Department of Communications, Marine and Natural Resources
Roinn Cumarsaids, Mara agus Acmhainni Nadura

Ocean Energy in Ireland

Marine Institute
Foras na Mara

SEI SUSTAINABLE ENERGY IRELAND

Ocean Energy in Ireland

October 2005

An Ocean Strategy for Ireland submitted to the Department of Communications, Marine and Natural Resources

Executive Summary

Ireland has a target of supplying 13.2% of its electricity consumption from renewable sources by 2010. The majority of this target is likely to be supplied from wind energy. It is likely that targets will increase in the longer term. This will require large deployments of other forms of renewable energy. Ocean energy, both wave and marine current tidal energy, may have a role to play in meeting longer term targets in Ireland. The resource, particularly the wave energy resource, is vast. Before these technologies become commercially viable researchers and developers must overcome the challenge of developing low cost, highly reliable, integrated systems. Given current efforts to develop technology, ocean energy may be deployed in small scale demonstrations by 2010; however it is not expected to contribute significantly to Ireland's electricity supply before 2020.

It is proposed to implement an ocean energy strategy to advance the speed at which ocean energy technologies are deployed in Ireland by increasing the capacity for research and development, both within academic institutions and commercial entities developing devices in Ireland. A structured and phased strategy of development supports may enable Ireland to utilize its ocean energy resource within a decade. The result could also see Ireland positioned with the potential to become a world leader in the manufacture and use of ocean energy systems.

Europe's accessible wave power resource is calculated to be of the order of 320,000MW with the highest resource available near the West of Ireland. Wave energy may be regarded as stored wind energy; it is therefore possible that the potential wave energy market is at least as large as that for offshore wind energy (estimated to be 70,000 MW by 2020). The corresponding European marine tidal current energy resource is estimated to be sufficient for 13,700MW of generation capacity. The ocean energy resource available to Ireland indicates a potential to supply 100% and 6% of the forecasted All Ireland electricity demand from wave and tidal energy sources respectively, however it is not yet known how much of this could be exploited economically.

Ireland has 3rd Level research expertise in the areas of turbine design at University of Limerick, wave tank model testing at the Hydraulics and Maritime Research Centre of University College Cork and wave energy modelling at Queen's University. In terms of prototype development, there are currently three wave energy developers in Ireland namely Ocean Energy, Hydam and Wavebob. These activities represent the early stages of a potential new industry in Ireland. To date, national agencies have provided an estimated €1.2m in grant aid to this sector, however, a more sustained long term commitment is required to enable ocean energy to contribute to energy demand in the next decade.

In addition to providing another clean indigenous source of energy to Ireland, success in building the capability to use the ocean energy resource could provide a new market for energy project developers, and potentially an export market for those designing or producing ocean energy devices. Offshore wind energy offers the closest reference market for a potential ocean energy market although the resource and technology are different. It is predicted that 70,000MW of offshore wind power may be installed in Europe by 2020. The total value of this market is estimated to be €81billion. The value of a domestic market for ocean energy in Ireland is estimated at €176million by 2020, increasing to €784million by 2025, with additional CO_2 reduction benefits accruing to the economy valued at €2m and €10m by 2020 and 2025 respectively. By securing 20% of the European export market, Irish developers could bring €360million in to the economy by 2020, creating 574 jobs, rising to €1,587million and 1,329 jobs by 2025.

A four phase strategy to capitalise on Ireland's ocean energy resource is proposed with review procedures and decision gates at the end of each phase:

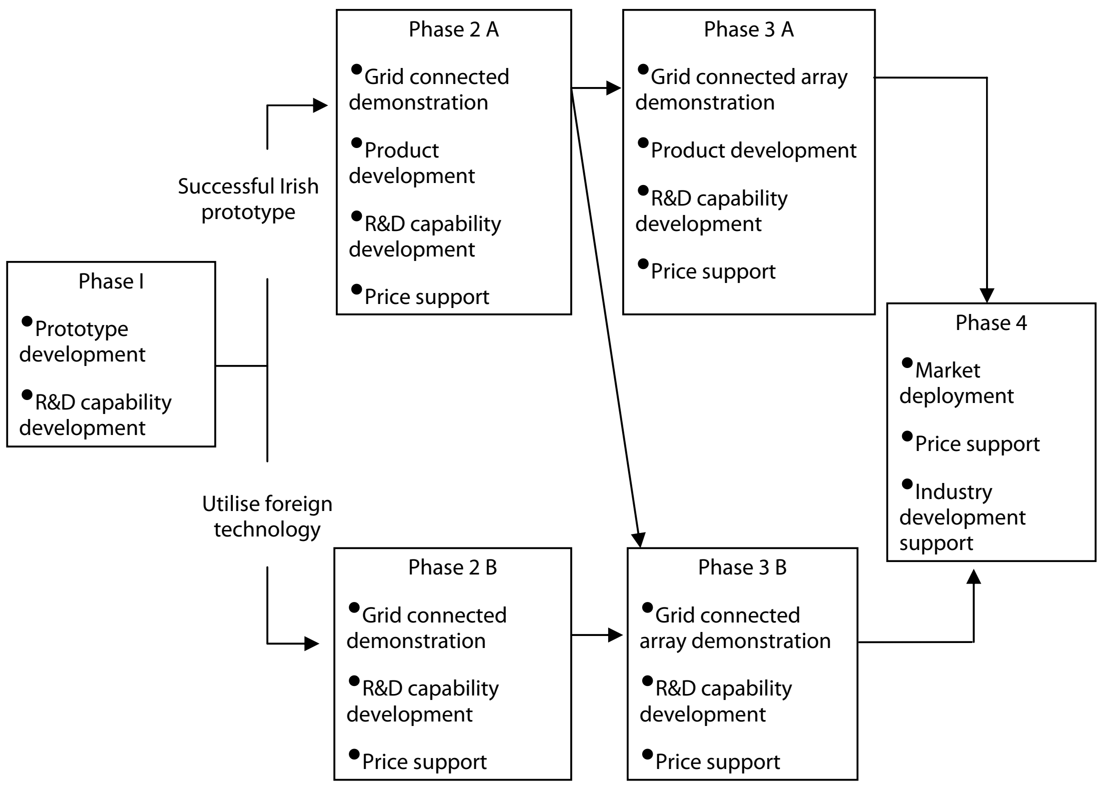
Phase 1 (2005 to 2007) focuses on development by supporting product R&D and research facilities. The objective of this phase is to develop and test large scale prototype concepts and develop technical leadership in this area. The estimated grant support cost for Phase 1 is €4.9m. Following a review of Phase 1, a decision to proceed to Phase 2 will be made.

Phase 2 (2008 to 2010) would support the development of pre-commercial grid connected devices with the objective of demonstrating the potential for a cost effective fully functional wave energy converter operating in the Irish electricity market. Here an option to support either a national developer or an external commercial developer is included. Grant support for product development and a test connection along with electricity price support of 15c/kWh could be offered. The maximum cost for Phase 2 is €10.5m. Following a review of Phase 2, a decision to proceed to Phase 3 will be made.

Phase 3 (2011 – 2015) could provide support for a 10MW large -scale array of devices to be connected to the grid. Some level of grant support for product development and grid connection, and possibly electricity price support, would likely be required. Following a review of Phase 3, a decision to proceed to Phase 4 will be made.

Phase 4 (2016 onwards), large scale market deployment for ocean energy. It is likely that some level of industry development support will be necessary at this phase; particularly if an export focused industry in ocean energy device manufacture is to be developed.

Figure 1: Four Phase Ocean Energy Strategy



In order to implement the Ocean Energy Strategy, an Advisory Group comprising relevant parties is proposed together with a step-by-step implementation plan.

Table of Contents

Introduction

Ocean energy, contained in the world's waves and marine tidal currents, provides an untapped source of renewable energy. The first technologies to exploit this valuable source of energy are currently under development. With the continuing rise in the price of energy and the rise in demand for cleaner energy, the commercial prospects for ocean energy technology look promising. This is potentially significant for Ireland, both in terms of its energy mix and the economic benefits of being a player in respect to the technologies involved. Ireland is particularly vulnerable to energy price and supply uncertainties as it imported 89% of its energy needs in 2003. However, Ireland has significant clean energy sources available to it in the form of wind, bio energy and ocean energy that can be utilized to offset this risk. Actions are in place to stimulate use of the wind and bio energy resource. This document addresses the need to put in place a strategy to stimulate exploitation of the ocean energy resource.

As ocean energy falls within the remit of both agencies, Sustainable Energy Ireland (SEI) and the Marine Institute (MI) have worked together to prepare this proposal which outlines a strategy to advance Ireland's research and development capabilities so that ocean energy can contribute to meeting Ireland's growing demand for renewable energy in the next decade and beyond. The resulting development could see Ireland well positioned to develop an export industry for ocean energy devices. This document summarises the market potential and return to the Irish economy from participation in a prospective ocean energy industry.

The Role for Ocean Energy in Ireland's Energy Policy

Recent steps by the DCMNR to develop a strategy for renewable energy in Ireland have been driven by the requirement to meet the EU RES-E Directive target of 13.2% of energy consumption being generated by renewable energy source electricity by 2010. Future targets will be driven by energy security concerns and future commitments to reduce greenhouse gases under the Kyoto Protocol, and are expected to require greater market penetration by renewables over time.

In 2003 the DCMNR released a consultation document that investigated potential means to meet the target, including consideration of the types of resource and technology that could be deployed in the relevant time- frame, as well as the types of mechanisms that could be used to encourage the private sector to deploy renewables. In this document ocean energy was not expected to play a role in meeting Ireland's targets until well after 2010. Wind was seen as the primary renewable resource to be exploited in the near term, with bioenergy beginning to be deployed in the near- term and used more widely in the next decade. Ocean energy and solar photovoltaic energy were expected to play a marginal role until the technologies advanced to the point that utilization of these resources became economically viable.

A result of the 2003 consultation exercise was the creation of the Renewable Energy Development Group, an advisory group of experts within industry and government. This group established subgroups to consider specific strategic or technology issues for renewables, including the Short Term Analysis Group, established to advise the DCMNR on technology targets for 2010, the Bio Energy Strategy Group and the CHP Strategy Group. No group was established to consider what role ocean energy could play, and at what pace, going forward.

A potential scenario for the renewable energy generation mix in the year 2010 will see wind energy providing 72% of renewable electricity, 17% being provided by existing hydro and 11% coming from bioenergy as described by Government's recent All Ireland Energy Market Consultation paper. However meeting higher targets in the future will require a greater capacity to use other renewable resources. Onshore wind is, at present, the most economic renewable resource, although one of the factors that will determine the final growth potential for onshore wind is public acceptance. Offshore wind is being demonstrated, but costs have been much higher than initially anticipated. Current demonstrations are in water depths of up to 20m, but as the shallow water locations become exploited, developers may be forced to look further offshore for deeper installations, thereby increasing the cost of offshore wind even further. Another factor limiting both onshore and offshore wind is the capacity of the grid operating system to accept intermittent electricity resources. Although bioenergy has significant potential, the resource is limited by the amount of biomass that can be economically collected for conversion to energy. Further research and development could expand the size of the viable resource for each of these technologies. In the longer term, directing R&D towards developing the capability to use the ocean energy resource could have a greater impact.

