3.4 Renewable Ocean Energy Research Programme

3.4.1 Introduction

Ireland's offshore renewable energy resources, in the form of wave and offshore wind, are considered as being among the best in the world. This resource, with the exception of the recently commissioned Arklow offshore wind farm, is completely unexploited.

3.4.2 Sector Profile

Offshore Wind

Foreshore leases have been granted for the operation of a 520 MW wind farm on the Arklow Bank and a 1,100 MW wind farm on the Codling Bank, both in the Irish Sea. To date, seven turbines totalling 25 MW have been installed on the Arklow Bank. This development features the world's largest installed offshore turbines. Licences have been granted for many of the other east coast offshore banks, as well as some west coast sites. There is potential to deliver a large energy supply into the system from offshore wind with existing technology. However, the key issues in respect to utilising offshore wind resources and developing technological solutions are:

> Policy

The successful development of an offshore wind energy industry depends, largely, on policy decisions.

> Infrastructure

The major limiting factor in respect to the introduction of the large electricity supply that the offshore wind sector can deliver in the short to medium term is the national grid's capacity to cope with this large intermittent resource.

> Price

Linked to the Policy issue mentioned above is the fact that there are financial implications for energy pricing associated with subsidies to renewable power generators. In turn, price is clearly an issue in respect to the viability of offshore wind schemes.

Since the dominant issues in respect to utilizing offshore wind resources are non-technical, this Strategy does not propose any significant RTDI effort in respect to this technology.

Tidal Energy

A recently completed tidal resource assessment for Irish coastal waters has indicated that there are marginal resource levels in Irish waters utilising existing technologies.[27] Significant activity in harnessing tidal stream energy for electricity generation is unlikely to occur in Ireland until technology that can operate effectively with low tidal flows is available. The overall status of tidal stream technology does not warrant a significant research effort at this time. However, a number of Irish groups are involved in the development of tidal devices for which there may be significant international markets and this provides justification for including technology development and innovation aspects of tidal energy in this Strategy.

Wave Energy

In terms of potential usefulness, the wave climate off the west coast of Ireland is one of the most favourable in the world. The development potential in respect to second-generation floating devices moored offshore is very significant. A comprehensive assessment of the offshore wave resource estimates the accessible wave energy resource as being up to 20.76 TWh/yr.[28]

There is a significant level of activity in Ireland in respect to the development of technologies to exploit wave energy resources.

> Two Irish developers of wave energy devices are ready to proceed to large-scale prototype phase.

> One developer has constructed a large-scale device, although funding and technical difficulties have resulted in delays to the programme.

> One company is successfully developing salt-water hydraulic pump systems for wave energy converters.

The critical issue for the wave energy sector, internationally and in an Irish context, is the demonstration of device prototypes in a real operational environment. This is the essential step in the process, which is gathering momentum internationally, of developing commercialisation models for a wave energy industry.

In view of its potential, the prospect that Ireland can become a significant player in this industry, and the high level of RTDI content in developing the technologies involved, this Strategy focuses primarily on wave energy, although aspects of the Strategy significantly affect tidal device deployment.

3.4.3 Key Opportunities and Challenges

There is increasing international recognition of the long-term potential for wave energy. A recent report by ESBI and Peter Bacon Economic Consultants concluded that Ireland has an important opportunity to develop an industry based on ocean energy.[29] This has the potential to lead to the creation of valuable intellectual capital, economic wealth and employment opportunities.

Furthermore, it would have a desirable regional spread, in the sense that much of the development would take place in areas of the country that are lagging economically.

Opportunities

> There is a very significant resource globally and a potentially large market in a number of key countries, in addition to niche markets elsewhere.

> There is, as yet, no proven ‘winning’ wave converter design. This provides a significant opportunity for Ireland to achieve a frontline position in the sector.

