Value Added (GVA).

In conclusion

1.17 If there is an appropriate level of investment in the OE sector, then it could provide long-term sustainable growth and wealth creation to the island of Ireland. However, such investment will need to be matched by OE development and deployment.

1.18 The short-term costs of Government subsidy would seem to be low compared to the possible long-term prize available to the Irish economy. Even with the most optimistic levels of deployment over the next 5 years, the outlays in terms of initial direct subsidy are unlikely to be much greater than €60 million. Competitively maintaining and developing the already significant island of Ireland OE expertise and industry over that period will allow the opportunity in future years to re-examine both the progress and the economic case with better and more certain data, whilst retaining the possibility to capture a significant portion of a home and global market.

1.19 With an OE sector based upon the island of Ireland's indigenous marine resource, once developed, this sector is very likely to remain within the island of Ireland providing significant employment.

1.20 In conclusion, for a relatively small initial investment over the next 5 years there is the possibility of continuing along the trajectory which may eventually produce a large OE sector with very large upside.

2: Introduction

2.1 The environmental case for developing an Ocean Energy (OE) sector is well established. It is known that electricity generated by wave and tidal devices can play a significant role in reducing the greenhouse gas emissions associated with the electricity generation mix for the Republic of Ireland and Northern Ireland (hereby referred to as the "*island of Ireland*"). However, the economic case for developing an OE sector is not as well studied; hence it is less well understood. Without detailed insight into the likely investment costs and potential economic benefits it is difficult for public sector leaders to make informed decisions about where, when, how (and whether) to support the development of an OE sector on the island of Ireland.

2.2 There is a wealth of evidence showcasing the potential for the island of Ireland as a location for the deployment of wave and tidal electricity generation technologies. In the Republic of Ireland wave potential dominates (primarily through resource located along the west coast) and a recent Sustainable Energy Authority Ireland (SEAI) study[2] estimated the accessible wave energy resource to be 21TWh (sufficient to supply 75% of the Republic of Ireland's 2006 electricity requirements). In contrast, in Northern Ireland, tidal energy dominates the resource potential with sites across the north east coast, Copeland Islands and Strangford Lough offering significant tidal flows that are capable of hosting tidal devices with an estimated installed capacity of up to 650MW[3]. This study explores the extent to which this potential for electricity generation may be translated into economic benefit for the island of Ireland from the industry and supply chain that could accompany the generation technologies.

2.3 The Irish Government has developed an OE strategy to accelerate the development and deployment of wave and tidal energy[4]. The strategy document recognised that the development of an OE sector could create a manufacturing industry in Ireland, reduce reliance on imported fossil fuels and help to reduce greenhouse gas emissions, and led to the decision to commit to a significant research and development programme for OE so that the Republic of Ireland would be well placed to become a technology leader in this field.

2.4 Peter Bacon and Associates and ESB International[5] carried out a study for the Irish Ocean Energy Strategy that went some way to quantifying the potential economic benefits to the Republic of Ireland; but it did not take an island of Ireland perspective and, due to the natural resource profile around the Republic of Ireland, was primarily focussed on wave technology development. Recognising this, and the potential synergies from looking at the economic case on an island-wide basis (which makes full sense given the island of Ireland's electricity market structure and electricity network that an active OE sector would sit within), this study has been jointly commissioned by Sustainable Energy Authority Ireland (SEAI) and Invest Northern Ireland (INI) to provide an evidence-based report on the economic benefits of OE that will inform

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[2] http://www.sei.ie/Renewables/Ocean_Energy/Ireland%E2%80%99s_Wave_Energy_Resource/

[3] The Potential For The Use Of Marine Current Energy In Northern Ireland. Department of Trade and Industry (DTI), the Department of Enterprise, Trade and Investment (DETI) and Northern Ireland Electricity, 2003. Available at: http://www.detini.gov.uk/energy-pubs-14

[4] Ocean Energy in Ireland, Department of Communications, Marine and Natural Resources, 2005. Available at: http://www.sei.ie/Renewables/Ocean_Energy/Ocean_Energy_Strategy/Ocean_Energy_Strategy_Report_18082006.pdf

[5] Analysis of the Potential Economic Benefits of Developing Ocean Energy in Ireland, Peter Bacon and Associates and ESB International, 2005. Available at: http://www.marine.ie/NR/rdonlyres/695CE345-9760-4022-ACB0-9CC3F7CA3DC8/0/OceanEnergyReport.pdf

planning for the ongoing development of a commercial OE industry sector in the island of Ireland.

2.5 To accurately inform policy decisions that may concern the structure of future support for the development of an OE sector, information is required from a broad range of technical and economic areas in order to evaluate the potential economic benefits to the island of Ireland. For this study we have therefore placed significant focus on collecting relevant and robust data from a number of sources including: stakeholder consultations, previous relevant studies and Government statistics.

2.6 All of the information collected has been analysed for relevance, fit within an island of Ireland context, potential optimism bias and, where appropriate, has been used to develop an OE economic model that provides SEAI and INI with a series of scenarios or potential development pathways for an OE sector on the island of Ireland up to 2030.

2.7 The OE economic model:

- incorporates the current status of the island of Ireland's and global OE industries in terms of installed capacity and employment
- predicts the likely volume of installed capacity over time (island of Ireland and global)
- evaluates the possible level of jobs and value associated with various installed capacities
- combines the above analysis to provide an overall picture of the jobs and value arising.

2.8 The OE economic model has been used to analyse potential economic benefits under nine different wave and tidal scenarios: each run using optimistic, central or pessimistic technology development and deployment scenarios - onto each of which an additional set of three scenarios for export potential are superimposed. The nine scenarios therefore examine sensitivities and differing scales of wave and tidal device deployment and varying export opportunities. A number of evidence based assumptions have been used to build up the scenarios including: potential deployment patterns for wave and tidal devices; likely costs of deployment and electricity generation, expected learning rates for wave and tidal technology development, likely future grid capacity on the island of Ireland, subsidy offerings for OE technology development and deployment, and the likely job requirements in the OE supply chain. The sensitivity adjustments have been used to vary these assumptions within, what is considered to be, a realistic range of potential outcomes and to therefore provide an evidenced economic valuation.

2.9 The remainder of this report contains the following chapters:

- Chapter 3 summarises the research findings focussed on: technology development and deployment; economic background; the policy and regulatory environment.
- Chapter 4 summarises the data gathered from the expert consultations to verify and expand the data gathered in Chapter 3.
- Chapter 5 outlines the possible trade opportunities afforded by exporting OE generated electricity within the island of Ireland, and further afield.

- Chapter 6 provides an explanation of the necessary scenario parameters to calculate the likely OE technical development and deployment and thus the local and global installed capacity to 2030.
- Chapter 7 outlines the economic valuation methodology and the parameters used.
- Chapter 8 describes the resulting OE economic valuations and evaluates the outcomes.
- Chapter 9 provides brief conclusions and recommendations.

3: Ocean Energy: Potential and Progress

Introduction

3.1 A literature review on Ocean Energy was undertaken to improve understanding of the linkages between technology development and deployment, regulatory regime, government support, market developments and the emerging island of Ireland supply-chain for these sectors. This chapter summarises the findings of the literature review for the *Economic Study for Ocean Energy*.

Process

3.2 The literature review has three strands:

- **Technology and Site Development Plans** – drawing on a number of published reports (such as the International Energy Agency's 2008 Ocean Energy Systems annual report[6]), press releases from wave and tidal developers and publically available information from marine test centres such as the European Marine Energy Centre (EMEC) and the New and Renewable Energy Centre (NaREC). Additionally the utility OE development plans draw on evidence from site developer announcements and published plans.
- **Existing Competencies and Economics** – drawing on a number of published and semi-published sources of supply chain capabilities, and the associated official sectoral statistics including the UK's Annual Business Inquiry, and Republic of Ireland's Central Statistical Office.
- **Policy, legislation and regulation** – drawing on a range of national policy documents and international reviews.

3.3 Each of these strands forms a chapter in the literature review. A concluding chapter draws together the findings, and highlights the outstanding issues identified in the course of the literature review.

Technology status review

3.4 This section summarises the findings from research undertaken by SQW Energy to characterise the current stage of development and deployment of the most significant wave and tidal energy devices in terms of commercialisation potential, and to understand the potential cost implications for early stage commercial projects. This information has been used to inform realistic scenarios for modelling economic impacts.

Ocean energy resource review

3.5 There is little doubt that there is a large global OE resource. Studies have estimated the "theoretical global potential of OE to be over 100,000 TWh/year (as a reference, current world electricity consumption is around 16,000 TWh/year). The global technical resource exploitable

[6] http://www.iea-oceans.org/_fich/6/Annual_Report_2008_(1).pdf

with today's technology is estimated to be in the order of 45,000 TWh/year for wave energy; and tidal current energy is in the order of 2,200 TWh/year."[7]

3.6 A recent SEAI study[8] estimated the accessible wave energy resource around the Republic of Ireland to be 21TWh, while the Northern Irish tidal resource is thought to be able to provide an estimated installed OE capacity of up to 650MW[9].

3.7 What is less certain are the technological developments and economics associated with capturing these vast energy resources.

Technology developer and deployment review

3.8 This research suggests that, for both tidal and wave technologies; there are currently around 10 developers that are likely to develop commercial OE projects in the next 5 years[10]. The operational and geographical location of these developers at time of writing is summarised in Tables 3-1 and 3-2 along with the proposed location of any publically announced future commercial projects.

3.9 Some summarised results for the technology developer review are listed in Annex A.

Table 3-1 Geographical information relating to some of the leading tidal device developers

Developer	Operational location	Potential location of first commercial projects (if known)	Potential Project size (installed MW, if known)
Atlantis Resources	Singapore	Scotland	30 MW
Hammerfest Strom	Norway	Norway	0.35MW (operational)
		Scotland	1MW 2010, 10 MW 2012
Marine Current Turbines	UK	Northern Ireland	1.2MW (operational)
		Canada, UK (Anglesey)	10.5 MW
Open Hydro	Ireland	Canada	1 MW (operational)
		Alderney (Channel Islands), France	2-4 MW

Source: SQW Energy

3.10 Whilst Ireland appears on this table both in terms of technology development operations and OE project locations there are other countries, most significantly Scotland, that are equally, if not better, placed to capture the early stage projects based on the level of developer activity located there and the government support provided at present (see Annex B for a summary of national support mechanisms).

3.11 There are a number of developers whose projects seem to have stalled due to problems with raising finance and not explicitly because of technical barriers (e.g. Wavedragon, Engineering Business, Swan Turbines and others). This information only re-iterates the importance of not underestimating the time and financial resources required to achieve commercial success in this sector.

[7] European Ocean Energy Association.
[8] http://www.sei.ie/Renewables/Ocean_Energy/Ireland%E2%80%99s_Wave_Energy_Resource/
[9] The Potential For The Use Of Marine Current Energy In Northern Ireland. Department of Trade and Industry (DTI), the Department of Enterprise, Trade and Investment (DETI) and Northern Ireland Electricity, 2003. Available at: http://www.detini.gov.uk/energy-pubs-14
[10] I.e. those classified as green under both "current status" and "future plans" in Annex A.

Table 3-2 Geographical information relating to some of the leading wave device developers

Developer	Operational location	Potential location of first commercial projects (if known)	Potential Project size (installed MW, if known)	Estimated Timescale (if known)
Aquamarine Power	Scotland	Scotland	Oyster 1 Oyster 2 (2.5MW)	Commissioned 2009 Planned for 2011 First fully commissioned wave farm scheduled for 2014[11]
Oceanlinx	Australia	Australia, USA and Mexico	Each up to 15 MW	Starting from 2010, expected completion dates unknown
Pelamis	Scotland	Portugal and Scotland	Portugal - not known Scotland - up to 20 MW	Portugal - not known Scotland – by 2014
Seabased	Sweden	Sweden	10 MW[12]	Not provided
Wavebob	Ireland	Ireland	Not all known 5MW - Tonn Energy	Not all known 2013 onwards
Wavegen (Voith Siemens)	Scotland	Scotland	500kW 4 MW	Islay - operational Estimated to be operational by 2011[13]

Source: SQW Energy

Larger Utility development and deployment plans

3.12 Although the previous tables outline some of the known initial plans and small OE arrays, if a commercially viable and competitive technology emerges it will be the appetite of the utilities to invest that will determine the success and value of the OE sector. A number of Utilities have announced specific OE plans, for example in Ireland Tonn Energy (in partnership with Vattenfall and WaveBob) plan to install 250MW of wave energy by 2020.

3.13 In the UK The Crown Estate have held the first round of a leasing competition for demonstration and commercial OE project sites in the Pentland Firth and Orkney waters, resulting in 1,200 MW of planned projects split between a number of Utilities and developers: SSE Renewables (200MW tidal, 400MW wave); Scottish Power Renewables (100MW tidal, 50MW wave); Marine Current Turbines (100MW tidal); Pelamis Wave Power (50MW wave); Tidal Development Ltd (200MW tidal: SSE and OpenHydro); and E.ON (100MW wave).

Review of technology costs

3.14 Information on the estimated costs of deploying wave and tidal technologies were extracted from a number of reports. Table 2-3 below provides a summary of the maximum, minimum and mean results for a number of cost parameters collated from the previously published research reports reviewed.

[11] http://www.aquamarinepower.com/news-and-events/news/latest-news/view/99/-10-million-successfully-raised-at-first-close-of-fundraising/
[12] http://www.fortum.com/news_section_item.asp?path=14022;14024;14026;25730;551;46818
[13] http://www.wavegen.co.uk/news_npower%20april%2008.htm

Table 3 -3 Summary of currently estimated and published cost data for wave and tidal technologies

Energy source	Cost of electricity (€/kWh)			Capital Cost (€/kW)			Operation and Maintenance Costs (€ cents/kWh)			O&M costs as % of Capital Costs		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Wave	0.05	0.48	0.24	1,265	11,000	3,820	2.09	4.60	3.53	3.0%	5.9%	4.5%
Tidal	0.10	0.26	0.13	1,050	8,800	2,896	2.15	3.05	2.27	2.5%	5.1%	3.8%

Source: SQW Energy, compiled using data from multiple sources

3.15 The range of results for each parameter is very broad due to the number of different types of devices that are considered and the expected locational variability in their performance. First-of-a-kind, pre-commercial installations – which might be focused on technology proving rather than maximising output – could be even more expensive than the costs noted above. However, in terms of scenario development for OE in Ireland, the figures provide a useful reference point for evaluating the stakeholder deployment and operating costs received during the project, and later used as inputs into the economic model.

Key technology cost data sources

3.16 A number of data sources were used and are summarised in Annex C. Key sources included:

- **Future Marine Energy – Carbon Trust Report 2006**. This report provided estimates for the capital costs and cost of energy from prototype devices, first production models and initial farms of up to 10 MW.
- **Marine Energy Challenge Cost Estimation Methodology – Entec Carbon Trust Report 2006.** This report set out the Marine Energy Challenge approach to estimating the cost of energy produced by marine energy systems, noting that "the most important comparator [of marine energy concepts] is the cost of energy."
- **EPRI Assessment Offshore Wave Energy Conversion Devices 2004**. Based on direct responses from 12 wave energy device developers EPRI developed cost estimates for Wave Energy Convertors (WECs), although they note that site development costs, grid connection and mooring are not included in their cost estimates.
- **Impacts of banding the renewables obligation – costs of electricity production – DTI 2007.** This report prepared by Ernst and Young for the UK Department of Trade and Industry developed cost scenarios for 2006, 2010, 2015 and 2020 for wave and tidal technologies.

Future estimates of technology costs with offshore wind

3.17 It is also worth comparing these figures with some of the most recent estimates for onshore and offshore wind, the intermittent renewable technologies that are the most likely to compete with Ocean Energy development and deployment in Ireland over the next 20 years.

3.18 According to the European Wind Energy Association (EWEA)[14], on average, the expected investment costs (capital costs) for a new offshore wind farm are currently in the range of 2.0 to

[14] Wind energy the facts, EWEA http://www.wind-energy-the-facts.org/en/part-3-economics-of-wind-power/chapter-2-offshore-developments/development-of-the-cost-of-offshore-wind-power-up-to-2015.html

2.2 million €/MW (€2,000 to €2,200 per kW). Whilst this is lower than the mean value seen across the data sources reviewed for wave and tidal energy (€3,820/kW and €2,896/kW) it is significantly above the minimum values observed: €1,265/kW and €1,050/kW for wave and tidal respectively.

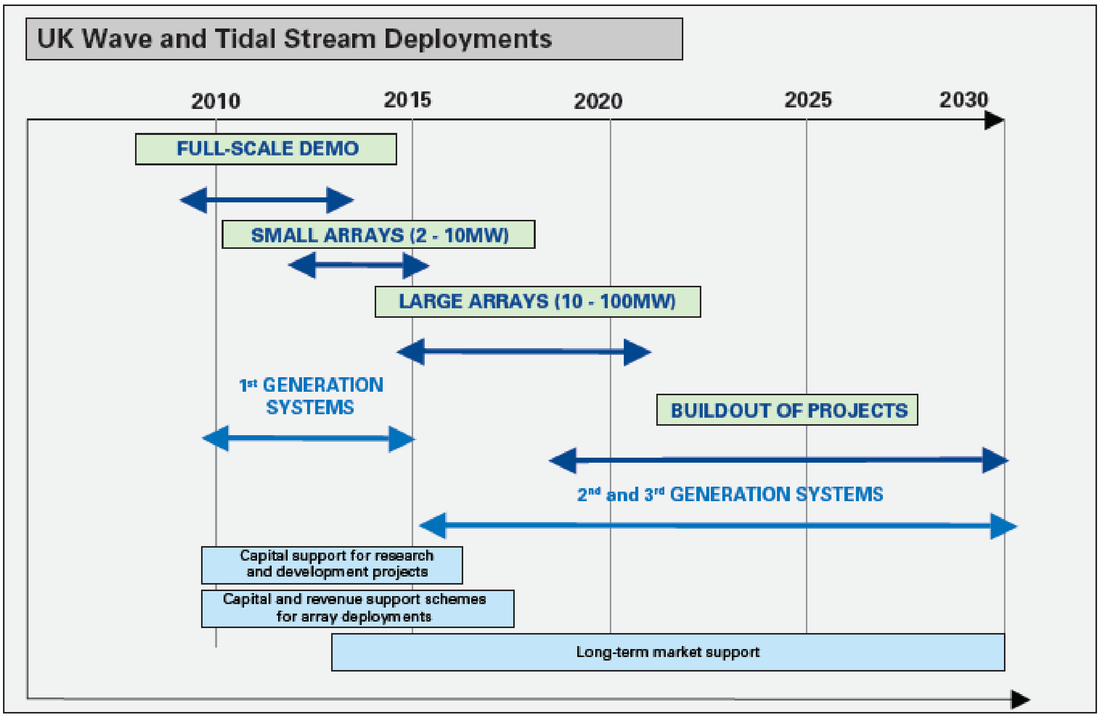
3.19 The EWEA have also provided estimates for the operation and maintenance costs of offshore wind farms in 2006 and for 2015, being 1.6 €cents/kWh and 1.3 €cents/kWh respectively (based on a capacity factor of 37.5%). These values are approximately 23% and 37% lower respectively than the minimum estimated value recorded for wave or tidal energy.

Conclusion on technology and deployment status

3.20 A number of countries have identified the opportunity to develop an OE sector in order to access the associated economic, environmental, energy security and social benefits. However, the technology required to gain these benefits is not yet at a status that allows commercially viable projects to be developed. Based on the progress of developers to date it appears that both wave and tidal technology will achieve full commercialisation but the time at which this will happen and the type of devices that will be successful are yet to be determined. Figure 3-1 outlines the UK Energy Research Centre's (UKERC) estimate of development and deployments as included within its roadmap.

3.21 Not all devices, which are currently at prototype stage, will prove to be commercially viable when they are scaled up. For many devices, access to commercialisation funding appears to be a major barrier to development or deployment and can lead to significant delays in technology improvement relative to projected timetables. In order to drive down existing cost estimates, these technology improvements must take place in the next 5 to 10 years if ocean energy is going to compete with offshore wind in the period from 2020 to 2030.

Figure 3-1 Potential deployment plans for wave and tidal stream technologies out to 2030



Source: UKERC Roadmap 2010

Existing island of Ireland competencies

3.22 The intention of this section is to build a picture of the energy sector and related industries in both the Republic of Ireland and Northern Ireland. In doing this we have researched the fit of the existing industrial base to the likely future requirements from ocean energy.

Current ocean energy activity - research

3.23 Between the Republic and Northern Ireland there are five universities involved in ocean energy research. These research centres are:

- Hydraulics and Maritime Research Centre (HMRC) – University College Cork
- Wave Energy Research Team, Mobile & Marine Robotics Research Centre –University of Limerick
- Department of Earth and Ocean Sciences, National University of Ireland, Galway
- Department of Electronic Engineering, National University of Ireland, Maynooth
- School of Planning, Architecture and Civil Engineering, Queens University of Belfast (QUB).

Current ocean energy activity – private sector

3.24 A diverse range of companies will be required to support the marine renewable sector – firms specialising in research and device design, device testing, component manufacture, device fabrication and assembly, foundation manufacture, grid connection and cabling, environmental assessment, project management, construction and installation, subsea and sea vessel services, operation and maintenance.

3.25 Supply chain requirements depend upon the type of project and its stage of development. However, apart from the information we have on the ocean energy research centres, there is little evidence available on which to base an assessment of the current state and volume of the specific industries and firms which will support the ocean energy sector. The best evidence available on the current state of the ocean energy supply chain is a study carried out by RPS Group (June 2009)[15], although the evidence provided is of a qualitative rather than a quantitative nature.

3.26 The RPS study assessed the current state of industry which may be available to support the development of ocean energy in Ireland. Table 3-4 summarises the findings.

[15] SEAI, *Review of Engineering and Specialist Support Requirements for the Ocean Energy Sector* (June 2009)

Table 3-4 Assessment of ocean energy supply chain in Ireland

Stage in supply chain	**Summary of available resources**
Design	Ireland has some exceptional world class resources in the 'Design' category, including one of the most experienced wave Project Design teams based at the Queen's University of Belfast under the direction of Professor Trevor Whittaker. Similarly, the research facility HMRC in Cork has extensive long-term experience working in the field of wave energy under the direction of Dr Tony Lewis. The facility has contributed on an international stage to many key projects. Also the Galway based specialist mooring and riser company MCS has a worldwide reputation in the oil and gas exploration and production industry.
Testing	Ireland is fortunate to have two world-class wave and tidal energy research establishment with experimental wave tanks and flume facilities. The first is at HMRC in Cork and the second at Queens University, Belfast (QUB). Both institutions have plans for enhancing the test tank facilities they offer. Also the Marine Institute, in association with SEAI established the Ocean Energy Test Site for quarter scale prototypes of wave energy devices in Galway. In addition, a new, full-scale, grid-connected wave energy test site is planned for Belmullet off the Mayo coast. QUB also has a 1/10th scale tidal testing device facility at Strangford Lough.
Manufacture	Ireland has a good level of expertise in general steel fabrication; however the facilities for heavy fabrication of tubes and plate up to 25 – 50 mm likely to be required for the fabrication of ocean energy devices are limited. Only a few existing companies could meet all of the requirements for fabrication of the devices under consideration and most would be limited in terms of the tonnage of steel which could be accommodated. The facility most likely to be capable of catering for the expected specification requirements and tonnages is the Harland & Wolff yard in Belfast which retains some capacity for heavy steelwork fabrication. This yard has the significant added benefit of also being able to provide suitable quay and dry dock infrastructure and has substantial areas available for marshalling and storage Ireland has a considerable concrete industry with expertise in both in-situ and pre-cast construction. There are a significant number of specialist pre-cast concrete producers with high-tech facilities for the production of very high quality finished products. Many concrete specialists have experience of the onsite fabrication of larger concrete elements and have the capability to produce required units. The current Irish concrete industry has the required capacity and expertise to support Ocean Energy developments in the future.
Installation	There are no specialist deep-water cable-laying contactors based in Ireland. Extensive and deep water cable laying operations, when required, are conducted by multinational companies from the UK and further afield. However, many of the specialist diving contractors in Ireland have experience in cable laying operations in coastal waters and the near-shore environment and would be well placed to support cable laying operations associated with OE developments. The installation of most devices will require the use of heavy-lift cranes which would need to operate from specialised heavy marine barges. Equipment of the capacity likely to be required is not currently available in Ireland. This type of equipment is generally provided on the international market being mobilised as and when required to specific locations. There may be limited opportunity for the domestic provision of such equipment. Use of smaller work platforms, work boats and tugs for various ancillary operations. Vessels of this type are currently available in Ireland and there would be an opportunity for the support of OE installation activities. Ireland is reasonably well served with tug boat availability. There are a number of Irish based Marine Civil Engineering Contractors and Marine Plant providers that can supply smaller barges and platforms (self propelled and un-powered) with capacities up to 550t. An opportunity also exists for the provision of vessels and crews to support OE developments during the operational phase.

Source: RPS, 2009

3.27 A study by Rodger Tym & Partners[16] provides evidence on the appropriateness of the industrial base in Northern Ireland for OE requirements. The study concludes that many of the companies in the relevant sectors have the skills to contribute a competent and necessary service to the

[16] Rodger Tym & Partners, (2008) , *NI Renewable Energy Supply Chain*

renewable sector. However, the major deficit identified is "product leadership" such as a complete systems design and integrator. Without clear product leadership, markets cannot be captured and supply chain needs defined and met. In the view of Roger Tym & Partners, the encouragement and nurturing of product leadership should therefore be high on the agenda for NI. This is a challenge that will take time, significant financial support and innovative team building to be successful.

3.28 Barriers to the development and deployment of OE have been identified in the literature mentioned above, particularly in the areas of ports and skills:

- Significant investment may be required in Irish ports in order to meet the needs of Ocean Energy on the scale being considered. In particular quay facilities with reasonable water depth greater than 5m, together with cranes and dry dock or synchrolift capabilities will be key resources along with tugs and support vessels.
- Skill shortages are a key potential barrier to capacity growth according to consultees. These shortages are already being cited by supply chain players, a situation that will worsen as the industry expands. Greater investment in training and skills development were cited as a requirement to ensure that Ireland delivers a skilled workforce capable of building the supply chain, particularly given the long lead times associated with education.

3.29 Specific gaps in the supply chain were noted in the RPS study "Engineering and Specialist Support Requirements for the OE Sector", as summarised in Table 3-5 below. A shortage of specialist deployment barges and working platforms was highlighted as a particular area of concern.

Table 3-5 Significant supply chain gaps in Ireland

Group	Subgroup
Design	
Electrical System design	Permanent Magnet Generators
Manufacture	
Energy Coupling Systems	Hose Pumps
Power Generation Equipment	Equipment Hydraulic Systems
Power Generation Equipment	Inverters
Power Transmission Equipment	Wet-Mate Connectors
Power Transmission Equipment	Electric Umbilical
Testing	
Prototype & Full Scale Testing	Power hook-up systems
Installation	
Cable Laying	Cable Laying

Group	Subgroup
Transportation	Barges/Working Platforms
Offshore Construction	Pile Installation

Source: RPS for SEAI 2009

3.30 Another SEAI study[17] examined the relationship between industrial development and offshore wind energy in the Republic of Ireland. Although not directly related to ocean energy, this does give an additional overview of the competencies of Ireland's industrial base.

3.31 The study finds that only a few companies have actually done work for the renewable energy industry so far[18], but many of them will quite easily be able to transform their services to cover several of the industry's needs, should the market develop to a sufficient size. Particularly in the areas of sub- delivery and in the high tech and software services the competencies are good. In the field of heavy steel manufacturing the competencies as previously mentioned are lower.

3.32 SEAI concludes that the main effort should be put into the strong competencies that already exist. Activities that would have the best opportunities for local work highlighted in the study were:

- preparation and planning
- transportation and erection work
- installation and cabling
- operation and maintenance

Summary of industry and supply chain

3.33 Ireland lacks many of the specialised supply chain industries likely to be required by OE developments and deployment. Some significant resource gaps in key supporting technologies and engineering capacity have been identified in the literature, and summarised above.

3.34 There are a wide range of companies across Ireland with the *potential* to contribute to the developing renewable energy sector, including OE. However the majority currently would only be able to provide general knowledge and services and product leadership is required in order to marshal their efforts.

3.35 Some significant resource gaps in key supporting technologies and engineering capacity have been identified in relation to the OE sector in Ireland. It is clear that there are many local industrial competencies and as a result many industries will, in theory, be able to transform their services to cover several of the industrial needs of the OE sector. To achieve this will however require more than happenstance – an improved flow of information, collaboration between complementary parts of the supply chain, and leadership by one or more companies are likely to be required.

[17] SEAI, (2004) , *Offshore Wind Energy & Industrial Development in the Republic of Ireland*

[18] For example: OE installation has been carried out by McLoughlin and Harvey (deployment of Open Hydro devices in Orkney and Bay of Fundy, Canada); testing and manufacture of OE devices has been carried out by Open Hydro, Harland & Wolff and Woodburn Engineering.

Issues identified

3.36 Given the early stage of ocean energy development, there is little detailed evidence available on the likely supply chain requirements of the industry, and on the industries that could potentially benefit from OE development in Ireland. The lack of detailed data makes the calculation of the economic impact of an OE sector on the island of Ireland challenging, particularly as no specific statistical GVA data for an OE sector currently exist.

3.37 A final and important question that the literature is unable to answer is the impact of a globalised ocean energy sector, should one or more technologies prove commercially successful. For the island of Ireland this has two ramifications:

- The attractiveness of Ireland as a location to manufacture and/or install OE devices – resulting in inward investment by non-Irish companies
- The ability of Ireland to develop an OE industrial base capable of exporting to meet global demands. This could potentially be a fully-integrated offer, led by Irish developers, or a partial offer contributing one or more elements of the supply chain.

3.38 These issues can only be addressed through primary research by Stakeholder consultation, following on from this desk-based review.

Policy, legislation and regulatory review

Introduction

3.39 This section reviews the policies, regulations and support packages that will influence the development and deployment of wave and tidal energy in Ireland and Northern Ireland. We begin with a discussion of policy and legislation, before considering OE support mechanisms and finally the wider regulatory environment influencing the development of the sector.

Policy Overview

European Commission (EC)

3.40 Europe has implemented a forward-looking political agenda to achieve its core energy objectives of sustainability, competitiveness and security of supply. The main legislation supporting renewable electricity at a European Union (EU) level is the Renewables Electricity Directive (ERD) on the promotion of electricity from renewable energy sources in the internal electricity market (2001/77/EC). The ERD requires each Member State to commit to specific targets for renewable energy production. It sets an indicative target to produce 22% of EU electricity from renewable sources by 2010.

3.41 The Framework Programme (FP) is the EU's main instrument for funding research and development, including OE development. FP1 ran from 1984 to 1987; FP7 began in 2007 and runs to 2013. Since 1995, the EC has allocated approximately €30 million to OE projects[19].

3.42 In 2008, a string of new EU policy measures were proposed to assist in tackling carbon emissions in the energy sector. The new Renewable Energy Directive/Fuel Quality Directive 2009 (RED

[19] http://ec.europa.eu/research/fp6/index_en.cfm and http://www.cordis.lu/fp7/

2009)[20] imposes stretching renewables targets for 2020 across the EU, including a 20% EU-wide renewable energy goal by 2020 (covering all energy, not just electricity) and a 10% renewable transport fuels target for the same year[21]. The UK target under RED 2009 is for renewable consumption to account for 15% of gross final energy consumption by 2020; Ireland's target is 16% by 2020[22].

Republic of Ireland

3.43 The Irish government is committed to ensuring that the national energy strategy addresses the challenges which are faced worldwide in the energy sector. These include ensuring:

- security of supply;
- environmental sustainability of the energy system; and
- competitiveness of energy supply.

3.44 Ireland has two separate targets for the increase in renewable energy capacity. The first arose from the Green Paper on Sustainable Energy (1999) which set a target to add an additional 500 MW of new, green generating plants to the electricity network by 2005, and the second target is increasing the consumption of electricity from renewable energy sources to 13.2% of national electricity consumption by 2010. The Minister for Communication, Energy, and Natural Resources has also set a target of 500 MW of ocean energy to be installed by 2020.

3.45 Energy policy priorities in Ireland are framed in the context of the European energy policy. Under the new RED, Ireland's individual 2020 target for renewable energy across three energy sectors (electricity production, heating/cooling and transport) is 16%. The Sustainable Energy Act 2002 aims to promote and assist the development of sustainable energy. The Irish government has also set a target of 40% of electricity production to come from renewable sources by 2020.

3.46 The Sustainable Development Strategy for Ireland (1997) sets out the key energy policy towards the reduction in, and the more efficient, use of energy as well as greater use of renewable energy[23]. The National Development Plan (2000-2006) provides support under the Economic and Social Infrastructure Operational Programme, for the promotion of alternative energy.

3.47 The Renewable Energy Research Development & Demonstration Programme (Renewable Energy RD&D) which ran from 2002-2006 had a primary focus of stimulating the deployment of renewable energy technologies that are close to market, and on assessing the development of technologies that have prospects for the future. Four ocean energy projects were awarded almost €0.3m in total under the programme[24].

