<u>Wave energy policy: innovation, manufacturing and deployment – focus Ireland and Denmark</u>

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1 Introduction

This paper uses Ireland as a case study due to the size of its resource (up to 21 TWh[1] per annum accessible resource according to ESBI (2005) and the extent of ambition behind the stated Government intent to ‘make Ireland a world leader for research, development and deployment of ocean energy technologies (DCENR (formerly DCMNR) 2007). This paper does not argue the merits of building a wave energy industry in Ireland that delivers all three elements. It does however seek to demonstrate what policy elements are necessary if the Government ambition is to be delivered.

Section 2 reviews what policies and measures have been employed in other sectors within Ireland to deliver goals associated with innovation, manufacturing and deployment. In the case of innovation policy, Ireland has established a clear goal for the economy to move up the value chain in terms of economic activity with a significant focus on fourth level training and innovation. The examples drawn on here relate to the biotechnology and ICT sectors. With respect to manufacturing Ireland developed a successful foreign direct investment policy that encourage US multinational to establish a European base in Ireland, particularly in the pharmaceutical and ICT sectors. This lead to high levels of economic growth over the period 1998 – 2002, reaching >10% GDP growth levels per annum, and full employment. The example drawn on for deployment is that of wind energy, which had a slow start due to incoherent policies and then accelerated more recently as these were addressed. Section 3 also draws on the success of the integrated strategy developed in Denmark for wind energy development and identifies key lessons that may be learned.

Section 3 outlines the current status of wave energy policy in Ireland and compares it with the status in other countries. It structures the discussion according to the three policy goals, namely innovation, manufacturing and deployment. This allows the authors to identify gaps in the delivery of the three policy goals within Ireland.

Section 4 brings together the key successful elements from section 3 that may be used to address the gaps identified in section 2. It points to what will be required to deliver on the Government intent, which is considerably greater than what is currently in place.

[1] For comparison, Ireland’s total electricity demand in 2007 was 25.9 TWh (Howley et al 2008)

This approach may clearly be replicated elsewhere and for other technologies. While energy policies tend to be built on previous experience within energy policy, this paper demonstrates a new approach whereby policies utilised in other sectors can be drawn on to point the way forward for successful wave energy policies. Section 5 draws some conclusions and points to other issues that need to be considered.

2 Background

Wave energy is at a critical juncture in its development as a renewable energy technology. Several demonstration power plants are in place with an individual turbine/generator capacity of up to 300 kW are operational and a 2.3 MW Pelamis device was installed during 2008 (Carcas 2009). In addition, a number of countries have ambitious targets and policies in place with the goal of accelerating development and deployment and reaping the associated benefits (AEA 2006). The International Energy Agency concludes however, in the Energy Technology Perspectives Report (IEA 2008) that ‘it is unlikely that the technology will play an important role before 2030’. It points to the need to scale up in order to withstand offshore conditions and high commercial risk. The development of appropriate wave energy policies and effective measures is essential to accelerate the development and deployment of wave energy technology and to address the barriers identified by the IEA.

A limited number of papers (Clément, et al. 2002, SEI and MI 2002) draw on the successful development of wind energy in Denmark when discussing both the potential benefits associated with wave energy development and the stimuli required to develop a wave energy industry harness the compare the potential associated with wave energy. Wave energy policy papers (AEA 2006, Andina-Pendás, et al. 2008, Batten, et al. 2006, Beck, et al. 2004) tend to be structured on the basis of RD&D development for technology development and market support for pre-commercial deployment. This paper takes a different approach. It identifies three policy goals at the outset that are necessary for wave energy technology to become a commercial reality, namely innovation, manufacturing and deployment. Innovation is required to scale up the wave energy technologies and to reduce costs. When mature, the manufacturing of wave energy devices for a European and global market offers significant potential economic benefits. Deployment is the final critical step required to penetrate the electricity market, to ensure wave energy contributes to meeting renewable energy and emissions reduction targets. While these three form a natural continuum for the development of a technology, they typically fall within the remit of separate Government Departments with their own priorities, mechanisms and success metrics. This paper reviews the success of policies associated with each of these goals in non-energy sectors and then seeks to establish how these may be applied to successful wave energy development.

Innovation policy falls under the remit of Departments responsible for science and engineering research with the goal of increasing the innovation capability within an economy and moving the economy further up the value chain. The key metrics are typically number of patents, active researchers, Doctoral graduates etc.

Manufacturing policy is generally the responsibility of Departments responsible for industrial development, enterprise and employment with policies targeting job and wealth generation to increase economic output and value added.

Deployment policies fall under the remit of Departments responsible for energy and environment, where the focus is on delivering targets relating to energy efficiency, renewable energy and emissions reduction.

3 Successful policies for innovation, manufacturing and deployment in all industry sectors

Section 2 demonstrated that while ambition exists in Ireland and elsewhere to develop and deploy wave energy technology, there remains a significant gap between the ambitions and the measures and policies required to deliver.

However, if other sectors are examined in Ireland, there exist many policies and measures that have been successful in delivering innovation, manufacturing and deployment.

Regarding innovation, Ireland has built a thriving biotech programme with a growing level of research activity and patents. In the area of manufacturing, Ireland has successfully developed an indigenous food industry and also secured significant foreign direct investment that has delivered employment in pharmaceuticals and IT. In deployment, Ireland's installed capacity from wind energy reached 1,161 MW[2] of, representing 15% of total installed generating capacity[3], generating approx 3,051 GWh per annum (Assuming a 30% capacity factor). Considering that the first turbine deployed was in 1993, the 15% power penetration is a commendable achievement.

The focus of this section is limited to identifying successful policies implemented in Ireland that may be used/adapted and hopefully applied to the wave energy sector.

3.1 Ireland

3.1.1 Policies stimulating innovation

Increasing innovative output is an important mechanism for approaching industrial and broader economic development issues (Collins, et al. 2006). Continuing improvements in national innovative capacity are intimately linked to sustainable growth in output and employment (Edquist, et al. 1999).

From 2004 -2008, successful policies and investment and innovation has led to an increase in Ireland's Innovation Index score from 0.48-0.53, and presently lies eighth in the list of European countries surveyed in the European Innovation Scoreboard (Figure 1)(2008).

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[2] www.eirgrid.com/media/Connected%20Wind%20Report%2020090901%20V1.pdf
[3] www.eirgrid.com/media/Connected%20(Other%20Types%20of%20Generators)_14092009.pdf

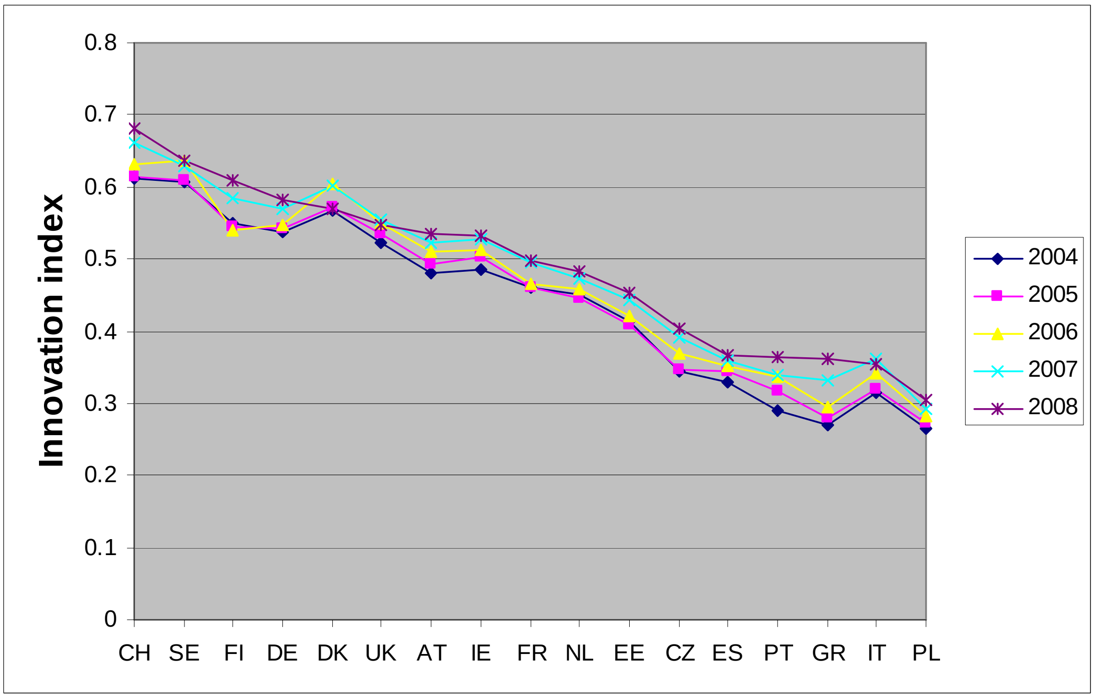

Figure 1: Innovation index. Data taken from Annex D (European Innovation Scoreboard 2008).

In the light of Ireland's eroding cost advantage in the 90's, there was a shift in focus from securing manufacturing activities to higher value added activities, such as advanced manufacturing and research and development (R&D) (Begley, et al. 2005). Irish State employed a flexible set of policy enactors. Policy change was marked firstly by the publication of the Culliton Report (1992) culminating in the establishment of the Science Technology and Innovation Advisory Council (STIAC) in 1995. The next year saw the publication of the White Paper on Science Technology and Innovation (Irish Government 1996). This was followed in 1997 by the formation of the Irish Council for Science, Technology and Innovation (ICSTI), under Forfás, to advise Government on the strategic direction of STI policy.

Europe has had a direct impact on Ireland's STI policy through structural funding and the framework programmes, placing a focus on knowledge-intensive industries and increasing spend on R&D. The EU's Framework Programme of Research and the ESPRIT[4] program channelled 2% of EU GDP into Ireland (Collins, et al. 2006). Closely related to the ESPRIT programme was the Programmes in Advanced

[4] http://cordis.europa.eu/esprit/home.html

Technologies[5] (PATs), which was one third supported by the European Regional Development Fund[6] (ERDF).

Table 1 list the most recent funding bodies which support a wide range of both academic and industrial research, with a total budget for 2008 of €2.5B, 1.5%GDP[7] (Irish Government 2009).

Funding agency	**First year funding**	**Funding focus**
Science Foundation Ireland (SFI)[a]	2000	SFI supports academic researchers and research teams, investing €1.4 billion. • Biotechnology • Communications and IT • Sustainable energy and energy efficiency 2009 budget is €191M[8]
Enterprise Ireland (EI)[b]	1998	Development and promotion of the indigenous business sector • R & D Funding • Innovation Vouchers • Technology Acquisition 2009 budget is €134M[9]
Irish Research Council for Science, Engineering & Technology (IRCSET)[c]	2001	IRCSET academic research funding for the sciences, engineering and technology. Funding for 2008 was €26.5M[10].
PTRLI- 4[d]	2007	€260 million 17 projects.
PTRLI- 5[e]	2010	commencing in 2010, €300m physical infrastructure, Ph.D. education.
Strategic Innovation Fund (SIF)[f]	2006-2013	€510M support for innovation in higher education institutions.
Dundalk 2020 – SEI[g]	2008-2020	Renewable energy research

Table 1: Funding agencies for research in Ireland since 1998.

([a] http://www.sfi.ie/content/content.asp?section_id=207&language_id=1
[b] http://www.enterprise-ireland.com/Publications/
[c] http://www.ircset.ie/Default.aspx?tabid=36
[d] http://www.hea.ie/files/files/file/Brief%20on%20PRTLI%204%20Projects.pdf
[e] http://www.hea.ie/files/files/file/PRTLI%20Cycle%205/PRTLI%20Cycle%205%20Call%20text.pdf
[f] http://www.hea.ie/en/sif
[g] http://www.sei.ie/Dundalk2020/What_is_Dundalk_2020_/

[5] http://www.irishscientist.ie/2001/contents.asp?contentxml=01p146.xml&contentxsl=IS01pages.xsl
[6] http://ec.europa.eu/regional_policy/funds/prord/prord_en.htm
[7] http://www.src.ie/news/other_research/application_dates.pdf
[8] (DETE 2008)
[9] (DETE 2008)
[10] (HEA 2008)

Government investment support for innovation in industry has led to industry financing their own innovation research, with investments sums totalling €1B 2007/2008 (Figure 2).

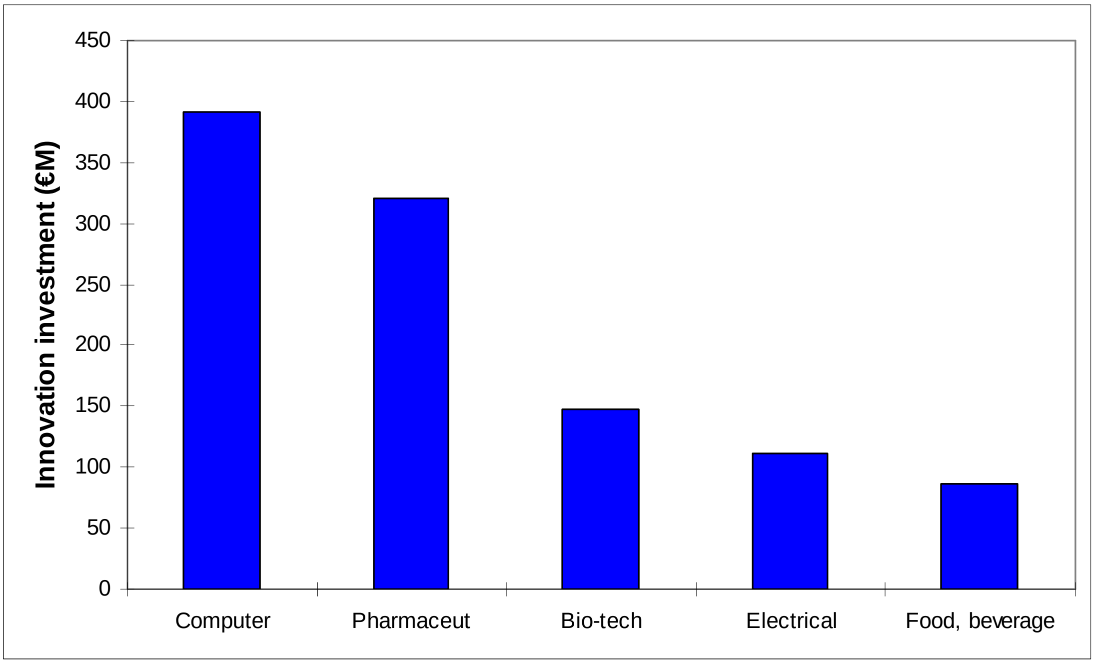

Figure 2: Industry sectors in Ireland which are investing the largest funds in innovation (sourced from Survey of R&D in the Business Sector, 2007/8 which was published in (Forfás 2009).