[27] Kirk McClure Morton (2005). Tidal and Current Energy Resources in Ireland, 2005. (Report Commissioned by SEI).
[28] ESB International (2005). Accessible Wave Energy Resource Atlas Ireland, 2005. (Report Commissioned by Marine Institute & SEI).
[29] Peter Bacon & Associates/ESBI (2005). Analysis of the Potential Economic Benefits of Developing Ocean Energy in Ireland. www.marine.ie

> A number of Irish companies are actively developing wave and tidal energy devices. Therefore, Ireland has the potential to establish commercially viable designs and exploit these locally, or in collaboration with overseas players.

> There is a growing level of investment in Research, Development & Demonstration (R,D&D) internationally; an increasing level of confidence that viable technologies will emerge, and evidence that effective development consortia are being formed, e.g. around the Pelamis system of the UK company, Ocean Power Delivery.

> Direct synergies exist with offshore wind, which should accelerate the development of wave and tidal service capabilities.

> Wave energy resources can provide sustainable energy to meet Ireland's growing demand for electricity in the medium to long term.

Challenges

Better pre-commercial support (e.g. capital grants and power-purchase terms) being provided elsewhere, may delay or stultify Ireland's development in the field. For example, the Scottish Marine Energy Group[30] predicts that by 2020:

> *10% of Scotland's electricity production can come from marine resources;*

> *There will be 1,300 MW of marine energy capacity installed in Scottish waters, increasing at a rate of 100 MW per year;*

> *Scottish-based marine energy companies could be supplying major international export markets;*

> *7,000 direct jobs could be created in a diverse marine industry in Scotland, supported by sustainable research development and skills bases; and*

> *Scotland should lead the world in the research, development and certification of marine energy devices.*

Greater market size and the development of standard designs abroad, coupled with economies of scale in production and rising costs in Ireland, may lead to manufacturing being carried out elsewhere.

The research resource could easily disappear, as it is led by a small number of key individuals facing uncertainty in securing regular funding leads it.

[30] Marine Energy Group (2004). Harnessing Scotland's Marine Energy Potential. Scottish Executive.

3.4.4 2020 Scenario

2020 SCENARIO

By 2020, given the continuing rise in the price of energy and the rise in demand for cleaner energy, the commercial prospects for Renewable Ocean Energy Technology will be clearly established.

Because of pro-active investment in Research, Demonstration & Development, Ireland will be a world leader in the manufacture and use of ocean energy systems. A programme of measures since 2006 will have enabled the systematic development and growth of an ocean energy sector. These include:

> development of research and technical support capabilities in the third-level sector;
> provision of a range of R&D and capital support measures for device developers;
> establishment of benign and open-sea test sites for prototype trials; and
> a co-ordinated approach to the delivery of an ocean energy research, development and demonstration programme.

A vibrant and growing export industry will have been established (conservatively valued as per Table 3.10).

Ireland will be recognised as a Centre of Excellence in Renewable Ocean Energy research and will have established competence in the design, modelling, deployment and operation of wave energy devices and in key technical areas of renewable energy, such as forecasting, power intermittency and management, and energy storage.

Table 3.10 Value of Renewable Ocean Energy Devices for Domestic & Export Markets (Peter Bacon & Associates/ESBI, 2005)

Activity	2020	2025
Annual Device Sales	119 MW	383 MW
Cumulative Device Sales	444 MW	2,072 MW
Annual Value of Market	€144 million	€478 million
Cumulative Value of Market	€541 million	€2,405 million
Number of Jobs Created	887	2,240

3.4.5 2013 Objectives

The following objectives have been identified as critical milestones to be achieved by 2013:

2013 OBJECTIVES

1 Achieve international recognition as a Centre of Excellence for Renewable Ocean Energy research with established competence in a number of key areas:

- Model Testing & Performance Validation
- Hydrodynamics & Modelling
- Power Take-off Technologies
- Mooring Design
- Wave Forecasting

2 Have a minimum of two full-scale, prototype ocean energy devices operational as pre-production models.

3 Establish suitable, and effective, technical approaches in the areas of forecasting, power intermittency and management, and energy storage.