3.48 In 2006, the Marine Institute and Sustainable Energy Ireland prepared the National Strategy for Ocean Energy. As Ireland has one of the largest wave energy resources in Europe, this phased strategy aims to support developers of wave energy devices through the concept of validation, model design optimisation, scale model testing and deployment. To achieve this target, the Irish government has provided a three year (2008-2010) financial package of about €26.6 million, to

[20] Directive 2001/77/EC will be repealed by RED 2009 from 1 January 2012.
[21] http://www.newenergyfocus.com/go/legislation/EU_clean_energy_legislation_an_overview.html?section=
[22] http://www.energy.eu/
[23] http://www.environ.ie/en/Publications/DevelopmentandHousing/Planning/FileDownLoad,1633,en.pdf
[24] http://www.iea-oceans.org/_fich/6/Review_Policies_on_OES_2.pdf

be administered by the Ocean Energy Development Unit. This support package includes a buy-in tariff of €0.22 /kWh for electricity produced from wave and tidal devices[25]. Table 3-6 illustrates the proposed budget for the strategy.

Table 3-6 Planned budget for Ireland's ocean energy strategy

Phase	**Year**	**Task**	**Cost (€M)**
Phase 1	2007	Prototype development	4.9
Phase 2	2008-2010	Pre-commercial devices	6.9-10.5
Phase 3	2011-2015	Pre-commercial array	10.1-11.15
Phase 4	2016	Market deployment	Support mechanism if required

Source: IEA-OES 2006 Review and analysis of ocean energy systems development and supporting policies

3.49 The Marine Institute, in association with Sustainable Energy Ireland and Enterprise Ireland, established an Ocean Energy Test Site for scaled prototypes of wave energy devices in Galway Bay. The Department of Communications, Marine and Natural Resources issued a foreshore lease for the site in March 2006.

3.50 The Irish Government *"has chosen the Sustainable Energy Authority of Ireland (SEAI) to play a lead role in developing the ocean energy sector in Ireland. The Ocean Energy Development Unit (OEDU) was set up by SEAI in 2008 with the objective of making Ireland a world leader in supplying ocean energy technologies internationally and in generating electricity from the abundant waves and tides off our surrounding coastlines".*

3.51 During November 2009 the Ocean Energy Development Unit (OEDU) announced a commitment to provide €4.3 million in funding to 10 Irish companies developing ocean energy technologies. The 10 companies were:

1) Key Engineering Services Ltd
2) Cyan Technologies Ltd
3) Technology from Ideas Ltd
4) Waveberg Ireland
5) Ocean Energy Ltd
6) OpenHydro Group Ltd
7) Martin Houston and Sons Ltd
8) Wavebob Ltd
9) Sea Power Ltd
10) Marine Renewables Industry Association Ltd
11) Jospa Ltd

[25] http://www.iea-oceans.org/_fich/6/Annual_Report_2008_(1).pdf

3.52 SEAI and the OEDU have also proposed plans to develop a National Wave Energy Test Site, off Annagh Head, west of Belmullet in County Mayo. The purpose of the wave energy test site at Belmullet is to provide a location for the temporary mooring and deployment of wave energy machines so that their performance in generating electricity and their survivability can be tested and demonstrated in open ocean conditions. It is proposed for the site to operate for up to 20 years with devices on site intermittently throughout the year.

3.53 The main mechanisms for support of renewable energy generation in Ireland are the Alternative Energy Requirement (AER), a tender scheme introduced in 1996, and the Renewable Energy Feed-in Tariff (REFIT) which has become the main Irish tool for promoting renewable electricity generation technologies.

United Kingdom including Northern Ireland

3.54 The development of the OE sector has primarily been motivated by significant RD&D financial support by the UK government. The Department of Trade and Industry (DTI) research and development programme provided £57m (1976-1982) for the first wave energy R&D programme. From 2000 to 2005 the DTI New and Renewable Energy (NRE) R&D Programme, which then became a part of the Technology Programme, committed approximately £10m to eight ocean wave device concepts. In the same period, the DTI's NRE R&D Programme also supported work to develop and evaluate a number of tidal current energy device concepts[26].

3.55 The primary policy in support of the UK for the expansion of emerging technologies in renewable electricity generation has been embodied in the Renewable Obligation (RO), which obliges all licensed electricity suppliers in England and Wales[27] to supply a specified and growing proportion of their electricity sales from eligible renewable sources, rising from 10.4% in 2010 to up to 20% in 2020[28].

3.56 The Energy Act 2008 introduced technology banding to the RO. This aims to improve the effectiveness of the RO and provide better support to emerging technologies with wave and tidal technologies each receiving 2 ROCs/MWh of eligible generation.

3.57 The devolved Government in Scotland has taken a lead in providing strong market and support measures, including: the suggestion of 3 ROCs/MWh for tidal energy and 5 ROCs/MWh for wave energy; the £13m Wave and Tidal Energy Support Scheme (WATES); and the recent £12m Wave and Tidal Energy: Research, Development and Demonstration Support Scheme (WATERS). Additionally the £10m Saltire Prize has been launched to accelerate the commercial development of marine energy. This will be awarded to the team that can demonstrate in Scottish waters, a commercially viable wave or tidal stream energy technology that achieves the greatest volume of electrical output over the set minimum hurdle of 100GWh over a continuous 2 year period using only the power of the sea.

3.58 The Carbon Trust Marine Energy Challenge (CT MEC)[29] is a technology acceleration programme focused on advancing the development of eight wave and tidal current concepts. Its activities were particularly related to cost of energy, focusing on key areas of potential cost reduction and performance improvement. The programme was completed in summer 2005, having run for 18

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[26] http://www.iea-oceans.org/_fich/6/Review_Policies_on_OES_2.pdf
[27] Parallel mechanisms operate in Scotland and Northern Ireland
[28] http://www.berr.gov.uk/energy/sources/renewables/policy/renewables-obligation/what-is-renewables-obligation/page15633.html
[29] http://www.thecarbontrust.co.uk/carbontrust/about/publications/FutureMarineEnergy.pdf

months, and provided £3 million for targeted engineering support which was intended to improve the understanding of wave and tidal current generation technologies, including costs and performance. The device developers involved claimed the rate of development has been improved through this specialist collaboration.

3.59 Other UK-wide marine renewable support measures include the Marine Renewable Deployment Fund[30] and the Marine Renewable Proving Fund[31]. Support is also available through a range of sources, including the Technology Strategy Board, Energy Technology Institute, and the Carbon Trust Marine Accelerator Programme.

3.60 The UK Renewable Energy Strategy, published in July 2009, set out a commitment to developing a Marine Energy Action Plan. The objective was to set out a vision for the Marine Energy sector to 2030 (with reference to 2020), outlining the actions required by both industry and the public sector to facilitate the development and deployment of marine energy technology and fulfil that vision. The Marine Energy Action Plan 2010[32] sets out the actions needed to drive the marine energy sector forward. Key recommendations include:

- Forming a UK-wide strategic coordination group to develop a planning and consenting roadmap for all types of marine renewables;
- Consideration of support levels for marine technologies under the review of banding of the Renewables Obligation in Autumn;
- Ensuring that the appropriate levels of targeted funding are available to bridge the technology market failures that exist in this developing sector, subject to the budgets in the next public spending round;
- Leveraging private equity, and in the longer term, project capital into the sector;
- Establishing guidelines and best practice in the development of new technologies; and
- Building a UK marine energy supply chain and utilising the current skills base already established from the offshore wind, oil and gas, and maritime industries.

Northern Ireland

3.61 Northern Ireland's current renewable energy target is for 12% renewable electricity by 2012. This target is scheduled to be met, mainly from onshore wind, but it is viewed as important to broaden the renewables base. The draft Strategic Energy Framework (SEF 2009) recently proposed new challenging renewable energy targets of 40% renewable electricity and 10% renewable heat by 2020 – it is expected that the SEF will be finalised during 2010. In addition to increased levels of onshore wind to meet this new renewable electricity target, development of other technologies including bioenergy and offshore renewables are being actioned by Department of Enterprise Trade and Industry (DETI).

[30] http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/lc_business/env_trans_fund/marine_fund/marine_fund.aspx
[31] http://www.carbontrust.co.uk/emerging-technologies/current-focus-areas/marine-renewables-proving-fund/pages/default.aspx
[32] Available at:
http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wave_tidal/funding/marine_action_/marine_action_.aspx

3.62 Earlier studies identified significant potential for offshore wind and marine renewables (mainly tidal) in NI waters. DETI is currently undertaking a Strategic Environmental Assessment of its draft Offshore Renewable Energy Strategic Action Plan to develop this resource – a requirement under EU legislation and also required by The Crown Estate (TCE) before any commercial development of offshore resources. It is expected that the SEA[33] and draft Action Plan will be finalised during 2010, facilitating the way for a commercial call for projects by The Crown Estate later in 2010-2011.

3.63 The draft Strategic Action Plan 2009-2020[34] (SAP) aims to optimise the amount of renewable electricity generated from offshore wind and marine renewable resources in Northern Ireland's waters (i.e. out to 12 nautical miles) in order to enhance diversity and security of supply, reduce carbon emissions, contribute to the proposed renewable electricity targets by 2020 and beyond and develop business and employment opportunities for NI companies.

3.64 The marine SAP will provide the framework within which offshore renewable energy can be developed through a competitive call, to be undertaken by The Crown Estate, for commercial projects. The SAP identifies a programme of enabling actions which will be essential to the development of this resource and proposes a target, subject to the outcome of the present consultation: To develop at least 600 MW of offshore wind and 300 MW from tidal resources in Northern Ireland waters by 2020.

3.65 The SAP key actions identified are:

- Develop an appropriate reinforcement programme of the NI electricity Grid, to be completed in time to handle efficiently the increasing renewable electricity generated offshore.
- Complete work by 2010 with Scotland and the Republic of Ireland on the joint Isles Project to assess the potential for an offshore regional marine electricity grid linking Ireland and Scotland and consider its findings and recommendations.
- Continue to work with Invest NI, The Crown Estate and others in promoting the opportunities for local manufacturing and service sectors to secure offshore energy supply chain business in relation to projects considering investment in NI waters and also in the wider international and national markets.
- Develop a practical way forward with the ROI for handling offshore renewable energy projects in waters in, around or adjacent to state boundaries near Loughs Foyle and Carlingford and agree appropriate operational arrangements.
- Continue to ensure that DETI's offshore energy interests are effectively represented within the development of policy and legislation for the forthcoming Northern Ireland Marine Bill and other marine related work e.g. the Marine Strategy Framework Directive.
- With The Crown Estate and the Northern Ireland Environment Agency, develop during 2010-2011 streamlined administrative guidance for developers and officials on the licensing and consenting regimes for offshore renewable energy projects.

[33] Strategic Environmental Assessment of Offshore Wind and Marine Renewable Energy, DETI – available at: http://www.offshorenergyni.co.uk/
[34] Consultation on an Offshore Renewable Energy Strategic Action Plan 2009-2020: Department of Enterprise, Trade and Investment, December 2009

- Work with DECC to put in place the necessary offshore energy production and decommissioning regime, similar to that in force in GB waters, for offshore renewable energy installations in NI waters.

- Continue to develop the Northern Ireland Renewables Obligation (NIRO) to encourage the generation of electricity from offshore and marine renewables and to agree with DECC the transfer of the vires from DECC to DETI to issue offshore Renewable Obligation Certificates.

- Ensure that Northern Ireland benefits from the range of NI and UK wide regimes supporting research, development and deployment of offshore renewable energy.

3.66 DETI NI is currently also developing a SAP for on-shore renewable generation. The SAP will set out high-level proposals for onshore renewables and high-level proposals for strengthening the electrical grid, which will be required to transmit energy generated by future renewable energy developments both onshore and offshore[35].

International support and incentives

3.67 OE technologies are still in an early stage of development compared to other renewable technologies. They are generally at the part-scale or full-scale prototype demonstration stages in the overall terms of RD &D[36]. Support for renewable energy technology development is one way to build a competitive industry that will have a global market. Specific support mechanisms for OE are not yet as widespread as other renewable support mechanisms – partly because not all countries have significant OE resource potential, and partly because of the relative immaturity of the sector.

3.68 A summary of how the different types of available renewable energy support mechanisms operate is provided in Annex B, alongside our analysis of the global availability of these support mechanisms. This is later used to support the economic modelling assumptions.

Regulation, planning and consenting

3.69 Regulation affects renewable energy projects at each stage of the project lifecycle: planning, construction, operation and decommissioning. Some of the key regulations affecting each stage in the various jurisdictions are highlighted below.

Republic of Ireland

3.70 Following on from the enactment of the Foreshore and Dumping at Sea (Amendment) Act 2009 responsibility for certain foreshore functions (relating to wave or tidal energy and associated infrastructure) have transferred to the Minister for the Environment, Heritage and Local Government with effect from 15 January 2010. The foreshore is the seabed and shore below the line of high water of ordinary or medium tides and extends outwards to the limit of twelve nautical miles.

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[35] A Onshore Renewable Energy Strategic Environmental Assessment (SEA) of the SAP is being undertaken on behalf of DETI - http://www.nigridenergysea.co.uk/

[36] http://www.iea-oceans.org/_fich/6/Review_Policies_on_OES_2.pdf

3.71 For offshore renewable energy developments, the Foreshore[37] (Environmental Impact Assessment) Regulations 1990 which provide for the applications for leases and licences under Section 2 of the Foreshore Acts 1933-2005[38] also need to be taken into consideration and includes:

- Foreshore Act 1933
- Foreshore (Amendment) Act, 1992
- Section 5 of the Fisheries and Foreshore (Amendment) Act 1998
- Fisheries (Amendment) Act, 2003 (Part 5)
- Maritime Safety Act 2005 No. 11 (Part 6)
- Foreshore and Dumping at Sea (Amendment) Act 2009
- Consolidated Foreshore Acts (Unofficial).

3.72 The legislation governing planning and sustainable development in Ireland is set out in the Planning and Development Act 2000-2006. It is underpinned by a series of regulations called the Planning and Development Regulations 2001[39] that prescribes the details of the various planning processes and procedures.

3.73 Permission for OE projects is in the first instance a matter for the Department of the Environment; in the second instance a matter for CER; and in the third instance for any impacted Local Authority. The Local Authority may have their own development planning process which will relate to the onshore elements (e.g. substations, overhead lines) but is subject to the conditions and requirements of the Planning and Development Act, 2002. Among other conditions, this requires planning authorities to consult with appropriate bodies to ensure that renewable generation planning developments have regard to wider considerations such as adverse impacts on neighbouring properties and wider local communities.

Northern Ireland

3.74 NI has its own distinct planning system with responsibility for town and country planning devolved to the Northern Ireland Assembly. The Department of the Environment (DoE) is now responsible under the Planning (Northern Ireland) Order 1991 for planning matters, although the Department of Enterprise, Trade and Industry (DETI) is responsible for the consent of renewable energy generators over 10 MW, and for all offshore renewable energy developments.

3.75 DoE is responsible for onshore planning matters and would be involved (for example) in consenting an onshore substation for an offshore facility. A FEPA licence is required from the NIEA in respect of placing anything/removing any material from the seabed.

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[37] http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=052277&database=FAOLEX&search_type=link&table=result&lang=eng&format_name=@ERALL
[38] http://www.clarecoco.ie/Planning/planninglegislation.html
[39] http://www.clarecoco.ie/Planning/planninglegislation.html

3.76 In addition, the Planning (Environmental Impact Assessment) Regulations (Northern Ireland) 1999[40] sets out the details on planning and the EIA process for renewable energy developments and the Planning Reform (Northern Ireland) Order 2006 makes provision for the DoE to reform and improve planning processes while also enhancing transparency and community involvement in the planning system[41].

3.77 The Northern Ireland marine programme comprises UK Marine and Coastal Access Act 2009[42] and UK-wide regulations to transpose the Marine Strategy Framework Directive and the proposed Northern Ireland Marine Bill. Northern Ireland is included in the UK Act for the provisions relating to the Marine Policy Statement, marine planning in Northern Ireland's offshore area (from the 12 nautical mile limit to the boundary of the Northern Ireland zone) and the reform of marine licensing insofar as it relates to the Food and Environment Protection Act 1985 and marine aggregates extraction.

3.78 Northern Ireland's Environment Minister has announced her intention to take forward similar proposals in Northern Ireland using a combination of the UK Act and a Northern Ireland Assembly Bill. The Northern Ireland Marine Bill will contain provisions for marine planning and marine nature conservation within Northern Ireland's territorial waters and subject to discussions with the other Government Departments may contain provisions for further streamlining of licensing for devolved functions. A consultation document A Northern Ireland Marine Bill Policy Proposals – Consultation Document proposes a framework for Northern Ireland's seas[43].

Leases and consents

3.79 Consents that are necessary for any offshore renewable energy projects in Ireland and NI are described below (Some consents for onshore and offshore developments are site dependent).

Republic of Ireland

3.80 The Foreshore Acts require that a lease or licence must be obtained from the Minister for the Environment, Heritage and Local Government for the carrying out of works or placing structures or material on State-owned foreshore which represents the greater part of the Irish foreshore.

3.81 Leases are granted under the Acts for the erection of long-term structures (e.g. piers), while Licences are granted for other works (e.g. laying of submarine cables) and purposes.

3.82 For offshore developments, licenses are approved in 2 phases. Phase 1, the "Site Investigation License", allows consortia to investigate whether the targeted site is suitable and economically viable. Under Phase 2 a full license can be granted in cases where all required approvals have been obtained.

3.83 The proposed Offshore Renewable Energy Development Bill will facilitate a much simplified, streamlined, transparent and fast-tracked planning and development framework for the

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[40] The regulations were amended in 2008: http://www.planningni.gov.uk/index/news/news_policy/legislation-impact-assessment-eia-amendments.pdf
[41] http://www.bwea.com/planning/uk_planning_legislation.html
[42] Full details of the UK Marine and Coastal Access Act 2009 available at: www.defra.gov.uk/environment/marine/legislation/index.htm
[43] A Northern Ireland Marine Bill – Policy Proposals Consultation Document: Planning and Natural Resources Division, Department of the Environment NI - April 2010
http://www.doeni.gov.uk/consultation_northern_ireland_marine_bill_-_policy_proposals.pdf

deployment of offshore energy renewable technologies in an environmentally sustainable manner while respecting the acquired rights of current leases[44].

Northern Ireland

3.84 Northern Ireland's offshore waters are subject to the same licensing and consenting system as the rest of the United Kingdom Continental Shelf.

3.85 The Crown Estate has powers to grant a lease for development of wind, wave or water-driven generating stations within UK territorial waters (including Northern Ireland) out to the 12 mile territorial limit. Beyond this limit, within UK territorial waters, The Crown Estate issues a licence to develop a renewable energy installation, rather than a lease.

3.86 Before a developer can deploy renewable energy devices in the sea they must get the agreement of the Crown Estate to a site licence or lease and obtain the relevant development consents/licences.[45] Only when all the necessary statutory consents are obtained will The Crown Estate grant a lease for development[46].

Grid connection arrangements

3.87 The Ireland and Northern Ireland electricity networks are fully liberalised with complex regulatory regimes defining the way in which connection and use of the system charges can be determined. Before selling electricity generated from a renewable energy technology it needs to be physically connected to an electricity grid. Several physical and contractual arrangements must be in place before this connection can be made. This consists of electrical infrastructure such as underground cables, overhead lines, switchgear and civil works to facilitate the electrical connection. The contractual arrangement includes agreements between the developer and other involved parties covering areas of connection arrangements, power purchase arrangements and wayleaves[47].

Republic of Ireland

3.88 In the Irish Republic, the Electricity Regulation Act 1999 is the principle piece of legislation governing electricity. The Commission for Energy Regulation (CER) is the regulatory authority for the regulation and granting of licenses for the generation, transmission, distribution and supply of electricity. Under the Act, a developer wishing to construct a new generating station must obtain an authorisation and a generation licence from the CER prior to commencing work[48].

3.89 In order to export or import electricity, the renewable developer must enter into a connection agreement with the Distribution Systems Operator (DSO) and a licence to generate electricity must be obtained from the CER.

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[44] http://www.oireachtas.ie/documents/committees30thdail/j-climate_change/press_release/20081216.doc
[45] http://www.berr.gov.uk/files/file15470.pdf
[46] http://www.thecrownestate.co.uk/offshore_wind_energy
[47] http://www.sei.ie/Publications/Renewables_Publications/connecting_RE_and_chp_to_network.pdf
[48] http://www.cer.ie/en/electricity-generation-licences-and-authorisations.aspx

Northern Ireland

3.90 In NI, the Electricity (Northern Ireland) Order 1992[49] sets out the procedures to develop and maintain an efficient, co-ordinated and economical system of electricity transmission. The Northern Ireland Authority for Utility Regulation (NIAUR) is the regulator for electricity, downstream gas, water and sewerage in Northern Ireland. Under the Order, a generation license is needed to cover the production of electricity and a supply license to cover its provision to premises (unless certain exemptions apply). As stated in the Sustainable Energy Framework (2009) there are plans to strengthen the NI grid, including the need to handle increased levels of renewable generation both onshore and offshore.

Decommissioning arrangements

3.91 The obligation to decommission disused installations is set out in the United Nations Convention on the Law of the Sea (UNCLOS), 1982, which requires abandoned or disused installations or structures to be removed, to ensure safety of navigation, taking into account generally accepted international standards under the International Maritime Organization (IMO) standards adopted in 1989[50].

3.92 Plans for decommissioning should be outlined at the planning application stage. Issues to be addressed include the removal of structures and equipment and restorative measures. A decommissioning plan may be covered in conditions and/or a legal agreement accompanying planning permission and/or a site lease, and will be triggered by the expiry of the consent or lease, or in the event of the project ceasing to operate for a specified period. Developers should demonstrate that funding to implement decommissioning will be available when required. It is likely that the duration of planning permission will be linked to the expected operational life of the renewable energy device.

Republic of Ireland

3.93 Any decommissioning scheme undertaken in the Republic of Ireland must comply with the mandatory requirements of the EU Decommissioning Regulation and will need to comply with all relevant national legislation at the time. Such legislation includes: Protection of the Environment Act 2003 and the Coastal Act 1963.

Northern Ireland

3.94 The UK Energy Act 2008 covers decommissioning onshore in Northern Ireland; provisions for the decommissioning schemes for offshore renewable installations are set out in Chapter 2[51]. However, NI waters are not included in the definition of geographical coverage used in the Act. DETI is working with DECC to put a similar regime in place in NI waters.

[49] http://www.opsi.gov.uk/si/si1992/Uksi_19920231_en_2.htm#(Ti)ititlecommencement
[50] http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm
[51] https://www.legislation.hmso.gov.uk/acts/acts2008/en/08en32-e.htm

Conclusions

Coverage of literature

3.95 The field of ocean energy has a well-developed literature, centred around regular reporting on the state of development of the sector. This reporting is most commonly carried out by specific studies tasked by the public sector on providing a snapshot of current progress, or by institutions funded by the public sector to develop ocean energy.

Gaps in data

3.96 For the technology strand, the major deficiencies in the literature are:

- Commercial confidentiality specifically related to transparent costs and performance on the part of developers
- The limited state of deployment, and therefore learning from real-world experience of installation and operation
- Accompanying these, substantial uncertainty exists over the likely costs of energy generation from these sources, with estimates of future generation costs having a very wide range

3.97 For the island of Ireland OE sectoral capabilities strand, the major issues arising from the literature are:

- The relatively sparse data on the *actual* capabilities of individual companies rather than more generic or qualitative statements about the industrial base
- Consideration of the impact of a global market in ocean energy and Ireland's potential role within this – this includes both inward investment and exporting potential
- The need to consider constraints/barriers alongside capabilities – the capabilities will only become operational if technology development AND constraints and barriers are addressed.

3.98 For the policy and legislative strand, the major issues arising from the literature are:

- The constantly shifting policy framework – in particular, the complex, country-specific and constantly evolving web of competitive support measures
- The lack of an international comparison of the different regulatory regimes for offshore energy that would allow an identification of the strengths and weaknesses of different approaches

Use of Literature Review Data

3.99 The study team developed the literature review data to inform, design and undertake a detailed Stakeholder consultation. This is described in the next chapter and was used to further develop a suitable data set from which to build the nine scenarios and frame the modelling work required to deduce the economic value of OE in Ireland.

4: OE Expert Consultation

Introduction

4.1 Although there are many issues surrounding OE, many of which have been reported in the previous chapter, the objective of this research is to calculate the possible economic value of an OE industry to Ireland (North and South).

4.2 In order to accurately determine the present and future levelised costs of OE and therefore to gain an impression of what the likely economic benefit from such an industry might be to Ireland reasonably accurate OE CAPEX and OPEX information is required. The literature review revealed that there was a wide range of cost data, both current and projected. As most of the costings were recorded some time ago in a rapidly moving sector it was necessary to approach experts in the field for any updates and indeed views on the island of Ireland OE sector. The stakeholders contacted and interviewed are listed in Annex D:, but included academics, government officials, technologists, developers and utilities.

Questionnaire

4.3 In order to provide a structure for stakeholder responses a questionnaire was developed to capture the specific parameters from which the economic value of OE could be determined. The broad range of information required (present and future) may be listed as:

- Capital costs
- Operation and maintenance costs
- Irish and global deployment plans
- Appropriate aids and subsidy required
- Employment in OE by SIC/NACE sector
- Employment in OE attained locally for a project
- Employment and value of export markets

4.4 An offer was made to most of the stakeholders to be interviewed, both with respect to their questionnaire responses and any other surrounding views. Many chose to take up this offer which proved most beneficial to better quantifying the variables in the economic modelling.

Responses

Summary responses

4.5 Table 4-1 and Table 4-2 outline the summarised responses from all stakeholders with regard to the estimated OE costs and capacity, and the appropriate aids and subsidy required to achieve this. It should be noted that there was no visible or consistent differentiation between wave energy and tidal energy in terms of cost, capacity and the appropriate subsidy and aids. Both technology categories presently retain a multiplicity of designs at an early stage of development: hence costs and the envisaged future economies of scale may tend to vary widely.

Table 4-1 Estimated OE costs and project size

	Range	2010[52]	2015	2020	2030
Capital costs of OE devices	Minimum	€7,000 /kW	€2,360 /kW	€1,574 /kW	€787 /kW
	Average	€13,000 /kW	€5,287 /kW	€3,525 /kW	€1,536 /kW
	Maximum	€20,000 /kW	€10,000 /kW	€6,000 /kW	€3,500 /kW
Operation and Maintenance costs as % of CAPEX per annum		4.3% - 5%	2.5% - 4.4%	2.9% - 8.3%	2.9% - 8.3%
Likely scale of typical project or farm		1 - 5MW	5 - 50MW	50 – 300MW	100 – 500MW

Source: SQW Energy

Table 4-2 Appropriate OE subsidy and aids

	Range	2010	2015	2020	2030
N. Ireland: appropriate ROC banding level for OE?	Minimum	x3	x3	x2	x1
	Average	x4.5	x4	x2.5	x1.3
	Maximum	x5	x5	x3	x1.5 - x2
Republic of Ireland: appropriate level of REFIT?	Minimum	€220/MWh	€220/MWh	€180/MWh	€140/MWh
	Average	€250/MWh	€250/MWh	€207/MWh	€145/MWh
	Maximum	€300/MWh	€300/MWh	€220/MWh	€150/MWh
What level of capital grants might be required for OE?	Average	50%	25%	0	0

Source: SQW Energy

Technology developers

4.6 Most technology developers approached responded with their own estimates of CAPEX, OPEX and future deployment scenarios. The lower CAPEX and OPEX figures tended to be quoted by the technologists, although the more developed technologies tended to have slightly higher costs for initial deployments reflecting their actual experience. The future costs were predicted as very similar, but many acknowledged that this would depend on the achieved learning rate which would only become clear as further deployments and scaling proceeded.

[52] It must be recognised that these are not full production costs, but initial prototype project costs often including environmental science which are predicted to rapidly decline in future.

The main point is to show that if, for example, the technology starts at an installed capital cost of around £5M/MW initial generating costs will be about £240/MWh so something in excess of this needs to be earned as revenue or the project will be loss-making. However by the time 1280MW have been installed it is probable that costs will be in the range £50 to £110/MWh – hopefully nearer the lower end of this band (in present day money). It shows the case for subsidy; clearly the high initial rate of subsidy can leverage the development of the technology on the scale needed to bring down costs to more acceptable levels at which point subsidies may be greatly reduced or even removed

4.7 With respect to the levels of support or initial subsidy required, most technology developers presented cost evidence to advise that further support would be required if companies would see the initial development of OE as financially attractive during the early period of development and deployment.

If a modest profit margin is added to produce an Internal Rate of Return sufficient to attract the private sector investment and mitigate risk for early stage projects, then in reality at least 5 ROCs seems to be needed.

It is worth pointing out that although subsidy is sometimes regarded as a "dirty word" and the fact that renewable energy technologies need them is sometimes used to suggest they will not be commercially viable, there are probably no energy technologies that did not receive major subsidies in some form or other in their early stages of development.

4.8 Both technologists and project developers (often contained within a single company due to the nascent nature of the OE industry) outlined a number of barriers that they felt inhibited OE development.

***Permitting process**: the process to allow commercial projects in Phase 3 [RoI] is not yet functional, open or effective. Economic support mechanisms should encourage collaborative and coordinated efforts, to avoid waste and delay arising from competitive or disruptive activity – in the early period (2020).*

***Grid access**: to achieve the 500MW targets in the 2020 time horizon, support will likely be required to facilitate the connection into the TSO, both at a regulatory level (alongside the GPA), but also in terms of basic economics. Developers will not likely absorb the full combined risk and cost of 500MW of wave at the pace required to achieve the 2020 target. In the longer term, the combined ambitions of both Wind and Wave far exceeds the TSO's capacity to accept the power generated. Substantial support will be required to put in place the interconnections required to export substantial quantities (>2000MW).*

***Infrastructure**: to deliver 500MW by 2020, full scale devices will need to be delivered, deployed and commissioned on site each day. This will require substantial port, transport and vessel infrastructure. Substantial economic support should be funnelled toward developing this infrastructure, as the OE opportunity is proven.*

***Technical enablers**: in addition to the core WEC [and TEC] technology, a number of enabling technologies must be available in Ireland to support OE. For example, wet mate connectors and underwater connection units must be commercially available, with service providers operating in Ireland. Economic measures should reach beyond the core WEC and site development work.*

Utilities and Site Developers

4.9 The utilities and large site developers approached were generally most helpful and transparent in how they had developed their costs and deployment scenarios. The subsidy and aids laid out in Table 4-2 were usually transparently calculated from first principles based on real and forecast project experience (Ireland and Overseas).

4.10 A very significant and time consuming challenge at present is the raising of the large amounts of capital needed to finance the verification activity for ocean energy. Investors can rarely justify footing the bill alone for a number of reasons:

- *It is inherently experimental and there can be no guarantees the findings of such activities will pave the way for immediate commercial roll-out of the technology.*
- *Even if demonstration is successful, the path to significant revenue from energy-production is long and not within a time horizon that is of interest to many venture capital or private equity investors. In addition, early investments in demonstration activity will tend to be diluted by follow-on investment*
- *The market does not seem to be capable of valuing "technology readiness", such that investors in this verification activity can get a return on their investment through share price increases. This is not helped by the lack of accepted independent standards against which technology developers "prove" their technology objectively. Investors need specialised technical skills to assess the value of such technology and these skills are not readily available. Without these skills or standards there is a lot of confusion in the market place.*
- *A significant dedicated technical project team is required to carry out such a full-scale test and a technology development company can be left with considerable liabilities during and after the testing phase.*

4.11 It was noted by many of the developers interviewed that a capital grant mechanism should be established to get the necessary resources to technology developers in Ireland in order to progress technology through the crucial experimental verification phase. This mechanism for supporting an enhanced tariff is required to give a positive medium term outlook for co-financing investors.

The revenue stream associated with energy production from a demonstration device will have a negligible contribution to covering the overall project costs. This is due to the main focus being to demonstrate, prove and test the technology rather than maximising the output from the device as would be the priority in a commercial installation. As a result, the electricity tariff has a much lower influence on the project economics when compared with the initial capital cost.

To encourage the development of technology in Ireland, which will also encourage the creation of an Irish supply chain industry, [it is] recommended that a capital grant system is established in order to attract early developments to Ireland. Without such a step, early developments will be drawn to jurisdictions where such funding is available such as the UK and Portugal and it will be ever more difficult to reverse this trend as the industry expands with the corresponding infrastructure and knowledge base becoming geographically embedded outside Ireland. The recent Marine Renewables Proving Fund (MRPF) in the UK is a good precedent for such a scheme.

4.12 Developers also noted that the incentives currently required to develop OE could produce very large economic gains in the future.

Once the industry starts to achieve cumulative levels of deployment similar to current onshore wind (greater that 1000MW in Ireland), many billions of Euros would have been spent within the Irish economy. However, achieving these levels of activity will require incentive for the industry now, so that Ireland stands to play such a large role. By 2030, the revenue from 1000MW of installed capacity would be €300m to €400m per annum at *tariffs of €100/MWh and the industry will sustain itself with the [appropriate] support levels.*

Research and Government

4.13 A number of government departments proved very helpful in outlining the policy and regulatory framework from which the Policy, legislation and regulatory review (page 17) was derived. Additionally the present situation with regard to subsidy and state aid was clarified with regard to future possibilities for OE. In general, there were no specific current and additional plans but if additional appropriate subsidy might be required in due course a consideration could be made.