Recently the DCMNR has gone to public consultation to consider the research and development needs in the energy sector going forward. The results of this consultation could further define what role ocean energy will be expected to play in Ireland's energy policy in the future. It is hoped that this programme will contribute to the development of Ireland's energy R&D strategies and priorities.

An additional policy consideration is the commitment by ministers in the Republic of Ireland and in Northern Ireland to cooperate actively on energy issues in both jurisdictions. For this reason the resource studies commissioned to inform this proposal have included consideration of the Northern Ireland resource. The UK government has shown a strong commitment to developing the capability to utilize its ocean energy resource in recent years. This commitment has included consideration of Northern Ireland based ocean energy research and development.

Ocean Energy Policy Development in Ireland

Consultation Process: Options for the Development of Wave Energy in Ireland

In November 2002 a consultation document on options for the development of wave energy was published. Responses were compiled and made available to the public.

Three strategy options were identified:
1. To become a technology leader in the field of ocean energy by committing to a significant development programme for ocean wave and tidal energy
2. To provide Ireland with the means to utilise the Irish wave resource and develop an exportable core of research excellence.
3. To maintain a watching brief in the field of wave and tidal energy.

Twenty-four responses were received from Ireland and abroad. The majority of respondents favoured option 2 and felt that the approach would make Ireland an attractive location for the installation of prototype and commercial technologies. Fifty percent of the respondents from Ireland favoured option 1. These included one developer and two researchers. Their responses reflected a belief that for Ireland to benefit fully from the development and deployment of wave energy technology, significant capital grant funding, accompanied by high price supports, and making R&D funding available to indigenous Irish developers and researchers would be required.

A summary report of the responses received, included selected comments, is available on the websites of SEI and the Marine Institute.

Policy Studies

In order to inform the development of the ocean energy policy and the strategy proposed in this document, Sustainable Energy Ireland and the Marine Institute have commissioned relevant studies in the area. A detailed summary of the goals and results of each study is presented in Appendix A.

The main studies conducted include:

- A development and evaluation protocol for Irish device developers.
- The economic benefits of developing ocean energy in the Republic of Ireland [1]
- The tidal and marine current resource around the island of Ireland [2]
- The offshore wave energy resource in the Republic of Ireland

This work serves to deepen the understanding of policy makers as to the potential contribution that ocean energy can make to meeting internal energy demands, and the potential economic benefits that can be derived from the development of an ocean energy industry in Ireland.

Indicative Size of the Resource

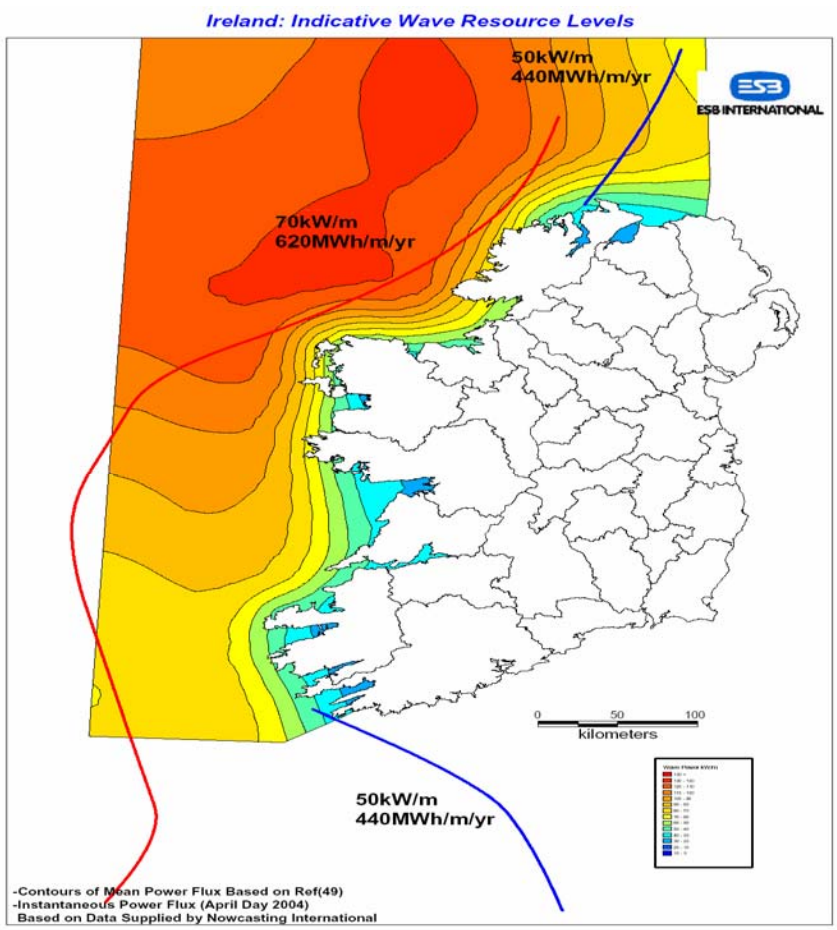
The studies listed above include two that will quantify and describe the ocean energy resource around Ireland. These studies are not yet published. However draft figures have been provided for the tidal and marine current resource, and along with previous estimations of the wave resource, these can be used to give an indicative measure of the size of the resource available.

The predicted All Ireland gross electricity consumption is 44TWh (i.e. 34TWh ROI and 10TWh NI) for 2010. The tidal marine current resource described below implies that the accessible tidal energy resource for Ireland is estimated to be 6% of 2010 consumption.

Resource	Description	
Theoretical	Gross energy content of the resource	230 TWh/ann
Technical	Theoretical resource constrained by efficiency of the available technology	10.5 TWh/ann
Practical	Technical resource constrained by physical incompatibilities	2.6 TWh/ann
Accessible	Practical resource constrained by institutional and regulatory constraints	2.6 TWh/ann
Viable	Accessible resource constrained by economic viability	0.9 TWh/ann

The practical **wave energy resource** offshore is estimated at greater than 6000MW, or 59 TWh/ann, per the consultation document *Options for the Development of Wave Energy in Ireland*. These figures will be updated upon completion of the report from ESBI on the offshore wave energy atlas for Ireland. Figure 1 below shows the estimated average wave power available around Ireland.

Fig. 1 Indicative Wave Resource Levels in Annual MWh/m (Source: Pontes, M.T. et al. [6])



Accessible Wave Energy Resource Atlas Ireland, ESBI, (Draft 2005)

Issues facing Ocean Energy

Technology development remains the critical issue for ocean energy systems. There have been a handful of prototype deployments at sea, including most recently the Pelamis wave energy converter and the Seaflow marine current turbine, both in the UK, and onshore wave energy devices that have been operational for many years. However there are far more examples of troubled prototype testing, or device concepts that have languished in the laboratory for years. There is a need for a successful commercial device to reach the market and provide access to data verifying that ocean energy is economically viable. The pace of current development would now suggest that this is only a few years away.

Ocean energy devices are required to operate in a harsh environment, and, in the case of ocean wave technology, a harsh and violent environment. Historically, offshore engineering focused on building structures that could simply survive ocean waves. Wave energy devices must be engineered to capture energy while surviving. There is an inherent compromise between cost and survivability. A larger device, with thicker walls or double walls, may be more likely to survive the ocean environment, but would require more basic materials and therefore be more costly. Optimisation of design and materials is an area where considerable research is underway and will be needed going forward.

Energy production forecasting and design simulation tools are well developed for use in the wind industry. They will be required for similar purposes for ocean energy devices in order to predict device behaviour in particular sea conditions, average production outputs, and to provide data to electricity system operators and other stakeholders. Testing and measurement standards also need to be further developed in order to provide a consistent means by which comparison between systems testing and operating at full scale can be made.

Commercial systems are expected to become available in the 2010 to 2020 period. During this time it is likely that wind energy will become the largest renewable resource deployed in Ireland. Both wind and wave energy are intermittent sources of energy. In the absence, therefore, of adequate low- cost reserve power or energy storage it is likely that the deployment of wind power may eventually become restricted in order to maintain system security. Additionally, given Ireland's relatively low electricity demand and rapid growth in wind power, there is the risk that by the time wave energy systems become commercially viable in 2010 –2020 the majority of the system capacity available to support intermittent power sources will be occupied by wind power. This may impact the system capacity available to support wave energy. In order to address this situation, the use of an efficient intermittency management system, increased interconnection and energy storage may need to be investigated.

Table 1 presents a comparison of some of the relative advantages and disadvantages of wave and tidal power in Ireland. Tidal has the significant advantage of being regular and predictable thereby reducing the reserve power requirements of the electricity system operator, whereas wave energy is intermittent and less reliable. Both offer the advantage of exploiting offshore resources and have less visual impact than offshore wind turbines. The results of resource assessments, based on best technologies available and scale of resource indicate that Ireland has greater wave energy potential than tidal current energy potential.

Table 1 Comparison of Ocean Energy Technologies

Technology	Advantages	Disadvantages
Wave Energy	• Ireland has a significant resource. • Converters can be placed offshore at sea level reducing visual impact of device and increasing public acceptability. • Wave energy is not synchronised with wind energy, which could possibly lead to reduced reserve power requirements. • No impact on bird migration.	• The technology is currently in a developmental phase with no commercial systems currently available with demonstrated reliability. The technology lacks demonstration experience. • Wave converters must be capable of surviving extreme weather loading which may add to the cost of the design. • Maintenance costs may be high.
Tidal Energy	• Outputs are predictable and regular, reducing the scale and cost of reserve power. • No impact on bird migration.	• The technology is currently in a developmental phase with no commercial systems currently available with demonstrated reliability. The technology lacks demonstration experience • May have limited resource potential for Ireland. • May be water depth limited to 20-40m • Growth of marine life on structures may impact on performance. • Turbines must be lifted out of the water in order to service components. This must occur in regions of high current velocity which may create access and maintenance issues. • High current velocities can occur in estuaries and bays which are used for leisure activities. This may impact on public acceptance. • Unknown environmental impacts associated with extraction of tidal energy.

Ocean Energy Industry Opportunity

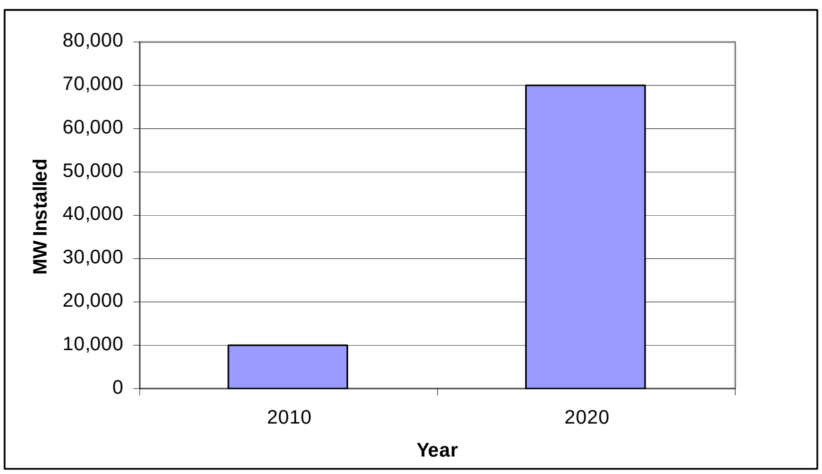
Potential size of a European Ocean Energy Market

In determining the market potential for ocean energy technologies it is useful to first examine the success of the wind industry in Europe. Since 1990, the market penetration of wind energy has grown steadily at an average rate of 30% per annum. By 2003 there was 28,000MW of wind generation installed, providing electrical power to the EU-15 countries. The European Wind Energy Association predicts 75,000MW of wind generation (onshore + offshore) to be installed in Europe by 2010 with this number expected to rise to 180,000MW by 2020 [3].