3.1.2 Policies stimulating Manufacturing

The economic turnaround in the Irish economy is marked by double-digit growth figures (Collins, et al. 2006). Through much of the last 50 years, Ireland's advantage has lain primarily in manufacturing with a pro-business environment a keystone for many successive governments (UNCTAD 2004). Employment rate soared from pre-Celtic rates in the 80's of 15% to a low of 4.4% in 2003[11]. The three main industry sectors contributing to the economy were food, pharmaceuticals and IT, contributing approximately one third of the GDP (Figure 3). At its peak from 1995-2000, industry achieved a 12% annual growth rate (Figure 4). Since 2000, industrial growth has been slower than economic growth and in 2005 industrial GVA grew by 3.4% whereas the economy grew by 5.5%. This was due to the fact that the construction industry (not represented in the graphs) became the dominant revenue earner for the Irish economy after 2004.

[11] http://www.cso.ie/statistics/sasunemprates.htm

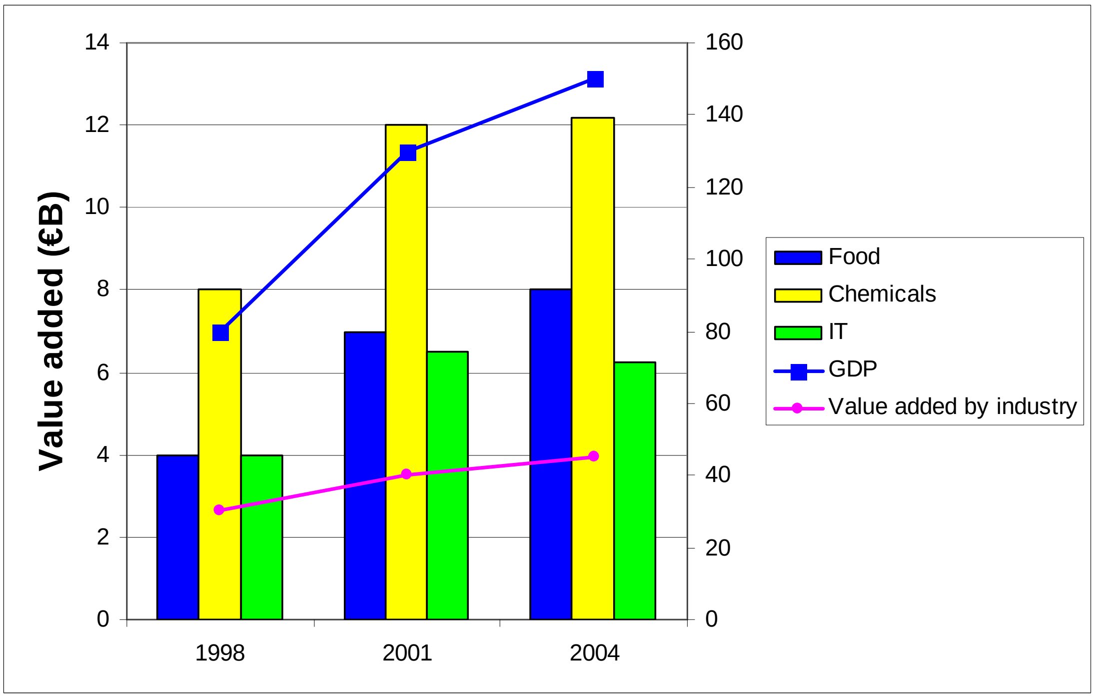

Figure 3: Gross Value Added in Industry 1998, 2001 and 2004 (adapted from (O'Leary, et al. 2007)).

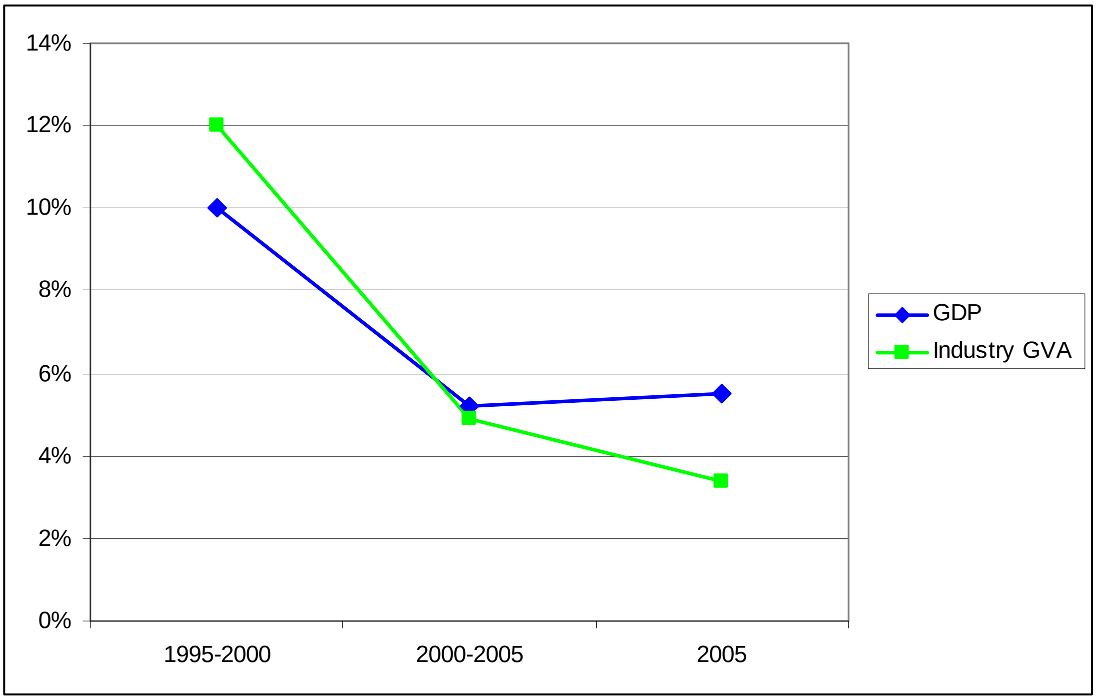

Figure 4: Irish GDP and Industry GVA Growth Rates from 1995- 2005 (adapted from (O'Leary, et al. 2007))

Ireland pursued its economic development path with a great deal of emphasis on exogenous factors, successfully attracting FDI and MNCs (Collins, et al. 2006). FDI in Ireland ranged from a total of US$164 million in 1985, to US$16.32 billion in 2000 (Collins, et al. 2006). From 1991–1998, foreign-owned firms accounted for 95% of the growth in Irish industrial exports and, by 1999, foreign-owned industry accounted for an estimated €38 billion, or almost three-quarters of total Irish exports. The stock of FDI in Ireland in 2002 was equivalent to 129% of gross domestic product (GDP), which placed it top of the Organisation for Economic Co-operation and Development (OECD) listings, far ahead of second-placed Netherlands with 75% of GDP.

FDI in Ireland originated mostly from export-oriented US MNCs (Table 1), which by 1998 were responsible for 70% of Irish industrial exports. Of the 1,025 foreign companies with facilities in Ireland, 489 (48%) were American. Of the 127,578 people employed by foreign companies, 89,158 (70%) worked for American companies. Of the $68 billion in 2003 sales revenue from exports by Irish subsidiaries, 75% came from American companies (Begley, et al. 2005).

The main driver for attracting FDI and MNCs to Ireland was the Industrial Development Agency[12] (IDA Ireland). Since its inception in 1949, it sold Ireland's advantages to the US, via its overseas offices. The agency exploited the US companies' need for a presence in Europe, through attractive incentive packages, including a controversially low corporate tax rate. In 1992 it was restructured and became the Industrial Development Agency.

An example of MNC success is the software industry. Ireland is cited as the world's second largest software exporter, with software exports valued at US$8bn in 2000 (Heeks 2002). Ireland produced about 40% of the packaged software sold in Europe and exported some 80% of output. In 2000, some 30,000 people were employed in the industry in roughly 700 firms, of which just over 100 (most of the largest and responsible for nearly 90% of exports) were foreign-owned.

In the last decade, the Irish government have endeavoured to nurture an indigenous manufacturing base, funded under the state body of Enterprise Ireland[13].

Food is Ireland's single largest indigenous industry with €7 billion in exports in 2005, and employs 47,000 people directly, with 40% of this figure in indigenous industry (Enterprise Ireland (EI) 2005). Examples of the largest players in the this sector are the Glanbia Group Innovation Centre, Dairygold Co-operative Society Applied Food Sciences R&D Centre, Kepak Group and Green Isle Foods which in 2005 invested €63M in innovation.

[12] www.idaireland.com
[13] http://www.enterprise-ireland.com/AboutUs/

IT is the other major indigenous success sector, employing an estimated 15,000 people and accounts for about €2 billion of Ireland's total software exports of €12 billion (Simpson, et al. 2009), representing 5% of the sector in revenue terms (Irish Software Association 2008)[14]. Successful indigeous IT companies include Iona Technologies[15], Sigma electronics[16] and LETSystems[17].

	Ireland advantage	**Industry type**	**MNC**
70's	Access EEC	Manufacturing	Pfizer's
	Low tax	Pharmaceuticals	Penn
	Low cost		Digital
	Capital grants		Wang
	IDA		
80's	Educated workforce	Medical	Bausch and Lomb
	Government responsiveness	Computers	Lotus
			Lucent
			Microsoft
			Apple
			Intel
90's	Clusters	Software	Dell
	Universities	Finance services	Citibank
			Accenture
2000's	R&D	e-business	EBay
	Enterprise Ireland	Bio-pharmaceuticals	Google
	Forfas		Wyeth
			Genzyme

Table: Evolution of Ireland's manufacturing industry, factors for success and example MNCs (adapted from (Begley, et al. 2005))

3.1.3 Policies stimulating Deployment

Deployment encompasses any infrastructure installation such as housing, roads and electricity networks. The Irish government has made concerted efforts to support and fund development for Ireland's future, with total funding available in the National Development Plan[18] of €184B till 2013. It provides €54B for investment in economic infrastructure and €20B for enterprise, science and innovation.

[14] This report quotes annual export sales on only €1B.
[15] http://www.ionainstitute.ie/home.php
[16] http://www.sigma.ie/
[17] http://www.letsys.com/
[18] http://www.ndp.ie/docs/NDP_Homepage/1131.htm

Irish wind energy deployment has been successful despite considerable initial delays and setbacks that were associated with incoherent policy decisions. It is an appropriate example to use in this paper as the deployment of wind and wave energy have a number of similar characteristics. They both represent new renewable energy technologies (wave energy now, wind energy in the early 1990's) that require

- new approaches to spatial planning as new infrastructures on the landscape or seascape,
- changes to the electricity network configuration and operation that traditionally delivers electricity from high voltage connected large scale thermal power plants through a transmission and distribution networks to medium and low voltage connected customers
- fair and appropriate treatment as new electricity suppliers within the electricity market.

Wind energy deployment was slow during the 1990s and early 2000s but accelerated rapidly since 2003 (Ó Gallachóir et al 2009)[19]. By 2009, there was 1.2 GW[20] of installed wind generating capacity in the Republic of Ireland, representing 15% of total installed generating capacity[21].

The initial support for wind energy in Ireland was in the form of an EU capital grant for the 6.5 MW Bellacorrick wind farm commissions in 1992. Growing interest in renewable energy lead to a target to deploy 75 MW additional renewable energy by 1997 and the introduction of the Alternative Energy Requirement (AER) program to support deployment to meet that target. The AER scheme was a competitive tendering process, similar in design to the UK Non-Fossil Fuel Obligation Scheme. (O'Gallachóir, et al. 2006).