4.14 Both the Hydraulic Marine Research Centre (HMRC) Cork and NUI Galway provided very helpful knowledge to the research. In particular HMRC who have undertaken their own analysis of the likely required initial incentives to attract private finance to engage with OE development.

[HMRC] examined the staggered installation of a total of 500MW over a period of 10 years in Irish waters. The purpose of the exercise was to estimate the initial cost of the entire project over the project period, the cost of the tariff (FIT) to the consumer, and finally the profit (Net Present Value (NPV)) and internal rate off return (IRR minimum 10%) to the developer.

4.15 The conclusion of the study showed that:

- *The future cost of cash, which makes projects more expensive in the future due to inflation and interest rates, will make the use of the present tariff rate of €0.22/kWh unprofitable for projects installed in the future.*
- *O/M and insurance costs will be crucial deciders of economic viability. An increase of O/M and insurance costs from 3% to 5% will require a tariff increase to €0.42/kWh to return an IRR of 10%.*
- *Index linking the tariff rate, would necessitate the tariff to start at €0.33/kWh at 2010 to achieve a 10% IRR*
- *Keeping the tariff rate at €0.22/kWh will require initial costs of project starting from the present to be reduced to 50% of that currently estimated.*

4.16 The HMRC results quantitatively back up the comments and analysis of other OE developers.

Conclusions

4.17 With regard to the current and envisaged CAPEX and OPEX it is clear that a wider range of values exists due to the early stage of OE development and the diversity of the technologies, installation procedures, operation and maintenance philosophy and the actual sites selected. Over time these will continue to converge and reductions in costs will be aided by deployed learning and economies of scale.

4.18 The current levels of funding through the REFIT and RO to incentivise private investment in OE in RoI and NI respectively are unlikely to prove effective based on the returns expected. Suggestions for increased revenue tariffs were given, but it was generally recognised that revenue tariffs are of limited value to early stage technology development, for which a capital subsidy of some kind is likely to be required for projects to achieve financial close.

4.19 As NI sits within the UK, the current levels of funding under the NIRO and UK capital grants are more attractive and recognise the need for both capital and revenue support. However the efficacy of providing 2 ROCs per MWh was noted by developers (wave and tidal) as being insufficient in the short term. Additionally generators are exposed to fluctuations in the SEM wholesale price.

4.20 An advantage of the REFIT over the NIRO is that the generator's income is fixed by prices in long-term contracts (i.e. is not dependent on the SEM wholesale price) and therefore offsets the risk exposure, which has implications for the cost of finance.

4.21 In addition to economic incentives, most respondents stated that there are other barriers that will delay or prohibit OE develop (in terms of time delays or significant additional costs). These are: electrical grid access; permitting, consenting and licensing processes; surrounding infrastructure requirements; training and retention of suitable employees; and enabling technologies.

5: Exporting OE Electricity

Rationale for export

5.1 Recent and proposed developments could bring the opportunity to export clean ocean energy to mainland UK and Europe, which could have a profound impact on an island of Ireland OE sector. The economic benefits of export are threefold:

- Excess sustainable and low-carbon OE may be sold elsewhere rather than constrained, so that maximum value can be obtained by developers
- All Ireland OE sector can be expanded, especially if Ireland can benefit from policy mechanisms in other countries enabling export at 'true cost'
- Balancing of both OE and other less reliable sources across borders ensures greater security of supply.

Routes for export

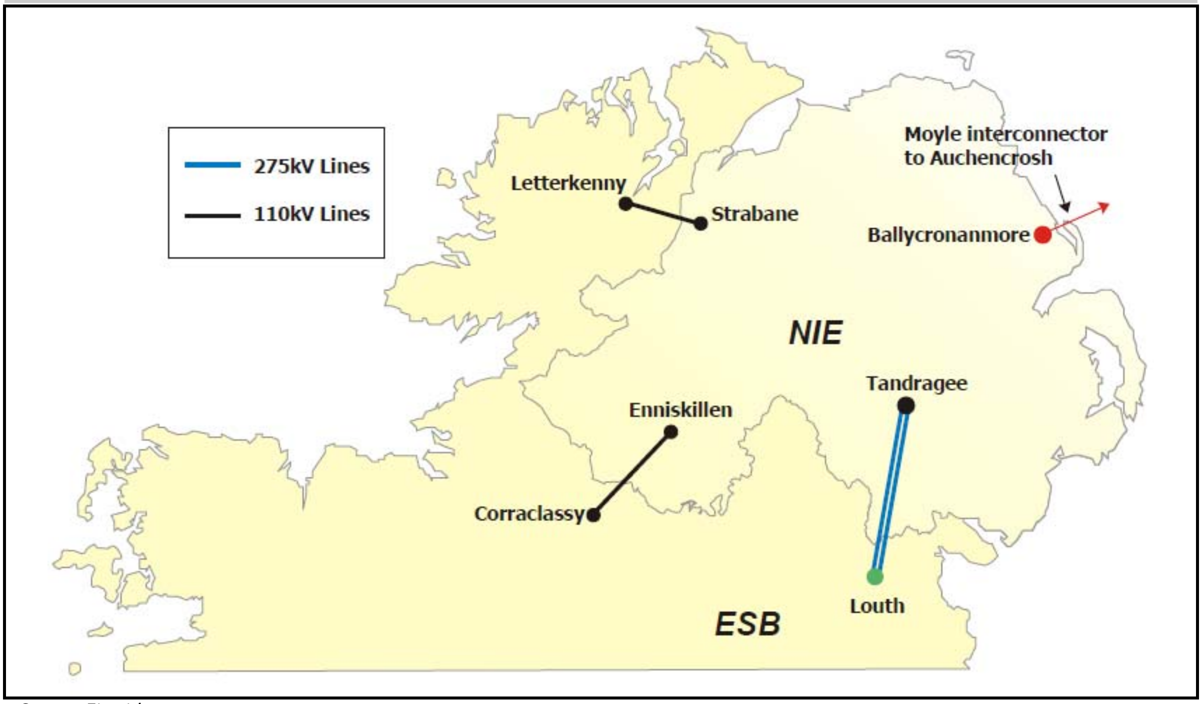
Export between the Republic of Ireland and Northern Ireland

5.2 Since the island of Ireland operates with a Single Electricity Market (the SEM) the most obvious route for export of OE would be between the two home nations, with close proximity meaning that transmission losses obtained from transferring electricity over long distances can be avoided. Historically, electricity flows have been in a North-South direction, and no South-North capacity has been purchased at auction[53].

5.3 The transmission network currently has three connection points between the Republic and Northern Ireland to enable cross-border transfers of electricity. The main interconnection, a 275kV (600 MVA) double circuit overhead line, connects Louth to Tandragee. In addition, two 110kV (300MVA) lines are in place to act as standby interconnectors so that the System Operator for Northern Ireland (SONI) and EirGrid can provide mutual short-term assistance[54]. Interconnections between Northern and the Republic of Ireland are shown in Figure 5-1. While technically, these connections are treated as interconnectors, in terms of their commercial arrangements, they are to be treated as embedded components of the transmission system so access charges applicable to other interconnectors do not apply[55].

[53] Northern Ireland Authority for Energy Regulation (NIAER) (2005) Interconnector Trading
From 1 April 2006. A Decision Paper by the Northern Ireland Authority for Energy Regulation December 2005.
[54] Commission for Energy Regulation (CER) (2010) Interconnection. Available at: http://www.cer.ie/en/electricity-transmission-network-interconnection.aspx
[55] CEER & ERGEG (European Energy Regulators): All-Island Single Electricity Market (SEM).

Figure 5-1 Interconnections between Northern and the Republic of Ireland



Source: Eirgrid

5.4 An additional connection has been proposed between the Republic and Northern Ireland. Northern Ireland Electricity (NIE) and EirGrid propose building a 400kV power line (circuit capacity of 900MW (ESB National Grid, 2006)) between the two electricity grids from Kingscourt (County Cavan) to Turleenan (County Tyrone). It is anticipated that the connection will be completed during 2012[56].

5.5 As we shall see, the current policy framework does not necessarily incentivise the practice of inter-trades due to the different policy mechanisms within the two countries (the Republic of Ireland has the REFIT, while Northern Ireland's main RE policy instrument is the Renewables Obligation). The possibility of a future European-wide policy framework which would allow Member States to count energy from renewable sources consumed in other Member States towards their own national targets, could greatly encourage export.

Exporting to Great Britain

The Moyle interconnector

5.6 The Moyle interconnector has linked the Northern Ireland and Scotland electricity grids since 2002. Historically, it has been used mainly for importing electricity into Northern Ireland rather than for export. This is reflected in the contractual arrangements applied to the interconnector. The maximum Available Transfer Capacity (ATC) for West to East export is 80MW at all times limited by Moyle's agreements for access to the GB transmission system[57]. Conversely, the maximum export from East to West consists of 450MW in the winter and 410MW during the summer period (April – October inclusive).

[56] Commission for Energy Regulation (CER) (2010) Interconnection. Available at: http://www.cer.ie/en/electricity-transmission-network-interconnection.aspx

[57] Moyle Interconnector Limited (2007) Moyle Interconnector Import Capacity/Moyle Interconnector Export Capacity – May 2007 Capacity: Invitation to Bid.

5.7 Furthermore, export to Great Britain from Northern Ireland on the Moyle interconnector has been in the past lower than the maximum ATC. For 2009, the monthly average export capacity MW allocations were as follows[58]:

- 30MW – allocated
- 50MW – not allocated (ATC not used)

5.8 Although not currently used the ATC could potentially be used in the future for OE, and if prices proved favourable or sufficient demand existed the ATC could possibly be increased. The Moyle interconnector is especially well positioned considering the nearby tidal resource potential which has been identified in the Strategic Environment Assessment (SEA) for Northern Ireland[59]. The SEA identified significant areas with a potential for tidal energy resource (within Strangford Narrows, around the Copeland Islands and Rathlin Island and off the north east coast between Fair Head and Runaby Headwave).

5.9 Even if the ATC to Great Britain is increased in the future, however, the Moyle Interconnector may not be the preferred route of exporting ocean energy: considering the amount of generation that is currently being grid connected in Scotland, there may not be sufficient demand and thus financial incentive to export. The potential from this interconnector is highly dependent on the new infrastructure, including both the reinforcements and new transmission routes that the UK is planning in order to increase the transfer capacity to England where demand lies,. Examples of the UK reinforcements required, include the proposed Western and Eastern High Voltage Direct Current (HVDC) Links between Hunterston and Deeside and Peterhead and Hawthorne Pit[60].

The East-West interconnector

5.10 The construction of a new interconnector between Ireland and Wales, which was granted planning permission in September 2009, will increase export opportunities for OE. Part funded by the EU TEN-E Initiative, the 500MW East-West interconnector will connect Dublin Region to North Wales and will be available for non-discriminatory third party access. Construction is due to start mid-2010 and will take approximately two years.

5.11 This interconnector will decrease the isolation of Ireland's electricity network and as the east end (UK) is closer to centres of demand in England, will eliminate the reliance on UK infrastructure between Scotland and England, although there are also similar issues relating to regional transmission constraints in Wales. Although, these are not as severe, power transfers may exceed network capabilities meaning that reinforcements, e.g. between Deeside and Trawsfyndd, are required.

Exporting to the rest of Europe

5.12 The possibility of developing OE export prospects from Ireland to the rest of Europe is also available using Great Britain as a transportation corridor: the East-West interconnector would indirectly open the Irish market to the wider European market. For example, in a report on meeting Ireland's energy needs post-2020, the Republic of Ireland's Joint Committee on Climate

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[58] Moyle Interconnector Limited: Moyle Capacity Allocations 2009-2010: updated 05/01/2010.
[59] DETI (2009) Offshore Wind and Marine Renewable Energy in Northern Ireland – Strategic Environment Assessment (SEA): Non-Technical Summary.
[60] Electricity Networks Strategy Group (ENSG) (2009) Our Electricity Transmission Network: A Vision for 2020.

Change and Energy Security suggested the possibility of development of a regional market which included France[61]. A selection of the most likely routes and associated initiatives for Irish OE to reach the rest of Europe are described below.

Current UK interconnections with the rest of Europe

5.13 The only current interconnection from the UK to mainland Europe is with France. The England-France Interconnector is a 2,000MW high voltage direct current (HVDC) link between the electrical transmission systems of France and Britain. Ownership is shared between National Grid and Réseau de Transport d'Electricité (RTE).

The BritNed link

5.14 An interconnector, 'BritNed', which would link Britain and the Netherlands, in a €600 million joint venture between National Grid and NLink – a subsidiary of TenneT, the Dutch transmission system operator – is also due to be constructed and operational by late 2010. The 1000MW interconnector will allow multi-directional power flows, with directions dependent on price differentials and demand patterns between the two power markets[62].

The EU TEN-E Initiative

5.15 The TEN-E initiative is a European Commission-led programme with a budget of around €20 million per year to help promote the 'interconnection, interoperability and development of trans-European networks for transporting electricity and gas' (Decision No 1364/2006/EC[63]). It should be noted that the funding is mainly for the financing of feasibility studies, and in general, the Commission argues that the market should dictate the actual construction and maintenance of European energy infrastructure.

5.16 As well as the East-West interconnector, in 2003 TEN-E funded the development and environmental permitting for a 1200MW interconnector between Easington, County Durham in the UK and Suldal, Rogaland County in Norway. While the project had stalled due to the inability to achieve agreement on the right commercial arrangements for the interconnector, the project was been given a new lease of life in 2009. National Grid and Statnett have signed a deal to explore the possibility of building the high-voltage electricity interconnector. A number of decisive issues will need to be settled by 2011 when the contract terminates, but if they are, planning and licensing applications will follow[64].

Charges for exporting ocean energy

5.17 If exporting ocean energy further afield (i.e. outside the SEM), transmission charges, especially to use the interconnectors have a significant bearing on the end-price of such electricity.

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[61] Houses of the Oireachtas, Joint Committee on Climate Change and Energy Security (2009) Meeting Ireland's Electricity Needs post-2020. Report of Public Consultation of Joint Oireachtas Committee on Climate Change and Energy Security.
[62] National Grid (2010) Interconnectors. Available at: http://www.nationalgrid.com/uk/interconnectors/
[63] European Commission (2006) Decision No 1364/2006/EC of the European Parliament and of the Council of 6 September 2006 laying down guidelines for trans-European energy networks and repealing Decision 96/391/EC and Decision No 1229/2003/EC.

[64] Joule Centre (2009) National Grid explores linking the UK and Norwegian electricity grids.

Interconnector costs

5.18 Access to most interconnectors is determined by yearly capacity auctions where bidders bid for a certain MW capacity. There are no separate 'use of interconnector' charges levied for the transit of electricity, across the Moyle interconnector, for example[65], and instead, auctions proceeds from the purchase of electricity pay for the annual operating costs of the interconnector.

5.19 Through the Moyle Interconnector, the price for the allocation of capacity at auction that could be obtained for OE from Northern Ireland may be below the price for allocation in the opposite direction from mainland UK, as evidenced by a disparity between the average import and export prices in the past. Between January 2007 and December 2009, for example, the mean price at capacity auction for export from Northern Ireland was £872.70MW/month, while the mean import price was £2,154.08MW/month[66]. The price differentials between the mean import and export prices clearly show that electrical energy imported into Ireland has a much greater value than that exported due to local demand-supply conditions.

- For the England-France interconnector auctions are held for the capacity required. The cost of transmitting electricity therefore varies, for example during January 2010 accepted bid values ranged from £0/MWh to £22/MWh depending on type and duration of contract.

Other transmission charges

Transmission charges within Republic of Ireland

5.20 Both generators and demand users (suppliers) have to pay Transmission Use of System (TUoS) tariffs in order to make use of the transmission network. Generators' TUoS are based on their Maximum Export Capacity (MEC) and on their location, while demand users' tariffs are calculated on the basis of their Maximum Import Capacity (MIC) and energy transfer[67].

Transmission charges for Northern Ireland

5.21 The TUoS charge for generators in Northern Ireland in the Single Electricity Market (SEM) was £290.07 for each MW of Generator Maximum Contracted Capacity for each monthly account period[68]. It should be noted that future generator charges are to be harmonised on an island of Ireland basis with the Republic of Ireland and thus will be locational, to be decided in 2010[69].

Other UK transmission charges

5.22 If Ireland is to export ocean energy to mainland UK and beyond, generators will also have to pay Transmission Network Use of System (TNUoS) tariffs within the Great Britain system. In the case of the Moyle interconnector, Moyle is responsible for paying these generation charges and

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[65] NIAER (2002) Auction of Interconnector Capacity on Moyle and North /South Links.
[66] Moyle Interconnector Limited (2010) Moyle Interconnector Ltd Auction Results: updated 05/01/2010.
[67] CER (2009) Determination of 2010 Transmission Allowed Revenue and Use of System Tariffs.
[68] System Operator for Northern Ireland (SONI) (2009) Statement of Charges: For Use of the Northern Ireland Electricity plc Transmission System 1st October 2009 to 30th September 2010.
[69] All Island Project (2010) Preferred Options to be considered for the Implementation of Locational Signals. Available at: http://www.allislandproject.org/en/transmission_current_consultations.aspx?article=c4fdb48e-4a1a-44d6-848d-af13746ddcb8

Moyle will pass on these charges to Moyle Interconnector Capacity Holders[70]. A similar system of Transmission Pass-Through Charges are applied for use of the England France interconnector[71].

5.23 Final generation TNUoS tariffs from Auchencrosh (location of Moyle interconnector) and South Yorks & North Wales (East-West interconnector) are shown in Table 5-1.

Table 5-1 National Grid set charges for 1st April 2009 to 31st March 2010

Tariff type	Tariff (£/kW)
Wider zonal tariff (Auchencrosh)	11.243738
Wider zonal tariff (South Yorks & North Wales)	4.197861
Local circuit tariff (mean for SPTL's network – for Moyle Interconnector)	£0.601638/kW
Local circuit tariff (mean for NGET's network – for East-West connector)	£0.661506/kW

Source: SQW Energy adapted from National Grid Data

5.24 In addition, TNUoS tariffs could include a 'Substation Local Tariff', with charges for 1st April 2009 to 31st March 2010 outlined in Table 5-2.

Table 5-2 Generation – Substation Local Tariff (£/kW) for 1st April 2009 to 31st March 2010

Sum of Typical Electricity Connection (TEC) at Connecting Substation	Connection Type	132kV	275kV	400kV
<1320 MW	No redundancy	0.135005	0.081631	0.065933
<1320 MW	Redundancy	0.304547	0.194659	0.156983
>=1320 MW	No redundancy	0	0.260591	0.210357
>=1320 MW	Redundancy	0	0.422807	0.340129

Source: National (2009) National Grid Final Generation TNUoS Tariffs 2009-2010.

Existing mechanisms allowing export at 'true cost'

The Renewable Obligation (RO)

5.25 To qualify for Northern Ireland Renewable Obligation Certificates (NIROCs), the renewable electricity must be generated in Northern Ireland, or alternatively, it can be generated in neighbouring waters but connected only to the Northern Irish grid[72]. Renewable Obligation Certificates (ROCs) and Scottish Renewable Obligation Certificates (SROCs) can also be obtained from electricity generated in Northern Ireland which is exported to Great Britain if all of the following conditions apply:

- The generating station sells the electricity through the SEM pool.

[70] Moyle Interconnector Limited (2009) Moyle Interconnecting Trading from 1 October 2009: Moyle access arrangements.
[71] NGIL and RTE (2009) Interconnexion France-Angleterre (France-England Interconnector): IFA Access Rules – Issue 7.0.
[72] The Renewables Obligation Order 2009. Statutory Instrument 2009 No. 785: Electricity, England And Wales.

- An electricity supplier purchases for the SEM Pool 'an amount of electricity (the "relevant amount") which is conveyed from a transmission or distribution system located wholly or partly in Northern Ireland to Great Britain through an electricity interconnector'.

- The supplier had previously agreed with the operator to purchase the relevant amount and supplies that amount to Great Britain[73]

5.26 Northern Ireland also can benefit from the Renewable Obligation of England and Wales and of Scotland because the schemes are linked. While the actual obligation on suppliers in Northern Ireland is lower than that for the rest of the UK[74], the scheme is effective because Great Britain suppliers may discharge the RO through the production of NIROCs. It is important to note, however, that this does not equate to the actual export of physical flows of electricity to Great Britain due to the decoupling of ROCs and electricity, each with a separate market.

5.27 Renewable Obligation Certificate prices at auction, from which Northern Ireland can benefit, have ranged between £39-£53/ROC[75]. Currently, both wave and tidal stream energy qualify for two ROCs per MWh, following the introduction of the banding regime in 2009. The UK Renewable Energy Strategy[76] included a commitment to revisiting the banding levels for wave and tidal stream.

5.28 While Northern Ireland can benefit from the RO schemes, the Republic of Ireland is at a disadvantage if it wishes to sell to the Northern Irish market. The NIRO excludes electricity generated in the Republic of Ireland, the only exception to this being if the generation is in the Renewable Energy Zone or more relevantly, in Irish (or other non-territorial UK) waters but is connected directly and only to Northern Ireland.

Renewable Energy Feed in Tariff

5.29 In the Republic of Ireland, the main tool for promoting renewable electricity generation technologies is the Renewable Energy Feed-in Tariff (REFIT) which has recently been expanded to include OE (wave and tidal)[77]. The REFIT is paid to the supplier as opposed to renewable energy generators. This means that electricity can be exported from elsewhere for consumption by the Irish market (for example, from Northern Ireland) if it is "eligible imported electricity", that is, produced from new electricity generation plant in another Member State, imported from that Member State, covered by a guarantee of origin, and that the Member State for a period of 15 years will not use that electricity to meet its own renewable energy targets[78].

5.30 Conversely, it is not possible for generators exporting elsewhere to gain directly from the Irish REFIT since to qualify, agreements to supply the electricity have to be between an electricity generator and a licensed supplier 'where the electricity is to be sold to final customers in the State [Ireland] for consumption in the State'.

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[73] The Renewables Obligation Order 2009. Statutory Instrument 2009 No. 785: Electricity, England And Wales and The Renewables Obligation (Scotland) Order 2009. Scottish Statutory Instrument 2009 No. 140: Electricity.
[74] Department of Enterprise, Trade and Investment (DETI) (2009a) Northern Ireland Renewables Obligation (NIRO).
[75] Non-Fossil Purchasing Agency Limited (NFPA)
[76] DECC (2009) The UK Renewable Energy Strategy.
[77] Department of Communications, Marine and Natural Resources (DCMNR) (2009) Renewable Energy Feed in Tariff Additional Categories (REFIT – 2009) A Competition for Electricity Generation from Anaerobic Digestion, Biomass powered high efficiency CHP , Ocean Energy and Offshore wind energy.
[78] DCMNR (2006) Renewable Energy Feed in Tariff (RE-FIT - 2006): A Competition for Electricity Generation from Biomass, Hydro and Wind.

5.31 With regard to REFIT eligible OE: the OE must be new plant neither built nor under construction on 1st of June 2008, but built and operational by 2020. The support for any particular project cannot exceed 15 years and may not extend beyond 2030. [79] Therefore to currently gain the full 15 year REFIT support lifetime it is necessary that OE projects are operational by 2015[80].

Climate Change Levy (UK)

5.32 The Climate Change Levy (CCL) is a tax levied on the supply of commodities such as electricity, gas and coal, and charged by energy suppliers to final business consumers. OE and other renewable generation is exempt from the tax and for each MWh produced, a Climate Change Levy Exemption Certificate (LEC) is awarded. These Certificates are required by suppliers to show that they are supplying renewable electricity for the purposes of the CCL. The nominal value of a LEC is £4.70/MWh (the rate at which electricity is currently charged under the Climate Change Levy[81]), though this may not be the price in reality agreed by a renewable generator and supplier.

5.33 Generators can benefit, provided that they can prove that the electricity will be consumed in the UK: "the amount of a supply of renewable source electricity is to be calculated at the point at which such electricity is first delivered from a generating station to a distribution or transmission system within the United Kingdom"[82]. This means that OE generators may be awarded LECs for export to Great Britain (in the case of Northern Ireland) and the whole of the UK (for the Republic of Ireland).

Renewable Energy Guarantee of Origin (REGOs)

5.34 The European Renewable Energy Directive 2009 mentions Renewable Energy Guarantee of Origin certificates (REGOs) which have the purpose of proving to a customer that a given amount of energy was produced from renewable sources. Unlike national green certificates used for support schemes, against which the European Directive explicitly distinguishes guarantee of origin certificates, REGOs will generally be used to fulfil green credentials but will have little explicit value as there is no foreseeable European market for renewable energy[83].

Potential mechanisms allowing OE export at 'true cost'

Possible changes to the Renewable Obligation

5.35 The Renewable Energy Strategy[84] contained the suggestion to extend the Renewable Obligation to power stations outside the UK. If this were to happen, OE produced in Republic of Ireland waters might benefit from the UK RO.

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[79] Renewable Energy Feed in Tariff, Additional Categories (REFIT – 2009) A Competition for Electrcity Generation from Anaerobic Digestion, Biomass powered high efficiency CHP, Ocean Energy and Offshore wind energy, available at: http://www.dcenr.gov.ie/NR/rdonlyres/3B13ECAA-9351-41E0-8B44-7C02E98E4F50/0/AdditionalREFITcetegories.pdf
[80] Work is however ongoing with the EC in Brussels to re-approve the REFIT post 2015.
[81] Ofgem (2010) Climate Change Levy: Renewables Exemption. Available at: http://www.ofgem.gov.uk/SUSTAINABILITY/ENVIRONMENT/CCLRENEXEM/Pages/CCLRenewablesExemption.aspx
[82] The Climate Change Levy (General) Regulations 2001.
[83] Nilsson, M., Nilsson, L., and Ericsson, K. (2009) 'The rise and fall of GO trading in European renewable energy policy: The role of advocacy and policy framing', Energy Policy, Vol. 37, No 11, pp. 4454-4462.
[84] DECC (2009) The UK Renewable Energy Strategy.

5.36 Following a consultation, where only half of the respondents were in favour, it was decided that a decision regarding this issue should be postponed, with further consultation to take place in 2010[85]. If this is to be carried forward, and although the full details are not clear, it is likely that the UK approach will be in line with potential trading arrangements across Europe. (The UK is currently working with the European Commission to establish a European framework for trading across Member States.) It was also proposed in the last consultation to limit eligibility to generators with a direct connection to the UK, although it was suggested that this may not be the most efficient way to run the scheme.

EU cooperation mechanisms

5.37 The EU Renewable Energy Directive of 2009 on the promotion of the use of energy from renewable sources contains many high level suggestions for developing the international market for renewable energy sources, including export prospects. Although, there has yet to be any firm commitment to signing up to these 'cooperation mechanisms', which are at this time optional, they could become more important in the future for Member States to reach their renewable targets.

5.38 The optional mechanisms are intended to:

- facilitate the consumption in Member States of energy produced from renewable sources in other Member States
- enable Member States to count energy from renewable sources consumed in other Member States towards their own national targets (Directive 2009/28/EC[86]).

Statistical transfer

5.39 Irish OE could benefit, for example, from 'flexibility measures' such as the statistical transfer mechanism. Through this mechanism, Ireland could benefit financially from statistically transferring renewable energy to another member state to be used for the latter's target. This could only be done if it did not prevent Ireland or the UK from fulfilling their own renewable energy targets.

5.40 This is far from the mandatory Europe-wide certificate trading scheme which was originally being considered by the European Commission, but was criticised because it may have endangered existing successful national support mechanisms[87]. Nevertheless, if Ireland decides to enter into these kinds of arrangements with other Member States, it could have a comparable effect as a single European green certificate market.

5.41 Some countries have already suggested their willingness to make use of 'flexibility measures' in order to meet their targets, including Ireland, Belgium and the Netherlands, although the latter is only on a contingency basis as it does not expect to have a shortfall[88].

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[85] Department of Energy and Climate Change (DECC) (2009) Government Response to the 2009 Consultation on the Renewables Obligation.
[86] European Commission (2009) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.
[87] European Renewable Energy Council (EREC) (2007) Providing Flexibility for Member States to meet the renewable energy target.
[88] European Commission (2010) Renewable energy – Forecast documents.

Summary of current status

5.42 The continued liberalisation of the European energy sector would seem to be the key to developing a cross-border Europe-wide market for renewable energy. The intermittency of a greater proportion of renewables in any single European state will make it increasingly difficult for the system operator to balance supply and demand at a local level, but additionally such a Europe-wide market would allow generation and consumption of the most efficiently produced renewable energy. OE from the island of Ireland's excellent resource could prove particularly effective in terms of an island of Ireland export opportunity in such a market.

Table 5-3 Examples of the main current costs and possible value of OE in various states

Destination	Cost-benefit factor	Cost	Benefits
Republic of Ireland	Generation TUoS (ROI[89])	€0 to €100.225/MW/month	
	Renewable Energy Feed-in Tariff (OE REFIT)		€220/MWh (15 years)
	Approximate Local Value[90] (€/MWh)	*€219.6/MWh to €220/MWh*	
Northern Ireland	Generation TNUoS (NI)	£290.07/MW/month	
	Wholesale electricity price (SEM)		€30-50/MWh
	Renewable Obligation (only if the ocean energy generation in Republic of Ireland waters is connected solely to Northern Ireland and not to ROI)		£92.50/MWh (£46.25 per ROC x2 – may be x3-5 in Scotland until 2037)
	Climate Change Levy		£4.70/MWh
	Approximate Local Value[91] (£/MWh)	*£126.1/MWh to £146.1/MWh*	
Great Britain	Generation TNUoS (GB)	£11.24/kW (wider zonal tariff[92]) £0.60/kW (local circuit tariff) £0.78/kW (substation[93])	
	Wholesale electricity price		£25-45/MWh
	Renewable Obligation (only if the ocean energy generation in Republic of Ireland waters is connected solely to Northern Ireland and not to ROI)		£92.50/MWh (£46.25/ROC x2 – may be x3-5 in Scotland until 2037)
	Climate Change Levy		£4.70/MWh
	Approximate Local Value[94] (£/MWh)	*£118.1/MWh to £138.1/MWh*	

[89] http://www.cer.ie/en/electricity-transmission-network-decision-documents.aspx?article=9d48e678-f247-457f-8d2e-44fb30d1337c
[90] Assumes an OE load factor of 35% and 730 hours in a month.
[91] Assumes an OE load factor of 35% and 730 hours in a month.
[92] Varies depending on demand and supply: the quoted figure is for Auchencrosh - Moyle Interconnector landing
[93] http://www.nationalgrid.com/NR/rdonlyres/0782D36F-3270-4FC2-9787-5B8EDA358441/31610/NoticeofTNUoSTariffs2009_10.pdf

Interconnectors	Moyle interconnector access (capacity) charge	Auction, but historical average data for last 2 years £872.70 /MW/month	
	England-France interconnector access (capacity) charge	Varies widely but last 2009 average around €420/MW/month[95]	

Table 5-4 Example cost & benefit categories and the possible value of exporting OE from NI and/or RoI

Origin	Destination	Via	Summary of Charges[96]	Summary of Benefits
Republic of Ireland	Northern Ireland (NI)	-	Generation TUoS (RoI) + Generation TNUoS (NI)	Wholesale electricity price + Climate Change Levy Exemption + ROC if solely connected to NI
	Great Britain (GB)	-	Generation TUoS (RoI) + East-West Interconnector Charges + Generation TNUoS (GB)	Wholesale electricity price + Climate Change Levy Exemption + ROC if project solely connected to NI
	Great Britain	NI	Generation TUoS (RoI) + Generation TNUoS (NI) + Moyle Interconnector Charges + Generation TNUoS (GB)	Wholesale electricity price + Climate Change Levy Exemption + ROC if project solely connected to NI
	France	GB	Generation TUoS (RoI) + East-West Interconnector Charges + Generation TNUoS (GB) + England-France Interconnector Charges	Wholesale electricity price + Any RE price premium
	Netherlands (TBC)	GB	BritNed not yet complete	
Northern Ireland	Republic of Ireland (RoI)	-	Generation TNUoS (NI) + Generation TUoS (RoI)	REFIT
	Great Britain (GB)	-	Generation TNUoS (NI) + Moyle Interconnector Charges + Generation TNUoS (GB)	Wholesale electricity price + Climate Change Levy Exemption + ROC
	France	GB	Generation TNUoS (NI) + Moyle Interconnector Charges + Generation TNUoS (GB) + England-France	Wholesale electricity price + Any RE price premium

[94] Assumes an OE load factor of 35% and 8760 hours in a year.
[95] http://clients.rte-france.com/lang/an/visiteurs/vie/interconnexions/all_histo/enchere_RU_daily.jsp?codePays=RU&type=daily
[96] The Regulatory Authorities have issued a decision that in the SEM TUoS charges for Generators shall be locational to reflect the usage of the All Island Transmission Networks.