4 Have in place user-friendly information systems that support the needs of offshore energy companies for access to environmental data.

3.4.6 RTDI Requirements/Key Outputs

The identified RTDI requirements and key outputs for delivering on the 2013 Objectives of the research programme are presented below.

Table 3.11 Research Requirements & Key Outputs for the Renewable Ocean Energy Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
1 Achieve international recognition as a Centre of Excellence for Renewable Ocean Energy research with established competence in a number of key areas:		
i) Model Testing & Performance Validation	i) Model Testing and Performance Validation > Maintenance and expansion of expertise in model testing & performance validation > Investigation of device array interaction and effect on performance > Use of remote systems for power and performance monitoring during large- scale benign site testing	> Availability of facilities and expertise for model testing at a useful scale and reliable performance assessment and validation for industrial device developers > Accelerated and more effective development of scaled energy devices
ii) Hydrodynamics and Modelling	ii) Hydrodynamics and Modelling > Maintenance and expansion of expertise base in hydrodynamics and modelling > Power take-off/hydrodynamics interaction	> Expertise in hydrodynamics and modelling

continued

Table 3.11 Research Requirements & Key Outputs for the Renewable Ocean Energy Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
iii) Power Take-off (PTO) Technologies	iii) Power Take-off Technologies	
	Hydraulics	
	> Investigation of use of seawater as hydraulic fluid, including seal effectiveness and longevity	> Use of 'environmentally friendly' fluids or seawater as hydraulic fluid devices and concepts
	> Effects of high forces during extreme events on hydraulic systems and components	> Reliable and efficient hydraulic PTO systems with short-term energy storage providing smooth output across a broad range of sea states
	> Investigation of short-term energy storage methods	
	Pneumatics	
	> Optimisation of impulse turbine design system and comparison with existing Wells turbines	> Proven high efficiency impulse turbine optimised for use in offshore devices
	> Optimisation of pneumatic turbines for use in offshore devices	
	Control Systems	
	> Technical and economic comparison of constant speed versus swash plate generator systems	> Analysis of the economic and technical benefits of various power quality and control strategies/ methods
	> Power quality optimisation and strategies for fault management	
	> Modelling of PTO effects on device (critical damping)	
iv) Mooring Design	(iv) Mooring Design	
	> Value engineering of mooring systems and components	> Optimised design for device arrays and reduction in mooring costs
	> Investigation of use of synthetic/high-tech materials	> Mooring systems for offshore wind devices capable of exploiting deep or exposed waters
	> Mooring design optimisation for array deployment	
	> Development and optimisation of mooring technologies for deep water offshore wind devices	
v) Wave Forecasting	v) Wave Forecasting	
	> Use of remote sensing and model prediction for accurate short- and medium-term prediction of wave climate and application of forecast to control strategies	> Tools to allow optimisation of operation and instigation of survival strategies for offshore wave devices

continued

Table 3.11 Research Requirements & Key Outputs for the Renewable Ocean Energy Sector to 2013

Objectives 2013	RTDI Requirements	Key Outputs
2 Have a minimum of two full-scale, prototype ocean energy devices, operational as pre-production models.	> Provide test facilities, including (a) a benign near-coast site for testing scale-models, and (b) an open-ocean test-site with power cable for testing full-scale devices and device arrays > Provide technical product R&D support for device developers in the following areas: • Modelling • Tank testing and performance validation • Access to basic open ocean test site for scale models • Deployment support for scale models in open ocean • Prototype design & build • Prototype deployment & monitoring	> Fully licensed, cabled and instrumented site allowing rapid deployment of prototype devices > Full-scale devices providing valuable long- term data allowing optimisation of device design
3 Establish suitable, and effective, technical approaches in the areas of forecasting, power intermittency and management, and energy storage.	Power Quality & Conditioning *Technical Considerations* > Investigation of in-situ onshore power rectification and conditioning *Economic Considerations* > Comparison of economics of differing strategies for power rectification and conditioning *Energy Storage Solutions* > Investigation of technical and economic benefits of a broad range of energy storage technologies with application for offshore energy in an Irish context	> Cost effective methodologies for generation of high quality power from offshore devices > Analysis of benefits of existing or novel energy storage solutions allowing storage of offshore generated energy
4 Have in place user-friendly information systems that support the needs of offshore energy companies for access to environmental data.	> There is a requirement to provide environmental monitoring data for use by developers and regulators of the sector. (See Knowledge & Information Management Section)	> Easily accessible database of relevant environmental data to Ocean Energy companies