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[19] Ó Gallachóir B. P., Bazilian M. & McKeogh E. J. 2009 *Wind Energy Policy Development in Ireland A Critical Analysis.* Chapter 8 in Wind Power and Power Politics ISBN: 978-0-415-96130-1 Routledge Press

[20] www.eirgrid.com/media/Connected%20Wind%20Report%2020090901%20V1.pdf

[21] www.eirgrid.com/media/Connected%20(Other%20Types%20of%20Generators)_14092009.pdf

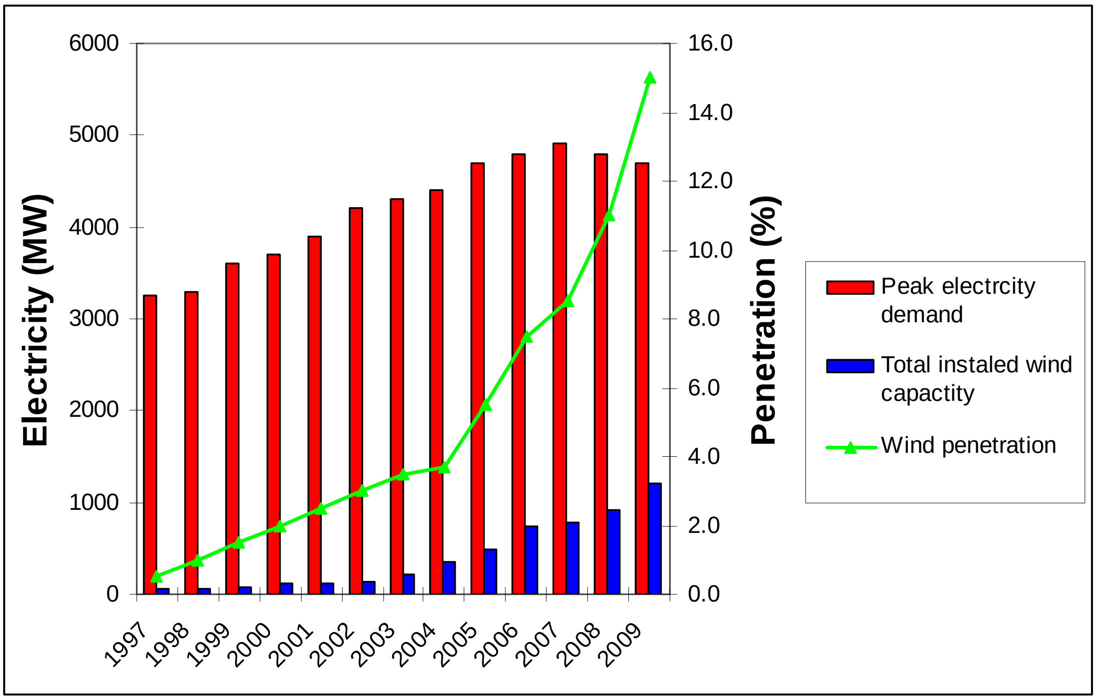

Figure 5: Historical growth in Irish electricity demand, installed wind capacity and wind penetration (information from Eirgrid, (O'Leary, et al. 2007), (Howley, et al. 2008))

The program had 6 separate competitions (AER I to AER VI) rolled out over the period 1993 - 2005. Each competition had a specific target for renewable energy and renewable energy developers were invited to bid in for guaranteed 15 year Power Purchase Agreement. Those with the lowest bid unit price for electricity generated were selected in sufficient numbers to meet the target. There were delays and misalignments between measures relating to market support with those relating to spatial planning and those relating to grid integration. The net effect was low growth to 2000 followed by ambitious targets to 2005. There was an 18 month delay in meeting these targets leading to a concentrated deployment over the period 2004 – 2006. the AER programme succeeded in installing 295MW (out of a promised 500MW). The program was complemented by tax relief of corporate investment under Section 62 of the 1998 Finance Act (O'Gallachóir, et al. 2005). The relief was capped for a single project at 50% of all capital expenditure (excluding lands), net of grants up to a limit of £7.5m. Investment by a company or group of companies in more that one qualifying project was capped at £10m per annum. This relief was extended to 2006 under section 39 of the Finance Act 2004.

In 2001, the EU Directive on the promotion of electricity from renewable energy sources (2001/77/EC) (European Parliament 2001) was implemented, establishing a 2010 target for renewable energy in Ireland of achieving 13.2% of gross electricity consumption form renewable energy sources by 2010, which translates to approximately 1,100 MW of wind energy (on-shore and off-shore)

In 2005, the electricity market was fully opened for green suppliers, based on the Electricity Regulation Act (CER 1999). The Act enabled third party access to the electricity network to wind (and other renewable) electricity suppliers to sell directly to all final customers, irrespective of the customer’s consumption. The Act provided wind farm developers with an alternative to the AER route to the market, and allowed access to sections of the market which pay most for electricity (commercial and domestic customers), and added a further 378MW to the gird. Thus, the majority of wind farm projects built were funded on the basis of forward sales of the electricity to green electricity customers within the Irish liberalised electricity market (O'Gallachóir, et al. 2006).

The poor performance of the AER scheme were attributed to a number of reasons (O'Gallachóir, et al. 2006):

- Misalignment between the AER process, the planning process and the grid connection process. Projects could secure an AER contract (market access) without having secured planning permission or grid connection approval.
- Delays in securing State Aid approval for the individual AER schemes.
- Delays in clearly identifying and addressing the technical issues relating to wind energy integration into the electricity network (including fault ride-through and dynamic modelling), lead to a moratorium on grid connection agreements during 2004.
- Delays in finalising the revised Department of the Environment, Heritage and Local Government Wind Farm Guidelines (2 years later than targeted for the draft version) resulting in local authorities being slow to provide increased clarity in development plans (with notable exceptions), in the absence of these revised guidelines.
- Deep connection charges which penalises the first applicant to get planning permission and connect.
- Level of ‘constraint’ not specified.
- Advanced wind forecasting researching a 48 hour time window had not been carried out.

Recent initiatives have greatly reduced the impediments to wind energy deployment investment. All planning applications for wind farms need prior EPA and grid connection approval. This initiative prevents misalignment of contract approvals and the possibility of the lapsing of planning permissions due to external approval delays. The Transmission Grid Code and Distribution Code was approved 2004, specifying the requirements for fault ride through, frequency response requirements, voltage requirements, signals, controls and communications (O'Gallachóir, et al. 2005). Grid connection applications would only be deemed complete when appropriate dynamic models of the wind generators were submitted.

Clustering of wind farm applications was encouraged, and €30M was made available in the National Development Plan (NDP 2000 – 2006) to fund grid upgrades based on perceived demand for shared infrastructure, and clusters with two or more projects (O'Gallachóir, et al. 2005).

The renewable energy feed-in tariff programme (REFIT)[22] was started in 2005 and supported the construction and operation of qualifying new renewable energy powered electricity generating plants in the liberalised electricity market in Ireland. REFIT was subsidised by the Public Service Obligations Levy (PSO)[23], which was an additional charge to consumers relating to the costs of purchasing of renewable energy purchased under REFIT.

Further initiatives that the Irish government carried out which supported wind energy deployment were:

- Survey on attitudes to wind energy were completed in 2004.
- The wind energy map was completed in 2004.
- The Wind Farm Planning Guidelines were issued in 2004, specifying suitable wind farm locations.
- Mandates to local authorities via the local energy agency to assess the economic viability of wind projects at potentially suitable locations (O'Gallachoir 1999). The Renewable Energy Feasibility Study Grant Scheme provided 50% grant support capped at €7,618, allowing for wind speed measurements to be recorded, financial mechanisms to be negotiated, environmental impacts to be studies and project costings to be determined.

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[22] http://www.dcenr.gov.ie/NR/rdonlyres/67F3BEFB-FAE2-443A-A93E-93C6DEE7485F/32331/REFITclarificationsfinal2.doc
[23] http://www.iwea.com/index.cfm/page/glossary?rgLetter=P&rgId=34

3.2 Denmark

The early support for wind energy by the Danish government in the 1970's created a big home market for wind turbines and gave the Danish manufacturers first mover advantages in the world market (Vestergaard, et al. 2004). Denmark ranks first in the world in terms of having the largest share of domestic electricity supply from wind (23 percent in 2006[24]), and fifth (after Germany, Spain, the United States, and India) in terms of total domestic wind energy deployment (3,136 MW). Denmark operates an electricity grid with areas such as Western Denmark integrating 41% of wind into its portfolio during January 2005 (Sovacool, et al. 2008). Denmark exported US$7.45 billion in energy technology and equipment in 2005, which was approximately 3.2% of GDP[25], approximately 8 percent of total Danish exports and one-third of the total world market.

3.2.1 Innovation

Innovation has been a keystone in the Danish wind success model. Danish support has historically been directed towards basic research (Krohn 2002b), unlike other governments who have tended to support wind turbine development. The knowledge acquired from the Danish publicly funded projects was available in the public domain, and that the know-how thus was available to the national wind industry. The first major initiative implemented by the Danish government in the early 80's was the completion of a comprehensive wind atlas (Buen 2006). This research both benefited researchers in wind knowledge but also the developers in siting turbines in the most efficient locations available.

Danish researchers took a bottom-up strategy of wind turbine development—a slow, crafts-oriented, step-by-step process including incremental learning through practical experience. The smith industry and tradition of building wind turbines, started in the late 19th century, and started as private/individual experiments (Vestergaard, et al. 2004). The strategy seemed superior to the top–down approach of science-oriented German and American researchers and manufacturers, who aimed at massive, centralized, quick and ambitious full-scale development (Heymann 1998).

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[24] http://www.windpower.org/composite-1463.htm

[25] http://ec.europa.eu/economy_finance/pdf/2009/springforecasts/dk_en.pdf

In 1974, energy taxes were imposed, resulting in electricity prices of €0.25/kWh, which was much higher than Germany and UK prices at the time (€0.19/kWh and €0.13/kWh respectively) (Sovacool, et al. 2008). R&D for wind energy was funded through these energy taxes. It was effective method for providing financial support for public research, while spreading the costs of that research among all electricity customers (Sovacool, et al. 2008). Such taxes are more equitable because they are based on the amount of energy consumed but funded just by ratepayers instead of all taxpayers.

The RISO research centre was established in 1978 with a purpose to help develop wind turbines for industrial production within a period of three years, and if successful, carry out standard testing for the manufacturers (Vestergaard, et al. 2004). The institute was instrumental in accumulating technology expertise in Denmark due to legislation requiring all wind turbines deployed in Denmark, that avail of the Danish investment grants, be initially tested and approved in RISO (Vestergaard, et al. 2004). This included design of the turbine, the tower, the base and the electrical systems. RISO thus accumulated a rapid repository of technical know-how in wind energy research, and had a flow on effect to developing a manufacturing base.

Further initiatives stemming from RISO was the capacity paradigm for wind turbines stating that all components should be dimensioned twice as powerful as the traditional norm stated (Vestergaard, et al. 2004). “This standard certification is one of the major reasons for the success of Danish wind turbines in the world market, as Danish turbines gained the reputation of being able to withstand the power of strong winds and therefore more reliable than other foreign designs”.

The Danish Research Consortium for Wind Energy (Landberg, et al. 2002) was established in 2002 comprising of 150 researchers working with meteorology, fatigue loads, aero- and structural dynamics, grid interaction etc. Danish research institutes and wind turbine manufactures presently hold 33 patents in wind technology (Danish Wind Energy Association 2009b).

3.2.2 Manufacturing

Denmark has the highest penetration of wind energy for electricity production in Europe in 2009 at 19.7% with a total of at 3GW capacity. The Danish wind turbine manufacturers hold a world market share of approximately 40%, employing 28,400 by the end of 2008, an increase of 5,000 from 2007 (Figure 6) (Danish Wind Energy Association 2009a). The wind industry is Denmark's third largest exporter (Buen 2006), contributing 12% of the total export trade . 95% of all turbines produced are destined for the export market. The Danish wind industry has experienced an explosive growth in the last 10 years. From turnover figures in 1996 at €0.4B, the turnover had in 2006 increased to €4.3B. This turnover only concerns production within Denmark. Including turnover from international facilities owned by Danish companies the turnover reached €6.5B in 2006. Global sales rose to €11.4B in 2008 an increase of 29% from 2007. By 2003, global offshore installations had reached 530 MW of which 492 MW were of Danish origin. Danish companies Vestas, NEG Micon and Bonus have all been among the 10 largest wind turbine manufacturers; in 2004, the two former merged and consolidated the Danish number one position in the world market, while the latter was bought by Siemens. The largest independent blade manufacturer (LM Glasfiber) is also Danish, and there are also many other leading subcontractors.

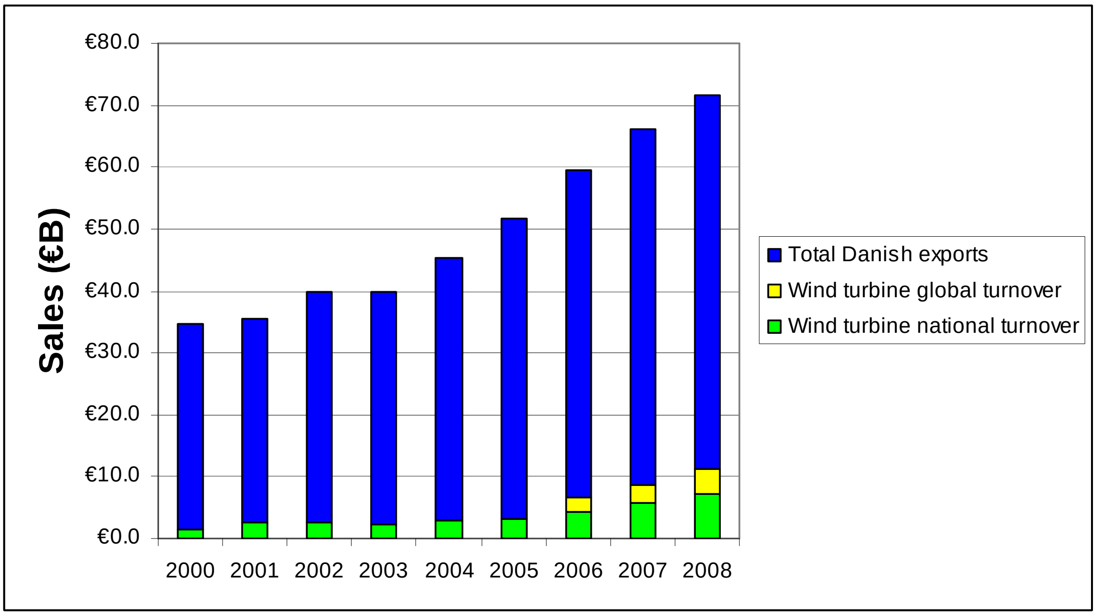

Figure 6: Wind turbine sales in Denmark, 1996-2008. Global wind turbine sales include turnover from international facilities owned by Danish companies, data only available from 2006-2008. (Danish Wind Energy Association 2009a). Danish exports extracted from http://www.indexmundi.com/g/g.aspx?c=da&v=85

The origins of Danish governments policy initiatives to stimulate wind turbine manufacturing began in the 70's with the implementation of high energy taxes, resulting in high domestic electricity prices, and were kept high even after fossil fuel prices dropped in 1980s. The wind turbine manufacturing industry could thus rely on unwavering electricity prices and secure local market for their product (Sovacool, et al. 2008). Further incentives for industry were low taxes on electricity used for manufacturing purposes, resulting in the lowest electricity prices in Europe, around €0.05-0.06/kWh (Krohn 2002a).