Origin	Destination	Via	Summary of Charges[96]	Summary of Benefits
			Interconnector Charges	
	Netherlands (TBC)	GB	BritNed not yet complete	

Source: SQW Energy

5.43 Any Europe-wide market for RE will also require greater electrical interconnection, particularly from the peripheries of the region where the best resources often exist. Lately the idea of a European 'super-grid' to achieve this has gained attention. Various super-grid concepts have been proposed, the main advantages being in terms of ensuring security of supply and creating such a market. The challenges faced are however great and include: technical and engineering difficulties; regulatory and harmonisation of grid codes; and the financial implications of development.

6: Modelling OE Development and Deployment

Introduction

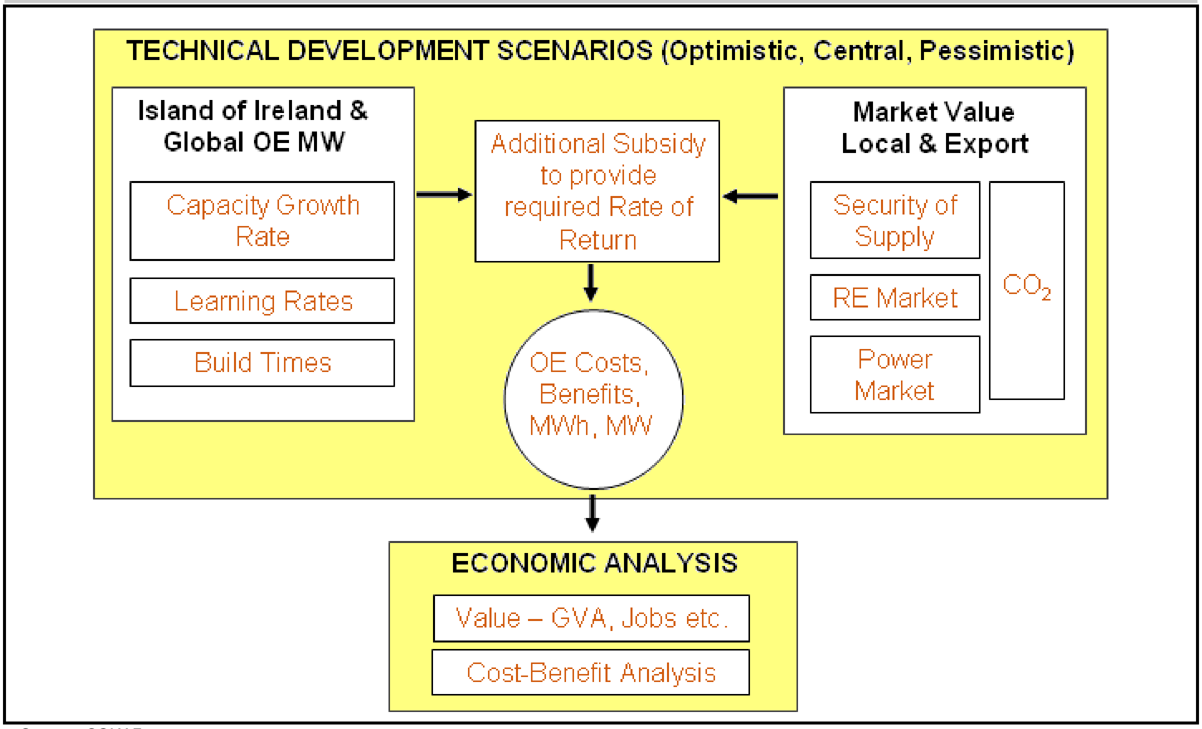
6.1 Determining the likely technology development, deployment and utility uptake to thereby determine the installed capacity of OE in the Island of Ireland presents a number of challenges, namely:

- All OE technologies are currently at best single development prototypes with a few years of operational experience.
- The rate of development and deployment of what is currently a subsidised industry is not set by the market, however investors are willing to take a certain level of risk based on the massive global OE resource and continuing demand for energy, particularly that which is sustainable and low-carbon.

Cost and production data

6.2 Forecasting the future cost and therefore production and uptake of OE devices necessitates use of the data captured during the literature review and from the Stakeholder consultations. Figure 6-1 describes graphically how the technical development and deployment scenarios (top box in diagram) are used to calculate the installed OE capacity (MW), OE outputs (MWh) and additional subsidies required. These parameters will later be used in the economic analysis.

Figure 6-1 Overview of OE technical development, deployment and capacity methodology



Source: SQW Energy

6.3 Both the Literature Review (Ocean Energy: Potential and Progress on page 8) and the Expert Consultation (page 29) returned a very wide range of cost and production estimates. As would perhaps be expected in the early days of any industry such variables are somewhat uncertain. Three technical development and deployment scenarios (pessimistic, base, optimistic) were therefore developed to specifically cover the variations in costs, the decrease in costs with production (learning rates) and the potential capacity growth rate which is a proxy for market 'appetite' for OE development and deployment. The main parameters and values chosen for the scenarios are detailed in Table 6-1 and Table 6-2 and are further described below.

Optimistic OE technical development and deployment scenario

6.4 The optimistic development and deployment scenario is based on capacity growth rates meeting the island of Ireland 2020 OE targets: 500MW of marine in the Republic of Ireland[97], and 200MW of tidal energy in Northern Ireland based on some of the optimistic scenarios (5 & 6) presented in the All Island Grid study[98]. These levels of installed capacity would be a dramatic achievement when compared with the existing OE capacity, grid infrastructure limitations and supply chain bottle-necks. The variables used to achieve this are optimistic and outlined in the tables below.

Central OE technical development and deployment scenario

6.5 The central development scenario is based purely on the existing plans for deployment and central estimates of the likely costs, learning and capacity growth rates inferred from other technologies and explained further in a section below.

Pessimistic OE technical development and deployment scenario

6.6 The pessimistic development and deployment scenario is based on the higher costs, lower production, and more pessimistic growth and learning rates.

6.7 Although more pessimistic scenarios could have been developed, there was little point within the study timeframe (to 2030) as the resulting economic value produced is significantly negative and any investment would not have been forthcoming even from a relatively early stage were this to happen.

Table 6-1 Basic modelling parameters for wave energy

Variable	Unit	Pessimistic	Central	Optimistic	Comments
Initial CAPEX	€/kW	5,000	4,500	4,000	Based on literature review and industry consultation (calculated from returns of actual estimated capital project costs without one-off early stage environmental appraisals etc.)
Minimum CAPEX (2030)	€/kW	1,500	1,250	1,000	Based on literature review and industry consultation
Initial OPEX	% of CAPEX	4	3	2	Based on literature review and industry consultation
Minimum OPEX	% of CAPEX	4	3	2	Based on literature review and industry consultation. Does not reduce over time

[97] DCMNR: Government White Paper - Delivering a Sustainable Energy Future for Ireland, 2007.
[98] DCENR and DETI: All Island Grid Study, Workstream 1, Renewable Energy Resource Assessment, January 2008.

Variable	Unit	Pessimistic	Central	Optimistic	Comments
					as CAPEX is already reducing.
Initial Project Hurdle Rate	% (pre tax)	12	10	10	Based on literature review and industry consultation
Final Project Hurdle Rate	% (pre tax)	10	8	7	Based on literature review and industry consultation
Project Build Time	Years	2.5	2	2	Based on literature review and industry consultation
Project Financial Lifetime	Years	20	20	20	Based on literature review and industry consultation
Physical Lifetime	Years	20	25	25	Based on literature review and industry consultation
Learning Rate	%	10	12.5	15	% reduction of costs associated with a doubling of capacity (MW)
Threshold for Learning Rate to begin – linear capacity growth	MW	10	5	5	Initial MW of experimental plant required before learning rate begins
Period of linear capacity growth	Years	4	3	2	Years in which experimental plant converges and/or learning begins in earnest.
Capacity Growth Rate	%increase per annum	30	35	40	Rate at which installation of renewables has been previously witnessed for other technologies
Load Factor	%	30	35	35	Although varying by development stage and site characteristic, this defines the basic measure of energy production as a percentage of maximal possible energy production

Source: SQW Energy

Table 6-2 Basic economic modelling parameters for tidal energy

Variable	Unit	Pessimistic	Central	Optimistic	Comments
Initial CAPEX	€/kW	5,000	4,500	4,000	Based on literature review and industry consultation
Minimum CAPEX (2030)	€/kW	1,500	1,250	1,000	Based on literature review and industry consultation
Initial OPEX	% of CAPEX	5	4	3	Based on literature review and industry consultation
Minimum OPEX	% of CAPEX	5	4	3	Based on literature review and industry consultation. Does not reduce over time as CAPEX is already reducing.
Initial Discount Rate	% (pre tax)	12	10	10	Based on literature review and industry consultation
Final Discount Rate	% (pre tax)	10	8	7	Based on literature review and industry consultation
Project Build Time	Years	2.5	2	2	Based on literature review and industry consultation

Variable	Unit	Pessimistic	Central	Optimistic	Comments
Financial Lifetime	Years	20	20	20	Based on literature review and industry consultation
Physical Lifetime	Years	20	25	25	Based on literature review and industry consultation
Learning Rate	%	10	12.5	15	% reduction of costs associated with a doubling of capacity (MW)
Threshold for Learning Rate to begin – linear capacity growth	MW	10	5	5	Initial MW of experimental plant required before learning rate begins
Period of linear capacity growth	Years	5	4	3	Years in which experimental plant converges and/or learning begins in earnest. Tidal also reflects greater environmental sensitivity in delaying capacity growth.
Capacity Growth Rate	%increase per annum	30	35	40	Rate at which installation of renewables has been previously witnessed for other technologies
Load Factor	%	30	35	35	Although varying by development stage and site characteristic, this defines the basic measure of energy production as a percentage of maximal possible energy production

Source: SQW Energy

OE capacity predictions

6.8 It must be noted that learning rates and capacity growth rates although interlinked are not the same. Learning rates reflect cost reductions, while capacity growth rates predict or record the actual installed capacity at any point in time.

6.9 The Gross Value Added methodology requires that the island of Ireland and global installed OE capacities are predicted in order to derive the employment within the sector. From these predictions, the costs, benefits and economic evaluation may then be derived.

Learning rates

6.10 Technology learning rates attempt to quantify the cost evolution of a technology as it matures and improves. A learning rate is often set as a percentage cost reduction with each doubling of capacity. For example, Table 6-3 summarises a number of studies undertaken to quantify the percentage learning rate of onshore wind technology. The learning rate is likely to be driven by a number of factors:

- Economies of scale in production, deployment and operation
- Learning and technology improvement in knowledge by doing
- Improvement in investment and financial, management and terms
- More efficient regulation with fewer associated risks
- Deployment experience and bespoke tooling

Table 6-3 Learning rates for onshore wind

Country	Time Period	Learning rate (%)	Performance measure	Experience measure	Source
EU	1980-1995	18	Production cost ($/kWh)	Cumulative Production (TWh)	IEA (2000)
Germany	1990-1998	8	Investment cost ($/kW)	Cumulative Capacity (MW)	IEA (2000)
Denmark	1982-1997	8	Investment cost ($/kW)	Cumulative Capacity (MW)	IEA (2000)
OECD	1981-1995	17	Investment cost ($/kW)	Cumulative Capacity (MW)	Kouvaritakis (2000)
California	1980-1994	18	Production cost ($/kWh)	Cumulative Production (TWh)	Loiter & Bohm (1999)
Germany	1990-1998	8	Investment cost ($/kW)	Cumulative Capacity (MW)	Durstewitz (1999)

Source: SQW Energy

6.11 The scenarios utilised within the economic model use an optimistic, base and pessimistic learning rate for OE based around the above figures.

6.12 It is also noted that for many technologies there is an initial period of experimentation with various rather diverse concepts before some form of technical convergence to an efficient concept becomes apparent. This neither infers that OE has currently converged, nor that no new and improved concepts can appear subsequent to any deemed convergence. To reflect the need for experimentation and learning by doing, a linear period of capacity growth is embedded in the initial OE capacity during which time there is a gradual convergence to production of the core efficient concepts and delivery - so that the cost reduction according to the learning rate can begin.

Capacity Growth Rates

6.13 In future it is envisaged that OE will be cost competitive with other forms of electricity generation, but for now it is an embryonic industry supported by public and private subsidy in the hope that it will eventually produce a good return.

6.14 At present therefore, the installed OE capacity is too small and there exists no mainstream market by which to infer future growth rates, however as witnessed with almost all other electricity generation technologies (gas turbines, nuclear, wind, etc.) the ensuing cost reductions through learning by doing encourage market uptake and installed capacity grows rapidly with declining cost. The focus is therefore on the technology developers to install the initial small levels of capacity (often with some utility help) to ascertain viability.

6.15 Following the initial technology development and as OE becomes commercial, it will require a period of further proving before financial risk is sufficiently reduced and uptake is large: i.e. the 'Utility appetite' will depend on return to shareholder.

6.16 There are likely to be incremental steps in installed capacity, but initially these are most normally small and at a low volume; increasingly large as the technology is proven and at a medium volume, and possibly very large once thoroughly proven. All of these incremental steps sum to the general uptake trend which has often been approximated and witnessed as some kind of exponential curve for a successful technology.

6.17 A 'Capacity Growth Rate' has therefore been introduced which deems what the likely year on year percentage increase in OE capacity will be once the learning curve begins. The capacity growth rates chosen are 30%, 35% and 40%. These approximate figures reflect respectively: 30% - the average capacity growth rate of Irish onshore wind 1992-present; 35% - the average uptake of wind during the past decade in the UK; and 40% - the average global onshore wind capacity growth rate since 1980. Both onshore wind and offshore wind statistics have been used as the installed capacity is likely to be proportional to utility appetite and most limiting factors should apply fairly equally to both on and off-shore projects (grid, finance, resource etc.).

Project lifetimes: build, operation, finance

6.18 The manufacturing of the current generation of OE devices have been mainly undertaken as bespoken projects of up to 3 devices. Most of these devices to date have been experimental, prototype or pre-production prototype and thus build times are somewhat greater than those likely for full production. However, it must be noted that the actual build time is not the significant contribution to the overall project development time, which up to now has been most often dominated by environmental concerns, consenting and survey. Project 'build' or development times are thus modelled as between 2 and 2.5 years.

6.19 As no OE device has been in the water for more than a few years the initial operational lifetimes are as yet unproven. The operational project lifetimes are therefore derived from the range of design lifetimes promoted by manufacturers and developers. Those from reputable practiced technology developers and utilities range from 15 to 25 years.

6.20 The financial lifetimes for OE devices or projects are unlikely to be greater than the physical lifetime associated with any project, but are normally taken to be 20 years. It is however likely that the ancillary investments such as sub-sea electrical cables would have lifetimes of up to 50 years and hence re-powering of sites is likely to occur at reduced financial 'project cost' after the initial financial lifetime. This has been witnessed in the onshore wind industry.

Predicting the development and deployment of OE

6.21 Figure 6-1 described the basic methodology for predicting the installed OE capacity, the cost to do this, and the benefits associated with the electricity produced. The following chapter outlines how these OE installed capacity or technical development and deployment scenarios (pessimistic, central, and optimistic) are evaluated according to their costs and benefits.

7: The Economic Model

7.1 This section of the report outlines the methodology used and explains the calculations behind each step of the economic impacts portion of the island of Ireland Ocean Energy Model.

7.2 These impacts are estimated for the wave and tidal sectors separately, but both in Euros for consistency and comparability. The economic impacts of the OE industry will for the first time therefore be calculated for the island of Ireland. The most likely deployment and development scenarios at present infer that the better or more commercial tidal resource is located in Northern Ireland, and the majority of the most efficiently captured wave resource is situated around the coastline of the Republic of Ireland.

7.3 The economic impact methodology converts the estimated wave and tidal energy (OE) output associated with the learning rates and capacity growth rates to estimate the required government support, net employment and net GVA impacts for both the Republic of Ireland and Northern Ireland. It should however be noted that a number of important factors impact on these calculations:

- There is currently no mature representation of a wave or tidal industry, hence actual economic data (GVA and jobs) for such an industry must be inferred from surrounding and similar sectors, e.g. general manufacturing, energy production etc.
- The Single Electricity Market (SEM) allows the trade of electricity within the island of Ireland, however it is possible that in future locally produced RE including OE might contribute to meeting electricity demand in countries to which Ireland is directly (GB) or indirectly interconnected (Continental Europe). Neither a pan European wholesale electricity, or RE, market currently exists, therefore presently the benefits of exporting OE are sub optimal. The base case economic modelling for the Irish OE electricity export scenarios are in line with those described as current in Chapter 5: Exporting OE Electricity, while in the optimistic cases unconstrained Irish OE export is allowed if the tariffs prove attractive.
- The economic value of Ocean Energy in Ireland, particularly to the OE development, technology, servicing and operating sectors, is inextricably linked to the global development and deployment of OE. This is particularly so with regard to the market for OE technology and the learning rate that will be borne on the back of global installation, which even if no export value to the island of Ireland was derived, would still deliver lower cost OE for the home market. Conversely should the island of Ireland be able to capture and supply a significant portion of an emerging world market, the potential economic benefits to Ireland are likely to rapidly accrue.

7.4 The final point above recognised that the island of Ireland could benefit significantly through the provision of products and services to any global OE market. To reflect these possible opportunities within the three core technology development and deployment scenarios (optimistic, central and pessimistic), the model introduces 3 further sub-scenarios for the potential economic impact for Ireland arising from:

- **Whale** – Irish companies have a fully-featured supply chain based on current and projected island of Ireland capabilities[99]. The majority of services and products are locally produced with a good proportion of the global export market.
- **Shark** – Irish companies possess elements of the supply chain and this expertise is mirrored in a small proportion of the global OE export market captured by the island of Ireland.
- **Minnow** – Irish companies are active only in local installation and maintenance. There is a minimal proportion of the global market serviced from Ireland.

(Table 7-4 and Table 7-5 later describe the proportions of jobs related to each of the market size scenarios.)

7.5 The over-arching elements of the cost benefit analysis are outlined in Table 7-1. Each major element is then described below.

Table 7-1 Major elements of the cost-benefit analysis

Cost-Benefit Element	Category	Comments
Economic Development	Benefit	Jobs created and the associated GVA Wider economic development impacts as reflected in displacement, leakage, multipliers, etc.
Carbon Savings	Benefit	Value of avoided carbon emissions
Security of Energy Supply	Benefit	Impact in terms of GDP saved and wider impacts on competitiveness
Consumer – 'subsidy'	Cost	Difference in total energy costs over existing generation

Source: SQW Energy

Economic development – job based valuation method

7.6 The development of an OE industry in the Republic of Ireland and Northern Ireland is expected to provide a benefit to both economies through the creation of additional jobs (direct and indirect) and additional investment monies from outwith the area.

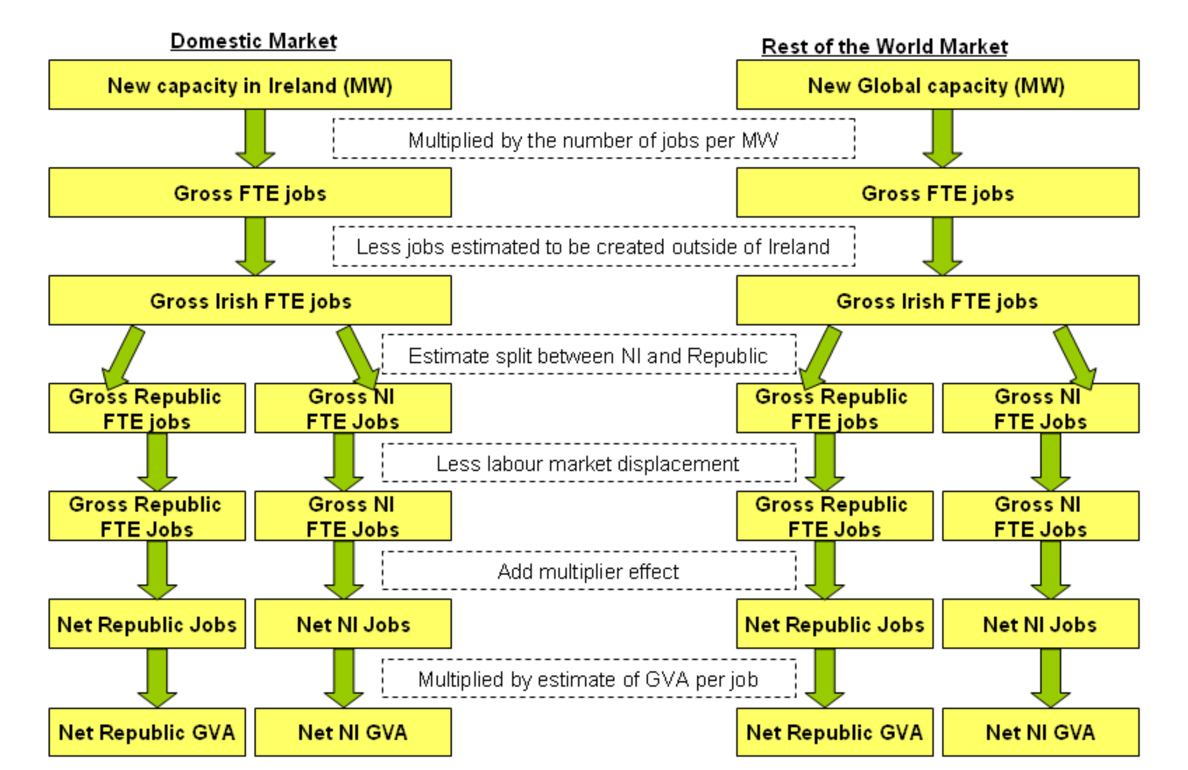
7.7 The two key measures of economic impact using this method are:

- Net full time equivalent (FTE) Job Years - for example, 10 FTE job years could represent one Full Time Equivalent (FTE) job for ten years, ten FTE jobs for a single year, or a combination in between
- Net Gross Value Added (GVA) - the total value of goods and services produced by the economy minus the value of goods and services used to produce the final products.

[99] Refer to the RPS report: Engineering & Specialist Support Requirements for the OE Sector, 2009. For example, secondary activities and sectors not directly connected to OE such as mineral extraction and processing, chemicals, banking and communications etc. are more likely to be geographically dispersed, whereas activities directly connected to OE design, servicing, manufacturing (industrial machinery, electrical machinery, metal fabrication etc.), installation, operation and maintenance, and transport could have high local content.

7.8 The economic impact model converts the estimated wave and tidal energy output into estimates of net employment and net GVA impacts for both the Republic of Ireland and Northern Ireland. This section of the report outlines the methodology used and explains the calculations behind each step of the model. Figure 7-1 provides a visual overview of the methodology used. This methodology has been applied to both the tidal and wave industries.

Figure 7-1 Overview of OE economic impact model



Source: SQW Energy

Estimating the total gross number of jobs

7.9 The first stage is to identify the amount of new OE capacity (in MW) that any new support will generate. This is explained in the previous chapter.

7.10 In order to convert the installed capacity into jobs, it is necessary to estimate the number of jobs per MW of energy generated. For both wave and tidal it is assumed that in the early industry there would initially be 15 FTE jobs per MW and that the number of jobs per MW would fall over time in line with the rate of reduction in levelised cost by using the same learning rate. The three learning rates used state that for every doubling of installed global capacity, the levelised costs (and FTE employment per MW) would fall by the following percentage depending on the scenario used:

- optimistic – 15 %
- central – 12.5 %
- pessimistic – 10 %.

7.11 It was also assumed that once the global industries had reached maturity, the number of jobs would fall no lower than 5 FTE jobs per MW.

7.12 In order to estimate how these FTE jobs were split between the various sub-sectors of the wave/tidal industry[100], the proportional split used by Bain[101] for offshore wind were used as an initial estimate. However, the operations and maintenance proportional share of employment used by Bain was increased from 4% to 10% (as per the stakeholder feedback) to reflect the greater technical difficulties associated with keeping wave and tidal machinery operational compared to wind turbines. Subsequently, the jobs per MW at each of the other stages were slightly reduced. Table 7-2 shows the initial number and final jobs per MW for each of the five project stages [102].

Table 7-2 Estimated FTE job years per MW for each project stage

Jobs, FTE/MW	Bain, offshore wind jobs per MW	Bain, offshore wind %	% updated	Initial jobs per MW	Final jobs per MW
Planning and development	1.2	9.0%	8%	1.1	0.4
Design and services	2.0	14.9%	14%	2.0	0.7
Manufacture and assembly	6.3	47.0%	46%	6.8	2.3
Construction, commissioning	3.3	24.6%	24%	3.5	1.2
Operation and maintenance	0.6	4.5%	10%	1.5	0.5
Total	**13.4**	**100%**	**100%**	**15.0**	**5.0**

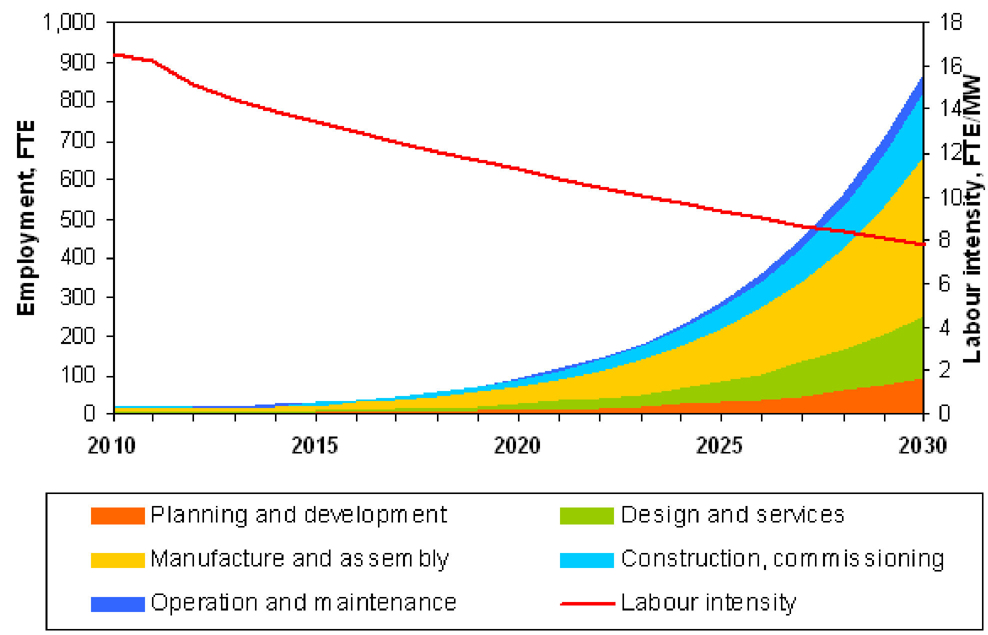
Source: SQW Consulting

7.13 Multiplication of the jobs per MW estimate by the MWs of capacity produced provides the total gross FTE jobs for each year for both wave and tidal.

7.14 Figure 7-2 depicts the additional net jobs calculated for each project component for an example modelling scenario.

[100] Sub-sectors: planning & development; design and services; manufacture and assembly; construction and commissioning; and operation and maintenance.
[101] Bain & Co. for BWEA, 2008: 'Skills and employment in the wind, wave and tidal stream industries' Available at: http://www.bwea.com/pdf/publications/Bain%20Brief_Wind%20Energy%202008_FINAL.pdf
[102] Although the jobs/MW figures are relatively uncertain due to the early stage of OE, a secondary approach valuation is outlined in the later section 7.39: Economic valuation - alternative valuation method.

Figure 7-2 Labour intensity and net additional employment for a pessimistic wave scenario



Source: SQW Energy

Estimating the total net number of jobs

7.15 In order to identify the level of additional employment - or the number of jobs which could occur over and above what would take place anyway - it is necessary to identify the net employment impact. This involves applying a number of factors to the estimates gross employment impacts. These factors explained in depth below include:

- deadweight
- displacement
- leakage
- multipliers.

7.16 This section will explain each of these concepts and discuss the assumptions and evidence used for each factor in the economic impact modelling.

Deadweight

7.17 Even without government support, it is likely that there would be some employment in the tidal and wave industries. This employment is known as deadweight (the gross direct effects which would occur even without government intervention) and cannot be counted as additional benefit arising from the new subsidy since it would have happened anyway.

7.18 It is assumed that neither the wave nor tidal industries in Ireland will develop significantly without government subsidy to support the industries in their infancy. Therefore, there is zero deadweight. In other words, all employment in the wave and tidal industries in Ireland is credited to the government support mechanism.

Displacement

7.19 Displacement is the proportion of intervention benefits that are accounted for by reduced benefits elsewhere in the target area. In this case, displacement would involve identifying how increased output and employment in the tidal and wave industries would affect other elements of the island of Ireland's employment market.

7.20 At this stage, the extent to which the development of wave and tidal industries in Ireland would affect employment in other sectors is unknown. However, it is possible to assume that the level of displacement will be different for the domestic and overseas market. If companies which had previously concentrated on the domestic market are, as a result of the new government support, able to sell their goods and services into the overseas wave and tidal markets, it is reasonable to assume that another Irish company will 'fill the gap' in the domestic market that is left behind. Therefore, the level of displacement of the Irish labour market is estimated to be low. Additionality guidance published by English Partnerships suggests a ready reckoner for low displacement of 25%. Therefore, we would expect that 75% of jobs associated with servicing the overseas wave and tidal industries could be counted.

7.21 For the domestic market, any new support mechanism should result in a high proportion of the goods and services needed (from planning and development through to operation and maintenance) being provided by local companies. In this case, Irish companies will, in the main, be competing against each other for the new work and therefore the employees needed to do the work. So for the domestic market, the level of displacement will be higher. The additionality guidance published by English Partnerships suggests a ready reckoner for medium displacement of 50%. Therefore, we would expect that 50% of jobs associated with servicing the domestic wave and tidal industries could be counted[103].

7.22 These values are assumed to hold across the five employment sub-sectors of both the wave and tidal industries and across each of the scenarios.

Table 7-3 Proportion of jobs that are displaced as a result of the new wave and tidal industries

	Planning & development	Design & services	Manufacture & assembly	Construction & commissioning	Operation & maintenance
Domestic market	50%	50%	50%	50%	50%
Overseas market	25%	25%	25%	25%	25%

Source: SQW

Leakage

7.23 Leakage is the proportion of outputs that benefit those outside of the intervention target area. In the case of government support for the island of Ireland wave and tidal industries, it needs to be recognised that the available support may result in firms outwith Ireland entering the market. This 'non-Irish' employment does not contribute to the island of Ireland's economy and therefore needs to be discounted from any measure of the net benefits.

7.24 The economic impact model has estimated leakage using a two stage process. Firstly, for both the domestic market and export market, an estimate of the proportion of jobs which will be located outwith the 'island of Ireland' needs to be made. Secondly, an estimate of regional

[103] For example, there may be some displacement of onshore or offshore wind from accessing the grid under the gate process.

leakage is made by looking at the split of employment between Northern Ireland and the Republic for each sub-sector of the wave and tidal industries.

Estimating the total number of 'island of Ireland' jobs

7.25 Not all employment associated with the wave and tidal industries in the island of Ireland and the rest of the world will actually be located locally. Table 7-4 shows the proportion of employment in each of the five industry sub-sectors associated with the domestic island of Ireland market that may be located there. The more developed the home industry, the greater the proportion of domestic market jobs that remain in Ireland. For instance in the whale scenario, where Irish companies have a fully-featured supply chain, at least half of all jobs involved in each sub-sector are based in the island of Ireland while in the minnow scenario, whereby local companies are only active in the installation and local maintenance sectors of the domestic ocean energy industry, it is assumed that only a very small proportion of the planning and development or manufacturing jobs needed for the wave and tidal industries will actually be located in the island of Ireland.

Table 7-4 Proportion of domestic market jobs that are located in the island of Ireland (non-leakage for 'island of Ireland' economy)

	Planning & development	Design & services	Manufacture & assembly	Construction & commissioning	Operation & maintenance
Whale	50%	50%	60%	85%	100%
Shark	25%	25%	30%	50%	95%
Minnow	5%	0%	5%	30%	85%

Source: SQW derived from evaluation of varied stakeholder feedback

7.26 Conversely, the island of Ireland's share of jobs in the global OE market is higher in the early stages of planning and development, design & services and manufacture because these jobs do not have to be based physically near the site location. Again there are different values for the three scenarios used, with Ireland having an increasing share of employment overseas the more developed the Irish supply chain is.

7.27 For both the wave and tidal models, these proportions are applied in order to identify the number of all Ireland jobs that are supported by the government support.

Table 7-5 Proportion of rest of world market jobs that are located in the island of Ireland

Scenario Values	Planning & development	Design & services	Manufacture & assembly	Construction & commissioning	Operation & maintenance
Whale	25%	30%	20%	15%	5%
Shark	10%	10%	5%	5%	3%
Minnow	2%	2%	0%	0%	0%

Source: SQW

Estimating the total number of jobs in the Irish Republic and Northern Ireland

7.28 Employment in the wave and tidal industries is likely to vary significantly between the Republic and Northern Ireland given the different industrial strengths and, more significantly, the location of suitable wave and tidal sites. For wave, the most suitable sites are located in the Republic of Ireland while the most suitable sites for tidal energy lie off the coast of Northern Ireland. Therefore the majority of employment in the wave industry may lie in the Republic of Ireland while most of the employment associated with the tidal industry could be in Northern Ireland.