When considering the potential development of an ocean energy market, the offshore wind sector offers a useful reference point. Figure 2 presents the predicted increase in offshore wind turbines for 2010 and 2020 [3]. The numbers indicate a total of 10,000MW capacity by 2010 and 70,000MW by 2020. Assuming an average installed cost of €1454/kW before 2010 and an average cost of €1115/kW before 2020 [4], the estimated value of the 2020 European offshore wind energy industry is estimated to be of the order of € 81billion in present value terms.

Recent studies have indicated that the available European wave energy resource is capable of delivering 320,000MW of electrical power [5,6]. Appendix B presents a summary of the latest international developments and technologies. As wave energy can be viewed as concentrated stored wind energy, it is considered that the energy resource, and therefore the market potential, may be as great if not greater than that for the offshore wind energy market.

Fig. 2 Predicted growth in offshore wind installed in Europe EU-15 Countries (Source: EWEA)



Studies to assess the marine currents resource have been carried out in the UK, European Union and in far-eastern countries. A 2001 paper on the European resource estimated that in the UK, Ireland, Greece, France and Italy, 106 promising locations could supply 48TWh/yr to the European electrical grid network using present day technology. This would require approximately 13,700MW of marine current generation capacity [5].

Value of a Domestic Irish Ocean Energy Market

While the scale of the ocean energy resource is appreciable, there are no commercially viable ocean energy systems available at present and the market for this technology is presently at a development stage. In the wind sector there are several large-scale manufacturers of wind turbines. A developed ocean energy market could similarly accommodate a number of ocean energy device manufacturing companies. Appendix C presents a summary of the status of research and industrial activities in Ireland.

The opportunity, therefore, exists at present to develop technical solutions that will allow the economic exploitation of this valuable energy resource. The benefits to the economy are described in terms of:

- Creation of a Manufacturing Industry – Job creation
- Security of Supply – Reduced reliance on imported fossil fuels
- Reduction in Greenhouse Gas Emissions – CO_2 avoidance

In calculating the economic benefit of the proposed Ocean Energy strategy, it is assumed that national developers will be able to produce fully developed commercially viable large-scale arrays of ocean energy converters suitable for the electricity market by 2016. Following this date it is assumed that the sector will develop at a rate similar to that of the wind industry during the 1990s. It is also assumed that all equipment is designed and manufactured in Ireland. The rate of job creation is based on figures determined for the Danish wind industry [1].

The key benefits are summarised in Table 1. A more detailed explanation of the figures and assumptions is provided in Table D.1 of Appendix D. Based on the programme outlined in this document, the cumulative value of the domestic Ocean Energy sector, excluding exports, in 2020 is estimated to be €176million leading to the creation of 313 jobs in the research, manufacturing, installation and maintenance sectors. Following a period of sustained growth, the industry could reach a cumulative value of €784million by 2025 supplying 911 jobs to the Irish economy.

The increased supply of renewable electricity will also help to reduce Ireland's import of fossil fuels and reduce the potential cost associated with CO2 production to the value of € 2m in 2020 and € 10m in 2025.

Table 1 Value to the Economy of Domestic Market for Ocean Energy

	2020	**2025**
Annual MW installed	24 MW	85 MW
Cumulative MW installed	84 MW	485 MW
Annual Electricity Produced	259 GWh	1,488 GWh
Annual CO_2 avoided	89,534 tonnes	514,860 tonnes
Annual Value of Market (Manufacture + Installation)	€ 49million	€ 180million
Cumulative Value of Market	€ 176million	€ 784million
Annual Cost of CO_2 avoided assuming €20/tonne	€ 2million	€ 10million
Cumulative Cost of CO_2 avoided	€ 5million	€ 34million
Cumulative Benefits (Market + CO_2)	€ 181million	€ 818million
Number of Jobs Created	313	911

Value of an Export Market

The UK low development rate scenario for wave energy assumes a market penetration of wave energy of 900MW by 2020 with the market beginning in 2012 [1]. In considering the export market potential for ocean energy in Ireland, Bacon [1] assumed that the UK market represents 50% of the penetration of wave energy in Europe by 2020. Bacon also assumes that a successful wave energy industry in Ireland would secure 20% of this market. It is likely that some amount of industrial development funding will be required to ensure Ireland develops a manufacturing and exporting industry. The estimation of such funding requirements is not a subject for this document.

In assessing the export potential for Ireland, the above assumptions are applied in order to estimate the total size of the export market for Europe only, with the additional assumption that Ireland secures 20% of this market. Additionally it is assumed that the ocean energy market begins to grow from 2012 onwards using the same growth rate profile as the European wind sector.

Summary results are presented in Table 2 (full details included in Table D.2 of Appendix D) indicating cumulative export sales of 360MW of ocean energy systems by 2020 and 1,587MW by 2025. This could provide, in addition to the national market described earlier, a value of €360m and an additional 574 jobs to the Irish economy in 2020. In 2025, these figures may then rise to €1,587m and 1,329 jobs respectively.

The gross benefits to the Irish economy are therefore a market valued at €536m with 887 jobs in 2020 increasing in value to €2,371m with 2,240 jobs created by 2025.

Table 2 Value to the Economy of the Export Market for Ocean Energy

	2020	2025
Annual MW Exported	95 MW	298 MW
Cumulative MW Exported	360 MW	1,587 MW
Annual Value of Export Market (Manufacture only)	€95million	€298 million
Cumulative Value of Market	€360million	€1,587million
Number of Jobs Created	574	1,329

Table 3 Cumulative Value of Domestic + Export Market for Ocean Energy

	2020	2025
Annual MW Supplied	119 MW	383 MW
Cumulative MW Supplied	444 MW	2,072 MW
Annual Value of Market	€144million	€478million
Cumulative Value of Market	€536million	€2,371million
Number of Jobs Created	887	2,240

Policy and Funding for Ocean Energy to Date

Policy Supports

Ireland has, to date, offered support for ocean energy research through the Marine Institute's RTDI programme and through SEI's Renewable Energy R,D&D programme. Some third- level funding has been provided, both in matching funds provided by the agencies and independently, by University College Cork, Trinity College Dublin, the University of Limerick, and NUI Maynooth.

In March 1997, the Department of Public Enterprise launched the AER III competitive tender that included ocean energy. One contract was awarded to Wavegen Ireland, a subsidiary of Wavegen Scotland, to build a shoreline mounted oscillating water column. The contract was subsequently abandoned by Wavegen.

Estimate of National Funding for Ocean Energy

The total funding for 3rd Level R&D is estimated to be €307,000 since 1994. The corresponding grant support provided to industry is € 883,000.

Table 4 Estimate of Funding Provided to date to 3rd Level and Industry

Year	Agency	Project Title	Company	3rd Level	Industry
2000 -2004	MI	Prediction of Ocean Wave Energy for Res	Wavebob		€ 66,563
	MI	High Pressure seawater pump for use in \	MTL Ltd.		€ 100,000
	MI	5th European Wave energy Conference	UCC	€ 5,000	
	MI	All Energy Opportunities Conference	Consultant	€ 2,000	
	MI	B2B2 Prototype	Ocean Energy		€ 59,925
	MI	Ocean Energy Conference	UCC	€ 500	
	MI	Site Visit - National Institute of Industrial E	Wavebob	€ 500	
1994-1999	MI	Wave Energy Resource Assessment	UCC	€ 185,000	
	MI	Wave Energy Rock Engineering	TCD	€ 42,000	
	MI	CFD, Wells Turbine (UL)	Univ Limerick	€ 72,000	
	MI	Devpt. of a wave buoy	Irish Hydrodata		€ 42,000
	MI	R&D Wavebob	Wavebob		€ 200,000
2002 - 2004	SEI	R&D Wavebob	Wavebob		€ 43,200
	SEI	R&D OE Buoy	Ocean Energy		€ 131,157
	SEI	R&D McCabe Wave Pump	Hydam		€ 26,685
	SEI	Tidal Resource	Kirk McClure Mc		€ 85,910
	SEI/MI	Economic Study	Bacon/ESBi		€ 47,500
2003	EI	R&D OE Buoy	Ocean Energy		€ 80,000
Total				€ 307,000	€ 882,940

The Ocean Energy Strategy

Introduction

The proposed Ocean Energy Strategy is outlined in the following sections. The strategy is structured so as to provide support for industrial developers, 3rd level researchers and facilities. The timeframes described in the strategy are based on progress with respect to technologies under development. These will adjust dynamically as the scenarios for this sector unfold.

The programme is structured into four phases. The end of each phase is marked by a progress review, followed by a formal recommendation on the form and structure of the succeeding phases. The proposed phases are described as follows:

- **Phase 1** Development: This phase focuses on furthering the research and development capabilities in Ireland, both institutional and industrial. Support will be given for the design and construction of scale model prototypes that will confirm performance predictions for devices, which will allow the commercial potential of a project to be assessed more accurately. Additionally, support will be given to strengthen research facilities, and to develop offshore test facilities.

- **Phase 2** Pre-Commercial Single Device: Following demonstration of commercial potential in Phase 1, this phase is focused on taking successful designs from the prototype stage and constructing a fully operational pre-commercial wave energy converter supplying power directly to the electricity network. The results of this phase will be used to assess the commercial viability of the technology and the resulting industrial opportunities available to Ireland.

- **Phase 3** Pre-Commercial 10MW Array: The cost of ocean energy systems will reduce as the numbers of devices produced, per offshore development, increase. However, unless the devices can be arranged effectively in an array, large scale deployment will not be commercially viable. The array must be structured to minimise spacing requirements and installation costs while maximising energy yield. It is therefore necessary to construct an array of multiple devices and demonstrate that the array can operate successfully by delivering electricity to the network for a sustained period of time. Following the success of this phase, a precise estimate of the cost of a fully integrated wave or tidal farm will be available. This information will then be used to determine the nature of support required to support full-scale deployment of ocean energy in Ireland.

- **Phase 4** Commercial Deployment: In this final phase of development support measures will be offered to ensure the continued growth in the deployment of ocean energy systems. Areas of support could include electricity price support, R&D support for further industrial development and further investment in 3rd Level facilities etc.

Table D.3 of Appendix D presents a summary of the Ocean Energy Strategy in terms of measures, timeframe and costs. Formal State Aid approvals from the European Commission will be requested for each measure of the programme.

Phase 1: Development (2005 to 2007)

Objective
The goal of this Phase is to support national developers of wave energy devices through concept validation, model design optimisation and scale model testing.

Table 1 in the attached spreadsheet presents a full list of tasks and costs for each Phase of the proposed programme.