The equivalent of the Irish development authority (IDA) was set up in Denmark in 1982, called the Danish Council for Technology[26], and was one of the first European government agencies setup to promote Danish manufacturing exports.

In 1985 and again in 1992, an agreement was reached between the government and the electricity utilities, committing the utilities to install a total of 200 MW over a five-year period (and fully implemented by 1992), providing a guaranteed market for turbine production.

The most important incentive introduced to boost wind turbine manufacturing was the 30% investment subsidy introduced in 1979 (Buen 2006). The subsidy was not given to suppliers, but to individuals and cooperatives based on residence criteria. The subsidy dramatically increased local demand for turbines and enabled indigenous manufacturing to prosper.

In 1986–87, the investment subsidy was reduced from 20% to 10% and completely removed in 1989 (Buen 2006). These abrupt changes in such a limited time, in combination with export market difficulties caused all Danish manufacturers apart from Bonus to go bankrupt or become technically insolvent. The only increase in installed capacity in the early 90's was due to the agreement between power companies and government in December 1985 that the former should install 100 MW of wind power within the end of 1990.

Danish wind energy industries that survived the subsidy withdrawal mostly started as small speciality services companies, who then branched out into the manufacturing of wind turbines. Nordtank (now merged into NEG Micon), was originally a manufacturer of road tanks for the oil industry but decided to utilize its experience in working with steel and designed its own wind turbine (Vestergaard, et al. 2004). The same situation occurred for Vestas – a former blacksmiths workshop – that utilized its know-how in machine production to make wind turbines for Bonus wind turbines.

In 1990, the "Danish Wind Turbine Guarantee" act was passed. This guarantee provided long-term financing of large wind projects that used Danish made wind

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[26] http://en.fi.dk/councils-commissions/the-danish-council-for-technology-and-innovation

turbines, reducing the risk of building larger projects and encouraging local manufacturing (Sovacool, et al. 2008). Local production created opportunities through the sales of new products, jobs, and an increased tax base, further enhancing economic growth. Manufactures used their domestic turbines as a real world laboratory to experiment, lower the cost of turbine equipment, and improve capacity factors (Lewis, et al. 2007).

Policy instruments to stimulate wind power and wind industry development in Denmark, such as investment and production subsidies, have been gradually removed in line with cost reductions and maturity of the industry. These policies enabled Denmark wind turbine manufacturing industry to establish itself and become a world market leader in the technology.

3.2.3 Deployment

Denmark has had the most successful history of deployment in Europe up till 2002, when a new government changed policy (Figure 7). Denmark has the highest penetration of wind energy for electricity production in Europe in 2009 at 19.7% with a total of at 3GW capacity.

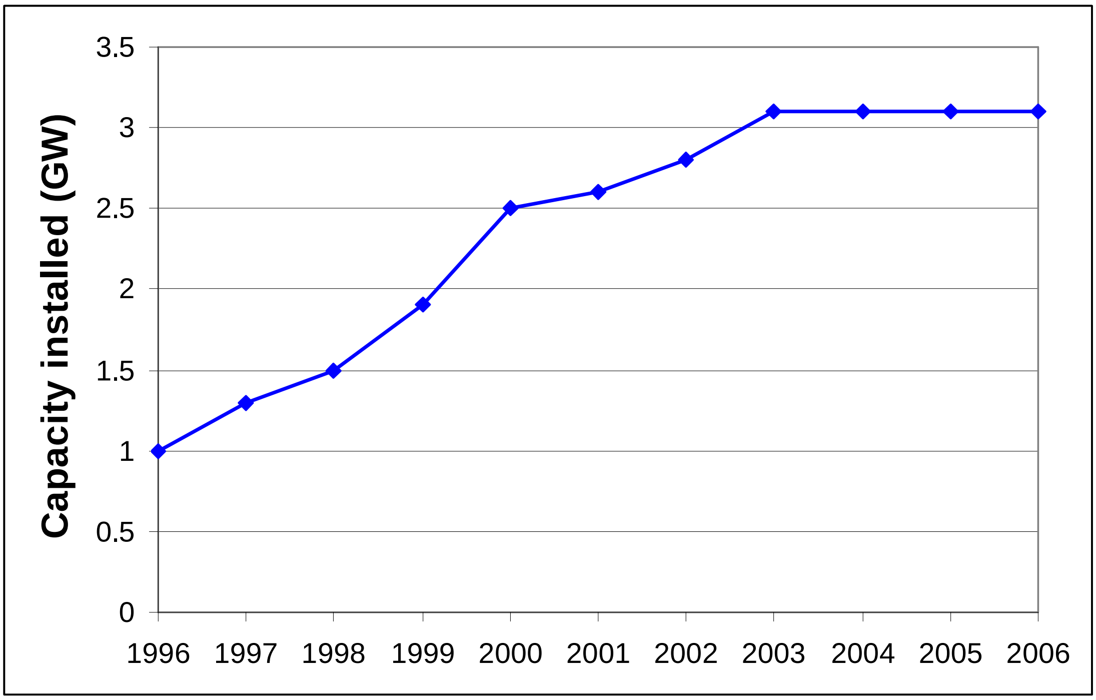

Figure 7: History of Denmark's wind turbine installation program (GW) http://www.windpower.org/composite-1458.htm

Denmark had an early carbon abatement program of reducing CO_2 emissions by 22% between 1988 and 2005 (Krohn 2002a). Thus, more than one third of that target was to be met using wind energy to replace coal-fired power generation.

Considerable increase in installed capacity occurred in 1980, and the subsequent gradual increase in installed capacity and average production capacity, correlated with the 30% investment subsidy introduced in 1979 (Buen 2006). Eligibility criterion for the investment subsidy stipulated that all turbines for deployment in Denmark be tested by RISO (Vestergaard, et al. 2004).

The Danish wind energy atlas was completed early in the 70's, funded by RISO, and enabled developers to efficiently site their turbines in the most efficient locations available (Krohn 2002b).

In 1981, a feed-in tariff was implemented which required utilities to buy all power produced from renewable energy technologies at a rate equal to 70 to 85 percent of the consumer retail price of electricity in a given distribution area, providing assured returns for develops of wind energy projects (Morthorst 2000).

Co-operatively owned wind turbines were exempted from tax, leading to tax expenditures in the order of DKr 70 to 90 million per year (O'Brien, et al. 2001).

In 1990, the Danish Energy Authority provided "open and guaranteed access to the grid", i.e. shallow grid connection charges where the wind turbine owner had to bear the costs of the low-voltage transformer and connection to the nearest connection point on the 10/20 kV distribution grid and the utilities had to cover the costs for reinforcement of the 10/20 kV distribution grid where needed.

In 1992, the government levied a general carbon tax on all forms of energy, adding around 1.3 eurocents per kWh of additional income for renewable energy generators. Sovacool, Lindboe, et al. (2008) comment that carbon taxes does not have deleterious effects on the overall economy, and that, implemented properly, can be a useful tool for promoting cleaner energy systems.

Also in the same year, an executive order from the Minister of the Environment and Energy ordered municipalities to find suitable sites for wind turbine siting throughout the country (Krohn 2002b). This "prior planning" with public hearings in advance of any actual applications for siting of turbines helped the public acceptance of subsequent siting of wind turbines considerably.

In 1990, a long-term planning initiative, Energi 2000 set a goal of 10% or 1500 MW of wind power by 2005. 4000 MW offshore wind power within 2030 was later added to the target, with the aim of 50% of Danish electricity should be covered by wind power in 2030.

In 2000, an ‘Executive Order’ required utilities to phase in an additional 200 MW of onshore wind in 2000, followed by a request to construct two 5 MW demonstration offshore wind farms to pave the way for a final agreement on a 160 MW offshore park (implemented in 2002) (Sovacool, et al. 2008).

From 2002, new Danish wind farms were awarded the market price plus a fixed premium per kWh. All offshore parks competed on open tenders, and were based on a fixed feed-in tariff for the first 12 years. Sovacool, Lindboe, et al. (2008) maintain that feed-in tariffs provide long-term certainty to renewable energy developers and investors.

In 2003, the government created the Danish Energy Authority and the “one-stop-shop” for offshore wind park planning applications, including the tendering of bids, approval of pre-investigation of sites, environmental impact assessments, construction and operation and licenses to produce electricity.

The Danish transmission and distribution system also assisted in Denmark’s wind energy experience, with a preponderance of high-voltage transmission lines delivering power over smaller distances with low voltage levels. The grid is “tight” and as such, efficiency losses are very low at just 5 to 6 percent. As a result of this efficient network, Norway, Sweden, and Finland have built extensive interconnectors through Denmark, sending three times the amount of energy needed in Denmark through its wires on most days, to markets both in Denmark and the rest of Europe (Sovacool, et al. 2008). Legislation has also encouraged the creation of many peaking plants and storage facilities e.g. cold storage plants. The ability to channel and store such large amounts of electricity from its neighbours adds significant amounts of regulating power, helping balance wind energy at low cost. There is a significant correlation between wind power production and export to neighbouring countries. It can be argued that this export is “stored” in the Nordic hydro reservoirs to be bought back in times with no wind (Sovacool, et al. 2008).

The development of the industry has been greatly affected by this positive encouragement from the public who has supported the national wind turbine industry almost from day one. Denmark has shown that a different model is possible, through the formation of local guilds and non-profit partnerships of wind turbine owners, who pool their capital investment in local wind turbines. In 1999, 50% of Denmark’s 3,200 turbines were owned jointly by 67,000 guild members (Vestergaard, et al. 2004). Public support and investment created an environment and national market, without which the industry as a whole probably could not have survived.

It would also be wrong to view the Danish experience in the wind industry as a result of clever, co-ordinated, long term political planning, involving several ministries and agencies. In some sense, Denmark was lucky in terms of timing of policies and in choosing the commercially right technology (Krohn 2002b). However, Denmark’s real success lay on foundation of mutually beneficial policies and strategies which cross benefited along the sectors. A major boon to the wind energy industry in Denmark has been the stability of Danish energy policy (until 2002), and the careful long-term planning scenarios and adhering to them (Krohn 2002b). This has given a sound base for decision making in the sector, and an international confidence in the Danish wind energy sector which has not waned - at least until 2002, when the government changed.

The early support mechanisms for wind energy sources from the Danish government had mutually beneficially and compounding effects on all three industrial sectors: R&D, manufacturing and deployment Table 2. They created a large home market for wind turbines and gave the Danish manufacturers first mover advantages in the world market. These advantages, however, could not have been as successful without the existence of an extensive learning-by-doing within the industry as well from the RISO institute, which consolidated the competitive advantages for the industry (Madsen, et al. 2003).

Policies befitting Developer + Deployment	**Policies befitting Manufacture**	**Policies befitting R&D**
Carbon abatement program and Targets →		
Tariffs and premiums (70% of retail rate) →		
Shallow connection charges →		
Carbon tax €0.01/kWh →		
Compulsory construction of 200MW of capacity →		
Compulsory construction of 150MW offshore wind →		
Danish Energy Authority – 'one stop shop' →		
High tech grid network and interconnectors allowing energy balancing →		
Peaking and storage plants →		
Municipalities to designate wind turbine zones →		
Tax exemptions ↔	Tax exemptions	
High retail electricity prices (energy taxes) ↔	Low industry electricity prices ↔	Carbon and Energy taxes (€0.25/kWh)
30% investment subsidy ↔	Compulsory Danish made turbines in order to be eligible for investment subsidy. "Danish Wind Turbine Guarantee" (finance for Danish made turbines)	
Stable government ↔	Stable government ↔	Stable government
Cooperative owned projects with targeted support →		
	Council for technology promoting exports	
	←	Bottom up design
	←	RISO national lab All turbine designs must be approved by RISO Danish made turbines to have double power rating
Comprehensive wind atlas ↔	←	Comprehensive wind atlas

Table 2: Historical policies in Denmark and the interrelationships relating to R&D, manufacturing and development in the wind energy industry.

4 Establishing the policy goals in wave energy

4.1 Current status and focus of wave energy policy in Ireland

4.1.1 Wave energy policy before 2008

Ireland took a lead role in recent years in developing a policy framework to support wave energy. In 2002 the Marine Institute (MI) and Sustainable Energy Ireland (SEI) undertook a joint consultation exercise to build consensus around a strategic approach to wave energy development in Ireland (SEI and MI 2002). The consultation document suggested three options distinguished in terms of strategic objective, risks, expenditure and benefits. Option 1 focused on Ireland becoming a wave and tidal energy technology leader, option 2 on the development of an exportable core of research excellence and option 3 on maintaining a watching brief on wave and tidal energy. In parallel with the consultation process, MI and SEI funded work on the economic benefits of ocean energy (Bacon 2005), the offshore wave energy resource in the Republic of Ireland (ESBI 2005) and a development and evaluation protocol for Irish device developers (HMRC 2004).