7.29 For the wave industry, it is assumed that the majority of employment at each project stage will be located in the Republic, with the exception of design and services where Northern Ireland already possesses a strong sector.

7.30 For the tidal industry, the vast majority of employment is expected to be located in Northern Ireland because this is where most of the tidal activity is expected to occur. However, some of the world leading tidal expertise is based in Dublin and therefore a proportion of the jobs (planning and development (20%), manufacture and assembly (30%) and operation and maintenance (20%)) are expected to be located in the Republic of Ireland.

7.31 Applying these factors gives estimates of the net direct number of FTE jobs in both the Republic of Ireland and Northern Ireland associated with:

- the domestic (island of Ireland) wave industry
- the global wave industry
- the domestic (island of Ireland) tidal industry
- the global tidal industry.

Multipliers

7.32 In addition to the net direct employment impact which the development of the island of Ireland's wave and tidal industries would have, there would also be indirect effects. This means that further employment will be generated by the project because of the "knock-on" impacts or multiplier effects. There are two elements to these multiplier effects:

- Type I multiplier – is a measure of the indirect effects of the project by estimating the impact on the supply chain needed to provide the inputs necessary for the creation of wave and tidal energy outputs.
- Type II multiplier – this includes the direct, indirect and induced effects of the increased activity supported by the government intervention. Induced effects consider the impacts of increased local spending of wages and salaries paid by new wave and tidal developers and their suppliers on the economy.

7.33 The Central Statistics Office for the Republic of Ireland produces Type I multipliers for the Republic of Ireland economy. However, the Type II multipliers are not published for the Republic of Ireland. We have therefore applied the available Type I multipliers to both the Republic of Ireland and Northern Irish economic impact scenarios. It should be recognised that the analysis therefore does not include the induced effects of the subsidy which, if included, might result in a somewhat larger impact.

7.34 In order to convert the published multiplier values into multipliers for the five sub-sectors of the wave and tidal sectors, we have used a system of weighted averages, assigning, for example, an equal average of the published multipliers for the 'Basic Metals, fabricated metal products' and the 'Other business services' sectors for the design and services sub sector of the wave and tidal industry. The assumptions for all five of the sub-sectors are shown in Table 7-6.

Table 7-6 Multiplier calculations

NACE	Sector description	Published Multipliers	Planning and development	Design and services	Manufacture and assembly	Construction, commissioning	Operation and maintenance
27-28	Basic Metals, fabricated metal products	1.463	0%	50%	100%	0%	25%
45	Construction work	1.827	0%	0%	0%	100%	0%
61-62	Land and water transport services	1.6015	0%	0%	0%	0%	25%
74	Other business services	1.513	100%	50%	0%	0%	50%
TOTAL			100%	100%	100%	100%	100%
Estimated Type I multiplier			1.513	1.488	1.463	1.827	1.523

Source: Republic of Ireland. I-O tables 2005

Estimating the value of the net employment impact

7.35 In order to gain an estimate of the value of the net employment impact, a GVA per job value was calculated. For both Northern Ireland and the Republic of Ireland, GVA per employee can be estimated from official statistics. For Northern Ireland, the NI Annual Business Inquiry 2007 provides employment and total GVA by sector while the same data is available from the Central Statistics Office (CSO) for the Republic of Ireland. The GVA per employee calculations for relevant sectors in Northern Ireland and the Republic of Ireland are shown in Table 7 -7 and Table 7-8.

Table 7 -7 Northern Ireland GVA per employee estimates, 2007

Sector (SIC)	Description	Employment	GVA (£ million)	GVA per employee (£)
D	Manufacturing	87,190	3,967	45,493
F	Construction	51,350	2,363	46,020
I	Transport, Storage and Communication	29,066	1,243	42,769
K	Real Estate, Renting & Business Activities	78,183	2,750	35,176

Source: NI ABI

Table 7-8 Republic of Ireland GVA per employee estimates, 2007

Sector (NACE)	Description	Employment	GVA (€ million)	GVA per employee (€)
27,28	Manufacture of basic metals, fabricated metal products	17,326	1,003,904	57,942
29	Manufacture of machinery and equipment	12,842	1,041,576	81,107
31	Manufacture of electric motors, generators and	7,869	775,515	98,553

Sector (NACE)	Description	Employment	GVA (€ million)	GVA per employee (€)
	transformers			
45	Construction	69,939	7,952,671	113,709
I	Transport, storage and communication	87,232	8,261,607	94,708
K	Real estate, renting and business activities	210,712	15,736,066	74,680

Source: CSO

7.36 The next stage was to translate these GVA per employee values from the SIC/NACE sectors into GVA per employee for each of the five sub-sectors of the OE industry. This involved estimating the proportion of employment at each sub-sector that will come from the selected sectors. For example, it has been assumed that all of the planning and development employment would come from sectors with the real estate, renting and business activities sectors, and so the GVA per job value is equal to the value for SIC sector K.

Table 7-9 Estimated GVA per FTE job by project stage, Northern Ireland (£)

Sector (SIC)	Description	Planning & developm ent	Design & services	Manufactu re & assembly	Constructi on & commissio ning	Operation & maintenan ce
D	Manufacturing	0%	50%	100%	0%	25%
F	Construction	0%	50%	0%	90%	0%
I	Transport, Storage and Communication	0%	0%	0%	10%	25%
K	Real Estate, Renting and Business Activities	100%	0%	0%	0%	50%
Total		100%	100%	100%	100%	100%
Value GVA per Job		£35,176	£48,587	£45,042	£45,695	£39,653

Source: SQW

7.37 The assumptions used to arrive at GVA per job for each OE sub-sector are outlined in Table 7-9 and Table 7-10 for Northern Ireland and the Republic of Ireland respectively.

Table 7-10 Estimated GVA per FTE job by project stage, Republic of Ireland (€)

Sector (NACE)	Description	Planning & developm ent	Design & services	Manufactu re & assembly	Constructi on & commissio ning	Operation & maintenan ce
27,28	Manufacture of basic metals, fabricated metal products, except machinery and equipment	0%	50%	70%	20%	25%
29	Manufacture of machinery and equipment	0%	0%	20%	0%	0%
31	Manufacture of electric motors, generators and transformers	0%	0%	10%	0%	0%
45	Construction	0%	0%	0%	80%	0%
I	Transport, storage and communication	0%	0%	0%	0%	25%
K	Real estate, renting and business activities	100%	50%	0%	0%	50%

Sector (NACE)	Description	Planning & development	Design & services	Manufacture & assembly	Construction & commissioning	Operation & maintenance
TOTAL		100%	100%	100%	100%	100%
Value GVA per Job		€ 74,680	€ 66,311	€ 66,636	€ 102,555	€ 75,503

Source: SQW

These GVA per FTE job estimates were then applied to the net employment impacts presented in the previous section.

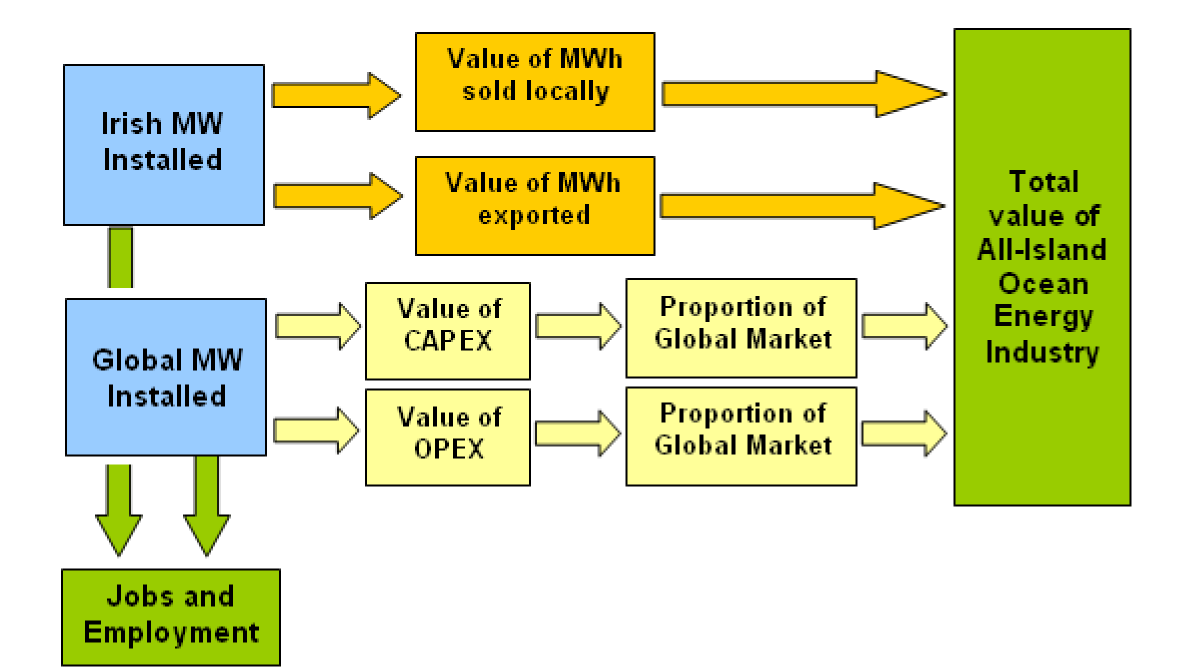
Economic valuation - alternative valuation method

7.38 It has previously been noted that valuing GVA per head at the early stages of an OE industry is problematic as the evidence base is either limited or non existent. Additionally the predicted numbers of jobs likely to be produced are estimates based on early and widely varying prototypes. The typical methodology for deriving economic benefit as applied to the OE industry is summarised in Figure 7-1. It is notable that a major variable for the accuracy of this method is the correct derivation of GVA per head based on FTE jobs in various subsectors.

7.39 To provide a comparative economic evaluation without a predominant reliance on derived GVA per head and job creation data (present and future) an alternative methodology was also derived to deduce economic development. Figure 7-3 outlines this methodology, which is based predominantly on the actual predicted value of production surrounding an island of Ireland OE industry, specifically:

- Island of Ireland MW installed OE capacity electrical output value prediction (local use and export)
- Proportion of Global installed OE capacity – captured value of CAPEX and OPEX.

Figure 7-3 Alternative economic development valuation methodology

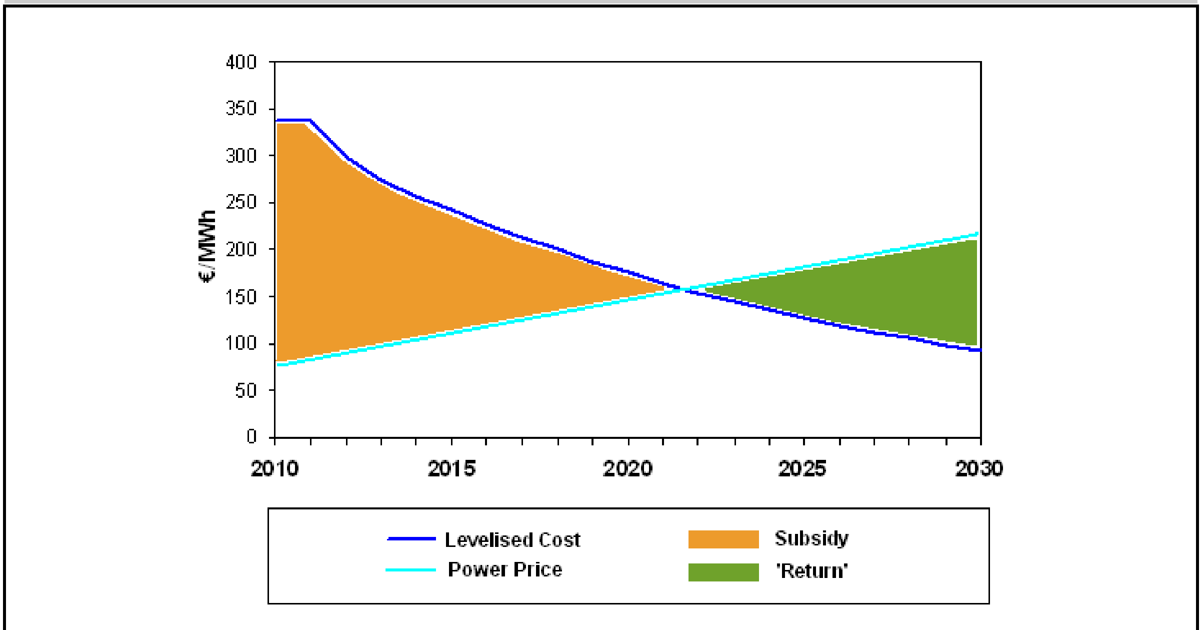


Source: SQW Energy

7.40 The predictions of jobs and the value added by an island of Ireland OE industry are therefore separated; their errors isolated, and any compound errors should be eliminated.

7.41 Figure 7-4 clarifies the value of locally generated and sold OE electricity; and the overall cost (initial subsidy and ongoing costs) associated with this in comparison to the possible return (lower electricity prices and greater competitiveness).

Figure 7-4 'Value' of local OE output over time



Source: SQW Energy

7.42 In terms of cost versus benefit (market values) it is envisaged that an efficient initial subsidy regime would make up the difference between the actual levelised OE cost (to materialise a sufficient return) and the levelised wholesale power price in any given year.

7.43 The orange area in Figure 7-4 illustrates the volume of money spent on such a subsidy. Once (or if) OE becomes cost competitive or indeed more competitive than the levelised wholesale price a benefit (green area) may be produced in terms of lower electricity prices. The volume of this benefit recycled to Government or indeed consumers depends on distributional effects such as the tax regime or indeed the passing on of such energy cost savings to consumers: these are beyond the scope of this research, but multipliers could be used to produce estimates.

7.44 The alternative valuation results are later included for cross-comparative purposes with the more normal GVA per person employed, jobs based economic valuation method.

Carbon savings

7.45 Carbon appraisal is a necessary part of meeting the legally binding carbon emissions targets for each EC country and associated region. Carbon savings have an associated cost and as OE provides a means of reducing carbon (over and above the current grid mix) there is a benefit that may be costed. Carbon valuation has previously been undertaken by utilisation of a Shadow Price for Carbon (SPC) based on the damage or impact value of carbon, but it is now better accepted to make use of the mitigation or abatement costs associated with carbon reduction.

7.46 The carbon prices used for this study are those published by DECC under the "Traded prices – Central Scenario" between 2010 and 2050.[104] The assumed carbon content of the SEM is 0.55637kg CO_2e/kWh.[105]

Security of energy supply

7.47 The addition of renewables (including OE) to a predominantly fossil-fuel dominated generating portfolio mitigates against price fuel shocks, and has the additional benefit of mitigating risk by diversification means or the so called portfolio effect (in a similar manner to a financial investor spreading risk by investing in uncorrelated shares)[106]. The least cost entrant into the power market at the instance of initial delivery is not therefore necessarily the least cost entrant if future circumstances such as oil price volatility were taken into account. The additional value (conservative) of OE (wave and tidal) to a predominantly fossil fuelled generating mix has been approximated as €155/kW ($200/kW) by Awerbuch and Sauter[107]. This study includes this benefit as the additional benefits of reduced risk to the island of Ireland from an increased security of supply.

[104] DECC, Carbon Appraisal in UK Policy Appraisal: A Revised Approach (July 2009), available at www.decc.gov.uk
[105] Ove Arup & Partners Ltd, Northern Ireland renewable Electricity Targets to 2020 for Department for Enterprise, Trade and Investment, November 2009.
[106] A fuller explanation by Shimon Awerbuch may be found at: http://www.awerbuch.com/shimonpages/shimondocs/Wind_Econ_overview.doc
[107] Awerbuch & Sauter, SPRU, University of Sussex 2005: Exploiting the Oil-GDP Effect to Support Renewables Deployment.

Cost of OE to the consumer

7.48 The cost of OE to the consumer is the cost that is passed through over and above those of the counterfactual or 'base' case: either the cost of electricity from the existing generation mix, or that predicted in the future. At present this relates directly to the higher price of electricity from OE which is subsidised by the consumer (through direct Government intervention or supplier obligation). Such intervention aims to provide the new market entrant (OE) with the ability to be financially attractive to leverage initial private sector investment from which it is hoped a fully competitive market entry will develop once learning effects and economies of scale are realised.

7.49 The future costs of electricity have been derived from the literature review and make use of the OFGEM Project Discovery predictions[108] and Irish projections[109]. In order to efficiently capture these rather uncertain predictions within the model a base wholesale generation SEM price of €55/MWh is increased by a percentage year on year to reflect the possible base price of electricity with the present and envisaged generation mix.

7.50 The future levelised costs of OE electricity are calculated by means of the associated CAPEX, OPEX and other costs. These costs vary over time depending on the assigned learning rates and the likely capacity growth rate of OE up to that year in both the local island of Ireland, and the global OE market. A full project finance assessment is carried out for each new MW of OE postulated for the given year based on all relevant monetary cost and benefit factors in that year and those predicted over the project lifetime. It is assumed that a developer will require a reasonable rate of return (listed in Table 6-1) in order to choose OE as the preferred investment option, and so the subsidy (if) required is added to the existing analysis in order to produce the required rate of return. This subsidy may be in any form, although the model principally allows existing and proposed tariffs:

- Feed in tariffs (e.g. REFIT)
- Obligations (e.g. NIRO)
- Capital Grants

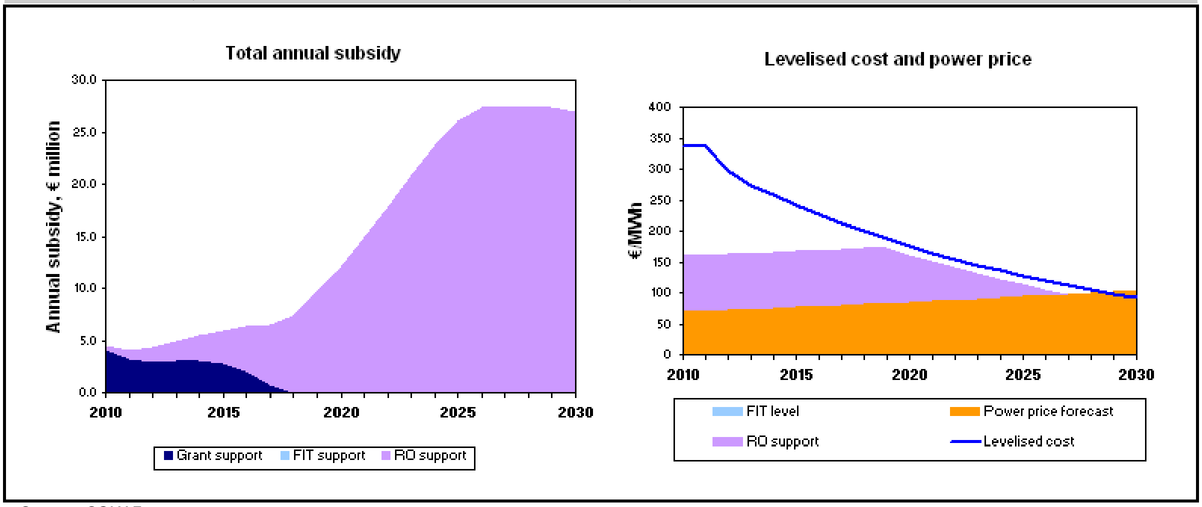
7.51 Only the direct government costs have been considered. The economic impact analysis and cost-benefit analysis have not taken account of other potential social costs of supporting the wave and tidal industries (e.g. potential costs to other industries such as tourism or fishing).

7.52 Figure 7-5 illustrates an example subsidy cost calculation, from which the required subsidy may be calculated for any given MW of OE in any given year and for the entire economy. It is notable that in this example 'central' scenario in the first (left-hand) graph additional grant support is required in reducing amounts for the first 7 years in order to support the current NIRO production based tariffs. The second (right-hand) graph illustrates the reduction in levelised cost for tidal energy and the point at which this becomes competitive with the prevailing power price forecast negating the need for an RO subsidy 'top-up' (shown as the gap between 'RO

[108] Ofgem: Project Discovery – Energy Market Scenarios October 2009, available at: http://www.ofgem.gov.uk/markets/whlmkts/discovery/documents1/discovery_scenarios_condoc_final.pdf
[109] DCENR & DETINI: All-Island Electricity Grid Study, 2008, available at: http://www.dcenr.gov.ie/Energy/North-South+Co-operation+in+the+Energy+Sector/All+Island+Electricity+Grid+Study.htm
Economic and Social Research Institute: MEDIUM-TERM REVIEW 2008-2015, May 2008, available at: http://www.esri.ie/UserFiles/publications/20080515155545/MTR11.pdf

support' and 'Levelised cost' which is provided by the additional 'Grant support' from the left-hand 'Total annual subsidy' graph).

Figure 7-5 Subsidy cost calculation example for NI tidal energy (RO supported – FIT not shown)



Source: SQW Energy

Cost-benefit analysis

7.53 Cost-benefit analysis attempts to measure all costs and benefits of an intervention in monetary terms, adjusted for the time value of money (known as discounting), in order to provide the 'present value' of all costs and benefits, which may then be expressed as a Benefit-Cost Ratio (BCR). BCR values greater than one indicate that the monetary value of the benefits of the intervention outweigh the costs of setting it up and running it. In economic theory, the policy/intervention under investigation should be adopted if it has a positive net benefit (this is called the 'net benefits criterion').[110]

7.54 Some of the advantages of using CBA include:

- it can give an indication of costs and benefits over time and provides estimates of what an intervention's costs and benefits are *expected* to be before implementation, thus, it informs investment decisions by providing robust appraisal
- it allows comparison between different scenarios (9 in this study)
- it provides a sound value for money technique, which is becoming increasingly important as part of public sector investment decisions on projects and programmes
- it supports the more efficient allocation of resources.

7.55 Some of the challenges of using CBA include:[111]

[110] According to Boardman et al. (2001), the CBA decision criteria is based on the *"Kaldor-Hicks criterion"* that a policy should be adopted only if those who are expected to gain could fully compensate those who will lose and still be better off. The Kaldor-Hicks criterion itself provides the basis for the "Pareto efficient rule" (commonly known as net benefits criterion) i.e. "an allocation of goods is Pareto efficient if no alternative allocation can make at least one person better off without making anyone else worse off".
[111] Based on SQW Consulting (2009) *Pushing the boundaries of Impact Evaluation.*

- estimating total costs – accounting for different types of costs is difficult and it should be recognised that this CBA has only taken into account the governmental cost of providing the subsidy. There is no consideration of private or social costs.
- capturing benefits – in terms of performance against selected outcomes; and in dealing with persistence effects (estimates of how long the benefits will last) and discounting over time
- benchmarking the findings to establish relative returns compared to initiatives seeking to achieve similar outcomes, and ensuring that BCRs are used in an informed way, e.g. in the context of understanding the non-monetary outcomes that may be delivered by projects.

7.56 The assumptions behind the costs and benefits used in this analysis have been explained in the preceding chapters. The costs and benefits were then discounted using a discount rate of 3.5%[112], in line with HM Treasury guidance in order to bring all of the monetary cost and benefit values into present values which can be compared against each other.

7.57 The final stage was to compare the present value GVA benefits against the present value subsidy costs associated with the project in order to compare the economic impact under the various scenarios used for both the wave and tidal industries.

[112] Not to be confused with the 'project hurdle rate' which is a project financier's required return below which a project would be deemed a bad investment.

8: Economic Value of OE to the Island of Ireland

Introduction

8.1 The technology development, deployment, and economic modelling variables and their values were introduced in the previous two chapters. The results from the modelling are now presented along with some evaluation and explanation.

8.2 For both the wave and tidal models, the three core technology development and deployment scenarios have been used:

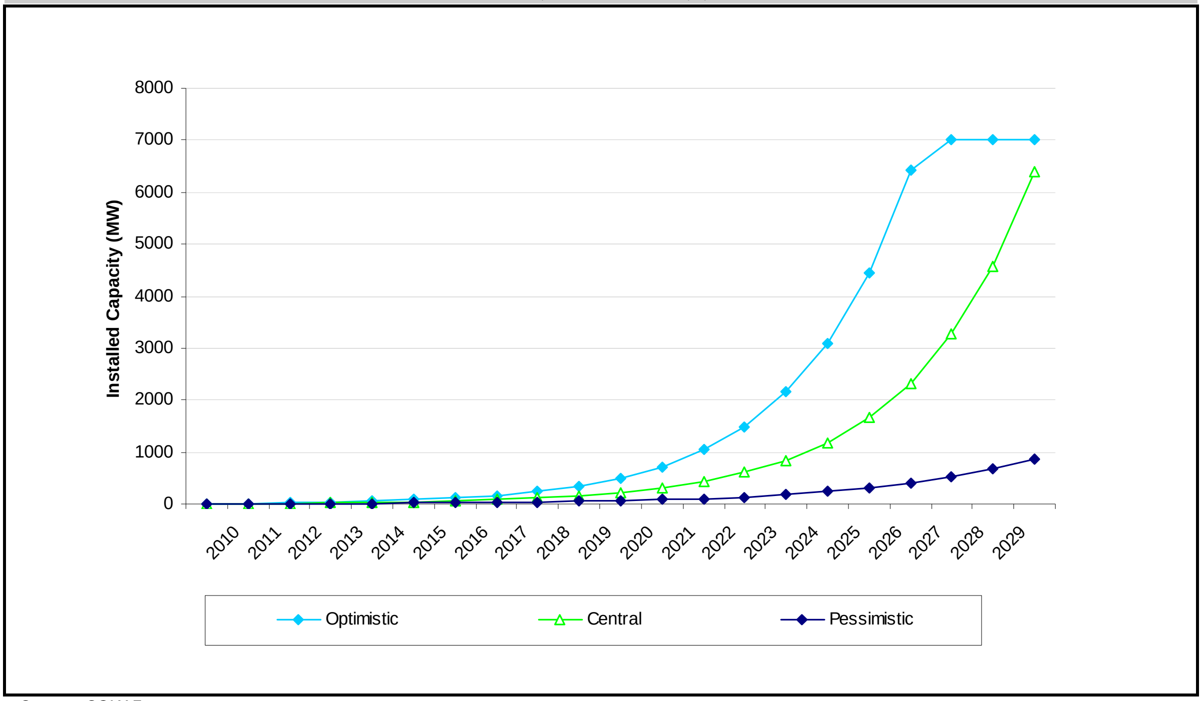
- **Optimistic**: the current optimistic OE technology costings, learning rates, deployment based on the **national targets** and other developmental factors are utilised to determine the likely installation of OE MW to 2030.
- **Central**: the current central estimates of costings, learning, deployment and other developmental factors determine the likely installation of OE.
- **Pessimistic**: pessimistic variables and scenarios (as compared to the central 'base' case) for OE technology development are chosen.

Table 6-1 and Table 6-2 summarised the variables associated with wave and tidal.

Installed capacity & subsidy for 3 wave deployment scenarios

8.3 Figure 8-1 outlines the predicted Irish wave capacity installation from 2010 to 2030.

Figure 8-1 Island of Ireland cumulative wave capacity installation by year



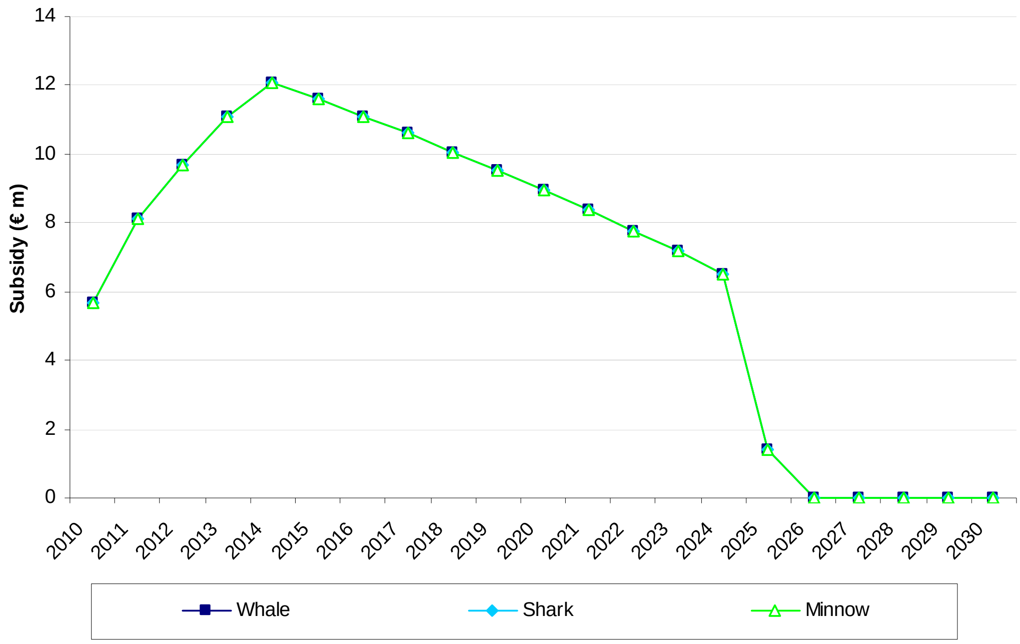
Source: SQW Energy

8.4 The wave capacities are calculated from the three (optimistic, central and pessimistic) technology development and deployment scenarios. The optimistic installed capacity is noted to stabilise in 2030 to reflect the current estimate for the island of Ireland's available wave resource, however the actual accessible wave resource may well increase as OE technology develops and the economics improve.

8.5 Each of the 3 technology development and deployment scenarios has a level of subsidy associated with its production. These levels principally depend on the capacity growth rates and the learning rate, until other external barriers such as resource limits, electrical grid access or environmental sensitivities intervene. The total subsidy required for wave energy under the three technology development and deployment scenarios are recorded in Figure 8-2 to Figure 8-4.

8.6 The 'optimistic' scenario shows a level of yearly subsidy, peaking at around €12m per annum in 2015 before diminishing to zero in 2027. The level of support is noted to diminish linearly for some time after 2015 as the capacity supported by the current 15 year REFIT marine tariff (€220/MWh) diminishes. Please refer to section 5.31.

Figure 8-2 Yearly wave energy subsidy for optimistic technology development and deployment scenario

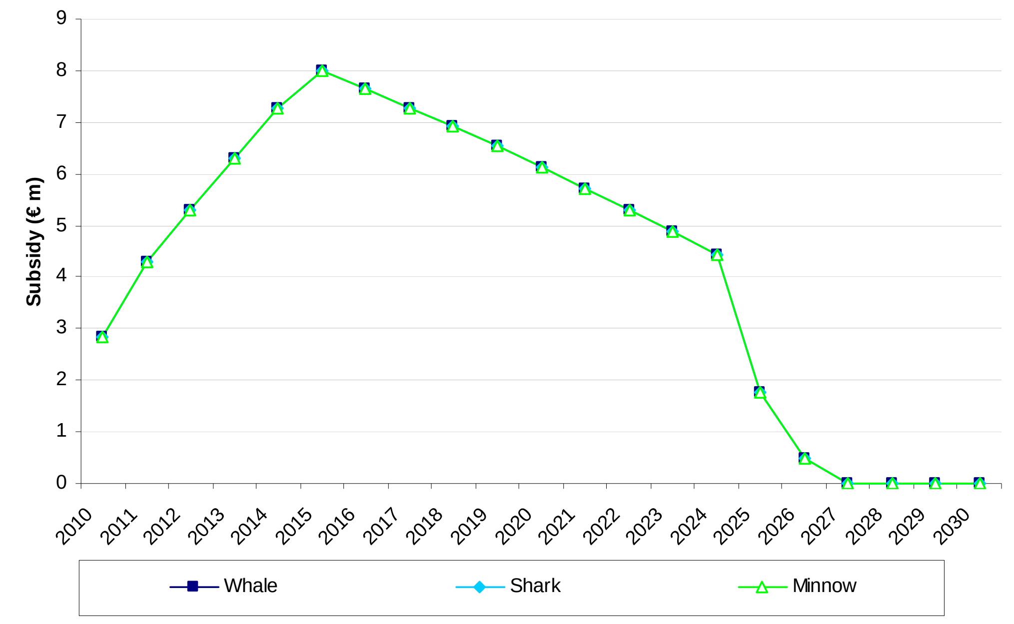


Source: SQW Energy

8.7 The central scenario (Figure 8-3) shows subsidy is required at lower levels to 2028 reflecting the higher initial CAPEX and OPEX costs, slower learning and capacity growth rates, and a central future wholesale electricity price estimate in this scenario. In 2028 wave energy becomes cost competitive with conventional generation.