Strategy Elements

- Product R&D: There are currently three developers of wave energy devices in Ireland. The goal of this section is to provide R&D support for developers to improve their modelling and performance prediction capabilities. Support will be provided for tank testing and detailed prototype design. Support will also be provided for up to two large scale prototype model demonstration of wave energy technology. The cost of Grant support based on 45% funding for this scope of work is estimated to be € 3.6m.
- Research Facilities: A technical support network for wave energy developers will strengthen Ireland's ability to capitalise on this potential new industry. It is recommended that support be provided for the development of a centre of excellence for wave energy in Ireland. This centre should build on existing engineering capacity and contribute to Ireland becoming a leading centre for research into the field of wave energy. The total cost of supporting this effort for a four year period is estimated to be € 1.125m.
- Test Facilities: In order to facilitate the process of testing large-scale prototype devices it will be necessary to establish a number of offshore test sites. Developers will require both a benign and heavy weather test location. A facility to connect the device to the electricity grid will also be required. In order to allow scale model testing at early stages of development, it is recommended to provide an interim test facility at a benign sheltered location. Developers meeting engineering and operational criteria should be allowed rapid access to the test site. Funding for this activity has been estimated to be €80k.
- Monitoring & Reporting: A steering group, with an executive co-ordinating officer, should be appointed to oversee the implementation of the ocean energy strategy. It is recommended that annual reports are made each year to assess the current state of wave energy technology and provide an opportunity to review the strategy for wave energy deployment. Funding for this activity is estimated to be €120k.

Source of Funds

Both SEI and MI have existing budgets which will be used to support these measures up until the end of the NDP in 2006. In order to continue supporting wave energy in line with this Phase, funds beyond 2006 may need to be sourced. **Total funding required from present to 2008 is €4.925m.**

Decision Gate

The decision to proceed to Phase 2 will be made in 2007. An independent detailed technical review of the Phase 1 projects will be made and a comparison in terms of cost, performance and reliability will be made with the existing competitors in the market place. A decision to seek further funds and the appropriate level of funds will be made following the results of this report. Following this review, the Ocean Strategy will be updated.

Phase 2: Pre-Commercial Single Devices (2008 –2010)

Objective: The goal of this Phase is to provide support for the development of pre-commercial grid connected full scale single prototype devices. Two options are considered here:

Option 2A: Product R&D support for two devices, connection facility and PPA.
Option 2B: No product R&D with support only for connection facility and PPA.

Option 2A Product R&D

Objective: The primary goal of this scope of work is to support the successful national devices developed in Phase 1 through the development of a full scale grid connected prototype operating as a pre-production demonstration of the device. This single device trial phase should last between 2008 – 2010.

Strategy Elements

- R&D Single Pre-Commercial Devices: Support will be offered to the successful devices of Phase 1 following a successful decision gate review. The cost for this scope of work is estimated to be €2.7m. If no Irish product is considered to be of sufficient commercial merit then Option 2.B will apply.

- Test Connection Facility: In order to support the introduction of wave or tidal energy to Ireland, it is recommended that support be provided to a test facility to allow tidal or wave energy products to be evaluated. This facility should ideally offer both a sheltered test location and a heavy weather test location. It will be necessary to construct the offshore connection cables and associated onshore power electronics conversion system which will be connected to the national electricity network. A facility to monitor and assess the performance of the device should also be provided to the developer and operated by the Research Facility. The facility should be flexible to offer connection support to either wave or tidal energy device developers. Therefore the site chosen ideally should serve both sets of developers. The site should have good seaport access and a good wave and tidal resource. Site locations may include for example the west coast of Co. Clare and the Shannon Estuary. Installation support could also be offered by the MI research vessels which are based in the port of Galway.
- Power Purchase Agreement (PPA): A short term (3 years) 15c/kWh Power Purchase Agreement should be made available to all successful projects. It is recommended to make 2MW capacity of connections available to developers. Awarding of a PPA should be done on the basis of commercial and technical merits.
- Monitoring & Research as for Phase 1.

Source of Funds
SEI/MI and Enterprise Ireland could provide support for the development of a Pre-Competitive Device demonstration. In order to support national developers in Ireland it will be necessary to provide 100% funding support for the connection and monitoring facility. The facility would be accessible to a number of developers. Funding could be via the existing programmes within the agencies, or through a levy on electricity customers. A levy could also be used to fund the PPA required.

Decision Gate
The decision to proceed to Phase 3 will be made in 2009. An independent detailed technical review of the Phase 2 projects will be made and a comparison in terms of cost, performance and reliability will be made with the existing competitors in the market place. A decision to seek further funds and the appropriate level of funds will be made following the results of this report. Following this review, the Ocean Strategy will be updated.

Option 2B No Product R&D
Objective: The primary goal of this scope of work is to provide the option for external product developers to perform pre-commercial market demonstration of their products in Ireland. This option will not provide product R&D support and will only provide support for electrical connection. This single device trial phase should last between 2008 – 2010.

Strategy Elements
- Test Connection Facility as for Phase 2A
- Power Purchase Agreement (PPA) as for Phase 2A
- Monitoring & Research as for Phase 1.

Source of Funds
SEI/MI and Enterprise Ireland could provide support for the development of a Pre-Competitive Device demonstrator. In order to attract the first external wave energy developers to Ireland it will be necessary to provide 45% funding support for the connection facility. The facility would be accessible to a number of developers. Funding could be via the existing programmes within the agencies, or through a levy on electricity customers. A levy could also be used to fund the PPA required.

Decision Gate
The decision to proceed to Phase 3 will be made in 2009. An independent detailed technical review of the Phase 2 projects will be made and a comparison in terms of cost, performance and reliability will be made with the existing competitors in the market place. A decision to seek further funds and the appropriate level of funds will be made following the results of this report. Following this review, the Ocean Strategy will be updated.

Phase 3 Pre-Commercial 10MW Array Demonstration (2011 – 2015)

Objective: The goal of this Phase is to provide support for the development of a 10MW pre-commercial grid connected full-scale array of ocean energy converters. An array could consist of multiple devices, for example 10 x 1MW converters. Optimisation of the layout and configuration will be an important area of research in order to minimise cost and maximise performance of large-scale ocean energy farms. Areas of interest include optimum spacing, orientation, mooring and electrical connection configuration of converters within an array. It is therefore necessary to provide R&D support to a developer in order to address the engineering risks associated with a large array of devices before full scale commercial operations can begin.

Therefore, whereas Phases 1 and 2 focus on optimisation of the ocean energy converter itself, Phase 3 will focus on the optimisation of a grouping of converters.

Two options are considered here:

- **Option 3A:** Product R&D support for up to one array plus grid connection and PPA.
- **Option 3B:** No product R&D with support only for grid connection and PPA.

Option 3A 10MW Array with Product R&D Support

Objective: The goal of this task is to demonstrate a 10MW multi-device array of ocean energy converters. The devices tested here must be viewed as near commercial with lower investment costs than Phase 2.A. If a commercially viable national R&D project is available from 2A, then a single converter type will be selected for array testing with product R&D support provided. If no viable device is available, then Option 2.B may apply. The expected timeframe for this Phase is 2011 – 2015.

Strategy Elements

- Array R&D: Support should be offered up to a level of 45% for design and manufacture of the demonstration device array, as well as any additional research and development required for a multi-device installation.
- Array Connection: The trial will be regarded as a pre-commercial trial and is likely to require a new large scale connection facility which will be owned and operated by the promoter. In this case, 45% support is recommended for developing this connection.
- PPA: The converter deployed in this Phase will be considered to be a near commercial product, however the experimental and high risk nature of deploying an array will likely require a higher than market price short term (5 to 10 year) guaranteed power purchase agreement.
- Monitoring and Research: Subject to the results of the Decision Gate 2 Review, the level of funding required for the Research Centre and its activities will be reviewed. For the purpose of this Strategy, it has been assumed that the Centre will attract external R&D contracts by 2011 therefore requiring less direct funding.

Source of Funds

SEI/MI/Enterprise Ireland would be the main funding agencies for the Array R&D element. As for Phase 2A, to the agencies could also fund the Array connection costs and the associated PPA, or alternatively a levy could be used to generate these funds.

Decision Gate

At the end of Phase 3, an independent technical evaluation of the array will be made. Additional to this, an assessment of the market for ocean energy converters in the context of the national and export electricity markets and the wind energy market will be made. The assessment will provide the best estimate of likely penetration levels and costs of ocean energy systems. Following this review, the requirements to support a general deployment of ocean energy converters will be determined and a recommendation for further support will be made to policy makers.

Option 3.B 10MW Array without Product R&D Support

Objective: The goal of this task is to demonstrate a large 10MW array of ocean energy converters. The devices tested here must be viewed as near commercial with lower investment costs than Phase 2.B. This option is provided to facilitate market demonstration of external ocean energy products in the Irish electricity sector. Support will be offered for grid connection and a PPA will be offered for one demonstration. The expected timeframe for this Phase is 2011 – 2015.

Strategy Elements

- Array Connection: The trial will be regarded as a pre-commercial trial and is likely to require a new large scale connection facility which will be owned and operated by the promoter. In this case, 25% support is recommended for developing this connection.
- PPA: The converter deployed in this Phase will be considered to be a near commercial product, however the experimental and high risk nature of deploying an array will likely require a higher than market price and a short term (5 to 10 year) guaranteed power purchase agreement.
- Monitoring and Research: Subject to the results of the Decision Gate 2 Review, the level of funding required for the Research Centre and its activities will be reviewed. For the purpose of this Strategy, it has been assumed that the Centre will attract external R&D contracts by 2011 therefore requiring less direct funding.

Source of Funds

MI/SEI support will be made available for R&D activities conducted at the Research Centre. As for Phase 2A, to the agencies could also fund the Array connection costs and the associated PPA, or alternatively a levy could be used to generate these funds.

Decision Gate

At the end of Phase 3, an independent technical evaluation of the array will be made. Additional to this, an assessment of the market for ocean energy converters in the context of the national and export electricity markets and the wind energy market will be made. The assessment will provide the best estimate of likely penetration levels and costs of ocean energy systems. Following this review, the requirements to support a general deployment of ocean energy converters will be determined and a recommendation for further support will be made to policy makers.

Phase 4: Commercial Deployment (2016 onwards)

Objective:
To support the deployment and facilitate the integration of large scale wave energy. The results of the Decision Gate at the end of Phase 3 will determine the potential scale and timeframe for deployment of commercial ocean energy converters. The scale of support offered to achieve this deployment will then be proportional to the economic and industrial opportunities offered by ocean energy to the nation.

Strategy Elements

- PPA: Determine scale and quantity of capacity offers to be made with regard to the results of Phase 3.

Source of Funds
Should price support be required to promote the deployment of ocean energy, it should be funded with the appropriate price support mechanism available to renewable energy generators at that time.

Implementation of Ocean Energy Strategy

This section outlines the supports requested from Government, the programme of implementation for the Ocean Energy Strategy, and key project tasks and timelines required for successfully delivery.

Advisory Committee

Following Government endorsement of the Ocean Energy Strategy, it is proposed to establish an Ocean Energy Advisory Committee to implement and monitor the programme. The Committee is likely to comprise representatives from the following areas/organisations at various phases of the strategy:

- SEI
- Marine Institute
- Entreprise Ireland
- National 3rd Level Institution
- Independent External Expert
- DCMNR
- ESB National Grid/Networks
- CER

The operation of the Committee and the implementation of the Strategy will be managed by a Programme Co-Ordinator to be appointed following the launch of the Strategy. The requirements of the role will be assessed at each Decision Gate.