Funding for a ¼ scale test site in Galway Bay was made available (to be determined from where) in 2002[27], providing a wave energy test zone where environmental impact assessments were waved for developers[28].

Based on the twenty four responses received during the consultation exercise, together with the results of the commissioned studies, MI and SEI published an Ocean Energy Strategy document (SEI and MI 2005). The strategy was structured so as to provide support for industrial developers, 3rd level researchers and facilities. The timeframes described in the strategy were based on progress with respect to technologies under development and were intended to adjust dynamically as the scenarios for the sectors unfolded. The strategy comprised four distinct phases relating to research and development, pre-commercial demonstration, pilot wave energy array and large scale market deployment (Table 3). The total funding proposed at the time ranged from €21.6M to a high of €34.5M depending on whether an indigenous manufacturing industry is established or whether the devices would be imported.

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[27] Personal communication Owen Sweeney (OEDU).
[28] http://www.sei.ie/Renewables/Ocean_Energy/Wave_Energy_Research_in_Ireland/

Phase	Year	Ireland Technology Leader	Ireland Technology Taker
Phase 1	2005-2007	€5M	
Phase 2	2008-2010	Yes = €10.5M	
			Yes = €6.5M
Phase 3	2011-2015	Yes = €19M	
			Yes = €10.1M
Phase 4	2016-2025	No amount set	
Total		**€34.5M**	**€21.6M**

Table 3: Ocean Energy Strategy 2005 proposed phases of wave energy development and supporting grants (condensed version of table 3 from (SEI and MI 2005))

Phase 1 stretched from 2005 and 2007. In that time period, €1.25M of funds was dispensed for R&D in the Hydraulics and Maritime Research Centre (HMRC) via the Blue Power scheme, with matching funds from University College Cork[29]. A further €3.6M for product R&D as well as €0.08M for the Bellmullet test site was proposed to be allocated in that time period but was not appropriated[30]. However, €1.1M of funds were appropriated to industry via Sustainable Energy Ireland (SEI) from 2005-2008[31].

In 2007, the Irish Government produced a White Paper on Energy (DCENR 2007a), increasing the existing targets and funding for wave energy. Here the Government specified an 'initial ambition' of 75MW by 2012 and at least 500 MW of installed ocean energy capacity by 2020 (originally 485MW by 2025) (DCENR (formerly DCMNR) 2007, Marine Institute 2007), effectively accelerating the ocean energy strategy timeframe by five years. The White Paper also contained the Government intent to 'make Ireland a world leader for research, development and deployment of ocean energy technologies.

[29] Personal communication Tony Lewis (HMRC).
[30] Personal communication Owen Sweeney (OEDU) (not confirmed yet).
[31] Personal communication Brian O'Mahony (SEI).

4.1.2 Current wave energy policy – beyond 2008

In January 2008, over €26 million of funding for an Ocean Energy Development fund was announced by the Minister for Energy for the sector spanning a three year period till 2011 (DCENR 2008). The funding in effect superseded the funding outlined in the 2005 Ocean Energy Strategy document for Phase 2 and possibly phase 3. Table 4 lists the indicative funds which were proposed to be allocated in 2008. The policy initiatives stemming from the 2008 announcement may be categorised according to the focus areas of this paper, i.e. whether they support innovation, manufacturing or deployment, drawing on the results of (Dalton, et al. 2009).

1.	€1 million towards a world class, state-of-the-art National Ocean Energy facility in UCC. The Facility will now have an advanced wave basin for the development and testing of early ocean energy devices.
2.	€2 million to support to develop a grid-connected wave energy test site at Annagh/French Point near Belmullet, Co. Mayo.
3.	€2 million in grants this year under the Ocean Energy Prototype Fund. This will help developers to make their devices commercial.
4.	The introduction, of a new feed-in-tariff under the REFIT scheme for wave energy of €220 per MegaWatt Hour.
5.	€500,000 this year to establish an Ocean Energy Development Unit as part of Sustainable Energy Ireland (SEI). Operating with the support and assistance of the Marine Institute, this unit will oversee the implementation of the initiative.

Table 4: Minister of Energy 2008 statement for Ocean energy Development fund, proposed expenditure for 2008 (DCENR 2008).

4.1.2.1 Policies Supporting Innovation (Ireland)

	2008	2009	2010 (proposed)r	2011 (proposed)
R&D (HMRC)	€1M	€1.5M	€4M (indicative)	
R&D (Charles Parsons Fund)	€3.47M (till 2014)			
Prototype fund	€0M	€10M (indicative)		
Test site	€0M	€10M (indicative)		
Marine Institute R&D		€0.3M	€0.1M	€0.1M
OEDU operations		€0.25M	€0.25M	€0.25M
OEDU consultation		€0.36M	€0.36M	€0.36M
Tariff (€0.22/kWh)	€0M (not expected to be drawn upon till after 2011 and funds to accessed from Public Service Obligation (PSO) Levy)			

Table 5: Actual and future indicative spending of the Ocean Energy Development fund (personal communication with Brian O’Mahony (SEI) and Richard Browne (DCENR)

The Ocean Energy Development Fund is dominated by support for innovation. Table 5 lists recorded spending from the fund for 2008 and 2009, and proposed spending till 2011[32].

Research and Test Centre - The Hydraulics and Maritime Research Centre[33] (HMRC) in University College Cork operates wave energy test tank facilities and also provides independent consultancy and design support to technology developers. The Centre offers support with physical model testing, concept design, computer modelling, device performance validation, resource assessments and offshore data monitoring. €1M was allocated and spent in 2008 and €1.5M in 2009 towards equipment upgrade and additional facilities, with a further indicative capital program of approximately €4M for future construction of a new building to house new facilities (Lewis 2009).

OEDU – The Ocean Energy development Unit was established in late 2008, with an allocated fund of €0.5M in 2008. Approximately €?M will be allocated for the 3 years till 2011, covering administration as well as the conduction of the following studies:

- Economic feasibility study
- Strategic Environmental Assessment (SEA).
- Engineering studies.

Prototype fund – €2M was assigned in 2008 to support ocean energy developers in making their devices commercial. Due to the delay in setting up the OEDU in 2008 and further administrative delays persisting into mid 2009, the funds were not administered[34]. An indicative sum of €10M funding will be made available to developers from 2009-2011. €18M worth of projects have already applied for this funding.

Test site - The Ocean Energy Development Strategy plans for a grid-connected wave energy test site at Annagh / French Port near Belmullet, Co. Mayo, capable of accommodating 5 berths totalling 5MW. Environmental impact assessment (EIA) will be carried out, and grid connection and offshore cabling will be included in the project development. Due to the delay in set-up of the OEDU, the €2M allotted for 2008 was not dispersed and spent. An indicative sum of €10M is proposed till 2011,

[32] The majority of the table information was sourced from a personal communication from Brian O'Mahony, SEI.
[33] http://www.ucc.ie/research/hmrc/
[34] Personal communication from Brian O'Mahony from SEI.

which is hoped to cover the cost of getting the site operational (cabling, connection etc). Details of the plan for the test site are still being developed. Final budget will be dependant on the result of site investigations which are currently underway, with the final near-shore survey to start soon, followed by geotechnical ground investigation works. It is possible that the cost of installing the test site may be much larger. A study by the author indicated that the cost could vary from €8M to €17M depending on the number of cables and layout, but could be as higher according to other as yet unpublished reports.

Tariff – As the test site will not be operational till post 2011, funds for the tariff will not be taken from the €26M development fund. Funds for the tariff will be sourced from will be sourced from the Public Service Obligation (PSO) Levy (more details in the next section).

Additional R&D funding

In parallel with the funding delivered in accordance with the Ocean Energy Strategy, additional funding for innovation of €3.47M has been secured for wave energy research from the Charles Parsons Energy Research Awards[35] to support 4 researchers, 3 PhD students (4yrs) and 2 summer placements (each yr) in the HMRC running until 2014 (DCENR 2007b).

4.1.2.2 Policies Supporting Manufacturing (Ireland)

There are currently no policies in Ireland which are targeted for supporting the wave energy manufacturing industry in Ireland. There are significant supports available for manufacturing as outlined in section 3.1.2 and a number of these may be accessed for wave energy manufacturing.

4.1.2.3 Policies Supporting Deployment (Ireland)

Policies supporting renewable energy deployment typically focus on capital grant support (at an early stage of development) followed by market support (generally in the form of a feed in tariff or obligation on suppliers). In Ireland the feed-in tariff and targets are the policies that most stimulate wave energy deployment. Provision of a

[35] http://www.sfi.ie/content/content.asp?section_id=742&language_id=1

tariff can also stimulate innovation by facilitating revenue returns for testing (discussed in the above section), but is principally intended to support deployment.

Revenue support – Feed-in Tariff (FIT or REFIT)

A feed-in-tariff under the REFIT scheme was introduced by the Minister of Energy in 2008 (NDP 2008) for wave energy. The tariff offered is €0.22/kWh and is primarily aimed at supporting device deployment in Belmullet test site, which has a planned capacity of 5MW. However, the tariff will also be available for other wave and tidal projects until approximately 2015, with project finance available for a 15 year period. In that timeline till 2015, the tariff will not be constrained by wave farm size and pertains to both commercial and demonstration deployment. Furthermore, there will not be a sliding scale of tariffs both in relation to size of the development or reduce sequentially with time. Subsequent to that date, there will likely be a scaled tariff rate available similar to the Portuguese scheme, detailed in a later section of this report. It is not anticipated that the test site nor any device will be ready before 2011, thus funding for the tariff will be not be sourced from the Minister's €26M, but will be derived from the from the Public Service Obligation (PSO) Levy.

Targets

A 500MW target for installed wave energy by 2020 has been currently set by DCENR (2007) in its white paper. However, it is quoted in the paper only as an 'ambition', although adding that 'at least' 500MW would be the desired minimum. The 500MW target is an increase from that originally set in the 2005 strategy paper of 84 MW installed by 2020 and 485MW for 2025. The white paper has also set a short range target of 75MW for 2012. This target may be ambitious considering the slow development of R&D and pre-commercialisation projects to date (DCENR 2007a, Marine Institute 2007).

Grid network upgrades

A total of €4B has been allocated under the Grid 25 plan to the ESB and ESBI for the upgrade of the State transmission network to cater for increase renewable energy penetration over the next decade (Eirgrid 2008). The funds have been split regionally as follows: North West €750M, North East €300M, West €315M, East €800M, Midlands €310M, South West €730M, South East €830M.

		Innovation	Manufacturing	Development/ Deployment
Countries	**Strategies**			
Ireland	**Tariff**	€0.22/kWh	NR	€0.22/kWh
	National strategy	✓	X	✓
	Targets	NR	X	75MW 2012 500MW 2020
	Grants	€3.5M Parsons fund for all energy research €10m prototype research (estimate)	X	X
	Test site + commercial sites	Belmullet 5MW - €10M (estimate)	NR	NR
	Grid connection charges	NR	NR	Shallowish
Portugal	**Tariff**	<20MW - €0.26/kWh 20-100MW - €0.21/kWh	NR	< 100MW - €0.16/kWh 100 – 200MW - €0.11/kWh >250 MW - €0.075/kWh
	National strategy	X	X	X
	Targets	NR	X	50MW 2010 550MW 2020
	Grants	PRIME- DEMTEC + QREN €6M	X	X
	Test site + commercial sites	250MW (planned)	NR	250MW (planned)
	Grid connection charges	NR	NR	Deep
Spain	**Tariff**	NR	NR	€0.06/kWh + €0.05/kWh
	National strategy	X	X	X
	Targets	NR	X	5MW by 2010
	Grants	PSE-Mar- €25M	X	X
	Test site + commercial sites	BIMEP 20MW- €15M Mutriku 0.3MW - €6M Santona 1.35MW - €3M	NR	Test sites could become commercial
	Grid connection charges	NR	NR	Deep
UK	**Tariff**	1ROC=0.045/kWh UK 2 ROC Scotland 5 ROC	NR	1ROC=0.045/kWh UK 2 ROC Scotland 5 ROC
	National strategy	X	X	X
	Targets	NR	X	X
	Grants	Carbon Trust: £3.5M MRDF: pre-commercial funds Scotland: SEMEF- £13M Saltire Fund- €10M	X	ETI matching funds to £1B MRDF: £50M
	Test site + commercial sites	EMEC 20MW , £14M Wave Hub 20MW, £26M (planned)	NR	Test sites could become commercial
	Grid connection charges	NR	NR	Shallowish
Germany	**Tariff**	€0.06/kWh	NR	€0.06/kWh
	National strategy	X	X	X
	Targets	NR	X	X
	Grants	X	X	X

	Test site + commercial sites	X	NR	X
	Grid connection fee	NR	NR	Shallow
France	**Tariff**	€0.15/kWh	NR	€0.15/kWh
	National strategy	X	X	X
	Targets	NR	X	X
	Grants	X	X	X
	Test site + commercial sites	SEM-REV 2MW - €5M	NR	X
	Grid connection charges	NR	NR	Shallow
Denmark	**Tariff**	€0.08/kWh + 0.05/kWh	NR	€0.08/kWh + 0.05/kWh
	National strategy	X	X	X
	Targets	NR	X	X
	Grants	RTD - €13M	X	X
	Test site + commercial sites	Nissum Bredning	NR	X
	Grid connection charges	NR	NR	Shallow
Italy	**Tariff**	€0.34/kWh + 1.8 ROC	NR	€0.34/kWh + 1.8 ROC
	National strategy	X	X	X
	Targets	NR	X	X
	Grants	X	X	X
	Test site + commercial sites	X	NR	X
	Grid connection charges	NR	NR	Deep

Table 6: Wave energy policy in Europe relative to the industry sectors of innovation, manufacturing and deployment. (X implies not existing or no current information, NR implies not relevant).