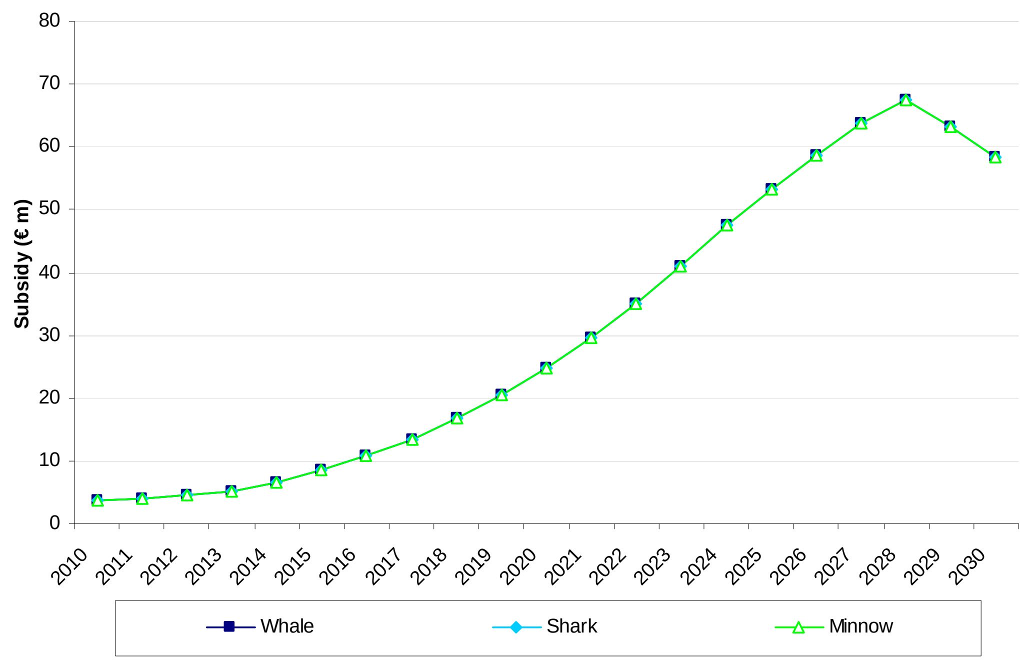
8.8 The pessimistic scenario (Figure 8-4) illustrates that due to low energy prices and the cost of wave energy not reducing significantly over time, the subsidy and hence cost to society increases significantly over time, only beginning to reduce once somewhat more cost competitive from 2028. If this were to become apparent during the next 5-10 years it is postulated unlikely that investment would be forthcoming and this scenario would never develop.

Figure 8-3 Yearly wave energy subsidy for a central technology development and deployment scenario



Source: SQW Energy

Figure 8-4 Yearly wave energy subsidy for a pessimistic technology development and deployment scenario



Source: SQW Energy

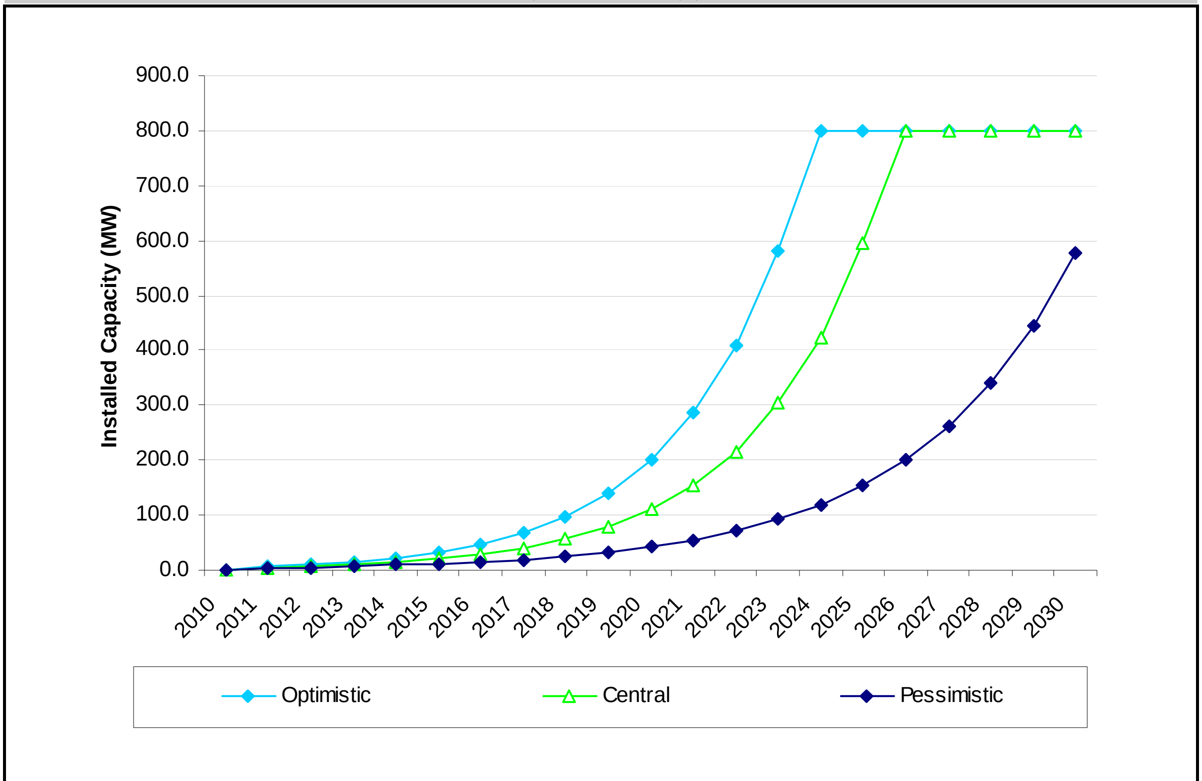
8.9 The analysis of more pessimistic scenarios was undertaken but as these never pay back we do not report on what is thereby produced in terms of jobs or GVA as any subsidy or programme would be cancelled on grounds of expense long before such (expensive) results emerged.

8.10 It must be noted that the subsidies predicted are based purely on the existing costs associated with OE and the current wholesale electricity market predictions, which account for a proportion of the decrease in subsidy post 2015. The externalities or non costed benefits (security of supply and carbon reduction) are specified later within the overall cost-benefit analysis.

Installed capacity & subsidy for 3 tidal deployment scenarios

8.11 Figure 8-5 outlines the presumed Irish capacity installation from 2010 to 2030 as calculated from the three (optimistic, central and pessimistic) technology development and deployment scenarios and their respective capacity growth rates. The optimistic capacity growth rate is noted to be limited from 2026 to 800MW reflecting the island of Ireland's technically available resource.

Figure 8-5 Island of Ireland cumulative tidal capacity installation by year



Source: SQW Energy

8.12 The subsidies required for tidal energy under the three technology development and deployment scenarios are recorded in Figure 8-6 to Figure 8-8.

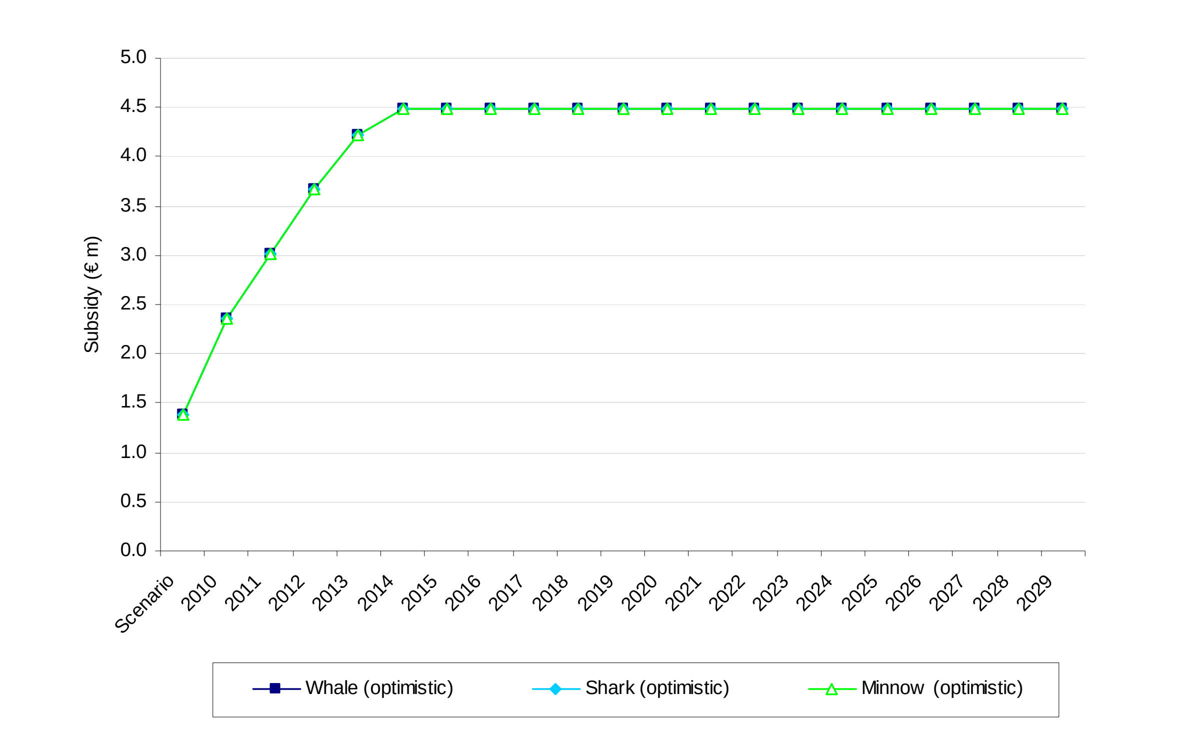
8.13 The 'optimistic' scenario (Figure 8-6) shows the level of relatively significant yearly subsidy, peaking at around €4.5m per annum in 2014 and continuing until 2037 (not shown) as the Renewable Obligation that is likely to fund tidal energy (based mainly in Northern Ireland) is thought likely to persist until then for projects developed during the early years. This subsidy would in effect only be available throughout early project's lifetimes, rather than those more cost effective and being delivered after 2015.

8.14 The central scenario (Figure 8-7) shows subsidy is required at lower (than the optimistic target driven scenario) but significant levels to 2028 reflecting the higher initial CAPEX and OPEX costs, slower learning and capacity growth rates, and a central future wholesale electricity price estimate in this scenario. In 2029 tidal energy becomes cost competitive with conventional generation.

8.15 The pessimistic tidal scenario (Figure 8-8) illustrates that due to low energy prices and the cost of tidal energy not reducing significantly over time, the subsidy and hence cost to society increases significantly over time with only a very late post 2030 potential for beginning repayment through benefits.

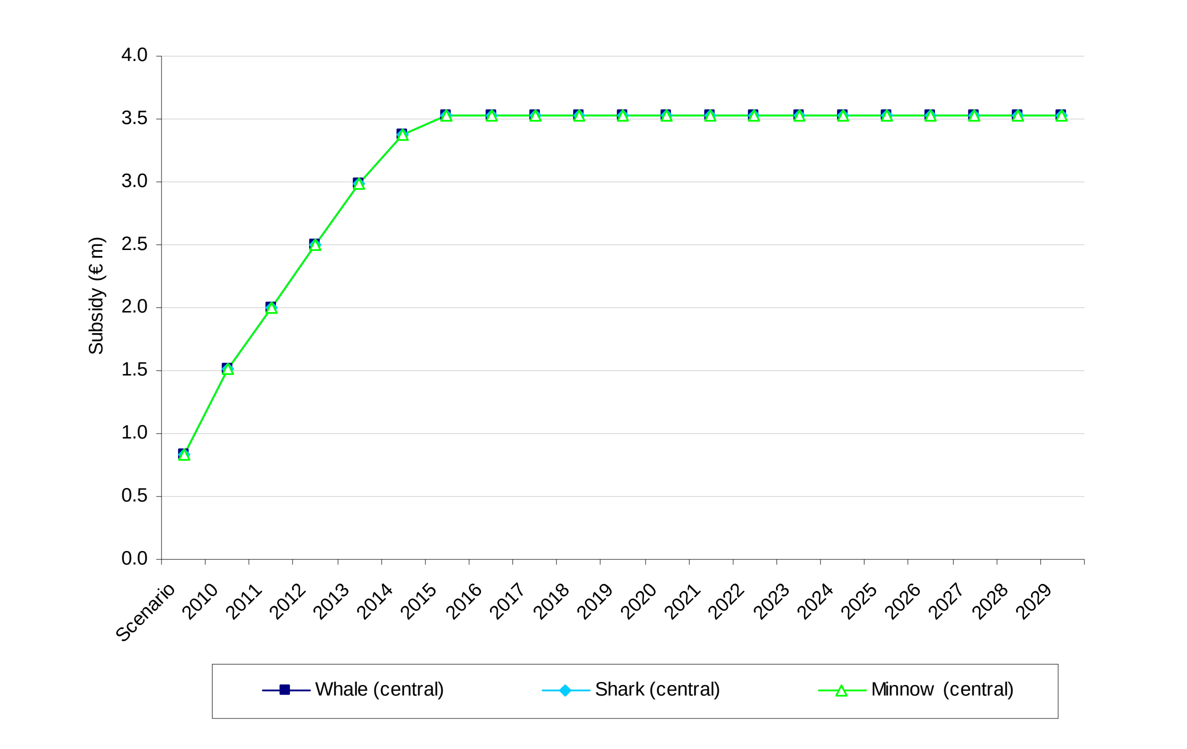
8.16 As with the research undertaken on very pessimistic wave scenarios, very pessimistic tidal scenarios are unlikely to be pursued for many years as the costs mount. Evaluations of these types of scenarios are therefore not pursued further.

Figure 8-6 Yearly tidal energy subsidy for optimistic technology development and deployment scenario



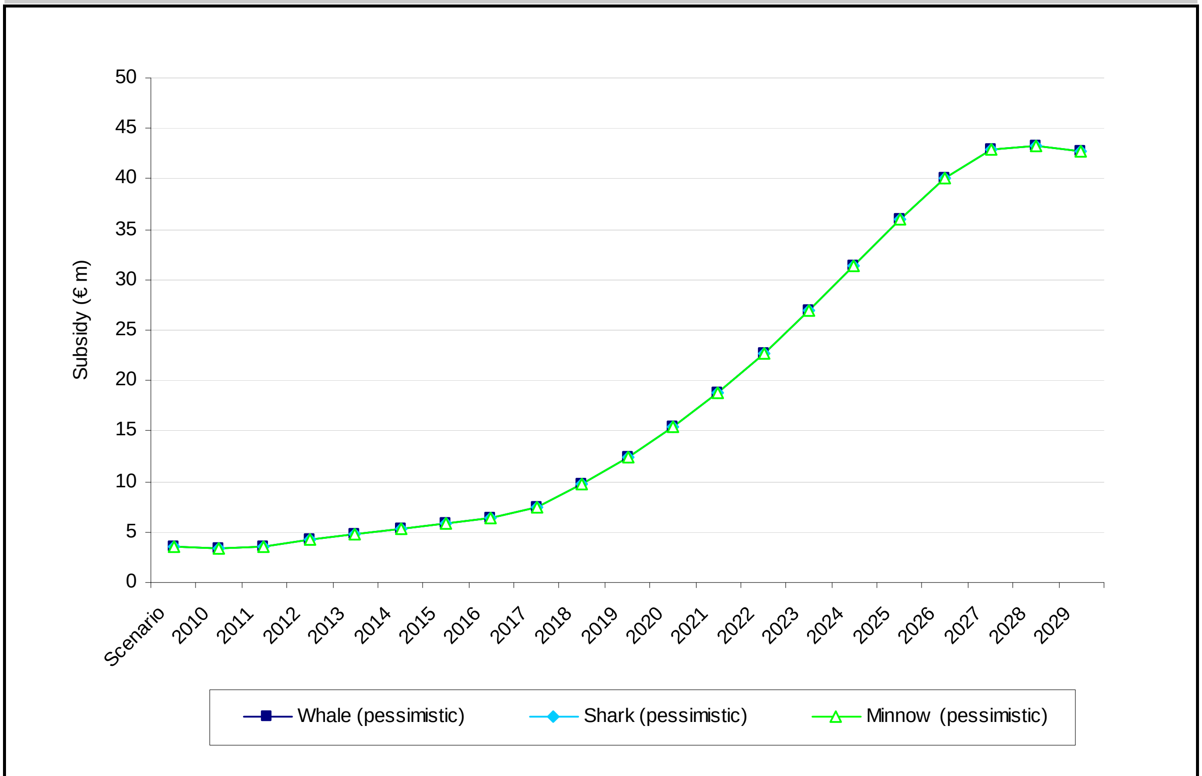
Source: SQW Energy

Figure 8-7 Yearly tidal energy subsidy for a central technology development and deployment scenario



Source: SQW Energy

Figure 8-8 Yearly tidal energy subsidy for a pessimistic technology development and deployment scenario



Source: SQW Energy

Economic scenarios (Whale, Shark and Minnow)

8.17 Within the three core technology development and deployment scenarios, the model determines the potential economic impact for Ireland arising from three additional overlaid economic and supply chain capture scenarios:

- **Whale Scenario** – Irish companies have a fully-featured supply chain and provide the majority of services and products locally with the addition of capturing a good proportion of the global market.
- **Shark Scenario** – Irish companies possess elements of the supply chain and this expertise is mirrored in capturing a small proportion of the global OE market.
- **Minnow Scenario** – Irish companies active only in local installation and maintenance. There is a minimal proportion of the global market serviced from Ireland.

The previous chapter summarised the variables used as inferred from developer and utility company feedback.

8.18 The outcomes from the combined technology scenarios (optimistic target driven, central and pessimistic) and the economic scenarios (whale, shark, minnow) are described below. (Their combinations are listed in Table 8-1 for added clarity.)

Table 8-1 Summary of all nine OE scenarios modelled for both wave and tidal

Technology Scenarios (Development & Deployment)	**Economic Scenarios (Local & Export Proportions)**		
	Whale	Shark	Minnow
Optimistic	1	4	7
Central	2	5	8
Pessimistic	3	6	9

Source: SQW Energy

8.19 The net present value and the Benefit to Cost Ratio (BCR) associated with each scenario is presented for each of the economic development scenarios.

Economic development – Whale scenario

Island of Ireland Whale wave scenarios

8.20 Table 8-2 outlines possible cost, benefits, jobs and NPV for the wave industry under the Whale scenarios.

Table 8-2 Results from Whale Wave Scenarios

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
2020	Optimistic	236.6	84.5	57.3	91.2	287.2	4.1	500	888	1,431

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
	Central	121.6	36.2	26.5	57.0	127.2	3.2	219	440	691
	Pessimistic	33.6	9.7	7.9	93.5	-42.2	0.5	63	126	155
2025	Optimistic	1045.6	442.0	492.0	111.6	1868.1	17.7	3,099	5,562	8,455
	Central	436.6	166.2	198.7	71.3	730.1	11.2	1,189	2,378	3,149
	Pessimistic	87.4	31.0	39.7	224.0	-65.9	0.7	233	467	457
2030	Optimistic	5245.7	2299.8	2561.2	111.6	9995.1	90.6	7,000	34,402	52,154
	Central	1834.5	754.8	1402.7	71.6	3920.3	55.7	6,401	12,803	16,927
	Pessimistic	221.2	97.6	194.0	391.9	120.9	1.3	865	1,731	1,350

Source: SQW Energy

8.21 The optimistic Whale wave scenarios return an increasingly positive BCR and eventually return in 2030 very high NPVs greater than €9bn. Exports from Ireland to the rapidly expanding Global OE market provide a significant part of the accrued benefit in every year. While previously this scenario could be seen to be over-optimistic, the situation of the Danish wind industry would certainly mirror and better this scenario in terms of Global share of market, jobs and added value. The FTE jobs created (greater than 52,000) are of a similar level to those witnessed in Denmark, Spain and Germany for similar levels of installed RE capacity.

8.22 The central Whale wave scenario takes slightly longer to become profitable but requires less initial subsidy volume. The BCR in 2020 is 3.2, rapidly increasing thereafter to 55.7 in 2030. The economic advantages to Ireland of exporting equipment, services and wave produced electricity are good as the global market is expanding (around 12GW by 2030).

8.23 The pessimistic Whale wave scenario shows more limited capacity growth and therefore the returns take longer to be realised as the costs remain high through a lack of learning by doing and economies of scale. Only towards 2030 is a positive NPV returned. This situation would likely apply not only to the island of Ireland, but also globally under this scenario.

8.24 It is notable that under the central scenario, it is envisaged that around 219MW of wave capacity will be installed by 2020 in Irish waters. This is a function of the previously referenced maximum capacity growth and learning rates as witnessed in onshore wind. There is however a possibility that with the various and current imperatives (climate change, security of supply, etc.) that OE will deliver capacity well beyond these previous experiences as outlined in the 2020 targets for wave energy (500MW).

Island of Ireland Whale tidal scenarios

8.25 Table 8-3 outlines possible cost, benefits, jobs and NPV of the island of Ireland tidal industry.

Table 8-3 Results from Whale Tidal Scenarios

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
2020	Optimistic	88.9	33.4	23.4	34.3	111.4	4.2	200	321	609
	Central	58.6	18.1	13.4	25.3	64.9	3.6	110	221	389
	Pessimistic	18.3	6.5	5.4	53.8	-23.7	0.6	42	85	99
2025	Optimistic	341.5	167.5	168.1	48.7	628.4	13.9	800	1,894	2,929
	Central	203.9	83.1	99.7	36.5	350.1	10.6	595	1,191	1,584
	Pessimistic	47.9	20.7	26.7	126.7	-31.5	0.8	156	312	293
2030	Optimistic	1555.9	833.2	425.8	60.8	2754.1	46.3	800	11,165	17,259
	Central	808.6	377.4	357.4	46.0	1497.4	33.5	800	6,403	8,465
	Pessimistic	121.5	65.1	129.6	236.9	79.3	1.3	577	1,155	862

Source: SQW Energy

8.26 The results of the Whale tidal scenarios are similar in nature to those of the Whale wave scenarios, however the level of return is more limited (BCR of 46.3 compared to 90.6) due to the lesser extent of the island of Ireland's or global tidal resource.

8.27 The optimistic and central scenarios again produce a positive net benefit in all years post 2020, the pessimistic scenario only becoming competitive (BCR of 1.3) around 2029 but expanding beyond that.

Economic development – Shark Scenario

Island of Ireland Shark wave scenarios

8.28 Table 8-4 outlines the resulting possible cost, benefits, jobs and NPVs for the wave Shark scenarios.

8.29 The Shark scenarios relate to a reduced level of global export and local OE development input. The value to the island of Ireland is therefore diminished under the three technology development and deployment scenarios (optimistic, central, and pessimistic). Although the NPVs and BCRs show a similar pattern to those for the Whale scenarios, a reduced level of benefit is clearly reflected.

Table 8-4 Results from Shark Wave Scenarios

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
2020	Optimistic	118.7	84.5	57.3	91.2	169.2	2.9	500	888	626

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
	Central	59.9	36.2	26.5	57.0	65.6	2.2	219	440	297
	Pessimistic	14.5	9.7	7.9	93.5	-61.4	0.3	63	126	59
2025	Optimistic	522.8	442.0	492.0	111.6	1345.3	13.1	3,099	5,562	3,696
	Central	215.1	166.2	198.7	71.3	508.6	8.1	1,189	2,378	1,356
	Pessimistic	37.7	31.0	39.7	224.0	-115.6	0.5	233	467	175
2030	Optimistic	2619.5	2299.8	2561.2	111.6	7368.9	67.0	7,000	34,402	22,792
	Central	903.2	754.8	1402.7	71.6	2989.0	42.7	6,401	12,803	7,281
	Pessimistic	95.5	97.6	194.0	391.9	-4.8	1.0	865	1,731	517

Island of Ireland Shark tidal scenarios

8.30 Table 8-5 outlines the possible cost, benefits, jobs and NPV of the tidal industry Shark scenarios.

8.31 Both wave and tidal show very similar benefit-cost ratio patterns for each of the optimistic, central and pessimistic scenarios, the NPV's being greater for wave as reflected by the greater market size and resource.

Table 8-5 Results from Shark Tidal Scenarios

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
2020	Optimistic	40.9	33.4	23.4	34.3	63.4	2.8	200	321	271
	Central	26.1	18.1	13.4	25.3	32.4	2.3	110	221	167
	Pessimistic	8.1	6.5	5.4	53.8	-33.9	0.4	42	85	42
2025	Optimistic	156.9	167.5	168.1	48.7	443.9	10.1	800	1,894	1,305
	Central	90.7	83.1	99.7	36.5	237.0	7.5	595	1,191	682
	Pessimistic	21.1	20.7	26.7	126.7	-58.2	0.5	156	312	125
2030	Optimistic	714.3	833.2	425.8	60.8	1912.5	32.5	800	11,165	7,679
	Central	359.6	377.4	357.4	46.0	1048.3	23.8	800	6,403	3,642
	Pessimistic	53.7	65.1	129.6	236.9	11.5	1.0	577	1,155	368

Source: SQW Energy

8.32 It is notable that for Shark, the pessimistic technology development and deployment scenarios (for both wave and tidal) only break even by 2030. This benefit would however begin to accrue slowly in later years if the OE market continued to expand.

Economic development – Minnow Scenario

8.33 The Minnow scenarios reflect the situation where the island of Ireland contributes less to local OE development, becoming a 'venue' for deployment, rather than having a well featured supply chain. This in turns allows for little ability to service export opportunities within the global market place.

Island of Ireland Minnow wave scenarios

8.34 Table 8-6 outlines the possible cost, benefits, jobs and NPV for the wave scenarios.

Table 8-6 Results from Minnow Wave Scenarios

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
2020	Optimistic	40.1	84.5	57.3	91.2	90.6	2.0	500	888	158
	Central	19.7	36.2	26.5	57.0	25.4	1.4	219	440	73
	Pessimistic	4.7	9.7	7.9	93.5	-71.2	0.2	63	126	15
2025	Optimistic	174.7	442.0	492.0	111.6	997.1	9.9	3,099	5,562	925
	Central	70.4	166.2	198.7	71.3	364.0	6.1	1,189	2,378	331
	Pessimistic	12.3	31.0	39.7	224.0	-140.9	0.4	233	467	44
2030	Optimistic	871.6	2299.8	2561.2	111.6	5621.0	51.4	7,000	34,402	5,694
	Central	294.6	754.8	1402.7	71.6	2380.4	34.2	6,401	12,803	1,772
	Pessimistic	31.3	97.6	194.0	391.9	-69.0	0.8	865	1,731	129

Island of Ireland Minnow tidal scenarios

8.35 Table 8-7 outlines the possible cost, benefits, jobs and NPV of the tidal industry scenarios.

8.36 Only the optimistic and central technology development and deployment scenarios within the Minnow economic scenario produce a positive but reduced benefit as compared to the previous more positive scenarios for both wave and tidal.

Table 8-7 Results from Minnow Tidal Scenarios

Year	Scenario	Economic Development (€m)	Energy Security (€m)	Carbon Savings (€m)	Costs (€m)	NPV (€m)	Benefit-Cost Ratio	Irish MW	Global MW	Net Additional Jobs (FTE)
2020	Optimistic	11.1	33.4	23.4	34.3	33.6	2.0	200	321	71
	Central	6.7	18.1	13.4	25.3	13.0	1.5	110	221	41
	Pessimistic	2.1	6.5	5.4	53.8	-39.9	0.3	42	85	11
2025	Optimistic	42.3	167.5	168.1	48.7	329.2	7.8	800	1,894	339
	Central	23.2	83.1	99.7	36.5	169.4	5.6	595	1,191	167
	Pessimistic	5.5	20.7	26.7	126.7	-73.9	0.4	156	312	31
2030	Optimistic	191.5	833.2	425.8	60.8	1389.7	23.9	800	11,165	1,986
	Central	91.4	377.4	357.4	46.0	780.1	17.9	800	6,403	887
	Pessimistic	13.9	65.1	129.6	236.9	-28.3	0.9	577	1,155	92

Source: SQW Energy

8.37 The pessimistic scenarios show a rapidly failing OE sector where no cost reductions are realised or no OE capacity may be installed. In addition there is little export opportunity to compensate for this lack of local opportunity.

Cost-benefit analysis: summary for all scenarios

8.38 For both the wave and tidal industries, it is clear that the benefits in terms of GVA created are significantly greater than the subsidy costs required in the Whale and Shark Optimistic and Central scenarios by 2030.

8.39 The Whale and Shark scenarios for both wave and tidal produce the best returns under both Optimistic and Central technology development and deployment assumptions as capturing even a small proportion of the Global OE market with exports provides great benefit.

8.40 The benefits from tidal although very positive under some scenarios are lower than those from wave. This is due to the more limited tidal resource, and that Northern Ireland GVA figures are slightly lower than those for the Republic of Ireland.

8.41 It is expected that as the OE industry develops the number of FTE jobs per MW will decrease in line with greater efficiencies and economies of scale. The modelling has taken this into account by reducing the employment intensity (FTE jobs/MW) at the same rate as the technology learning rate. It would also be expected that GVA per head would increase under these circumstances to a level commensurate with the associated OE economic value per MW of installation or output. Future levels of GVA per person employed do not exist so the current estimated values have been used and the alternative economic valuation method (refer to page 64) was used to produce a check on the valuation produced by the standard GVA per head method. The two very different methodologies produced similar results thus cross-validating the outputs as published. The comparative example of the two methodologies as applied to the wave and tidal Whale scenario results for benefit-cost ratio are listed in Table 8-8.

Table 8-8 Comparison of two OE valuation methods: benefit-cost ratios for Whale scenarios in 2030

Scenario	Traditional GVA per Job Method Benefit : Cost Ratio	Alternative Valuation Method Benefit : Cost Ratio
Wave - Whale (optimistic)	90.6	88.5
Wave - Whale (central)	55.7	54.1
Wave - Whale (pessimistic)	1.3	1.8
Tidal - Whale (optimistic)	46.3	50.4
Tidal - Whale (central)	33.5	36.4
Tidal - Whale (pessimistic)	1.3	2.1

Source: SQW Energy

8.42 It is immediately noticeable from the summary figures above that the differences between the 3 core 'technology development and deployment' scenarios have a great effect on the overall value of the OE industry. In order to examine the variability of the island of Ireland's OE 'value' due to the variables perceived as most sensitive, a sensitivity analysis was completed and is summarised in the next section.

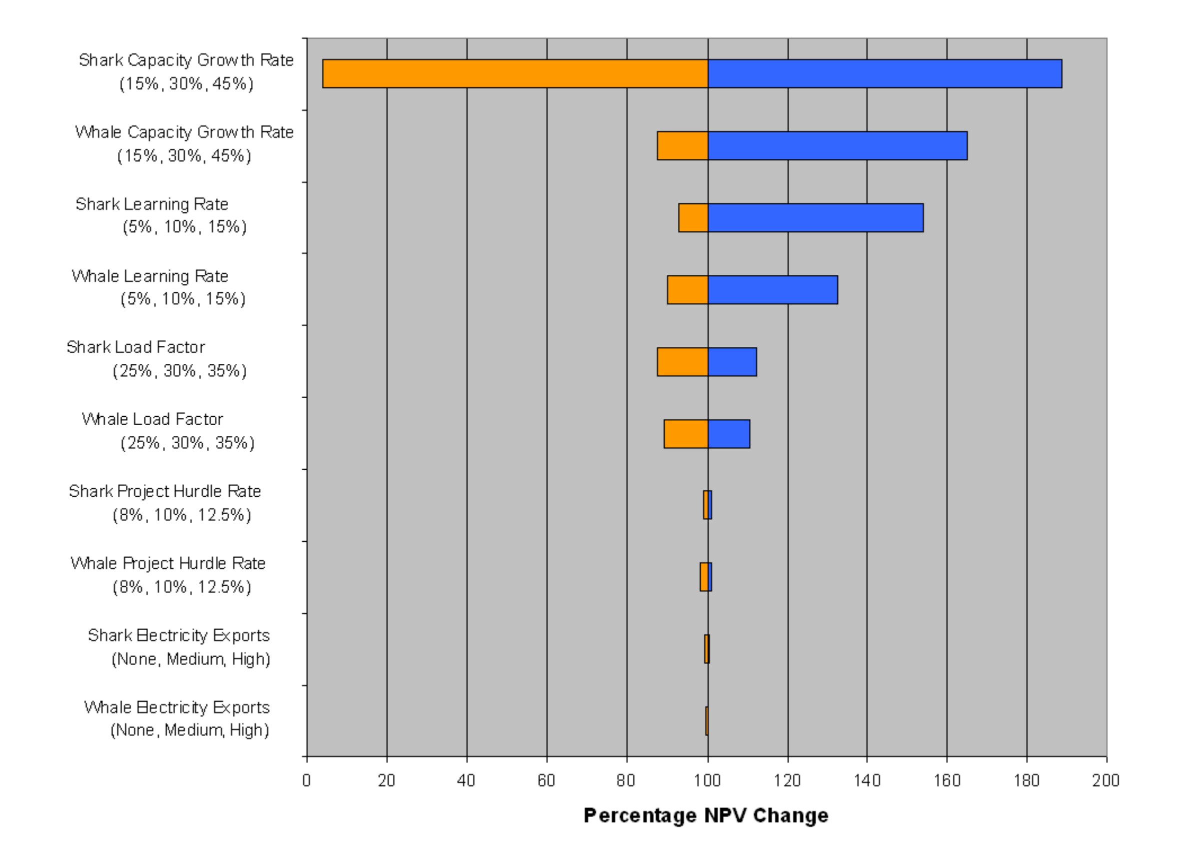
Sensitivity of all scenarios

8.43 The technical development and deployment scenarios (optimistic, central and pessimistic) contain a number of parameters critical to the economic valuation of OE in the island of Ireland. Those evaluated as most critical to the outcome are:

- the capacity growth rate
- the learning rate
- technology load factor
- project hurdle rate
- the value of electricity exports

8.44 A sensitivity analysis was carried out to determine the effects of varying these critical parameters, most specifically on net jobs, installed capacity (MW) and NPV in 2030. The results for the central wave scenarios for NPV (calculated from the modelled MW and GVA) are summarised and described in Figure 8-9. The middle value of each sensitivity scenario illustrated is the base case (e.g. Shark Capacity Growth Rate 30% relates to the original variable returning 100% of the NPV), around which the sensitivities are calculated in percentage terms. Those for the central tidal scenarios show very similar trends.