Implementation Plan

Table D.4 of Appendix D presents a detailed list of each task required to implement the Ocean Energy Programme. The table highlights the key decision points in the programme.

The main elements of the Implementation Plan are summarised as follows:

Phase 1: Development (2005 to 2007)

Key Deliverables

a) Creation of Ocean Energy Advisory group to implement strategy
b) Creation of a Centre of Excellence for ocean energy research in Ireland
c) Operating large scale offshore ocean energy converter prototypes
d) Establishment of a benign Interim Test Site

Funding Support Required for Phase 1

Table 5 describes an estimate of the total funding required for R&D and the Centre of Excellence for each year of Phase 1. Funding available from both SEI and MI is estimated to be sufficient for the first two years of the Strategy. In the final year of Phase 1, 2007, of the programme, the maximum level of additional support required to implement the Strategy would be €2.4m. The majority of this funding will be required to fund the construction of ocean energy converters. This number assumes that two high quality demonstrators will be built and tested.

Table 5 Cost of Support for Phase 1 (in Euro thousands)

Year	R&D + Monitoring + Interim Test	Center of Excellence	Total Cost	Estimate of Existing Funding(MI+SEI)	Additional Funding Required
2005	€ 288	€ 200	€ 488	€ 488	€ 0
2006	€ 1,149	€ 500	€ 1,649	€ 1,649	€ 0
2007	€ 2,363	€ 425	€ 2,788	€ 435	€ 2,353
Totals	€ 3,800	€ 1,125	**€ 4,925**		

Phase 2: Pre-Commercial Single Device (2008 to 2010)

Key Deliverables

e) Construction of a Test Facility with sheltered and exposed test locations.
f) Operating large scale grid connected ocean energy converter prototypes

Funding Support Required for Phase 2

Funding required for Phase 2 is dependent on which development path is selected following Phase 1. Option A assumes that successful national developers have emerged from Phase 1. In this case product support will be provided. The total cost for Option A is estimated to be €10.5m, including €2.1m in price support for electricity produced by the prototype devices.

Option B assumes external developers would seek to test prototypes in Irish waters. In this case only grid connection support will be offered along with a PPA. The total cost of the option is estimated to be €6.9m, also including €2.1m in price support for electricity produced by the prototype devices.

A detailed breakdown of annual budget costs will be made following Phase 1 Decision Gate Review.

Phase 3: 10MW Pre-Commercial Array (2011 to 2015)

Key Deliverables

g) Offshore grid connection to the national electricity network
h) Operating large scale array of ocean energy converters

Funding Support Required for Phase 3

Funding required for Phase 3 is dependent on which development path is selected following Phase 2. Option A assumes that a successful national developer has emerged from Phase 2. In this case product support will be provided. The total cost for Option A is estimated to be €11.1m plus the cost of providing a short term PPA to the Array operator.

Option B assumes an external developer would seek to test their product in Irish waters. In this case only grid connection support will be offered along with a PPA. The total cost of the option is estimated to be €1.3m plus the cost of the PPA.

A detailed breakdown of annual budget costs will be made following Phase 2 Decision Gate Review.

Phase 4: Commercial Operations (2016 onwards)

Key Deliverables

i) Support mechanism to secure long term development of market for ocean energy

Funding Support Required for Phase 4

Following Phase 3, an assessment of the industrial and electricity market potential for ocean energy will be made. This review will indicate the nature and scale of support required to ensure continued development of ocean energy in Ireland. Support may include for example market support for PPA for ocean energy generators.

References:

1. Bacon, P, "The Economic Benefits of Developing Ocean Energy in the Republic of Ireland", Bacon Associates, Dublin, 2004 (report prepared for MI and SEI).

2. Dr. Michael Shaw, "Marine Current Tidal Energy Resource Study of Ireland", Kirk McClure Morton, Belfast, 2004 (report prepared for SEI).

3. European Wind Energy Agency, "Wind Energy – the Facts: An Analysis of Wind Energy in the EU-25 (Executive Summary)", EWEA, Brussels, 2005.

4. Riso, "Offshore Wind Energy and Industrial Development in the Republic of Ireland", Riso-I-2166(EN), 2004 (report prepared for SEI).

5. Pontes, M.T., Falcao, A., "Ocean Energies: Resources And Utilisation", 18th World Energy Conference, Buenos Aires, Argentina, 2001.

6. Pontes, M.T. et al., "The European Wave Energy Resource", 3rd European Wave Energy Conference, Patras, Greece, 1998.

7. ESBI, "Accessible Offshore Wave Energy Resource Atlas Ireland 2005", Draft 2005 (report prepared for MI and SEI)

8. Dr. Anthony Lewis, "A Strategic Assessment of the Irish Wave Energy Resource", Hydraulics & Maritime Research Centre, University College Cork, 2000 (report prepared for MI).

Appendix A: Summary of Ocean Energy Studies Funded by Marine Institute and SEI

A Development and Evaluation Protocol for Ireland

The Marine Institute and the Hydraulics and Maritime Research Centre in University College Cork published a development and evaluation protocol for second generation buoyant wave energy devices that prescribes standard productivity and economic indices to facilitate the comparative evaluation of devices throughout a five-phase model testing development programme. The Protocol is similar to that established by NASA for engineering research establishments and is in line with the standards proposed in the IEA Ocean Energy Systems Implementing Agreement Annex II report on recommended practices for testing and evaluating ocean energy devices.

Development stages include:

- Stage 1: Validation model
- Stage 2: Design model
- Stage 3: Process model
- Stage 4: Prototype device
- Stage 5: Demonstration unit

Bacon Report on The Economic Benefits of Developing Ocean Energy in the Republic of Ireland [1]

This report examined the opportunity to develop an ocean energy industry in Ireland. The report stressed that an opportunity exists based on Ireland's extremely strong resource in wave energy and high degree of specialist expertise in ocean energy research in several Irish universities. Offsetting these strengths are the fact that a) the existing supply chain relevant to ocean energy is relatively weak in Ireland due to the lack of a significant industrial base b) some of the technical expertise available in Ireland is in strong demand from other applications, and c) the structure of the Irish economy is moving away from the sectors most closely concerned with the development of ocean energy beyond the initial experimental stage and towards higher value-added activities.

A development programme for ocean energy must be based on a national decision to either wait for technology development to occur in a more industrialised country and then access and apply this knowledge to the natural resource to produce energy, or seek to become a technology maker in the sector and maximise the potential economic gains available.

These economic gains were estimated at €97/MWh produced, made up of:

	Value per MWh (€)
Electricity	47
Emissions avoided	7
Security of supply	1.5
Regional development	10
Knowledge created	32
Total	97.5

The €10/MWh for regional development and the €32/MWh for knowledge creation are specific to ocean energy, while the emissions avoided and security of supply contributions are specific for all renewable energies.

The value for regional development is based on planning, construction and O&M employment in the regions where ocean energy is deployed at a value of €4030 per MW per year for O&M and approximately 45 construction jobs per MW per year installed. The total value assumes 200 MW are installed by 2020. Total employment of 1900 jobs appears feasible. The metrics used are based on international experience with ocean energy and wind energy.

The value for knowledge creation is based on a 2002 report assessing the value of costs and benefits of supporting offshore wind energy. The value is assumed to come from knowledge created by R&D investment in to the industry that may yield returns under the following headings:

- A better understanding of the ocean wave and tidal resources, their character, magnitude and distribution and amenability to commercial development.

- Improved and realistic understanding of the cost and timescale implications of ocean energy development and its integration into the Irish sustainable energy portfolio.
- Setting the scene for introduction of commercial ocean energy conversion systems, developed by either home or overseas developers, in Irish waters.
- Potential for development of ocean energy export industry with consequential improved employment and wealth creation opportunities.
- Fostering of consulting, project management and project development expertise with import substitution and export potential.
- Integration of disparate teams and organisations so that administrative, technological and manufacturing capacity of the country becomes more streamlined, focussed and competitive.
- Improved university teaching resources in the several technological fields that find application in ocean energy research.

Based on 200 MW of deployment, Bacon estimates that the total value of output at €97.5/MWh is €227 million over the period to 2020.

Tidal and Marine Energy Resource in Ireland [2]

This study's objectives were:

- To identify areas which have the potential for cost effective exploitation of the tidal stream and marine current energy resource.
- To prepare detailed analyses of areas considered to have the greatest potential for the extraction of tidal energy.
- To calculate the tidal and marine current energy resource available with existing technology and to assess the additional contribution which future technology is expected to make.
- To compare current evaluation of the energy resource with previous estimates.

Resource amounts as reported in the final draft of this as yet unpublished report are included below:

The total electricity demand predicted for the All Ireland electricity market in 2010 is 44TWh (i.e. 34TWh ROI and 10TWh NI based on estimate s provided in the Government All Ireland Consultation document).

The **theoretical** resource, estimated using computational modelling of the zone between the 10m depth contour and the 12 nautical mile territorial limit is 230 TWh/year, which is more than 5 times the predicted electricity consumption in Ireland for 2010.

The **technical** resource, the theoretical resource limited by what can feasibly be extracted using currently available technology, is 10.46 TWh/year.

The **practical** resource, the technical resource constrained by physical limitations including sea bed conditions, shipping lanes, military zones, licensed disposal sites, etc., is estimated at 2.633 TWh/year which would be sufficient to supply 6.3% of the 2010 All Ireland electricity market demand.

The practical resource will be further constrained by institutional and regulatory constraints to provide a currently **accessible** resource that takes account of locations designated as environmentally sensitive where development will not be allowed. As the environmental impact of tidal stream devices is not fully understood, this study did not estimate a further restriction of the resource on this basis.

Finally, an economically **viable** resource estimate was given as 0.915 TWh/year based on technology that has been prototype tested, providing an 8% project return for a 20 year project.

While the current level of viable resource represents just 2% of the projected energy consumption in the year 2010, this number could increase to 6% with further technological development.

Irish Accessible Offshore Wave Energy Resource Project

This study was commissioned in November 2004 and completion is expected in April/May 2005. The study's objective is the production of digital mapping to characterise the wave power resource applicable for third generation floating wave power converters. The energy estimates will be based on historical hindcast data referenced against contemporary measurements made by meteorological buoys.

In a report funded by the Marine Institute produced in April 2000 entitled "A Strategic Assessment of the Irish Wave Energy Resource", the near shore wave energy resource potential was estimated to be 48TWh [7]. This study focused on near shore devices fixed to the seabed in water depths of 20m or less. The new study will examine the resource potential for floating wave energy converters which will include water depths greater than 20m.

Appendix B: Status of Research & Development Activities Internationally

Status of Research and Development Activities Internationally

A number of research activities are underway at present to develop the first commercially viable ocean energy systems. This section provides a brief summary of some of the leading developers in the field and provides information on support mechanisms available in other countries.