4.2 *Wave energy policy elsewhere*

It is useful to compare policy developments in Ireland with those elsewhere, in order to draw insights into additional measures that may be usefully employed in Ireland. Table 6 presents Ireland's wave energy measures in addition to those in place in a number of other EU Member States. The discussion of Table 6 focuses on the three distinct policy goals of innovation, manufacturing and deployment.

4.2.1 Policies Supporting Innovation (Europe)

Research centres

Research centres form the foundation for nascent innovation in technology. The majority of these centres also contain wave tanks which facilitate prototype device testing and analysis. Table 7 lists the wave energy research and test centres (with wave basins) across Europe.

UK	New and Renewable Energy Centre (NaREC) based in Northumberland, UK.
	SuperGen is a consortium of universities funded by the UK Engineering and Physical Sciences Research Council (EPSRC).
	HR Wallingford University
	Cardiff University
	University of Plymouth's Marine Institute
France	Laboratoire de Mécanique des Fluides (LMF) de l'Ecole Centrale de Nantes.
	Palaiseau, INSA (wave basin).
	Chatou, LNHE (wave basin)
Portugal	INETI – Instituto nacional de Engenharia
	Wave Energy Centre - WAVEC[36], founded in 2003. University of Porto (wave basin)
Spain	CETMAR is a Technology Centre (Public Foundation)
Denmark	DHI Water and the Environment
	Technical University of Denmark, ISVA.
	Aaborg University
Norway	Norway University of Science and Technology.

Table 7: Wave energy research and test centres in Europe (IEA 2003).

[36] http://www.wavec.org/

Grants

There are a multitude of grants schemes provided by other European countries to support wave energy innovation. Perhaps the most comprehensive is that provided by the UK. These consist of:

- Marine Energy Accelerator (MEA) (2006) £3.5M. This fund was organised by the Carbon Trust (2008), with a directive to accelerate progress in cost reduction of marine energy (wave and tidal stream energy) technologies. The project follows on from the Marine Energy Challenge.
- Marine Renewables Deployment Fund (MRDF) (total £50M). A portion of the funding is aimed at the early stage pre-commercial operation and sea trials of a number of wave and tidal current energy technologies (AEA 2006).

Scotland has set up a number of separate support schemes for ocean energies:

- The Scottish Executive Marine Energy Fund (SEMEF)[37] – aims to support the development of key technologies and processes that will enable measurable growth in the Scottish Marine Energy sector. Projects targets include subsea connectors, oceanographic instruments, anchoring & seabed monitoring devices, direct drive low speed generators.
- The Scottish Executive has named nine marine energy projects (WATES) that will share grants worth more than £13M (IEEE 2007, Scottish Government 2009). The largest grant goes towards Scottish Power's scheme to moor four floating generators, designed to convert wave movement into electricity, off the European Marine Energy Centre (EMEC) in Orkney.
- Saltire Prize - £10M will be awarded to a project that can demonstrate a commercially viable wave or tidal energy technology in Scottish waters. The project device must achieve a minimum electrical output of 100GWh over a continuous 2 year period using only the power of the sea[38].

In Spain, the Special Strategic Marine Energy Project (PSE-MAR) is co-funded by the Ministry of Education and Science and aims to position Spain as a world leader in the marine energy sector (IEA, et al. 2007, Scottish Government 2009). The project, coordinated by Technalia[39], has a budget of €25M for 2005-2009 (or €3,5M for the

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[37] http://www.interface-online.org.uk/view_item.aspx?item_id=3033
[38] http://www.scotland.gov.uk/Topics/Business-Industry/Energy/saltire-prize/detail
[39] http://www.tecnalia.info/down/Energia_Tecnalia_eng.pdf

period 2008-2010[40]) and focuses on the development of three of the most promising Spanish technologies for harnessing wave energy – the technologies developed by PIPO Systems, Hidroflot and OceanTec.

In Denmark, special grants exist for support of R&D and €13M (4 x 25 M. DKK) have been allocated for the period up to 2011 for wave energy and other emerging energy technologies (Neumann 2009b). In Portugal, PRIME- DEMTEC[41] (2000-2006) was a fund of approximately €6M to support more than 21 innovative technologies and this is being continued by QREN (2007-2013) (Neumann 2009b).

Test sites

The necessity for nationally funded test sites to support research for local technologies has been recognised by many countries in Europe. To date, six countries have provided funds for their development.

The UK is the most advanced with two test sites. The European Marine Energy Centre[42] (EMEC) currently provides the worlds only multi-berth 20MW, purpose-built, open sea test facilities to date for wave and tidal energy converters, and has a funding of £16M investment (Scottish Government 2009). There are two test sites:

- Wave energy test site: Billia Cro, Orkney. Four test births in 50m of water.
- Tidal energy test site: fall of Warness, Island of Eday.

A fee is charged which covers cable and connection costs.

The other UK test site is the proposed WaveHub[43] off Cornwall. In the current proposals, it will have connections for four kinds of wave energy converter with a total capacity of 20MW and funding of over £40M (South West RDA -£21.5M, Department of Trade and Industry £9.5M, £20M from European Regional Development Fund (New Energy Focus 2009)). Currently there are three wave device developers confirmed. The three confirmed developers are:

- Fred Olsen Limited
- Orecon Ltd[44].
- Ocean Power Technologies (OPT) Limited

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[40] http://www.waveplam.eu/page/default.asp?id=192
[41] http://www.prime.min-economia.pt/PresentationLayer/prime_Noticias_00.aspx?activeitem=7&activesubitem=0&idioma=2&accaoid=92&noticiatipoid=1
[42] http://www.emec.org.uk/facilities.asp
[43] http://www.wavehub.co.uk/
[44] http://www.orecon.com/en/news/wave-hub-chooses-orecon-as-new-device-developer/

Energy company E.ON and partner Ocean Prospect who will be using the Pelamis device, withdrew from the Wavehub test site in 2009 and will now be testing in EMEC[45].

The Portuguese are planning a test site called the Pilot Zone, facilitating 80MW in the first phase and 250MW in the second phase (IEA, et al. 2007). The zone will be supervised by a Management Body, which will facilitate:

- ‘One-stop shop’ planning/permit application.
- Grid connection and cable.
- EIA
- Data collection support infra-structure.

The service has to be paid for by the developers via a rent. There are still a number of unclear issues regarding financial and planning details needing to be discussed (Neumann 2009b). “The initial plans to have the pilot zone operational already shifted from 2009 to now 2010, which only in the ideal case will be possible, and also only for a fraction of the planned zone”.

Spain has three tests planned or already in operation. The first is in Mutriku, in the Basque country. It consists of an oscillating water column integrated in a breakwater[46]. The total investment is €6M investment, 4M€ for civil work and the rest for electro-mechanic work and grid connection. The plant consists of 16 turbines, 18,5kW each, with an estimated overall power of 296kW. The Basque country is also proposing plans for a larger fully serviced test site, BIMEP (EVE 2008). It will consisting of 4 berths and total of 20MW capacity costing €13M. Facilities will include cable and data monitoring. The site is due to be operational by the end of 2010. The third site is based in Santona, Cantabria, where Iberdrola Energías Marinas de Cantabria S.A plan to test OPT’s Powerbuoy[47]. The site will include grid connection for 9 buoys of 150kW each. Affiliated groups involved are Iberdrola Renovables, Total, OPT, IDEA and Sodercan. The budget for the first phase, which includes the electrical marine infrastructure, amounts to €3M.

Other smaller test zones proposed or operational are:

[45] http://pressreleases.eon-uk.com/blogs/eonukpressreleases/archive/2009/04/29/1380.aspx
[46] http://www.waveplam.eu/page/default.asp?id=192
[47] http://www.waveplam.eu/page/default.asp?id=192

- France: 2.5MW SEM-REV[48] test zone of the coast of Nante, €5.5M funding, which includes cable and instrumentation.
- Denmark: Nissum Bredning used for testing Wavedragon[49].

Tariff support for demonstration projects

Deployment of devices in tests sites which produce electricity to the grid is essential part of the R&D process for wave energy device development. Device innovators will need to be reimbursed for the electricity they supply to the grid in order to finance the cost of connection and possible upgrades to the network required. Portugal is the only other country in Europe besides Ireland (which has already been discussed) which has tailored tariff support for demonstration projects, promising €0.26/kWh for the first five demonstration projects, with total output of 20MW (Sarmento 2008) (Figure 8). Other countries advertise FIT, but for undesignated project sizes and purposes. These are discussed in the following sector under deployment.

4.2.2 Policies Supporting Manufacturing (Europe)

The authors found no policies currently in place in other Member States which target support specifically for wave energy manufacturing. However, there are a number of supports for manufacturing in many Member States that may be drawn on to support wave energy.

4.2.3 Policies Supporting Deployment (Europe)

The support mechanisms available in other Member States for deployment of wave energy devices comprise capital grants (only available in the UK) and feed in tariffs (or ROCs in the UK). Aspects of the capital grant support, FIT and targets included here could also be considered as innovation support.

Capital grants

The only country in Europe which has grant funding tailored for the deployment sector is the UK. Other EU Member States do have capital grant support available but for pre-commercial deployment which is already covered in section 4.1.2.3 and considered a support for innovation.

[48] http://www.oreg.ca/docs/2008_Fall_Symposium/Mouslim.pdf
[49] http://www.wavedragon.net/index.php?option=com_content&task=view&id=12&Itemid=14

The Wave and Tidal Stream Energy Demonstration Scheme is a scheme within the Marine Renewables Deployment Fund (MRDF) (AEA 2006), with funds of £42M out of a total £50M. The scheme will support the deployment of multiple, full-scale wave or tidal stream electricity generating devices connected to the UK grid. It will do this through a combination of capital grants (25% of eligible costs) and revenue support (£0.10/kWh in place for a maximum of seven years from commissioning). Funding covers grid connection and infrastructure costs.

The second source of funding is provided by the Energy Technologies Institute[50] (ETI). Its supports development and demonstration projects in marine energy, and is a public/private partnership backed by companies including BP, Caterpillar, EDF Energy, E.ON, Rolls-Royce and Shell. Its target is to secure up to 11 private sector investors, each contributing £5 million per year for 10 years, with the UK Government matching these investments to create a potential £1 billion investment fund for new energy technologies (ETI 2008).

Feed-in tariff (FIT) / Renewable Obligation (RO)

The majority of Western European countries with Atlantic access have proposed some form of Power purchase agreements (PPA). Feed-in tariff (FIT) schemes are the most prevalent in Europe. Italy leads with the highest proposed tariff of €0.34/kWh (EREC 2007). Portugal follows with the perhaps the most developed tariff scheme. Five pre-commercial projects will be supported of 20MW each, with FIT of €0.16/kWh (Sarmento 2008) (Figure 8). FIT rates for commercial projects range from €0.16/kWh for under 100MW farms, €0.11/kWh for 100-250MW and €0.075 for farms over 250MW.

[50] http://www.energytechnologies.co.uk/Home/Technology-Programmes/marine.aspx

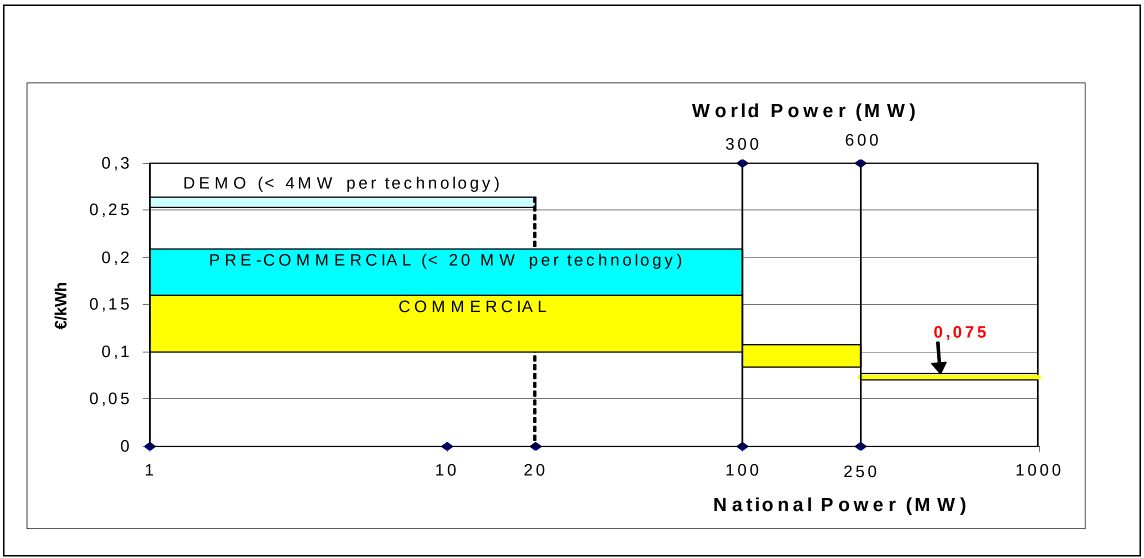

Figure 8: The proposed range of FIT offered in Portugal for the various stages of R&D and capacity deployed (Sarmento 2008).