Figure 8-9 Sensitivity of NPV to major parameter variability for the central wave scenarios



Source: SQW Energy

8.45 Figure 8-9 clearly illustrates that the economic value of OE are most highly affected by variances, firstly in the capacity growth rates, secondly with respect to the learning rates, and thirdly with respect to the OE device load factors. Lessons may be drawn directly from these sensitivities backing up developer assertions, namely that:

- the removal of barriers limiting capacity growth rates (e.g. electrical grid capacity, supply chain, inefficient regulation and consenting etc.) are of first importance outside of the initial technology proving
- the learning rate for OE technology must achieve a reasonable level to provide benefits within a reasonable timescale
- the increased reliability and productivity of OE devices play a significant part in delivering value to the Irish economy.

8.46 The prevalent project hurdle rates and the ability to export electricity have a much smaller affect on overall OE value to 2030. The likely explanation for this is that the economic modelling provides any additional subsidy required to meet the shortfall in project finance until OE becomes cost effective. It is therefore interesting to note that as long as the learning rate progresses to eventually provide competitive OE a good return is experienced even after inclusion of any initial subsidy.

Economic valuation - summary

8.47 The OE industry is currently at an early stage of development and a very wide range of future estimates for cost and deployment are therefore currently published and mooted by developers. Although much of this data is thoroughly developed and based on the soundest of principles, there is still very little production and historical data by which a developer may prove the veracity of these estimates. The ranges and errors in these estimates are compounded by the timescales to 2030 for which a prediction for even a very traditional and stable market would perhaps be difficult to quantify with reasonable accuracy. The output economic valuations carried out for this research therefore vary widely as they are only as good as the input data and assumptions available as published.

8.48 It is however clear that there exists a wide range of opportunity for an island of Ireland OE industry which could produce very significant benefits in the order of many billions of Euros over the next two decades. With sufficient learning rates encouraged and proven through initial subsidy it is possible that an island of Ireland wave energy industry meeting the 500MW target could produce 1,431 additional FTE jobs and an NPV of €0.25bn, increasing to 17,000-52,000 FTE jobs and an NPV of between €4-10bn by 2030. Similarly a tidal industry providing 200MW of capacity by 2020 may deliver around 600 FTE jobs and an NPV of €111m, increasing to 8,500-17,000 FTE jobs and an NPV of between €1.5-2.75bn by 2030.

8.49 The critical variables to achieving success are (at least initially) directly within the influence of Government, namely those factors associated with enabling efficient and timely capacity growth: electrical grid capacity; supply chain; efficient regulation, consenting and licensing.

8.50 To determine whether an intervention may be deemed as 'value for money' a number of metrics have been employed including:

- That objectives of intervention are met
- Sufficient benefit to cost ratios (BCRs).

In terms of the objectives of an intervention in OE, it is clear that carbon savings, increased security of supply and additional employment are achieved by an island of Ireland OE sector, however the cost of doing so against the counterfactual or indeed competing technologies is better measured or compared by means of BCRs. Table 8-9 summarises the BCRs realised in 2025 for both wave and tidal technologies under the central scenarios. These are noted to be highly dependent on the extent of the export market captured (the main difference between the Whale, Shark and Minnow scenarios): the Whale scenarios providing an attractive rate of return in comparison to similar investments in comparable sectors[113], and the Shark scenario reporting reasonably good promise also.

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[113] A BCR of 8.3 for achieved & future potential GVA returns of business development and competitiveness interventions for GB RDAs (2002/03-2006/07) in science, R&D and innovation infrastructure was reported by PwC. Impact of RDA spending – National report – Volume 1, Department for Business, Enterprise & Regulatory Reform, March 2009.

Table 8-9 BCRs in 2025 for OE under Whale, Shark and Minnow central scenarios.

Scenario	Wave	Tidal
Whale	11.2	10.6
Shark	8.1	7.5
Minnow	6.1	5.6

Source: SQW Energy

8.51 In addition the economic analysis has shown that OE technologists and developers currently require additional subsidy (over and above that currently on offer) if they are to achieve an acceptable level of return on their co-investment. This will initially require reasonable levels of Government investment to encourage and to allow 'learning by doing' in order to better quantify the likely opportunities for learning (second most sensitive critical variable) which are at present somewhat uncertain. In all the economic scenarios modelled the likely additional funding required to meet the investor's 'project hurdle rates' have been added in to the overall OE cost-benefit and NPV analysis.

8.52 As much of the OE data is currently at best a good estimation, a series of reviews should be undertaken every few years to assess whether the development produced matches the realistic expectations (as modelled here) over time. This will begin to determine the actual value of OE to a sufficiently accurate level for increased large-scale investment (public, but increasingly private).

9: Conclusions and Recommendations

OE sector progress

9.1 The literature review revealed a wide range of OE development activity, and therefore an equally broad spectrum of cost and performance data, both current and projected. The stakeholders contacted and interviewed (academics, government officials, technologists, developers and utilities) provided up to date information that built on the initial literature review to produce a 'current' snap-shot of the OE industry.

9.2 It is clear that there exists much interest and activity in the island of Ireland's OE sector, premised somewhat on the scale of the island of Ireland's marine renewable resource, which if successfully developed, could make a major contribution towards economic growth and renewable energy targets – both locally (including exports) and globally.

9.3 Developing these emerging technologies is extremely challenging and the costs at this stage of early development are therefore comparatively high. This has limited the OE conversion technology developer's ability to prove their device capabilities and effective operation. There are however a small number of promising technologies (wave and tidal) with up to a couple of years of in-sea operational experience, and utilities are showing significant interest in scaling up their OE ambitions.

9.4 In addition to the enormous technical challenges it is also apparent that some in the sector have struggled to balance technology development with the ability to raise investment capital or indeed receive sufficient incentives to continue in this sector.

Projected economic value of OE to the Island of Ireland

9.5 There is currently sound quantitative evidence that a fully developed island of Ireland OE sector providing a home market and feeding a global market for RE could by 2030 produce a total NPV of up to €9.9 billion and many thousands of jobs to the Republic of Ireland and Northern Irish economies.

9.6 In summary with sufficient learning rates encouraged and proven through initial subsidy it is possible that an island of Ireland wave energy industry meeting the 500MW 2020 target could produce at least 1,431 additional FTE jobs and an NPV of €0.25bn, increasing to 17,000-52,000 FTE jobs and an NPV of between €4-10bn by 2030. Similarly a tidal industry providing 200MW of capacity by 2020 may deliver around 600 FTE jobs and an NPV of €111m, increasing to 8,500-17,000 FTE jobs and an NPV of between €1.5-2.75bn by 2030.

9.7 These NPVs are calculated with the inclusion of all subsidies required in the early years, and may increase significantly post 2030 as by then subsidy was a factor of the past only.

9.8 Although the optimistic scenarios may seem just that (optimistic), it is worth noting that many of the factors and variables chosen are similar to those witnessed for the onshore wind industry over the past 20 years. It is apparent that even since the onshore wind experience governmental priorities have further shifted and are increasingly focussed on low carbon RE capacity. This is motivated by the legally binding emissions targets, an imperative for increased security of supply and an opportunity to use home advantage not only to deliver these, but also to gain economic benefit through capture of local and export opportunities.

9.9 The economic analysis clearly shows that a number of actions are likely to have greatest impact on providing economic value for an island of Ireland OE sector.

Early actions required: 1) subsidy

9.10 The current levels of subsidy are unlikely to be sufficient to aid and retain local OE development. The monies currently available to OE under the REFIT although greater per MWh than those of the RO have a much shorter duration of 15 years. This has been proven by developers, academics and this study to be very unlikely to sufficiently incentivise OE development in the Republic of Ireland to meet its own OE targets.

9.11 Additionally most developers have also shown that the levels of funding under the RO are also currently insufficient to provide a significant incentive to gain matching investment; at least for the more expensive production prototypes that are currently being deployed. It is however likely that such subsidy will rapidly decrease in future should the predicted learning rates and cost reductions emerge. As there is a wide spread in the reported costs of OE it is difficult to conclude on an appropriate subsidy (in terms of value, volume and timing), although it is envisaged a further work-stream may wish to investigate this based on a much closer examination of recent developer costs.

9.12 There is also good evidence that a 'production based' credit system (such as the REFIT or NIRO) is of limited use in delivering a new technology as there is a gap in funding between R&D and full commercial production. This gap exists for pre-commercial demonstrators that are unlikely to have high load-factors due to variability and test or reliability factors while they also do not benefit from the economies of scaled production. It is therefore suggested that a form of capital grant should be implemented to allow full development of OE in Ireland. The UCC-HMRC Wave Energy Testing Protocol summarises the likely stages of project development along with the corresponding costs.

Early actions required: 2) promoting local capacity growth rates

9.13 In addition to the technical and economic factors, it is clearly proven in the analysis that barriers to capacity growth rates such as the ability of the electricity grid to transport the OE power to demand centres; regulatory and environmental delays or barriers; and supply chain availability have the greatest long term affect on economic viability. The efficient working or removal of these barriers is of utmost importance and will allow competitive advantage for foreign investment in OE over those regions that lag. If these critical enablers (many of which are fortunately within the Government's power) are put in place in a timely fashion the OE opportunity can be exploited and the associated benefits can flow.

Early actions required: 3) promoting learning for cost reduction

9.14 The major impact on economic viability is the rate at which learning develops leading to greater productivity and lower costs. The wide range of devices and concepts confirms that there is still much to learn, and the local capacity of research organisations (academic and industrial) will be critical to creating Intellectual Property and maintaining the relevance of the island of Ireland's knowledge base. This in itself has been, and will be, central to both developing the local supply chain and attracting international finance or companies.

9.15 While some have argued that it would be better to concentrate on single 'already proven' OE technologies, and although some convergence in technology choice is observed in tidal devices it is not yet evident that any one presently available device is going to provide the final most competitive long term solution. We absolutely do not say that one of the existing devices may not achieve such market dominance and therefore that the more developed devices should not be well funded, however to balance the risk of backing the wrong investment a portfolio of risks should be invested in – from very early concepts that show novel and real potential through to full-scale devices showing similar promise.

9.16 Additionally it is worth noting that outside of bespoke OE technical or device requirements there is a great deal more in the value chain which will require development and collaboration. Many of these are all-Ireland specific (e.g. electricity grid, ports, skills, research, etc.) and are generic in terms of which technologies become dominant. Any supports and therefore learning in these areas will be used by the entire industry.

Early actions required: 4) promoting OE exports

9.17 Although a home market is likely to be the initial driver for island of Ireland companies to engage with the OE sector, the economic analysis has shown that gaining a good share of the global OE market through exports (products and services) allows maximum leverage of local capabilities and thus significantly increases net GVA.

9.18 Promotion of the island of Ireland OE resource and capabilities overseas is therefore necessary, but equally local suppliers should be informed of the probable opportunities as they emerge.

Uncertainties

9.19 Although the factors determining the success of an island of Ireland OE sector are not entirely certain at present due to the early stage of technology development, there is a good precedent for a belief that OE will deliver on its promise: the technology development and cost reductions of onshore wind and electricity generating gas turbines being prime examples.

9.20 A home market advantage already exists in the form of Europe's best wave resource and a very large proportion of Europe's tidal resource. Additionally there already exist world-leading OE companies, utilities, ocean engineering sectors and marine research capabilities, although the ability to capture the opportunities is presently difficult to quantify in such a nascent industry. A well informed industry is however likely to be able to deliver appropriate products to the OE sector and begin specific OE supply chain development.

9.21 The short-term costs of Governmental subsidy would seem to be low compared to the possible long-term prize available to the Irish economy. Even with the most optimistic levels of deployment over the next 5 years, the outlays in terms of initial subsidy are unlikely to be much greater than €60 million. Competitively maintaining and developing the already significant island of Ireland OE expertise and industry over that period will allow the opportunity in future years to re-examine progress and the economic case with better and more certain data whilst retaining the possibility to capture a significant portion of a home and global market.

In conclusion

9.22 As the economic valuation bears witness to, and only the regular future analysis of development will confirm – there is a great opportunity that further investment will provide long-term sustainable growth and wealth creation to the island of Ireland.

9.23 In conclusion, for a relatively small initial investment over the next 5 years there is the possibility of continuing along the trajectory which may eventually produce an OE sector with very large upside. Such a sector based on the home resource advantage and once developed is likely to remain within the island of Ireland providing significant employment.

Annex A: Ocean Energy Developer Review

A.1 A list of wave and tidal energy device developers was drawn up using the team's underlying knowledge of the Ocean Energy (OE) sector and a review of the publically available documents listed below:

- The Ocean Energy Research area of the Marine Institute, Ireland (http://www.marine.ie/home/OceanEnergy.htm)
- The European Marine Energy Centre (www.emec.org.uk)
- The New and Renewable Energy Centre (www.narec.co.uk)
- Wavehub (www.wavehub.co.uk)
- The International Energy Agency Ocean Energy Group (www.iea-oceans.org)
- The British Wind Energy Association – Marine area and 2009 conference material (www.bwea.com/marine/index.html)
- The All-Energy 2009 conference material (http://www.all-energy.co.uk)

A.2 The company websites for each of the device developers was visited and the most recent news items and technology developments were noted under two headings:

- Current status – to clarify how close to undertaking a commercial project they are at present
- Future plans – to set out information on any solid future developments (identified projects of more than 1MW that are publicised as being developed on a 'commercial' basis) and the associated timescales envisaged.

A.3 Internet searches for recent news articles from other reputable sources were also undertaken. Where no information was available this was also noted. One developer was contacted directly via email in order to clarify information presented on their website and a response was forthcoming.

A.4 The findings from the research were collated into separate tables for wave and tidal technologies and developers were classified under a traffic light coloured system depending on their current status and future plans as follows:

Current status

- **Green** was applied if the developer had successfully tested a full-scale prototype at sea.
- **Orange** was applied if the developer had successfully tested a less than full-scale prototype at sea or has firm plans for a full scale prototype to be deployed in the next 2 years
- **Red** was applied if a developer was considered not to have proven their device as seaworthy.

Future developments

- **Green** was applied if the developer has announced plans to work with a utility company and is looking to get commercial projects underway in the next 3-5 years
- **Orange** was applied if more full scale prototype work appears to be forthcoming
- **Red** was applied if no information was available or a development appears to have stalled.

A.5 The findings are presented overleaf.

Figure A-1 Status Summary of Wave Device Developers

Developer	Current status	Future developments
Aquamarine Power	Onshore test rig produced grid connected electricity (NaREC, April 2009) Deployed full scale grid-connected Oyster 1 device (350kW) at EMEC (November 2009)	Aquamarine has an agreement with Airtricity, the renewable energy division of Scottish and Southern Energy to develop sites capable of hosting 1,000MW of marine energy by 2020 The company will begin deployment of Oyster 2, which consists of three flaps linked to a single onshore 2.4 MW hydro-electric turbine at EMEC in Summer 2011.
AWS Ocean Energy	Deployed (Loch Ness, Scotland) a 1/9th scale of its AWS-III device, a ring-shaped multi-cell surface-floating wave power system during 2010.	AWS Ocean Energy is aiming to deploy a full-system prototype AWS-III during 2012 and a pre-commercial demonstrator plant during 2013.
Finavera renewables	The company placed a 72-foot-long buoy in the waters off of Oregon in September as part of an ongoing effort to assess the commercial potential for wave power. The buoy, however, sunk in 115 feet of water on October 27, according to a report on RenewableEnergyAccess.com (http://news.cnet.com/greentech/?keyword=Finavera)	Appear to have moved away from wave energy at present focussing on wind (abandoned one wave project in 2009 (http://hydrovolts.blogspot.com/2009/02/finavera-waves-goodbye.html)) but holding on to Aquabuoy IP to seek future opportunities.
Fred Olsen Renewables	The FO3 Wave Energy Converter, developed by Fred Olsen, is being assisted by SEWEEC, an EU funded project and is participating in the United Kingdom's Wave Hub project planned for launch in the spring of 2010	No information available
Green Ocean Energy	Tank testing only to date	A full scale prototype of Wave Treader is scheduled for deployment next year (2010).
Ocean Energy Ltd	1/4 scale prototype tested at sea (Galway) in Dec 2006 validated by the HMRC	Looking to move to near full scale prototype deployment
Ocean Power Technology	Scheduled to deploy their PowerBuoy at EMEC in summer 2009	5MW array due to be installed at Wavehub (2011?)
Oceanlinx	Deployed its full-scale wave energy conversion unit (450kW) at Port Kembla (south of Sydney) in early February 2009 Grid-connected its 3rd Generation Wave Energy Converter, the Mk3PC March 2010	Portland (Victoria, Australia): progressing the permitting stage for the deployment of multiple units into a wave energy array. Rhode Island (USA): a Memorandum of Understanding ("MOU") with Rhode Island State authority for a 1.5MW unit, followed by a 15 to 20MW electricity generating facility off the mainland. GPP (Namibia): a signed contract with GPP, part of the listed Southern African Utility SELCo for a 1.5MW unit. Once unit achieves agreed performance criteria to be followed by additional units, equivalent to 15MW. Hawaii (USA): a signed MOU with an island in Hawaii for up to 2.7MW. Mexico: a proposed project at Rosarito in Baja California, to be jointly developed with CFE and DEFAESA (the renewable arm of Grupo R) from 2010.
Orecon Limited	Will occupy the fourth berth at Wave Hub, which aims to be operational from August 2010 (but devices will not be operational there until 2011)	Appointment of Liquidators – March 2010

Source: SQW Energy

Figure A-2 Figure A-1 (continued)

Developer	Current status	Future developments
Pelamis	A set of three Pelamis attenuator devices (3 x 750 kW) became operational off the Portuguese northern coast in September 2008. Fincnicla difficulties of project partner Babcock and brown have led to this stalling at present (http://www.pelamiswave.com/media/statement_on_aguadoura_project.pdf).	E.ON are scheduled to deploy a Pelamis P-2 device (750kW) at EMEC in conjunction with Pelamis Wave Power in 2010. Aegir (a JV between Pelamis and Vattenfall) is working towards installing multi-machine array, with an installed capacity of up to 20MW off the Shetland Islands by 2014.
Seabased	The first prototype was installed at sea 2006 and is expected to remain in operation until 2014.	The local authority in Västra Götaland has given permission to deploy up to 40 buoys and a maximum of 10 wave power devices at the site. The research facility is scheduled to be complete by 2009/2010 and will be in operation until 2013-2014 when all the equipment will be removed
Trident Energy	Trident Energy is currently in the final stages of preparing for the deployment of 20kW demonstrator (in Lowestoft, Suffolk) prior to the design and deployment of the company's first full scale commercial 1MW rig	Unknown
Wave Dragon ApS	Tested prototype in Denmark	Looking to deploy 7MW pre-commercial demonstrator in 2009 (Pembrokshire) but UK manager confirmed that delays in the consenting process and additional funding requirements have put the project on hold at present and no 2009 deployment will be possible
Wave Energy AS	The construction of the pilot started in 2007, due to be finished by the spring 2008 and ready to be installed during summer 2008. Environmental issues have demanded a movement of the project to another location.	Unknown due to relocation issues
Wavebob Ltd	1/4 scale prototype tested at sea (Galway)	The company has signed a research and development agreement with Vattenfall AB. The two companies will collaborate on bringing the prototype Wavebob device to readiness for a full-scale commercial wave farm. Wavebob Ltd. intends the device to be used at a later stage in a commercial wave farm off the west coast of Ireland
Wavegen (Voith Siemens)	LIMPET operational since 2000 (100kW)	Siadar Wave Energy Project granted approval by SG (4MW, Lewis), operational by 2011?
Wavestar Energy	The Wave Star scale 1:10 grid connected wave energy machine has been operating in the sea for nearly 3 years (since 2006)	The first 500 kW machine has been under development since 2007. The first section of the 500 kW Wave Star machine is launched in the North Sea outside Hanstholm in September 2009 The 500kW machine is expected to be doubled in size in a few years. When the machine is doubled in size - and thus can handle twice as large wave height - it is expected that the machine's power will increase 11 fold. This means that future generations of the Wave Star machine are expected to operate at a maximum rating of 6 MW.

Source: SQW Energy

Figure A-3 Status Summary of Tidal Device Developers

Developer	Current status	Future developments
Atlantis Resources Corporation Pte Ltd	In September 2006, Atlantis connected a tidal current turbine to grid. Atlantis became the first company in the world to decommission a tidal current test site in May 2008. Atlantis completed the installation, grid-connection and commissioning of a 150kW Nereus™ tidal current turbine in May 2008 at San Remo, Australia. In August 2008, Solon™ became the world's largest horizontal axis turbine to be tow-tested	Bidding in current crown estate leasing round for the Pentland Firth. Plan to power an onshore data centre rather than connect to national grid. The ultimate goal is reported as being to install 150MW of turbines at a cost of about £400m after a first trial phase of 30MW is built. This scaled-up version would include 150 turbines, at 1MW each, an offshore transformer platform and a single cable that would link to the data centre.
Engineering Business Ltd	150kW prototype tested at Yell Sound off Shetland 2002/2003	The final stage in EB's development model for the Stingray was the completion of a 5 MW grid-connected Stingray tidal farm. In total, ten Stingrays were supposed to be installed, each rated at 500 kW. The first 500 kW Mach II Stingray was ready to be installed and tested in 2005. Four more would have been installed in 2006, with the remaining five following in 2007. Although a location was not finalised, a site off the Shetlands looked likely for the farm. However, EB subsequently discontinued development of the Stingray as the funding available was "not on the scale or basis that would allow EB to rapidly or profitably make Stingray a commercial reality". (http://www.nsnmmedia.co.uk/joomla15b/images/stories/aquaret/pdf/cstsstingray.pdf)
Hammerfest Strom	300kW Prototype installed in 2003 in Kvalsund, Northern-Norway. In place for 4 years, re-installed 2009 for more testing Deployed an ADCP and turbulence meter at EMEC, preparatory to their device deployment in 2010	Manufacture commencing 2009. Planned installation in Scottish waters in 2010 (6 months test period before delivering the 10MW commercial park in 2012 for Scottish Power).
Lunar Energy	1MW commercial prototype's power train synchronised to a simulated grid and produced electricity in dry testing (May 2009)	Commercial prototype unit is also expected to be deployed at the European Marine Energy Centre (EMEC) in Orkney over the next year (comment from May 2009). Agreement with Korean Midland Power Co (KOMIPO), to supply a giant 300-turbine field in the Wando Hoenggan Water Way off the South Korean coast. The field is expected to supply electricity generated by tidal power to 200 000 Korean homes by 2015
Marine Current Turbines	1.2MW full scale device deployed in Strangford Lough, May 2008	10.5MW tidal energy farm off the coast of the Welsh island of Anglesey (JV with Npower). Aiming for a commissioning date in 2011
Ocean Flow Energy	1/10th scale unit that has been successfully tested in Strangford Narrows, Northern Ireland. Testing of the 10th scale unit started in June 2008 and has continued through into 2009 including a period of deployment during the winter months	Ocean Flow Energy is currently developing a 1/5th scale Evopod based on the 1/10th scale unit that has been successfully tested in Strangford Narrows. The 1/5th scale Evopod has a rated output of 22kW
Open Hydro	Prototype connected and generated onto National Grid, May 2008. 1MW device deployed in Bay of Fundy (Canada) for in Bay of Fundy (November 2010) Nova Scotia Power	Plan to install array of large Open-Centre Turbines for Alderney Renewable Energy in the Channel Islands
Ponte di Archimede SpA	In 2002 a prototype was deployed in the Strait of Messina and it continues since then grid connected operation. The tests indicate that the turbine produces 25kW of power in a current speed of 1.8m/s	Next steps for the testing and development include deployment of three further prototypes – in China (Zhoushan Archipelago), Indonesia and the Philippines. The construction of the Kobold II in Indonesia has started and the plant will be installed just outside the coast of Lombok by the end of 2009.
Pulse Tidal Ltd	100kW Humber prototype system generated gird connected power (July 2009)	Currently negotiating the location for first full-scale project, which they are hoping will begin operation in 2012

Source: SQW Energy

Figure A-4 Figure A-2 (continued)

Developer	Current status	Future developments
Scotrenewables	Very little information available as website is under reconstruction. Total website (shareholder) states that a 1/5 scale model is expected to be tested offshore in 2009. Construction of a full-scale prototype is scheduled for 2010	Scotrenewable has raised £6.2 million to build a working prototype of a floating tidal turbine that it says will be cheaper to install and maintain than others being tested now. The 8-meter-long prototype, ideally, will go into the water at the European Marine Energy Centre (EMEC) Tidal Test Site that sits just down the road from ScotRenewables in 2010. Total holds a 16% interest in Scotrenewables Marine Power.
SMD Hydrovision	Tested prototype (1:10) at NaREC but the Hydrovision website has been subsumed by SMD main website so suspect development has stalled	No information available
Statkraft and Hydra Tidal	No evidence of any sea trials of a prototype of any size to date	Concession to deploy the Morild power plant (one full scale prototype initially) in the Gimsøysund tidal current at Lofoten Islands was granted by Norwegian authorities in May 2009.
Swan Turbines	No evidence of any sea trials having been undertaken to date	Swanturbines is seeking new investment to take the technology to the next stage of commercialisation
Tidal Generation Ltd	Currently installing a half-scale device (500kW) at EMEC (July 2009)	No information available
Tidal Steam	Tank testing	No information available
Tocardo International BV	In summer 2008 the first T50 turbine (up to 50kW) was installed in the Afsluitdijk barrage and has been fully operational and grid connected since	The first T150 (up to 150kW) units will be installed in Holland summer 2010, followed by the large T500 (up to 500kW) turbines, which will be installed in the Pentland Firth summer 2011
Underwater Electric Kite Corporation	The first demonstration/test of the UEK System was in 2000. A 3m twin UEK System turbine was installed in the flume of the DeQew hydro station operated by Ontario Power Generation (OPG).	Was cleared to demonstrate technology in Bay of Fundy, Canada (news as at Jan 2008) with environmental approval being granted May 2008. However a 2009 news report went as follows: Minas Basin (the company behind the UEK) won the contract to build a tidal energy test facility in the Bay of Fundyworth $12 million to $14 million. The facility includes designing and operating a structure to receive electricity from the turbines and process data. But delays occurred in selecting an ideal test spot, and underwater cable will not be installed until 2010. Minas Basin also won the right to test a turbine in the Bay of Fundy, but its plan has run into trouble. Company president Scott Travers confirmed the original plan to launch an underwater electric kite has been scrapped. Minas Basin and a new partner will announce a substitute for the underwater electric kite. Minas Basin decided to dump the underwater electric kite mainly because of "the requirement to be sufficiently confident of technical development to meet demonstration facility target dates," said Mr. Travers said in his email. [Sources: The Telegraph Journal, The Chronicle Herald]
Verdant Power	Completed the RITE Project's Phase 2 Demonstration of the full scale Free Flow System delivering electricity generated from the tides of the East River to New York businesses. Over this two-year period, Verdant Power operated six full-scale turbines in array.	Now in the process of applying for a pilot license from the Federal Energy Regulatory Commission (FERC) to expand the project. This license would allow Verdant Power to build out the RITE Project into a 30-turbine 1 MW pilot project and to commercially deliver the energy generated.
Voith Siemens	Voith state that they are following a risk-minimising staged approach, i.e. in the first two phases only a limited number of turbines will be installed and seriously tested. Upon proof of concept and reliability, production will be ramped up, and their South Korea project will be gradually installed	Comment from Dr. Jochen Weilepp (Head of Ocean Energies, Voith Siemens Hydro Power Generation GmbH & Co): "After conceptual engineering of the machines is completed, detailed engineering and lab-based component testing for all relevant and new technologies is the next risk-mitigating step. This will be followed by installation of a 1:3 scale model and then a gradual scaling up, ultimately resulting in a product that can be manufactured in series production. We intend to install our pilot scale machine in winter 09/10 to provide a solid proof of concept."

Source: SQW Energy

Annex B: Support mechanisms for renewable energy projects

Overview of support mechanisms

B.1 A summary of the existing types of renewable energy support mechanisms is provided below, followed by an analysis of the global availability of these support mechanisms (see Tables B1 to B4).

Capital Investment Grants

B.2 Grants are made available to businesses that are undertaking investment projects but need financial help to go ahead. They are often designed to fund demonstration projects for renewable energy in an effort to reduce the financial risks faced by developers.

B.3 For example, the UK Wave and Tidal Stream Energy Demonstration Scheme made available up to £42 million to provide capital grants and revenue support to demonstrate pre-commercial farms of ocean energy systems in the UK; and the UK Carbon Trust Applied Research Grant which has provided £2.5 million of grant funding for specific ocean energy research projects since the scheme started in 2001.

B.4 With the Scottish Executive Marine Energy Fund, a total of around £13m was made available to developers to provide up to 40% of capital costs and additional revenue support up to 100% of eligible costs, for projects deploying devices at the European Marine Energy Centre in Orkney (funding was announced for nine wave and tidal power projects).

Guaranteed prices and feed-in tariffs

B.5 A feed-in tariff (FIT) involves paying set, guaranteed, tariffs for renewable energy, usually over a long time period (e.g. 15 years). FITs are also known as Electricity Feed Laws, Advanced Renewable Tariffs (ARTs), Renewable Tariffs, and Renewable Energy Payments[114].

B.6 The tariffs are funded out of electricity consumers' bills, and can be implemented via an obligation for utility companies to buy electricity generated from renewable sources at above-market rates set by the government[115].

B.7 FITs come in many forms – for example: they can be awarded for all electricity generated by the renewable energy system, or as an additional bonus for energy which is 'exported' to the grid; they can guarantee a fixed price for renewable energy generated, a fixed mark-up to market prices, or a combination of the two (e.g. with cap and floor prices).

B.8 FITs are widely and successfully deployed in continental Europe to promote renewable energy. For example, in Germany starting in 1991, renewable energy producers could sell their power to utilities, who were obliged to buy the power at 90% of the retail market price (i.e. well above wholesale power prices). The German EFL was changed in 1999; the new law fixed both the payment and the number of years during which the owner would receive support under the programmes.

[114] http://www.wind-works.org/articles/feed_laws.html
[115] http://en.wikipedia.org/wiki/Feed-in_Tariff

B.9 Since the start of EFL in Germany, the installed wind generating capacity has increased to more than 12,000 MW and an increase has also been experienced in the amount of generation from other renewable sources of energy. This remarkable success has been attributed to Germany's ground-breaking EFL[116].

B.10 The EFL and other FITs are widely viewed as having been successful in increasing the deployment of renewable generation, but less successful in reducing the price.

Mandatory Purchase Law (MPL)

B.11 This mechanism places an obligation on the usual wholesale purchaser of electricity:- be it the grid operator, federal/state utility, electricity transmission, or distribution company to buy and transmit a given proportion of the electricity from eligible renewable energy sources, independently from the short-term demand. This guarantees access to the grid for all renewable electricity producers. Usually, this would be a priority obligation, so that electricity from renewable energy sources is purchased ahead of electricity from other sources. The consequence of this obligation is that conventional/fossil fuel power generation plants must reduce their production[117].

B.12 Introducing a mandatory purchase law/obligation is one of the most important features of a good FIT law. In Italy, an obligation for electricity generators to feed a given proportion of RES-E into the power system (in 2006 the target percentage was 3.05%), while in Finland, guaranteed grid access for all users and renewable energy producing plant is implemented under the Electricity Market Act No 385/1995. A MPL is important to increase investment security, because producers will be assured that each unit produced can be sold.

Investment tax credit and production tax credits

B.13 Production Tax Credits (PTCs) are credits awarded to renewable energy generators for every MWh of renewable electricity sold (hence *production*)[118].

B.14 The credits can be presented in lieu of corporation tax payments. In the US, they are an important part of the wider strategy to promote science and innovation. The value of a PTC can be different for different technologies and indexed with inflation. It is usually a corporate tax credit, meaning that it does not apply to residential renewable energy production[119].

B.15 PTC was first established in the US in 1993 and it is typically renewed every 2 years. Companies that generate wind, solar, geothermal, and "closed-loop" bioenergy (using dedicated energy crops) are eligible for the PTC which provides a 2.1-cent per kilowatt-hour (kWh) benefit for the first ten years of a renewable energy facility's operation[120]. The levelised value (i.e. the value per MWh spread over the life of the project) will depend on the project lifetime. The US PTC now extends to renewable electricity produced by wave and tidal energy through to 2013.