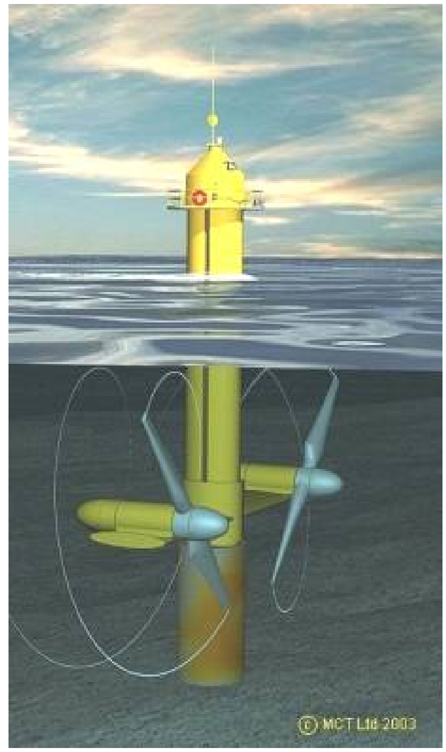
Pelamis Wave Energy Converter – Ocean Power Delivery, UK

The Pelamis project is the first deep-water, grid-connected trial of a full-size wave power generator to take place anywhere in the world. The Pelamis wave power machine is currently installed and undergoing sea trials at the European Marine Energy Centre in Orkney. Designed and built by Ocean Power Delivery in Scotland, the prototype Pelamis is 120 metres long, 3.5 metres wide and 700 tonnes in weight. When floating on the sea, hinged joints between its articulated cylindrical sections move with the waves, powering hydraulic motors that generate electricity. Each single 750-kilowatt Pelamis could generate the same amount of power as a wind turbine, and a 'wave farm' covering a square kilometre of ocean could provide a power output of 30 megawatts, enough electricity for 20,000 homes.

Seaflow - Marine Current Turbine, UK

Marine Current Turbines Ltd is running a programme of tidal turbine development through research and development and demonstration phases to commercial manufacture. MCT have installed a 300kW 11m diameter device called the Seaflow project near Lynmouth in Devon. The initial R&D phase will be completed by 2006, when commercial installations will be started. It is planned that 300 megawatts of installations will be completed by 2010.

In March 2005 the DTI awarded MCT £3.8m (€5.6m) to begin Phase 2 which is the development of a 1MW pre-commercial prototype device. MCT have selected the narrows of Strangford Lough as their test site due to its high current velocities and proximity to the grid. MCT have begun site surveys and plan to install the device in 2006 subject to planning permission.



European Marine Energy Centre, Orkney, UK.

The European Marine Energy Centre (EMEC) was set up to provide developers of wave and tidal energy devices with a purpose-built performance testing facility. Over £6m (€8.8m) has been invested in providing the world class wave test facilities. The location around Stromness, in Orkney, has been chosen because of the proximity of an excellent oceanic wave regime, strong tidal currents, grid connection, sheltered harbour facilities and a "centre of excellence" for renewable energy and environmental issues that exists within the local community.

UK DTI Marine Renewables Deployment Fund

A joint DTI / Carbon Trust Renewables Innovation Review, was published in February 2004. It identified the need for a support mechanism to fund early stage pre-commercial demonstration projects. Device developers had identified this "gap" as a barrier to the commercialisation of the marine renewable technologies. The Secretary of State for Trade and Industry announced the setting up of a Marine Renewables Deployment Fund that aims to support innovative and visionary businesses to bring their wave and tidal-stream energy technologies to market.

The DTI recently announced the launch of this fund providing a £42m (€62m) programme of investment for the development of marine energy technology. Capital grant support of 25% will be provided together with electricity revenue support equivalent to 15p/kWh (22c/kWh).

US Assessment of Wave Energy Devices

In 2004, the Electricity Innovation Institute EPRI (E2I) in the US led a government/industry, public/private collaborative program to assess and demonstrate the feasibility of offshore wave power to provide efficient, reliable, cost-effective, and environmentally friendly electrical energy.

E2I EPRI contacted all known Wave Energy Conversion (WEC) Device manufacturers in December, 2004. Information needed to assess the potential application of WEC devices to offshore sites was requested from those manufacturers. The WEC Device information received was assessed and compared in February and March 2004 in order to establish a decision-making basis for the advisors in this project. Manufacturers were classified in 3 Groups as follows:

Group 1 – Development near completion and full-scale long-term testing in the ocean underway

Group 2 – Development near completion, only deployment, recovery and mooring issues are yet to be validated. Construction of full-scale devices is in some cases completed.

Group 3 – Most critical R&D issues are resolved. Additional laboratory and sub-scale testing, theoretical simulations and systems integration work is needed prior to finalization of the full-scale design

Group 1 consists of Ocean Power Delivery. This device manufacturer has chosen a low risk technical approach by using a highly survivable design and well-proven technologies and has recently started in-ocean trials at full-scale. The device development program, which was carried out over the last couple of years, provides a significant amount of reassurance, that the device will operate as predicted.

Group 2 consists of Energetech, WaveDragon and Wave Swing. These devices are at a stage where critical R&D issues are resolved and the device manufacturers have funding for and are getting ready for in-ocean technology demonstrations at full scale within the next year. The group may still have some outstanding issues, most of which relate to the deployment & recovery and mooring design.

Group 3 consists of AquaEnergy, INRI, OreCon and **WaveBob**. These devices are at a stage of development where critical R&D issues are mostly resolved. Some R&D issues remain to be addressed and full-scale engineering still needs to be carried out. As discussed in the appendices, in some cases, additional laboratory and sub-scale testing, theoretical simulations and systems integration work is needed prior to finalization of the full-scale design. The group may still have some outstanding issues in respect to: device optimisation, economic optimisation and systems integration, many of which can be addressed with R&D programs.

Opportunities for International Collaboration

There is appreciable interest at EU level in stimulating the development and take up of ocean energy technologies. Irish institutions, notably UCC, have already had some success in gaining funding under the EC's Framework Programmes. Such work brings benefits from international collaboration in addition to funding. The current Framework Programme 6 draws to a close this year but Framework Programme 7 is already being planned. Encouraging and supporting the participation of Irish companies and research organisations in future Calls for Proposals is an integral part of this strategy. This will be achieved through close working between researchers and SEI EC contact staff. Funding for the preparation of proposals will also be facilitated.

Appendix C:
Status of Research and Development Activities in Ireland

Status of Research and Development Activities in Ireland

In order to capitalise on the industrial opportunities offered to Ireland by this emerging industry, it will be necessary develop the necessary skills and embryonic companies required to drive the industry forward.

3rd Level Activities

Including the Republic and Northern Ireland, there are three universities involved in 3rd Level research at present:

- Hydraulics and Maritime Research Centre – UCC: Modelling and wave tank testing.
- Wave Energy Research Team - University of Limerick: Turbine testing and modelling.
- Queen's University: Wave energy modelling

Hydraulic and Maritime Research Centre - UCC

The Hydraulics and Maritime Research Centre (HMRC) is a centre for research in support of the Maritime Engineering sector in Ireland. The Centre is embodied within the Department of Civil and Environmental Engineering of University College Cork and is thus non-profit making.

Since its establishment in 1979 the HMRC has undertaken a wide variety of basic and applied research projects in a number of topics. These activities can be grouped into four theme areas as follows:

1. **Coastal Engineering**

2. **Offshore Engineering**

3. **Coastal Resources including:**
   - Marine Environment: wave climate analysis, coastal circulation, wave atlas.
   - Wave Energy: pilot plant design, fundamental behaviour of O.W.C. devices, model testing, site selection, tidal currents.
   - Aquaculture Cage Engineering.

4. **Supporting Activities including:**
   - Instrumentation, transducer development, automatic data acquisition.
   - Physical model construction, wave energy device models, sea-bed models.
   - Tank testing, simulation of real sea states, wave generator design.
   - Numerical models, wave refraction, numerical wave basin.
   - Library, marine reference database, computer based cataloguing.

Summary of research facilities:

- 2 Academic Staff
- 1 Technician
- Postgraduate and undergraduate students
- Wave tank test facility with computer controlled 3D irregular wave generation capability.
- Fully equipped engineering workshop
- Software packages include: wave modelling capability WAMIT

Funding for projects is derived from a mixture of research funds and repayment contracts. Research funding is derived from EU contracts as well as National funding coming from the Marine Institute, Sustainable Energy Ireland and Enterprise Ireland.

European Funding – FP5 and FP6:

- CA-OE – This is a project funded under FP6 and is a Coordination Action involving over 50 partners in Europe. The HMRC is one of the core contractors and sits on the Steering Committee. The work plan for this Action relates to all aspects of Ocean Energy Development and the activity will involve a series of specialist workshops covering "gap" areas identified.

- WAVETRAIN – This is a Marie Curie Research Training Network for wave energy development which has just started under FP6. It involves a consortium of eleven Universities, Research Centres and SME's from all over Europe who will all host one Marie Curie Fellow for the three year duration of the contract. In the case of HMRC there will be a Marie Curie Early Stage Researcher registered for a Ph.D. The subject of the research will relate to the physical and numerical modelling of pneumatic wave energy systems.

- EMCSquared – this is a Specific Support Action funded under FP5 and deals with the coordination of a series of Conferences for Marie Curie Research Fellows specifically related to Non-Nuclear Energy Research. These Conferences are held twice per year in different locations with a local organiser responsible for day to day activity. The HMRC then handles the coordination and general organisation and runs the website (www.mariecurieenergyfellows.org).

National Funding:

- Development and Evaluation Protocol – this has been developed with funding from the Marine Institute and is published on the website www.marine.ie.

- Marine Resource Development – HEA PRTL II – this research is aimed at developing an understanding of linear hydrodynamics of floating wave energy devices. Numerical models using the WAMIT code are being evaluated against tank testing.

Commercial Activity:

- POWERED – this is a project for Clean Power Technology Ltd. funded by the Marine Institute Industry Programme. It is a collaborative project with the Department of Applied Mathematics and relates to the prediction of wave parameters for the control of wave energy devices

- OEBuoy Optimisation – this is a project for Ocean Energy Ltd funded by the Marine institute Industry Programme. It involves tank testing and optimisation of the layout of a floating wave energy convertor.

- OEBuoy Engineering Development – this is a project for Ocean Energy Ltd. funded by Sustainable Energy Ireland. It involves large scale tank testing and the engineering development of a prototype 1MW wave energy device

Other Contributors within UCC:

- Department of Applied Mathematics – Dr Gareth Thomas
- Power Electronics Group – Department of Electrical Engineering. – Dr. Michael Egan and Dr John Hayes

Wave Energy Research Team – University of LimerickThe Wave Energy Research Team (WERT) was established in 1990 in University of Limerick (see www.ul.ie/wert for further details). The goal of the team is to develop turbine technology for wave energy power plants for Ireland, Europe and the International market. WERT has attracted funding from EU, National and Industrial organisations.