France, Denmark Spain, and Germany also have FIT which are respectively, €0.15/kWh, €0.08/kWh, €0.06/kWh and €0.06/kWh (EREC 2008), however it is uncertain as yet as to whether these tariffs pertain to demonstration, pre-commercial or commercial projects ,and whether they will scaled for larger projects.

The UK has placed a Renewable Obligation on electricity suppliers, mandating them to deliver a certain proportion of their electricity from renewable sources, evidenced each year through the submission of the appropriate amount of Renewable Obligations Certificates (ROCs). ROCs are distributed to each renewable energy generator for each MWh of electricity sold. This effectively establishes a market ROCs that is separate to the market for electricity. The price of a ROC in 2008 was approximately £0.047 (Scottish Government 2008). From April 2009, two ROCs will be issued for each MWh of wave generated electricity in England and Wales (equating to a value currently of £0.09/kWh), that is supplementary to the price received for the electricity). In Scotland five ROCs will be allocated for each MWh of wave generated electricity (equating to £0.225/kWh based on current prices), also in addition to the electricity market price.

Targets and leases

Targets are becoming increasingly recognised as driving engines for action. Some targets, such as atmospheric pollution reduction, are legally binding international commitments. Wave energy targets currently reflect the aspirations of national governments. Two countries in Europe besides Ireland have proposed targets for wave energy deployment. Portugal's National Strategy for Energy in 2001, set a target of 9,680 MW for additional electricity generating capacity from renewable energy systems (RES) by 2010, of which 50 MW referred to wave energy (AEA 2006), but still to be ratified (Neumann 2009a). This target has recently been increased to 550MW by 2020[51]. Spain is the other country with a target policy and has set a 5MW installed capacity goal for 2010[52] in the Basque country, and 50MW for the Canary Islands by 2015[53]..

The UK has bypassed targets, and has commissioned the Crown Estate to extend a round of leasing opportunities in the Pentland Firth / Orkney / North Sutherland area of Scotland[54]. Thirsty eight companies have successfully pre-qualified in early 2009.

Grid upgrades and reinforcements

The capacity of European grid transmission and distribution system to incorporate large amounts of renewable energy is being increasingly challenged. In the majority of European countries, national grids were designed to accommodate central generation, resulting in weak transmission lines available in coastal areas. The coastal areas of Ireland and Scotland are poorly serviced by high capacity transmission networks. Considerable grid upgrading and reinforcement will be required for the introduction of large scale wave energy farms. Several studies at national and European level are now underway to back up the plans for upgrading the European transmission system, in order to facilitate large-scale renewable integration. The most important international studies are the European Wind Integration Study[55] (EWIS) and TradeWind[56].

Countries with existing high capacity grid systems and interconnectors include Denmark, which does not plan reinforcements in any "anticipation of need /strategic way" (Scott 2007). Coastal areas with good transmission systems include Portugal and SW UK (Neumann 2009b).

In the UK, the Electricity Networks Strategy Group (ENSG) quoted that approximately €6.5B will be needed to upgrade the network for renewables[57]. The

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[51] http://www.unep.org/climateneutral/Default.aspx?tabid=803
[52] http://download.southwestrda.org.uk/interes/interest-event---bristol/waveenergy.pdf
[53] http://www.waveplam.eu/page/default.asp?id=192
[54] http://www.waveplam.eu/page/default.asp?id=260
[55] http://www.wind-integration.eu/downloads/library/2009-02-05-EWIS-Offshore-Onshore-Grid-Perspectives.pdf
[56] http://www.trade-wind.eu/
[57] http://www.rechargenews.com/business_area/innovation/article173405.ece

Highlands and Islands Enterprise (HIE) has commissioned Xero Energy to carry out a grid upgrade study[58]. This estimated that the grid upgrades required in the North of Scotland alone could cost between £150 and £435M. There are plans to upgrade connections of the Beauly–Denny 400kV overhead electricity transmission line which will replace the existing 132kV transmission line between Beauly, west of Inverness, and Denny, west of Falkirk (Scott 2007). The proposed upgrade to the overhead electricity transmission line will enable the Western Isles to be opened up to WECs, and is currently subject to a public inquiry.

Germany has plans for 850km of new transmission lines[59]. In Spain, reinforcement works and extensions will total around €500 million (Scott 2007). In the regions with major RE wind power development, reinforcement measures are planned involving approximately 250km of new 230kV lines, and over 1600km of 400kV lines. This does not however constitute strategic grid planning as such but is an anticipation of things to come. Italy has approached the network issue by installing 30 million smart meters in Italian homes since 2001[60]. Although customers only save about $1.5 Euros a month, the Italian utility ENEL has paid back its 2.2 billion Euro investment in just four years.

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[58] http://www.waveplam.eu/page/default.asp?id=260

[59] http://www.wind-integration.eu/downloads/library/2009-02-05-EWIS-Offshore-Onshore-Grid-Perspectives.pdf

[60] http://www.smartgridnews.com/artman/publish/news/Energy_bill_could_hit_utilities_hard_NIST_accelerates_standards_efforts_Consumers_could_block_demand_response_Ember_s_cash_cup_runneth_over-559.html

5 Policy gaps in Irish wave energy industry

The Irish wind energy experience has in large been a successful one from a deployment perspective, due to definitive initiatives by the Irish government with regard tendering programs, targets, tariffs and somewhat delayed planning and grid infrastructure upgrades. However, the two remaining sectors of the wind energy industry in Ireland, R&D and manufacturing, did not get established.

In comparison, Denmark succeeded in establishing the three sectors successfully to create an industry that became one of the world's market leaders and centres of excellence in the technology.

Present policy in place for wave energy in Ireland has been successful in addressing most of the needs of two of the industry sectors; innovation and deployment, and is quite comprehensive in comparison to other international initiatives. However, the manufacturing sector has been relatively ignored.

The following sections list measures which could be taken to address the policy gaps in wave energy strategy in Ireland, and summary of the mutual synergies and flow-on benefits are indicated in Table 8.

5.1 Innovation

From 2000 onward, science innovation became an increasing focus for job creation strategy for the Irish government, with the culmination of a the Strategy for Science, Technology and Innovation report in 2006 (DETE 2006). Both the Irish government and Department responsible for energy policy DCENR released the white papers on sustainable and renewable energy (DCENR 2007c, Irish Government 2008) and in 2008, the Irish Energy Research Strategy was published (Irish Energy Research Council 2008) advocating applied research in renewable energy, energy efficiency and carbon capture. Science Foundation Ireland (SFI) took over this brief in 2009[61].

[61] SFI will be reviewed with a 'value for money report' (SFI 2009) in an attempt to assess the benefit of investment in innovation to Ireland's GDP (results of the report have not yet been published).

Irish government funding for renewable energy projects and research rose from €2.5M in 2005 to €8.3M in 2008, of which wave energy research received a total of €3.3M in that time period (Figure 9) (IEA & SEI 2008). Renewable energy research received a further €1.3M from EU sources, of which wave energy were apportioned 40% approximately. In 2005, MI and SEI published an Ocean Energy Strategy document (SEI and MI 2005). In 2007, the Irish Government produced a White Paper on Energy (DCENR 2007a), increasing the existing targets and funding for wave energy. Here the Government specified an 'initial ambition' of 75MW by 2012 and at least 500 MW of installed ocean energy capacity by 2020 (originally 485MW by 2025) (DCENR (formerly DCMNR) 2007, Marine Institute 2007), effectively accelerating the ocean energy strategy timeframe by five years. The White Paper also contained the Government intent to 'make Ireland a world leader for research, development and deployment of ocean energy technologies.

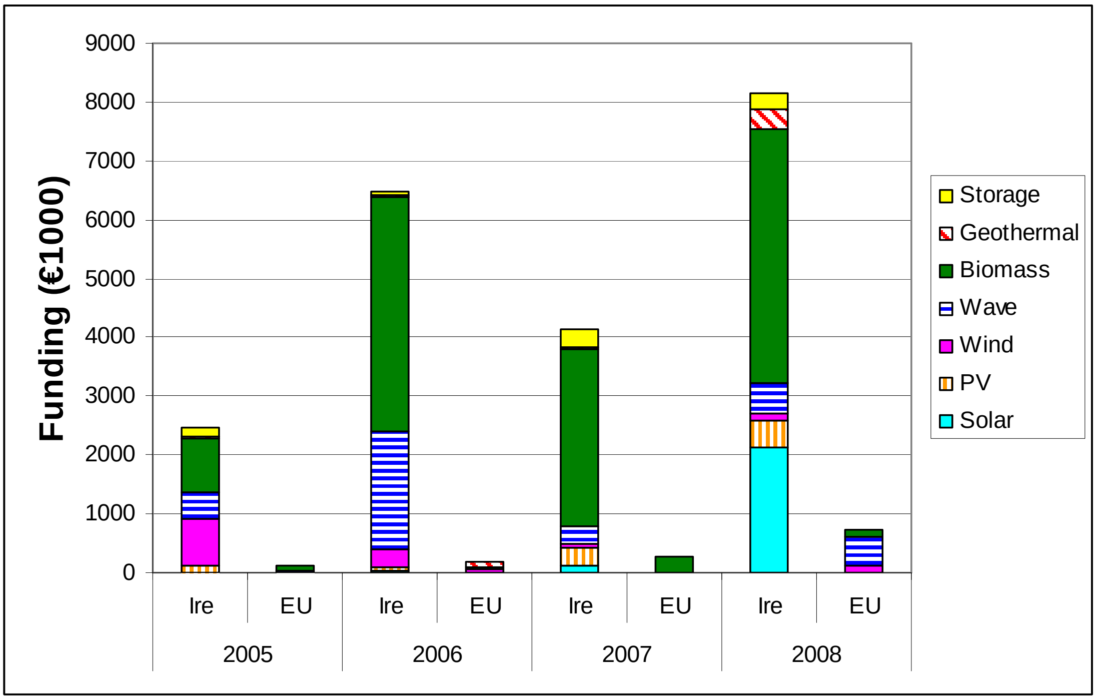

Figure 9: Funding for renewable innovation projects 2005-2008. (Ire=Irish government based funding, EU=European based funding) (IEA & SEI 2008)

Funding for wind energy research in Ireland has been historically very small, with no MNC company setting up operations in Ireland. Ireland did not establish a national research centre for wind research, like RISO in Denmark. Public revenue creation for funding innovation (e.g. from environmental taxes) was not addressed. Minor university research projects currently focus on grid integrations issues and storage.

Irish wave energy innovation sector has been a relatively successful enterprise compared to international experience. The RISO equivalent for wave energy R&D in Ireland is the Hydraulics and Maritime Research Centre (HMRC)[62], and is well supported by grants and subsidies. Further centres of research include Limerick University, Maynooth University and Queens University. A wave atlas has been produced by the Marine Institute and SEI (ESBI 2005), and a Strategic Environmental Assessment (SEA) is being currently carried out.

The two main initiatives learnt from the Danish experience that are present absent from Irish policy are:

- A RISO type mandate stipulating all wave energy devices deployed in Irish waters have approved testing by the centre. This would substantially add to the centres bank of expertise and benefit current research. This policy would also have a flow on affect to the manufacturing sector which would benefit from skilled expertise accrued.
- A 100% redundancy rating requirement for all Irish designed wave energy devices, similar to that stipulated for Danish wind turbine devices. This policy would directly impact the manufacturing industry, and would ultimately elevate the reputation of Irish designed devices.

Further initiatives that Ireland could address or implement are:

- Funding provision for the most vulnerable stage of device development, i.e. the stage between prototype completion and pre-commercial stage (sometimes referred to as the “valley of death”).
- Carbon and energy taxes to provide extra finance for innovation.
- Department of Enterprise, Trade and Employment (DETE) to liaise with other government departments in manufacturing and deployment to coordinate a cohesive plan and strategy for wave energy industry.
- Development of national standards for wave energy devices, in conjunction with other EU directives.

62 http://www.ucc.ie/research/hmrc/

5.2 Manufacturing

The inherent short term nature of MNCs cultivated a lack of embeddedness and linkages between foreign-owned operations and the local economy (Telesis 1982). As a result, local businesses benefited little, with only 174 sub-suppliers created specifically to service MNCs out a total 2,667 small and medium-sized enterprises (SMEs) (Breathnach, et al. 1999). The economic downturn of 2008-2009 saw the flight of many MNC to lower cost economies resulting in unemployment rates returning to pre-Celtic tiger levels.

There has been little success in nurturing an indigenous or MNC based renewable energy manufacturing sector to date in Ireland. In 2009, one small scale wind turbine manufacturing operation has opened in Galway, Ireland, with the promise of 250 jobs in full production. However, the top-10 wind turbine manufactures in the world control 97% of the market (Beck, et al. 2009), and base the majority of their operations their native countries. Locating MNC manufacturing plants near to sites of deployment does not appear to be economic at present, with the example of Vestas Wind turbines withdrawing the only wind turbine manufacturing operation in UK in 2009, with the loss of 700 jobs[63].

The wind energy manufacturing industry in Ireland, despite a readily available market did not develop in Ireland due to a lack of policies and initiatives to foster it. Current wave energy policies in Ireland for R&D and deployment also unlikely to have a flow-on effect to manufacturing.

Analysis of the Danish wind energy experience demonstrated that there were very few direct manufacturing policies. The manufacturing sector responded to positive conditions created in the R&D sector as well as in deployment. Additional policies that would directly benefit Irish wave energy manufacturing would be:

- Investment subsidies, production subsidies and tax exemptions which require eligible developers to manufacture devices in Ireland. These would be reduced in time to stimulate competitiveness in the industry.
- An agreement between the government and utilities requiring the latter to invest and construct at least 200MW in wave farms, similar to the mandate in Denmark for offshore wind.