B.16 An Investment Tax Credit (ITC) reduces federal income taxes for qualified tax-paying owners based on capital investment in renewable energy projects. Investment tax credits, earned when the capital equipment is placed into service, help to offset upfront investments in renewable energy projects and provide an economic incentive to develop and deploy more capital-

[116] http://www.fuelandfiber.com/Athena/ElectricityFeedLawsNewAthenum.doc
[117] http://onlinepact.org/p2.html
[118] http://www.social.mtu.edu/gorman/RenewableProductionTaxCredits.htm
[119] http://www.awea.org/policy/ptc.html
[120] http://www.ucsusa.org/clean_energy/solutions/big_picture_solutions/production-tax-credit-for.html

intensive renewable energy technologies. ITCs do not currently extend to wave and tidal stream energy[121].

Obligations

B.17 The Obligation mechanism requires licensed electricity suppliers to source a specific and annually increasing percentage of the electricity they supply from renewable sources, effectively guaranteeing a market for the renewables which are less cost competitive than conventional generation[122]. The Renewables Obligation (RO) is the British Government's main policy instrument for supporting renewable energy. The current obligation level in the UK is 9.1% for 2008/09 rising to 15.4% by 2015/16[123].

B.18 A Renewables Obligation Certificate (ROC) is a green certificate issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers within the UK by a licensed electricity supplier. One ROC is issued for each megawatt hour (MWh) of eligible renewable output generated.

Renewables Portfolio Standards (RPS)

B.19 The RPS mechanism, common in the US, is very similar to the UK Renewables Obligation. It provides a mechanism to increase renewable energy generation using a cost-effective, market-based approach that is administratively efficient. It requires that a minimum percentage of generation sold or capacity installed be provided from renewable energy sources[124].

B.20 Typically, RPS obligations are placed on the final retailers of power. Obligated utilities must ensure that the target is met, either from their own generation, power purchases from other producers, or direct sales from third-parties to the utility's customers. Certified renewable energy generators earn certificates for every unit of electricity they produce and can sell these along with their electricity to supply companies[125]. The ultimate goal of the RPS is to stimulate market and technology development so that energy will be economically competitive with other conventional forms of electric power generation[126].

B.21 The level of obligation typically increases over time, with several US states (e.g. California) setting ambitious targets. The cost of the RPS would therefore also be expected to rise over time, though most States include an overall cost cap, to protect consumers from high prices. Each RPS is tailored to the particular conditions within each state, including: the degree of political support; existing and potential future RE resource; market structure; and the lobbying power of incumbent interests[127].

B.22 Utilities that do not meet their RPS target are obliged to make and Alternative Compliance Payment. The funds collected from ACPs are often held in a fund to be used in support of green energy investment (unlike the UK RO, where this "buyout fund" is recycled to utilities in proportion to their compliance).

[121] http://www.wri.org/publication/bottom-line-series-renewable-energy-tax-credits
[122] http://www.ofgem.gov.uk/Sustainability/Environment/RenewablObl/Pages/RenewablObl.aspx
[123] http://www.berr.gov.uk/energy/sources/renewables/policy/renewables-obligation/what-is-renewables-obligation/page15633.html
[124] http://www.epa.gov/chp/state-policy/renewable_fs.html
[125] http://en.wikipedia.org/wiki/Renewable_portfolio_standard
[126] http://www.epa.gov/chp/state-policy/renewable_fs.html
[127] SQW Energy (2008) 'International prices for wave power': A report for Aquamarine Power Ltd

B.23 The majority of US states have enacted an RPS, with targets ranging from 1% to 30% of electricity generation. In Europe, the Netherlands has been a leader among RPS initiatives. Dutch utilities have adopted an RPS voluntarily, based on targets of 5% of electricity generation by 2010, increasing to 17% by 2020. Other countries with RPS-type regulatory requirements include Australia, Brazil, Belgium, Denmark, France, Japan, Spain, Sweden, and the UK[128].

Renewable Energy Certificates (RECs)

B.24 RECs – also known as Renewable Energy Credits, Tradable Renewable Certificates (TRCs), Tradable Green Certificates (TGCs) and Green Tags – are tradable environmental commodities which represent proof that a unit of electricity has been generated from an eligible renewable energy resource. These certificates can be sold and traded or bartered and the owner of the REC can claim ownership of the "green" attributes of the renewable energy[129]. RECs are emerging as a way for utilities and customers to trade renewable energy production and/or consumption credits in order to meet obligations under RPS and similar policies.

B.25 RECs are used to represent the 'greenness' of a unit of renewable electricity generation. They allow units of renewable electricity to be divided into and traded in two distinct parts – the physical electricity and its associated 'greenness'. TGCs have developed as an efficient support mechanism for achieving ambitious targets for the deployment of renewable energy within liberalised electricity markets[130].

B.26 RECs and TGCs are gaining ground in the US, UK, Belgium, Denmark, and Australia. Europe embarked upon a "test phase" of an EU-wide renewable energy certificate trading system during 2001 and 2002[131].

Research & development (R&D) tax incentives

B.27 R&D is considered to be amongst the most important areas for the future development of renewable energy as the technology is often relatively immature compared to conventional alternatives, and R&D offers the promise of improved performance and reduced costs. R&D tax incentives usually provide for a reduction in the cost of research by reducing the amount of corporation tax paid (similar to ITCs above). They are an indirect approach to increasing national R&D expenditure and compliment government's expenditure in this regard. The incentives generally apply to most kinds of renewable energy, and:

- Improve the economics of renewable energy technologies and accelerate market adoption
- Stimulate the economy by creating jobs in the renewable energy sector and
- Encourage private sector investment in renewable technology research and development[132].

Competitive Tendering

B.28 In a tendering system, a national authority invites bids to provide a certain quantity of electricity or heat from renewable sources. The winners of the tender usually get a fixed price for the

[128] http://www.martinot.info/Martinot_NAR.pdf
[129] http://en.wikipedia.org/wiki/Renewable_Energy_Certificates
[130] http://www.berr.gov.uk/files/file15148.pdf
[131] http://www.martinot.info/Martinot_NAR.pdf
[132] http://www.hmrc.gov.uk/consult_new/rd-taxcredit.pdf

length of the contract. The tariff must be high enough to make the projects attractive, but the tendering process should reduce the risk of deadweight funding[133].

B.29 The United Kingdom tried competitive bidding for renewable energy resource obligations during the 1990s under its "Non-Fossil-Fuel Obligation" (NFFO) policy. Under the NFFO, power producers bid to provide a fixed quantity of renewable power, with the lowest-price bidder winning the contact. An analysis of the experience of renewable energy deployment in Europe shows that competitive mechanisms, such as the UK's Non-Fossil Fuel Obligation (NFFO) have been very successful in reducing the price paid for renewable generation, but less successful for deploying capacity. Other countries with similar competitively-bid renewable resource mechanisms have included Ireland, France, and Australia[134].

Concessionary loans

B.30 Governments or government agencies can support renewable generation by making low-cost loans available. Low interest rates and long payback periods differentiate this type of loan from a standard commercial loan.

B.31 The loan can cover all or part of equipment and installation costs and support can take a number of forms:

- A low interest/long-term loan directly available from a government agency.
- A loan, available on favourable terms from a bank, guaranteed or refinanced by the government (i.e. the government assumes some or all of the repayment risk).
- The loan can be available to project developers and/or to equipment suppliers and installers (who can pass on the benefit to their customers by offering low-cost financing).

B.32 Concessionary loans are often used in combination with other support mechanisms. For example in the United States they are used in conjunction with federal and state tax incentives.

B.33 Low-interest loans offered by major banks and refinanced by the federal government have been an important element in Germany's success in promoting renewable generation. Loans provide the capital to allow small firms, farmers and individuals to invest in renewable development. They are readily available and open to all technologies that meet the lending bank's investment criteria. They have been successful as part of a portfolio of measures which includes feed-in tariffs, direct investment subsidies, public information campaigns and favourable grid connection arrangements.

[133] http://www.hm-treasury.gov.uk/d/Tenders_RE_CDM_V1.3_rev.pdf
[134] http://www.martinot.info/Martinot_NAR.pdf

Table B-1 EU renewable energy support mechanisms

Country	Renewable Energy Target	Support Mechanism
Belgium	6% of electricity generation from renewable sources by 2010	Tradable green certificates (10 MWh per certificate)
Denmark	29% of electricity generation from renewable sources by 2010	Tender schemes have been used in the past for large offshore wind energy generation Subsidies for tidal energy range from 30-100% of total costs[135]
Finland	31.5% of electricity generation from renewable sources by 2010	Certain tax exemptions for renewable energy Discretionary investment subsidies of up to 40% awarded on individual basis Guaranteed grid access for all users and producing plant under the Electricity Market Act No 385/1995
France	21% of electricity generation from renewable sources by 2010	Advanced renewable tariffs (ARTs) of €0.13 /kWh offshore wind) base rate for 15 years[136] Tendering for large RE plants Tax reduction and capital grants available up to 50% 40% subsidies for biomass heating plant No tidal expansion beyond the 240 MW plant at la Rance is foreseen
Germany	12.5% of electricity generation from renewable sources by 2010	Feed-in tariffs on a stepped scale, de-escalating from €0.091 /kWh for duration of 20 years (plus €0.062 /kWh for the duration for offshore wind). The 250 MW Wind Programme also provides feed-in support of up to €0.031/kWh Large "soft loans" available The Nutzung erneuerbare Energiequellen (renewable energy sources) programme provides subsidies for RE electricity giving up to 100% capital grants. The BMU-Programme fur Förderung von Demonstrationsvorhaben (finance for demonstration projects) finances loans of up to 70% over 30 years for RE demonstration projects. The ERP-Umwelt und Energiesparprogram (environment and energy savings program) will finance via 10 year loans of up to €0.5M a maximum of 50% (East) or 75% (West) of investment costs. Tax incentives are also available
Greece	20.1% of electricity generation from renewable sources by 2010	Feed-in tariff available for a guaranteed 12 and possibly 20 years[137]. An obligatory purchase agreement for 10 years is also covered by the Electricity Law[138] National Development Law (NDL) 2601/98 provides subsidies of either 40% investment cost plus a 40% contribution to the interest on a loan, or 40% loan interest contribution plus full tax deduction for the investment The National Operational Programme for Competitiveness / CSF III (2000-2006) provides subsidy of up to a maximum of 50% (wind) of a total investment cost of between €44k-44m. Location was irrelevant except for solar.

[135] 2004, "Renewable Energy Policy Review - Denmark" European Renewable Energy Council, Belgium
[136] http://www.legifrance.gouv.fr/WAspad/UnTexteDeJorf?numjo=INDI0607865A
[137] 2004, "Renewable Energy Policy Review – Greece" European Renewable Energy Council, Belgium
[138] 2004, IEA Report "Market & Policy Trendsin IEA Countries," France

Country	Renewable Energy Target	Support Mechanism
Ireland	13.2% of electricity generation from renewable sources by 2010	Renewable Energy Feed-In Tariff (REFIT) – provides a fixed rate tariff of €0.059 or €0.057 (wind <5MW and >5MW respectively) and is the main support mechanism. The Sustainable Energy Authority Ireland (SEAI) Pilot Sustainable Energy Incubator Programme provides annual grants and other support for initial phases of a small number of "high potential" sustainable energy ventures.[139] National Development Plan (NDP) provides a new power capacity from renewable sources with budget is £8.5million in 2007[140]
Italy	25% of electricity generation from renewable sources by 2010	TDCs valued at €109/MWh (2006) An obligatory purchase agreement of for electricity from RE sources available Feed-in tariff plus a subsidy for capital investment is paid by the utility providers. The subsidy is only available for 8 years, and is evaluated on a case by case basis[141] Capital cost offsets are available for certain RE technology including wind power between 20-100kW capacity to the tune of up to 30% refund of initial cost[142]
Netherlands	9% of electricity generation from renewable sources by 2010	Milieukwaliteit van de Elektriciteitsproductie (MEP – environmental quality of power generation) is a feed-in tariff subsidy paid to grid connected generators at source specific rates from the national budget in the form of redeemable Green Certificates[143]. Tax reduction/exemption is available to energy possessing a Green Certificate
Portugal	45% of electricity generation from renewable sources by 2010	Programa de Incentivos à Modernização da Economia (PRIME – under the EU FPs) has support measures for RE providing grants and low interest loans for investment up to 40%.[144]. Tax reductions include a reduction in VAT (from 21% to 12%) on purchased equipment associated with RE[145] New Decree-Law 225/2007[146] specifies feed in tariffs however they must be individually calculated via complex equations on a case by case basis.
Spain	29.4% of electricity generation from renewable sources by 2010	Under Royal Decrees 661/2007[147] feed-in tariffs provide support for some offshore RE of €0.069/kWh for 20 years, however the exact final subsidy is determined by equation Low interest loans of up to 80% costs are available An obligatory purchase agreement available
Sweden	60% of electricity generation from renewable sources by 2010	TDCs are the main support tool, with generation companies receiving 1 certificate per 1MWh generated over a maximum of 15 years. Tax relief on purchased green energy
UK	20 of electricity generation from renewable sources by 2020 (likely to increase soon)	Obligatory targets with a Renewable Obligation, and tradable certificates (ROCs) UK and devolved government grant funding provided for ocean energy

Source: European Commission 6th Framework Programme (2007): Co-ordinated Action on Ocean Energy: Tidal Renewable Energy Research, Development and demonstration Roadmap.

139 http://www.sei.ie/index.asp?locID=1093&docID=-1
140 http://www.ndp.ie
141 2004, "Renewable Energy Policy Review – Italy" European Renewable Energy Council, Belgium
142 http://www.incentivi.mcc.it/
143 http://www.minfin.nl/en/home
144 http://www.qren.pt/
145 2004, "Renewable Energy Policy Review – Portugal" European Renewable Energy Council, Belgium
146 2004, "Renewable Energy Policy Review – Portugal" European Renewable Energy Council, Belgium
147 http://www.invenia.es/boe:iberlex:2007.10556

Table B-2 International renewable energy support mechanisms

Country	Renewable Energy Target	Support Mechanism
Australia	Legislation has just been given Royal Assent that is designed to ensure that 20 per cent of Australia's electricity comes from renewable sources by 2020[148] Previous to this the renewable energy target sought to raise the contribution of renewable energy sources in Australia's electricity mix by 9500 GWh per year by 2010 and maintain this requirement until 2020.	No specific programmes have been implemented in Australia for ocean energy, but an expanded programme has aimed at increasing the installed capacity of renewable energy within Australia and it does qualify for support under the more general renewable energy schemes such as the Mandatory Renewable Energy Target (MRET). The government's renewable energy target seeks to raise the contribution of renewable energy sources in Australia's electricity mix by 9500 GWh per year by 2010 and maintain this requirement until 2020. Under this measure, tradable Renewable Energy Certificates (RECs) are used to demonstrate compliance with the objective. State level incentives are also in operation for which ocean energy technologies would qualify; The Australian Capital Territory's (ACT) feed-in tariff scheme pays households and businesses that install renewable energy generation technology AUD 0.5005/kWh generated for systems up to 10kW. In practice therefore it is unlikely to provide much financial support for ocean energy. In Victoria a Renewable Energy Target scheme has been set up, being a market-based measure whereby all electricity retailers and wholesale purchasers of electricity in Victoria have a legal liability to contribute towards the generation of additional renewable energy by acquiring Victorian renewable energy certificates (VRECs). The aim is to increase the share of electricity consumption in Victoria from renewable energy sources to 10% by 2016.
Canada[149]	Canada has no mandatory renewable energy targets	Grant funding is available for ocean energy technology commercialisation projects through Sustainable Development Technology Canada. The ecoENERGY for Renewable Power programme provides production linked incentive payments of CDN 1 cent per kilowatt-hour for up to 10 years for electricity generated from eligible renewable energy projects (including ocean energy) commissioned between April 1, 2007 and March 31, 2011, inclusive. It is estimated that the programme will provide CAD1.5 billion of investment towards increasing Canada's supply of clean electricity. A tax incentive is also available in the form of an accelerated Capital Cost Allowance (CCA). This allows investors an accelerated write-off of certain energy efficient equipment or capital equipment used to produce energy from alternative renewable sources including ocean energy
Chile	10% renewable energy by 2024[150]	The 2008 non-conventional energy law requires companies providing energy from an installed capacity base of greater than 200MW to demonstrate that 10% of their total energy trade was injected in the system by non-conventional energy sources. The energy can be produced by their own plants, or by contacting from third-party companies. The quota will come into force at the start of 2010, and until 2014 will require 5% of electricity to come from non-conventional renewable energy sources. Starting from 2015, the obligation will be increased by 0.5% annually, reaching 10% in 2024

[148] Australian Government web pages (http://www.climatechange.gov.au/renewabletarget/index.html)
[149] Information taken from Global Renewable Energy Database (http://www.iea.org/textbase/pm/?mode=re)
[150] http://www.senado.cl/prontus_galeria_noticias/site/artic/20080122/pags/20080122105612.html (Official Web Site of the Chilean Senate Chamber)

Country	Renewable Energy Target	Support Mechanism
New Zealand	90% renewable energy by 2025[151]	The New Zealand government set up the Marine Energy Deployment Fund (MEDF). The fund aims to promote marine energy by offering NZD 2 million per annum over the next four years in grant funding to develop new ocean energy technologies, as well as testing how technology used overseas perform in New Zealand conditions. Applications for Funding Round Two (2008/9) closed on 24 November 2008, with two more funding rounds taking place in the future.
Philippines	Increase renewable energy capacity by 100% by 2013[152] Additional 1200MW of geothermal energy within the next 10 years Additional 2950MW of hydro power in the next 10 years	The Renewable Energy Act of 2008 provides a seven-year income tax holiday and tax exemptions for carbon credits generated from renewable energy sources. A 10% corporate income tax (compared to the regular 30%) is also provided once the income tax holiday expires. Renewable energy facilities will also be given a 1.5% realty tax cap on original cost of equipment and facilities to produce renewable energy. The law also prioritises the purchase, grid connection and transmission of electricity generated by companies from renewable energy sources and power generated from renewable energy sources is value added tax-exempt.
Republic of Korea	11% renewable energy by 2030[153]	A Renewable Portfolio Agreement is in place between the Government and energy suppliers in Korea. Korea Electric Power Corporation and six power companies including Korea Hydro & Nuclear Power Company, South-East power company, Midland power company, Westland power company, Southern power company, East-West power company and nine other companies including Korea District Heating Corporation and Korea Water Resources Corporation agreed to invest USD 1.260 million for three years between 2006 and 2009. A pilot renewable portfolio standard has been proposed which would legally require utility companies to generate at least three per cent of their electricity from low carbon energy sources by 2012. Businesses operating in the field of alternative energy technology are exempted from tax audits for three years from the first profitable year.

[151] New Zealand Energy Strategy (http://www.med.govt.nz/templates/ContentTopicSummary____19431.aspx)
[152] Philippine Renewable Energy Briefer (http://www.scribd.com/doc/18545900/Philippine-Renewable-Energy-Briefer)
[153] Korea Goes for "Green Growth", press release 2008 (http://www.iea.org/Textbase/Papers/Roundtable_SLT/korea_oct08.pdf)

Country	Renewable Energy Target	Support Mechanism
USA[154]	The United States have no mandatory renewable energy targets	In 2007 the US Department of Energy (DOE) got authorisation to establish a research programme in marine and hydrokinetic energy, including wave, current (tidal, in-stream and ocean), and ocean thermal energy conversion (OTEC). As a result, DOE spent USD 10 million on water power research in 2008, predominantly on ocean energy. The primary focus of federal level activity has been the provision of grants to support companies and institutions active in ocean energy in the United States. Fourteen companies and organisations received over USD 7 million in grants for a diverse and complimentary set of projects covering a wide spectrum of ocean energy technologies. The Emergency Economic Stabilization Act of 2008 included the Energy Improvement and Extension Act and extended production tax credits (PTC) and investment tax credits (ITC) for renewable energy projects including the creation of a new ITC for electricity produced by marine and hydrokinetic renewable energy systems with a rated capacity of at least 150 kilowatts and placed in service by 2011. Ocean energy also become eligible for the renewable energy PTC in 2008, but the rate of USD 0.01/kWh is only half of that granted wind, solar and closed-loop biomass generation. In addition, in 2008 DOE launched a competitive grant solicitation for ocean-energy device manufacturers looking for commercialisation support under Phase I of the Small Business Innovative Research (SBIR) programme. The total amount that will be allocated is not yet known, but interest in the SBIR programme has so far been very high.

Source: SQW Energy compiled from sources listed

[154] Information taken from Global Renewable Energy Database (http://www.iea.org/textbase/pm/?mode=re)

Table B-3 Summary of EU renewable energy support mechanisms

Renewable Energy Policy Support Mechanism		Belgium	Denmark	Finland	France	Germany	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	UK
	Specific Ocean Energy Mechanism							•			•			•
	General RE Feed-in Law		•	**	•	•	•	•	•	****	•	•	*****	**
	Renewable Portfolio Standard								•					•
	Tradable Renewable/Green Certificates	•	•	•		•			•	•			•	•
	Tendering Scheme		•		•			***			***			
	Mandatory Purchase Law			•			•		•			•		
	Tax Exemption /Credits		•	•	•	•	•		•	•	•		•	•
	Capital Grants/Subsidy Scheme	•	•	•	•	•	•	•	•		•			•
	Loan Scheme					•					•	•		

Sources: http://www.berr.gov.uk/files/file15148.pdf, http://www.globalbusinessinsights.com/content/rbef0001m.pdf, http://www.wind-works.org/FeedLaws/Finland/FinlandList.html, http://eetd.lbl.gov/ea/ems/reports/57666.pdf and http://ec.europa.eu/energy/energy_policy/doc/factsheets/renewables/renewables_se_en.pdf

Table B-4 Summary of international renewable energy support mechanisms

		Canada	USA*	New Zealand	Australia*	Chile	Republic of Korea	Philippines
Renewable Energy Policy Support Mechanism	Specific Ocean Energy Mechanism	•	•	•				
	General RE Feed-in Law				•		•	
	Renewable Portfolio Standard		•			•		
	RE Production Linked Incentive Payment	•						
	Tradable Renewable Certificates		•		•			
	Tendering Scheme							
	Mandatory Purchase Law						•	
	Tax Exemption /Credits	•	•					•
	Capital Grants/Subsidy Scheme	•	•	•	•			
	Loan Scheme							

Sources: The Global Renewable Energy Policies and Measures Database as updated in June 2009 (www.iea.org/textbase/pm/grindex.aspx), ecoENERGY for Renewable Power (www.ecoaction.gc.ca/ecorp), New Zealand Marine Energy Deployment Fund, Fund Definition Document, July 2009 (www.eeca.govt.nz/sites/all/files/medf-definition-document-july-09.pdf), IEA Ocean Energy Systems Annual Report 2008 (www.iea-oceans.org/_fich/6/Annual_Report_2008_(1).pdf)

Annex C: Literature Review Bibliography

Author	Date	Title/Source
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BERR	2007	Energy white paper: meeting the energy challenge, available at http://www.berr.gov.uk/files/file39387.pdf
Carbon Trust	2006	Future Marine Energy, available at http://www.thecarbontrust.co.uk/carbontrust/about/publications/FutureMarineEnergy.pdf
Carbon Trust	2005	Oscillating Water Column Wave Energy Converter Evaluation Report, available at http://www.carbontrust.co.uk/NR/rdonlyres/8F79783B-9969-45F9-957A-BD6A662EE688/0/owc1.pdf
CSO	2006	Enterprise Statistics on Distribution & Services
CSO	2007	2007 Census of Industrial Production, available at http://www.statcentral.ie/viewStat.asp?id=24
CSO	2008	Ireland: North & South: A Statistical Profile 08, available at http://www.cso.ie/releasespublications/ireland_statistical_profile_2008.htm
CSO	2009	Supply and use and input-output tables available at http://www.cso.ie/releasespublications/2005_input_output_table.htm
DCMNR	2005	Ocean Energy in Ireland, available at http://www.sei.ie/Renewables/Ocean_Energy/Ocean_Energy_Strategy/Ocean_Energy_Strategy_Report_18082006.pdf
DCMNR	2007	Energy Policy Framework
DTI	2002	Future Offshore: A Strategic Framework for Offshore Wind Industry, available at http://www.berr.gov.uk/files/file22791.pdf
DTI & MCEU	2004	Offshore Wind Farm Consents Process: Guidance Notes, available at http://www.berr.gov.uk/files/file22990.pdf
DTI	2005	Planning and Consents for Marine Renewables, available at http://www.berr.gov.uk/files/file15470.pdf
EC	2007	Co-ordinated Action on Ocean Energy -Tidal Renewable Energy: Research, Development and Demonstration Roadmap, available at http://www.eu-oea.com/euoea/files/ccLibraryFiles/Filename/000000000458/European%20Tidal%20Roadmap.pdf
EC	2007	An Energy Policy for Europe
EIA	2008	World Energy Outlook, available at http://www.worldenergyoutlook.org/
EIB	2007	Pros and Cons of Policies Promoting Renewables
EIB	2007	EU Policy Objectives and Energy Investment Decisions
EPRI	2007	Power and Energy from the Ocean Energy Waves and Tides: A Primer
ESRI	2007	Ireland Climate Policy for 2012 Assessment, available at http://www.esri.ie/UserFiles/publications/20071219164742/QEC2007WIN_SA_Tol.pdf
EWEA		Wind Energy: The Facts, available at http://www.wind-energy-the-facts.org/en/part-3-economics-of-wind-power/chapter-2-offshore-developments/development-of-the-cost-of-offshore-wind-power-up-to-2015.html
Forfas	2006	Enterprise Statistics –at a glance 2006, available at http://www.forfas.ie/publication/search.jsp?ft=/publications/2007/Title,678,en.php
Forfas	2007	Irelands Energy Policy - Major Documents
Forfas	2008	Energy Tetralemma - initial research
HMRC	2009	Dalton G, Lewis T, Alcorn R: "Case study feasibility analysis of the Pelamis wave energy converter in Ireland, Portugal and North America"
IEA	2004	Renewable Energy : Market & Policy Trends in IEA Countries, available at http://www.iea.org/textbase/nppdf/free/2004/renewable1.pdf
IEA	2007	Energy Policies of IEA Countries - Ireland 2007 Review, available at http://www.iea.org/textbase/nppdf/free/2007/ireland2007.pdf
IEA	2007	Irish Energy Review

IEA	2007	Ireland Energy Policies - Exec Summary
IEA-OES	2008	Harnessing the Power of the Oceans, Energy Technology Bulletin 52
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Marine Energy Group	2004	Harnessing Scotland's Marine Energy Potential, available at http://www.scotland.gov.uk/Resource/Doc/1086/0006191.pdf
Marine Institute Ireland	2007	Summary Status of the Ocean Energy Development Strategy, available at http://www.marine.ie/home/OceanEnergy.htm
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Rodger Tym & Partners	2008	NI Renewable Energy Supply Chain
RPS Group	2009	Engineering & Specialist Support Requirements for the OE Sector
SEAI	2007	Energy in Ireland 1990 – 2006, available at http://www.sei.ie/Publications/Statistics_Publications/Energy_in_Ireland/Energy_in_Irl_1990-2006_Fnl_07_rpt.pdf
SEAI	2006	Renewable Energy Development
SEAI	2008	Energy in Ireland, Key Statistics, available at http://www.sei.ie/Publications/Statistics_Publications/EPSSU_Publications/Energy_in_Ireland_Key_Statistics/Energy_in_Ireland_Key_Statistics_2008.pdf
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SEAI	2006	Energy in Ireland 1990 – 2005: Trends, Issues, Forecast and Indicators, available at http://www.sei.ie/Publications/Statistics_Publications/Archived_Reports/Energy_in_Irl_1990-2005_Final_Nov06_WEB.pdf
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SEAI -Marine Institute	2005	Accessible Wave Energy Resource Atlas: Ireland 2005, available at http://www.marine.ie/NR/rdonlyres/90ECB08B-A746-4247-A277-7F9231BF2ED2/0/waveatlas.pdf
SQW Energy	2008	International prices for wave power : A report for Aquamarine Power Ltd
UCC	?	Renewable Energy - Beyond Wind, available at http://www.ucc.ie/serg/pub/REBW.pdf
UKERC	2008	Marine renewable energy technology Roadmap, available at http://ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf

Annex D: Stakeholder Consultees

D.1 The Stakeholder Consultees approached are listed below. Not all provided full feedback, but many provided in depth information, particularly with regard to OE technology and development plans.

D.2 Although many people (see list below) provided excellent information as requested, very special thanks must go to a number of people and organisations who put very significant time and resource into informing this research:

- Gordon Dalton and Ray Alcorn from HMRC who provided additional research and commentary on the economic modelling.
- ESBI who gave access to their marine energy team and openly provided their own financial calculations for both wave and tidal developments to 2030.
- Puregen Marine Power and the Global Marine Alliance who contributed many insights into the existing Irish OE sector and the vision for the future.

Companies and Organisations Consulted

- Department of Enterprise, Trade & Investment Northern Ireland
- Enterprise Ireland
- ESB International
- Harland and Wolff Ltd
- HMRC Cork
- Invest Northern Ireland
- Queens University Belfast
- Marine Current Turbines Ltd
- Marine Renewables Industry Association
- OpenHydro Ltd
- Open Ocean Energy Ltd
- Pelamis Wave Power Ltd
- Pure Marine Gen Ltd
- SSE Renewables (nee Airtricity)
- Sustainable Energy Ireland
- Tonn Energy Ltd
- Vattenfall
- Wavebob Ltd

Annex E: Stakeholder Questionnaire

Economic Study for Ocean Energy Development in Ireland

SQW Energy has been contracted by Sustainable Energy Ireland, Enterprise Ireland and Invest Northern Ireland to undertake a study entitled an "Economic Study for Ocean Energy Development in Ireland (North and South)". This work involves undertaking a review of the present and future wave and tidal technology options, the likely home and export markets, and their related value chain. This information will be used to determine the potential net economic benefits to Ireland under various development and policy scenarios including possible enhanced and accelerated measures for Ocean Energy (OE).

Within the rapidly moving OE sector there are however a number of areas of uncertainty (e.g. costs, market, employment etc.). To help form policy to maximise Ireland's OE industry we would be grateful if you could take a little time to record your opinions on some of these factors. This would greatly aid delivery of the correct picture to the policy makers throughout Ireland in order to help maximise the possible success of OE.

All data received from you will be deemed strictly confidential and be completely anonymous if recorded in any written report. Although a complete response would provide us with the most accurate picture, any partial responses or estimates are also valuable to us.

Should there be any further discussion that you may wish to have with us, please do not hesitate to contact: Gary Connor, SQW Energy, 12 Melville Street, Edinburgh, EH3 7NS.

Tel: 0131 220 9964, Fax: 0131 225 4077, www.sqwenergy.com

Questions:

1) Please provide your views on the **estimated OE costs** (tidal or wave depending on the technology you represent) **and possible capacity deployment over time** in the table:

Year	Unit	2010	2015	2020	2030
Capital costs of OE devices?	€/MW				
	Or £/MW				
Operation & Maintenance costs?	€/MWh				
	Or £/MWh				
Likely scale of typical project or farm?	MW				
Your company's Irish deployment plans? (If any.)	MW				
Your company's estimated global deployment scenarios?	MW				
Total (all developers) international market estimate?	MW				

2) **Appropriate Aids and Subsidy**: please provide your thoughts on the OE related topics below for OE technology in Ireland.

Year	Unit	2010	2015	2020	2030
N. Ireland: appropriate ROC banding level for OE?	E.g. x2, x3 etc.				
Republic of Ireland: appropriate level of REFIT?	E.g. €220/MWh for '15' years				
What level of capital grants might be required for OE?	% of Capex				
Any other support to enhance / accelerate OE development?					
Any other comments?					

3) **Entities Employed in OE Projects**: please input your **estimated** proportions of cost and labour to the table below. If you are short of time we would encourage you to fill in the 5 **yellow** shaded "Totals" rows under each Project Stage, but we would be delighted if you also filled in any **white** cells that you can. See gray italics for example entries. This data will allow an estimation of the value and distribution of services that OE might engender.

Project Stage and Tasks	Estimated proportion of overall project cost? (%)	Estimated proportions of total stage/task spend in country of deployment? (% task cost)	Estimated total labour intensity for task? (Person yrs)
Planning & Development (P&D)			
Surveys: resource, geotechnical etc.		*e.g. 90% of surveys are local spend.*	*e.g. 3 person years for surveys*
Operations planning			
Environmental and EIA			
Vessel hire, divers & ROV			
Financial and legal, permits & consenting			
Totals	*e.g. 20% total project cost*	*e.g. 70% P&D stage cost*	*e.g. 12 person yrs P&D stage*
Design & Project Management			
Device design, optimisation and certification			
Research including consultants			
Totals			
Manufacture & Assembly			
Support structure			
Moorings & foundations			
Prime mover (rotor, foils, floats, absorbers, etc.)			
Power train (mechanical, electrical, etc.)			
Control & communications			
Cables & associated			
Fabrication & assembly			
Totals			
Construction, Installation & Commissioning			
Logistics and dockside facilities			
Foundations, moorings, & navigation markers			
Installation vessels			

Subsea / onshore cable			
Power conditioning, control & SCADA			
Transformer, switchgear & protection			
Project commissioning			
Totals			
Operation & Maintenance			
Inspection			
Device retrieval			
Dedicated staff			
Port facilities			
Engineering			
Totals			
Other Stage or Task?			
Please fill in….			
Totals			

Thank you very much for your valuable input. We would hope to feed back the results of the research to you once the study is completed.