Key Group Research areas:

- Development of Turbine (Wells and Impulse) technology
- Pendular Wave Energy Converter and Development of Navigational Buoy

Summary of research facilities:

- 11 Academic Staff
- 1 Technician
- 8 Postgraduate
- 4 Undergraduate
- Fully equipped 0.6m Wells & Impulse Turbine experimental test rig to operate at speed comparable with OWC Wave Energy Power Plant
- CNC for manufacture of up to 2.5m diameter turbine blades
- Rapid Prototype Machine
- Fully equipped engineering workshop
- Software packages include: Computational Fluid Dynamics FLUENT/GAMBET, PRO – Engineer, PRO – Mechanica
- High Spec PC Work Stations

Key research areas:

- Development of Turbine (Wells and Impulse) Technology
- Pendular Wave Energy Converter
- Development of Navigational Buoy

Current research projects:

- Engineering Analysis and Manufacture of 2nd generation of Wells Turbine for Azores, Portugal Wave Energy Power Pilot Plant
- Experimental Performance Evaluation of Impulse and Wells turbine under steady and unsteady uni-directional flow
- Computational Fluid Dynamics (CFD) Analysis of Impulse & Wells Turbine
- Numerical Analysis to Evaluate Performance of turbine under irregular, unsteady real sea conditions
- Noise Character tics of Impulse & Wells turbine for Wave Power Conversion
- Turbine blade and Guide Vane design optimisation
- Application of Computer Aided Engineering – Stress Analysis & Concurrent Engineering Methodology using Rapid Prototype for manufacture of turbine blades
- Knowledge Based Computer Aided Program for Wave Energy Power Plant Design
- Mechanical Design and matching of Backward Duct Bent Buoy with Power Take-Off Devices Operating under Off-Shore conditions
- Design Analysis of Wave Energy Converter – Pendular

Funding Sources

WERT has been successful in attracting funding from the EU, Marine Institute and ESBi.

Queen's University Belfast

Queen's University Belfast (QUB) have developed wave energy modelling expertise and have collaborated with University of Limerick in the past on ocean energy projects. QUB have also participated in tidal stream resource assessments. QUB are currently supporting the UK company Marine Current Turbines (see description later) with their 1MW tidal stream project which could be ready for installation and testing in the Strangford narrows by 2006. This project represents the state of the art in marine current turbine design and is likely to become the first commercially available tidal current turbine device. QUB are providing technical, monitoring and environmental impact assessment support to this project. The Strangford project is likely to build key skills which will be of benefit to an attempt to develop and Ocean Energy industry in an All Ireland context.

Summary of National Ocean Energy Converter Developers

In the Republic of Ireland, there are three wave energy device developers at various stages of development. The following section provides a brief summary of the companies involved, the status of the projects and the levels of funding provided. The companies are as follows:

- Ocean Energy
- Hydam
- Wavebob

Ocean Energy Project

Fig. 1 Ocean Energy - Backward Bent Duct (scale model before delivery and testing in France (2004))

Product: Backward Bent Duct (BBD)
Company: Ocean Energy
Grant support to date: € 131,000 (SEI); € 80,000 (Enterprise Ireland (estimate)); € 59,925 (MI)

Description of Device:
The BBD uses wave energy to compress air in a plenum chamber. This compressed air is then expanded through an air turbine to generate electricity.

Development Status:
The Ocean Energy have completed model design and wave tank trials at the HMRC wave tank facility in Cork and also at a large scale wave tank in France. They have recently completed a detailed design of a large scale prototype and are ready to proceed to the construction of the prototype.

Hydam Project

Fig. 2 Hydam – McCabe Wave Pump (SEI site visit to Carrigaholt Bay, Co. Clare, January 2004)

Product: McCabe Wave Pump (MWP)
Company: Hydam
Grant support to date: € 26,685 (SEI)

Description of Device:
The MWP comprises two articulated pontoons connected about a third central pontoon. The devices measures 25m long by 4m wide. The pontoons rise and fall with each wave and the action is used to drive hydraulic rams which create pressurised fluid which can be used to drive an hydraulic motor and generator.

Development Status:
Hydam have constructed one of the few large scale ocean energy converters currently in existence in the world. The MWP is presently anchored in the Shannon Estuary. Hydam are currently being funded by SEI to develop improved numerical simulation models. Following this work, Hydam intend to upgrade the MWP with improved systems and begin performance sea trials of the device.

Wavebob Project

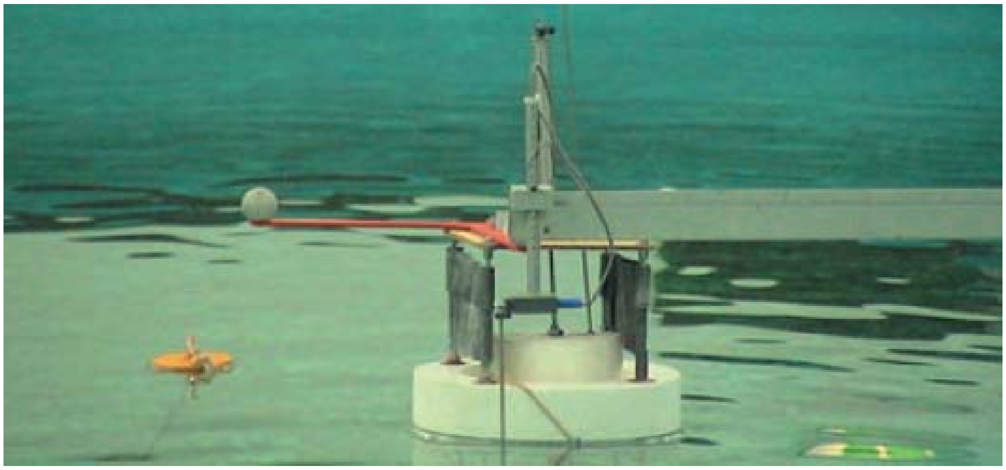


Fig. 3 Wavebob (water tank test trials 2004)

Product: Wavebob
Company: Wavebob
Grant support to date: € 43,200 (SEI); € 267,000 (MI)

Description of Device:
The Wavebob is described as a point absorber device and generates power from each wave through the counteractive movements of a bob suspended from a floating Taurus. The Wavebob has the advantage of optimised power recovery dependant on the wave energy condition and does not require orientation with respect to the waves.

Development Status:
Clearpower have completed small scale model design and testing and are now proceeding to the detailed design of a large scale prototype.

Appendix D: Tables, Spreadsheets and Graphs

Table D.1 Value to Economy of Domestic Market for Ocean Energy

	Year	Cumulative MW installed	MW Installed p.a.	Jobs/MW Installed	Number of Manufacturing & Installation Jobs Created	Number of Operation & Maintenance Jobs Created	Total Number of Jobs Created	Electrical Energy (GWh)	CO2 avoided @ 346t/GWh (tonnes)	Cost of CO2 avoided @ 20euro/t (million Euro)	Value of Market in Ireland - Equipment + Installation (million Euro)	Total Benefit (million Euro)	Cumulative Benefit (million Euro)
Phase 1	2005	0	0	15.3	0	0	0	0	0	€ 0	€ 0	€ 0	€ 0
	2006	1	1	15.3	15	0	16	3	1,062	€ 0	€ 4	€ 4	€ 4
	2007	2	1	15.3	15	1	16	6	2,123	€ 0	€ 4	€ 4	€ 8
Phase 2	2008	2	0	15.3	15	1	16	6	2,123	€ 0	€ 0	€ 0	€ 8
	2009	3	1	15.3	15	1	16	9	3,185	€ 0	€ 3	€ 3	€ 11
	2010	4	1	15.3	15	1	17	12	4,246	€ 0	€ 3	€ 3	€ 14
Phase 3	2011	4	0	15.3	15	1	17	12	4,246	€ 0	€ 0	€ 0	€ 14
	2012	7	3	15.3	46	2	48	21	7,431	€ 0	€ 6	€ 6	€ 20
	2013	10	3	15.3	46	3	49	31	10,616	€ 0	€ 6	€ 6	€ 27
	2014	14	4	15.3	61	4	66	43	14,862	€ 0	€ 8	€ 8	€ 35
	2015	14	0	15.3	61	4	66	43	14,862	€ 0	€ 0	€ 0	€ 35
Phase 4	2016	22	8	14.7	117	7	124	67	23,354	€ 0	€ 16	€ 16	€ 52
	2017	32	10	14.0	134	10	144	97	33,462	€ 1	€ 19	€ 20	€ 71
	2018	42	11	13.4	144	14	158	130	44,900	€ 1	€ 22	€ 22	€ 94
	2019	61	18	12.7	234	19	254	186	64,424	€ 1	€ 37	€ 38	€ 132
	2020	**84**	**24**	**12.1**	**286**	**27**	**313**	**259**	**89,534**	**€ 2**	**€ 47**	**€ 49**	**€ 181**
	2021	125	41	11.5	468	40	508	384	132,838	€ 3	€ 82	€ 84	€ 265
	2022	174	49	10.8	531	56	587	534	184,920	€ 4	€ 98	€ 102	€ 367
	2023	238	59	10.2	600	76	676	731	252,855	€ 5	€ 118	€ 123	€ 490
	2024	323	71	9.6	675	103	778	992	343,293	€ 7	€ 141	€ 148	€ 638
	2025	**485**	**85**	**8.9**	**756**	**155**	**911**	**1,488**	**514,860**	**€ 10**	**€ 170**	**€ 180**	**€ 818**
	2026	646	102	8.3	842	207	1049	1,981	685,576	€ 14	€ 203	€ 217	€ 1,035
	2027	868	122	7.6	933	278	1210	2,662	921,141	€ 18	€ 244	€ 263	€ 1,298
	2028	1158	146	7.0	1025	370	1396	3,551	1,228,791	€ 25	€ 293	€ 318	€ 1,615
	2029	1425	176	8.0	1406	456	1862	4,373	1,512,981	€ 30	€ 352	€ 382	€ 1,997
	2030	1755	211	9.0	1899	562	2460	5,384	1,862,896	€ 37	€ 422	€ 459	€ 2,456

Assumptions

a) 20euro/tonne CO2

b) 346t of CO2 per GWh CCGT emmissions avoided

c) Capital Costs after Market Opening 2016 = 2000euro/kW installed (which covers value of Manufacturing+Installation+Planning)

d) Growth Rate after 2016 as per EU-15 wind market 1990 - 2003

e) 35% Load Factor for Ocean Energy electricity generation

f) Jobs profile as per Danish Wind Energy Study [1]

g) All components sourced and manufactured in Ireland

Table D.2 Value to Economy of Export Market for Ocean Energy

	Year	Cumulative MW installed Europe (Bacon assumptions [1])	Cumulative Export MW 20% of European Market	20% of European Market MW Exported p.a.	Manufacture + Installation Jobs/MW Installed	Manufacture only Jobs/MW Installed	Number of Additional Manufacture Jobs	Value of Market to Ireland - Equipment only (million Euro)	Cumulative Benefit (million Euro)
Phase 1	2005	0			15.3	7.7	0	€ 0	€ 0
	2006	0			15.3	7.7	0	€ 0	€ 0
	2007	0			15.3	7.7	0	€ 0	€ 0
Phase 2	2008	0			15.3	7.7	0	€ 0	€ 0
	2009	0			15.3	7.7	0	€ 0	€ 0
	2010	0			15.3	7.7	0	€ 0	€ 0
Phase 3	2011	0			15.3	7.7	0	€ 0	€ 0
	2012	123	25	24.5	15.3	7.7	187	€ 25	€ 25
	2013	176	35	11	15.3	7.7	81	€ 11	€ 35
	2014	236	47	12	15.3	7.7	92	€ 12	€ 47
	2015	338	68	20	15.3	7.7	157	€ 20	€ 68
Phase 4	2016	470	94	26	14.7	7.3	193	€ 26	€ 94
	2017	697	139	45	14.0	7.0	319	€ 45	€ 139
	2018	970	194	55	13.4	6.7	366	€ 55	€ 194
	2019	1,326	265	71	12.7	6.4	454	€ 71	€ 265
	2020	**1,801**	**360**	**95**	**12.1**	**6.1**	**574**	**€ 95**	**€ 360**
	2021	2,701	540	180	11.5	5.7	1032	€ 180	€ 540
	2022	3,596	719	179	10.8	5.4	970	€ 179	€ 719
	2023	4,832	966	247	10.2	5.1	1259	€ 247	€ 966
	2024	6,445	1289	323	9.6	4.8	1542	€ 323	€ 1,289
	2025	**7,936**	**1587**	**298**	**8.9**	**4.5**	**1329**	**€ 298**	**€ 1,587**
	2026	9,771	1954	367	8.3	4.1	1519	€ 367	€ 1,954
	2027	12,031	2406	452	7.6	3.8	1726	€ 452	€ 2,406
	2028	14,814	2963	557	7.0	3.5	1948	€ 557	€ 2,963
	2029	18,240	3648	685	7.0	3.5	2398	€ 685	€ 3,648
	2030	22,458	4492	844	7.0	3.5	2953	€ 844	€ 4,492