[63] http://www.guardian.co.uk/business/2009/apr/28/vestas-wind-turbine-factory-close

- Long term financing for wave energy manufacturing projects.
- Low industry rate electricity prices to assist in reduction of costs. Ireland had the forth highest electricity prices for industry in Europe in 2008[64].
- An increased interest by the Irish Development Authority in promoting wave energy manufacturing. Coordination of policy initiatives is also required between the department of Industry and Trade promoting manufacturing, with other departments responsible for innovation and deployment.
- Guaranteed REFIT with defined time frames, would provide a guaranteed market foundation for manufacturing companies due to the increased sales of WEC resultant from prospective developers attracted to the high financial returns from deployment.

5.3 Deployment

Ireland has made some large steps in supporting the wave energy deployment industry with the introduction of the €0.22/kWh FIT. However, this tariff at present applies to the first 5MW deployed i.e. pertain to the test site deployments in Belmullet (DCENR 2009). A full tariff scheme valid for all farm sizes with defined project time periods has as yet to be finalised by the government (DCENR 2009). Delays in finalising this legislation will contribute significantly to developer reticence in considering Irish WEC deployment.

There are many other policies which could simultaneously assist the wave energy developer industry, and these include:

- An investment subsidy comparable to the 30% subsidy provided by Denmark. The policy would be enhanced by a stipulation requiring applicants manufacture their devices in Ireland in order to be eligible for the grant. The policy thus would not only benefit developers but would also have a direct flow on effect of stimulating the manufacturing industry.
- Executive order or mandates, decreeing utility built wave farm construction projects of the size of 100 to 200MW. These projects would require turbines to be manufactured in Ireland if they were to avail of the investment grant (flow on benefit the manufacturing sector).

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[64] http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-QA-09-025/EN/KS-QA-09-025-EN.PDF

- In order to reduce planning permit problems and delays, a government mandate decreeing compulsory designation by local authorities of sea area leases.
- Shallow connection charges for both distributed and transmission network connections. This would aid the young wave energy industry as the majority of connections in the early stages will be from small projects.
- Multiple interconnectors with both the UK and mainland Europe to provide export networks for the excess energy as well base load capacity to support high penetration of renewables. Two companies at present are competing for the €110M EU grant, Eirgrid and Imera[65]. The first cable is promised to be in place by 2012.
- High retail electricity prices, possibly via energy taxes, would provide higher returns for developers.
- In order to enable high penetration of wave energy into the grid system, more peaking plants as well storage plants will need to be planned, e.g. compressed air, pumped hydro, cooling plants etc.
- Grid network upgrade and reinforcement to cater for high wave energy penetration from the west coast of Ireland (planned under Grid 25 at present).
- A GIS site selection tool, providing premium locations sites for wave energy deployment in Ireland, including wave energy data, bathymetry, best port locations, nature reserves etc.
- Greater liaison and cooperation with regards unified policy and strategy between government department overseeing the deployment sector (Department of Communications, Energy and Natural Resources (DCENR)) and other departments responsible for innovation and manufacturing.

The following policies have already been considered or planned in the ocean energy strategy document by MI and SEI (SEI and MI 2005), but have yet to be implemented:

<u>One stop shop' for planning applications and permits.</u>

The OEDU, together with the DCENR, are promising that a 'one stop shop' facility will be up and running by 2010 (Sweeney 2009). In principle, this will mean that a

[65] http://www.examiner.ie/story/Business/idmhkfeykf/rss2/

developer need only apply to one centralised office for all the planning permits and foreshore licences, saving time and money on applying to the separate Departments.

In 2001, there was no specific legislation that pertained to offshore renewable energy generation. It was also realised that there needed to be harmony between the Foreshore Acts, 1933-2005 in the context of offshore electricity generation and the existing legal framework governing electricity, namely the Electricity Regulation Act, 1999. The document "*Offshore Electricity Generating Stations - Note for Intending Developers*" (Irish Government 2000) was published which was intended as a guideline indicating the relevant departments that needed to be approached. The list was not exhaustive and the document explained that that the specifics would vary on a case by case basis.

There are presently approximately 20 Departments, Offices/Organisations that will need to be approached. This list can be split in three categories:

1. Government Departments/ Agencies that needed to applied to for consent/licences:

- Department of Agriculture, Food and Fisheries for Foreshore Licence and Foreshore Lease (this was the responsibility of the Department of the Marine and Natural Resources in 2001);
- Commissioner for Energy Regulation (in relation to electricity supply licence);
- Adjoining Local Planning Authority (in relation to land-based elements necessary);
- National Parks and Wildlife (originally called Dúchas) for impact on any conservation area.

2. Agencies that are advised for consultation – Bord Gáis Éireann, Licensed telecommunications operators and the Office of the Director of Telecommunications Regulation (in relation to existing telecoms infrastructure), Commissioners of Irish Lights, Irish Aviation Authority, CHC Ireland, Irish Coast Guard and the Local Harbour Master.

3. Non-governmental organisations that are advisable to consult: BirdWatch Ireland, Royal Society for the Protection of Birds (N.I.), An Taisce (The National Trust for Ireland), Campaign Whale, Coastwatch Europe, Irish Wildlife Trust, Irish Women's Environmental Network, Joint Links Oil and Gas Environmental Consortium, Voice of Irish Concern for the Environment, Irish Offshore Coalition.

Four countries in Europe have already established “one-stop shops”. Scotland began the development of a one-stop shop for licensing of marine renewables in April 2009, overseen by the newly formed Marine Scotland[66]. In Spain, the Spanish Royal Decree 1028/2007 established a simple licensing procedure for wave energy installations (Neumann 2009b) and is administered by authorisation General Direction for Energetic Policy and Mines (Aranda 2008). However, it is still not clear how to apply for the BIMEP test zone (Neumann 2009b). Portugal has also recently introduced simplified planning application rules, but at present will only apply to the Pilot zone (Huertas-Olivares, et al. 2007). The Danish regulatory framework system is based on the “one-stop-shop” principle for off-shore wind and ocean, creating a simplified system for EIA and consent, with a much lower degree of uncertainty (Sovacool, et al. 2008).

Strategic environmental assessment (SEA)

The objective of the SEA process is to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of specified plans and programmes (O'Mahony 2009). SEA main purpose is to address the cumulative impacts of individual projects which are not considered or assessed by individual EIA. SEA is intended to provide the framework for influencing decision-making at an earlier stage when plans and programmes for large groups of projects are being developed. An SEA identifies all the potential wave energy zones in a state, and excludes all sites which are zoned for oil and gas, fisheries, cables, shipping zones, military use and nature reserves. Article 3 (2) of the E.U. Directive provides that an environmental assessment must be carried out for all plans and programmes which are prepared for eleven specific sectors[67] and which set the framework for future development consent of projects listed in the EIA Directive (as amended). Marine Renewable Energy is one of these sectors.

The SEA Directive is transposed into Irish law by way of two Statutory Instruments: S.I. 436 of 2004 - Planning and Development (Strategic Environmental Assessment) Regulations 2004 and S.I. 435 of 2004 - European Communities (Environmental Assessment of Certain Plans and Programmes) Regulations. The statutory environmental authorities that have been designated under the latter instrument are:

[66] Personal communication from EWTEC reviewer

[67] The sectors specified are agriculture, forestry, fisheries, energy, industry, transport, waste management, water management, telecommunications, tourism, town and country planning or land use.

- the Environmental Protection Agency (EPA);
- the Department of Environment, Heritage and Local Government (DEHLG);
- the Department of Communications, Energy and Natural Resources (DCENR).

Any future Irish programme for wave energy development will be subject to the SEA process. The SEA for the marine renewables sector (incorporating wind, wave and tidal) is due to be completed by 2010 (Sweeney 2009).

	Policies befitting R&D	**Policies befitting Manufacture**	**Policies befitting Developer + Deployment**
Policies already in place or planned	4 stage strategy OEDU		
	FIT		FIT
	Prototype funding		
	Research funding Parsons funds		€26 OEDU fund
	Test sites		
			Targets
			Grid upgrade (planned)
			One stop shop (planned)
			SEA (planned)
Suggested policies to foster wave energy sector evolution	RISO model + compulsory testing of international devices deployed in Ireland	High redundancy requirement for devices	
			Expanded Wave atlas
			Designation of sea zones
			Shallow connection charges for distribution
			Interconnectors
		Production grants and tax incentives, Irish made WEC + long term financing	Investments grants and tax incentives Irish made turbines + long term financing
			Compulsory construction of 200MW wave farm
		Low industry electricity prices	High retail electricity prices
		Carbon and energy taxes	Carbon and energy taxes
			Cooperative owned projects with support
	Staple government	Staple government	Staple government
	DETE	IDA and EI	DCENR

Table 8: Current and suggested policies to foster Irish avenger innovation, manufacturing and deployment, showing mutual synergies and flow-on benefits.

6 Conclusion

This paper has presented the current state of wave energy policy both in Ireland and in Europe, as well as presenting the successful cases of the Irish Celtic tiger, the Irish and Danish wind energy experiences. Irish wave energy policy was then examined to assess whether current policy, which is seen to be one of the most progressive in the world, could be improved upon. The purpose of this analysis stemmed from the ambition of the Irish Government not being matched by activity and stimulus. It does not provide a full cost benefit analysis but rather points to what policy mechanisms can be employed if Ireland wishes to become a world leader for research, development and deployment of ocean energy technologies.

Irish government initiatives in all three core areas of innovation, manufacturing and deployment were shown in the paper to be very successful in creating a positive environment for success, resulting in the Celtic Tiger experience. World class industries were established and continue to flourish in IT, bio-pharmaceuticals and food industry. The experience demonstrated that the Irish government has the capacity to successfully develop policy necessary to stimulate an industry once it sets out to do so. The Irish wind energy experience has shown that policies can be put in place that successfully deploy renewable energy plants in a relatively small timeframe. Government incentives and policies started only a decade ago, increased wind penetration from zero to one of the highest in Europe. However, the targets for wind energy were for deployment only and Irish R&D and manufacturing in wind energy did not evolve as a result.

Denmark, on the other hand, has been shown to be an excellent example of how prudent government policies can establish a successful wind energy industry spanning all three industry sectors of innovation, manufacturing and deployment. The Danish wind energy industry in its early years had no market and a weakly described technology. Lessons from Danish wind energy experience showed that the policy provision at an early stage created a relatively large user group from the beginning. This, greatly stimulated learning by using and learning by interacting between the turbine users and the turbine producers. The RISO institute was the cornerstone of this interaction, providing a repository of knowledge excellence in R&D and innovation. Denmark’s real success lay on foundation of mutually beneficial policies and strategies which cross benefited along the sectors. A major boon to the wind energy industry in Denmark was the stability of Danish energy policy for a long enough period to ensure successful establishment of the manufacturing sector, leading to becoming the world's largest international exporter of turbines. Subsequent changes in government policy had no deleterious effect on this manufacturing sector due to its strong international presence. It could be argued that this Danish example of providing support in the beginning and gradual withdrawal of support as the industry establishes could be a template for other governments trying to establish a new industry sector, creating a resilient industry that will survive in international competition.

Analysis of the wave energy policy in Ireland revealed that the basic strategy is correct, but the extent needs to be greatly expanded and the delivery needs to be guaranteed. The ratification of the €0.22/kWh FIT was a welcome initiative from the government, and can be viewed as a solid commitment by to positively support the industry. However, FIT are virtual until they are drawn upon, which in the international wave energy context could be many years away. Thus the FIT initiative can be possibly misleading, funding a future scenario while present policies and funding are lacking or in need of implementation.

Seven main policy initiatives were identified which could ensure the successful establishment of a full wave energy industry in Ireland:

- The Department of Communications, Energy and Natural Resources should establish a Wave Energy Strategy Group should be formed with a tight brief to develop a strategy to address the challenges facing delivery of the specific 500 MW target by 2020.
- Ireland needs to significantly increase the annual wave energy R&D budgets, including critical financing for the full-scale demonstration stage of innovation i.e. the stage between successful prototype demonstration and the pre-commercialisation stage. The current annual budget of €3.3M needs to increase approx one hundred fold over the next 10 years.
- Ireland's electricity system operators should include specific guidelines within the grid code for wave energy devices as is currently the case for wind energy devices.
- Establish a capital grant investment subsidy comparable to the 30% subsidy provided in the early stages of wind energy deployment in Denmark. The

policy would be enhanced by a stipulation requiring applicants manufacture their devices in Ireland in order to be eligible for the grant.

- Introduce a reduced corporate tax rate of 3-5% from year 4 to year 10, in addition to the 0% tax rate for the first three years. This would allow wave energy manufacturing companies to firmly establish themselves in the market.
- Fast tracking appropriate policy in the various government departments for planning permission, foreshore licences and suitable grid connection/infrastructure.
- Increase the current proposed FIT from €0.22/kWh to €0.30/kWh or €0.40/kWh, similar to that provided for PV in Germany.
- Standards for wave energy devices in conjunction with other EU countries.

Finally, a stable government is crucial for long term development of policy initiatives necessary to stimulate and promote the evolution of the wave energy industry, as was seen from the Danish experience. Liaison between all three relevant government departments responsible for innovation, manufacturing and development/deployment (DETE, IDA/EI and DCERN) are essential to coordinate a policy framework for simultaneous development of the all three wave energy sectors.

In conclusion, Ireland has the capacity and experience to successfully nurture and develop a wave energy industry. The great challenge will be for the government to identify the right balance of policies and incentives to sustainably nurture all three sectors of the wave energy industry.

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