Assumptions

a) Export Equipment cost assumed to be 50% of installed cost = 0.5 x 2000 = 1000euro/kW [4]
b) UK low scenario = 900MW in 2020 this target represents 50% of European market [1]
=> Total European market size= 1800MW in 2020
c) Growth begins in 2012 as per [1], profile used as per EU-15 wind market 1990 - 2003
d) Ireland secures 20% of European market
e) Jobs created in Manufacturing sector only which is assumed to be 50% of the job rate for both Manufacture and Installation in Domestic Market
f) All components sourced and manufactured in Ireland

Fig. D.1 Schematic of Ocean Energy Strategy

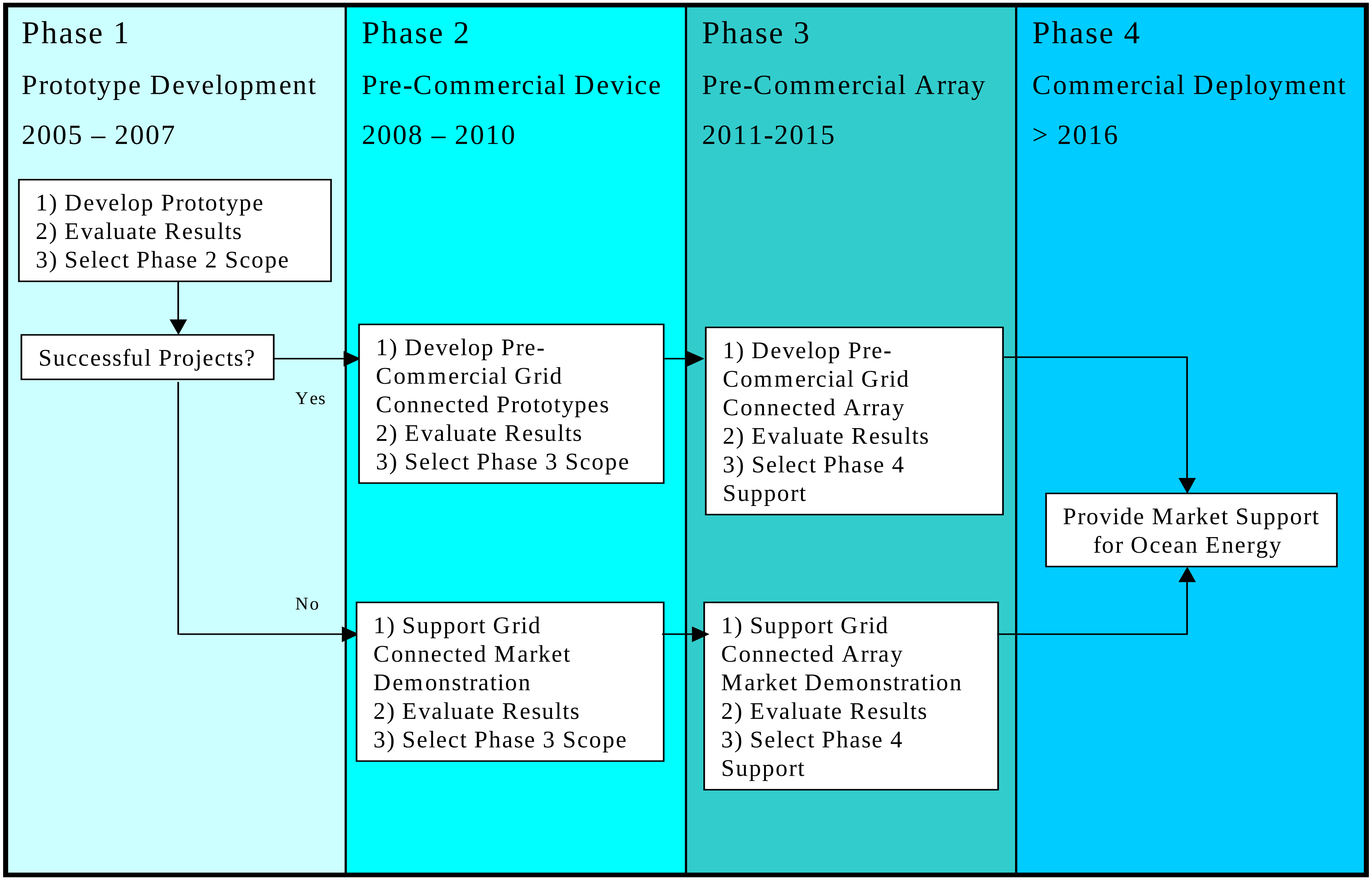


Table D.3 Ocean Energy Strategy: proposed Phases and associated costs

Phase	Period	Catergories	Item	No of Units	Output MW	Cost euro	Cost Euro	% Support	Cost of Support
Phase 1 (Development)	2005 - 2007		Research Facilities				€ 2,250,000	50	€ 1,125,000
			Monitoring Reporting				€ 120,000	100	€ 120,000
			Product R&D	2	2	4000	€ 8,000,000	45	€ 3,600,000
			Interim Test Site				€ 80,000	100	€ 80,000
									€ 4,925,000
Phase 2 (PreCommercial Single Device)	2008 - 2010	Option A: Product R&D	Research Facilities				€ 1,702,500	50	€ 851,250
			Monitoring Reporting				€ 60,000	100	€ 60,000
			Test Connection Facility				€ 4,800,000	100	€ 4,800,000
			R&D Pre-Commercial (up to 2MW)	2	2	3000	€ 6,000,000	45	€ 2,700,000
			2MW PPA (15c/kWh - BNE 5c/kWh)	2	2	3000	€ 2,103,840		€ 2,103,840
									€ 10,515,090
	2008 - 2010	Option B: No Product R&D	Monitoring Reporting				€ 60,000	100	€ 60,000
			Test Connection Facility				€ 4,800,000	100	€ 4,800,000
			2MW PPA (15c/kWh - BNE 5c/kWh)	2	2	3000	€ 2,103,840		€ 2,103,840
									€ 6,963,840
Phase 3 (PreCommercial Array)	2011 – 2015	Option A: Product R&D	Research Facilities Operational Costs 5yr				€ 500,000	50	€ 250,000
			Monitoring Reporting 5yr				€ 100,000	100	€ 100,000
			Array Connection				€ 4,000,000	45	€ 1,800,000
			10MW R&D Array Commercial	10	10	2000	€ 20,000,000	45	€ 9,000,000
			10MW PPA (10c/kWh - BNE 5c/kWh)	10	10	2000	€ 8,766,000		€ 8,766,000
									€ 19,916,000
	2011 – 2015	Option B: No Product R&D	Research Facilities Operational Costs 5yr				€ 500,000	50	€ 250,000
			Monitoring Reporting 5yr				€ 100,000	100	€ 100,000
			Array Connection				€ 4,000,000	25	€ 1,000,000
			10MW PPA (10c/kWh - BNE 5c/kWh)	10	10	2000	€ 8,766,000		€ 8,766,000
									€ 10,116,000
Phase 4 Comme (Commercial Deployment)	2016-2025	Ocean Energy 485MW	PPA (10c/kWh - BNE 5c/kWh)		485	2000			

Table D.4 Detailed Implementation Plan for Ocean Energy Strategy

Phase	Task	Description	Year	Funding Requirement	
				Option A	Option B
Phase 1	1	Secure Government endorsement of Ocean Energy Strategy	2005		
	2	**Secure Government commitment to Phase 1 funding**	**2005**	**€ 4,935,000**	**€ 4,935,000**
	3	Establish Steering Committee	2005		
	4	Establish Research Center plus work plan	2005		
	5	Establish Interm Test Site	2005		
	6	Construct and test large scale ocean energy converters	2006		
	7	Phase 1 Appraisal	2007		
	8	Conduct Preliminary Study for Test Connection Facility Location, Cost, Management & Operation	2007		
	9	**Decision Gate Review - Select Phase 2(A or B) requirements & update Ocean Energy Strateg**	**2007**		
Phase 2	1	Secure Government endorsement of updated Ocean Energy Strategy	2008		
	2	**Secure Government commitment to Phase 2 funding**	**2008**	**€ 10,515,090**	**€ 6,963,840**
	3	Agree PPA & Test Connection Facility Funding Mechanism	2008		
	4	Conduct Detailed Design of Test Connection Facility, select test site, secure permissions	2008		
	5	Award PPA and Grant Funding and Grid Connection Contracts	2008		
	6	Build & Commission Test Connection Facility	2009		
	7	Construct and test grid connected large scale ocean energy converters	2009		
	8	Phase 2 Appraisal	2010		
	9	**Decision Gate Review - Select Phase 3(A or B) requirements & update Ocean Energy Strateg**	**2010**		
Phase 3	1	Secure Government endorsement of updated Ocean Energy Strategy	2011		
	2	**Secure Government commitment to Phase 2 funding**	**2011**	**€ 11,150,000**	**€ 1,350,000**
	3	Agree PPA & Array Connection Facility Funding Mechanism	2011		
	4	Award PPA and Grant Funding and Grid Connection Contracts	2011		
	5	Construct array and electrical connection	2012		
	6	Test and monitor array performance	2015		
	7	Phase 3 Appraisal	2015		
	8	**Decision Gate Review - Select Phase 4 requirements & update Ocean Energy Strategy**	**2015**		
Phase 4	1	Secure Government endorsement of updated Ocean Energy Strategy	2016		
	2	**Secure Government commitment to Phase 4 supports**	**2016**		
	3	Agree PPA Funding Mechanism	2016		

Sustainable Energy Ireland
Glasnevin
Dublin 9
Ireland

t +353 1 836 9080
f +353 1 837 2848
e info@sei.ie
w www.sei.ie

Department of Communications,
Marine and Natural Resources,
29-31 Adelaide Road,
Dublin 2, Ireland

t +353 1 678 2000
f +353 1 678 2449
w www.dcmnr.gov.ie

NATIONAL DEVELOPMENT PLAN

Sustainable Energy Ireland is funded by the Irish Government under the National Development Plan 2000-2006 with programmes part financed by the European Union

This publication is printed on environmentally friendly paper

WWW.BENNISDESIGN.IE