3.4.7 RTDI Capacity/Capabilities

Although the area of general renewable energy and technologies research has shown significant increase in recent years, Ireland has a relatively small, but active, renewable ocean energy research community in the private and third-level sector.

Table 3.12 Overview of Current Renewable Ocean Energy Research in the Third-level Sector

Institutes	No. Research Groups	No. Researchers*	Research Focus
UCC UL NUIM	2 Large Groups 1 Medium Group	23	> Hydrodynamics of overtopping wave power devices. > Optimal formation of arrays of wave power devices. > Physical and numerical modelling > Tidal current research. > Development of turbine technology for wave power. > Pendular wave energy converter > Development of wave energy devices. > Control and electrical systems for ocean energy systems.

Large: >10 researchers; Medium: 5–10 researchers; Small: <5 researchers

* In some cases, research groups may focus on more than one theme and the total number of researchers in these groups is greater than indicated here. The total number of researchers in the groups identified is approximately 35-40.

Current Research Capacity

Third-level Sector

Three research groups in three universities are actively involved in wave and tidal energy research. Together, these groups comprise approximately 23 researchers in renewable ocean energy research (Table 3.12).

Other research groups in UL, UCD, NUIG and UCC have skills and research capabilities that can be drawn upon to meet the identified RTDI requirements. These include near-shore modelling, marine robotics, advanced materials, computational fluid dynamics, power system operation and integration of renewable energy in the electricity system, and wind and wave data analysis. In addition, several of the main third-level institutions have core competencies in the general area of electrical engineering and related fields.

Industry

There are 4–5 private companies, totalling 10–12 researchers, actively engaged in renewable ocean energy research. These include device developers and engineering consultancies engaged in resource assessment and device design and analysis.

Identification of Research Skills/Competencies to Meet Future RTDI Requirements

A summary, based on the identified future RTDI requirements, of the competencies required to meet the 2013 Objectives is presented in Table 3.13. Also included in Table 3.13 is an assessment of whether there are current strengths (S), areas that require strengthening (R), or gap areas (G), in relation to the identified requirements, within the existing research community.

Table 3.13 Competencies Required to Meet Future Research & Innovation Requirements for the Renewable Ocean Energy Sector

Objectives 2013	Competencies Required	Assessment
1 Achieve international recognition as a Centre of Excellence for Renewable Ocean Energy research with established competence in a number of key areas.	> Model testing and performance validation > Hydrodynamics and modelling > Power Take-off (PTO) technologies > Mooring design > Wave forecasting > Wave climate modelling	S S R S R S
2 Have a minimum of two full-scale, prototype ocean energy devices, operational as pre-production models.	> Prototype design, specification and construction > Electrical connection design and specification > Operational and deployment strategies > Data acquisition and performance validation	R R R S
3 Establish suitable and effective technical approaches in the areas of forecasting, power intermittency and management, and energy storage.	> Power quality and conditioning technologies > Application of energy storage methodologies > Economic modelling	R G S
4 Have in place user-friendly information systems that support the needs of offshore energy companies for access to environmental data.	Refer to Environmental and Knowledge & Information Management Programmes	

* S – Current Strength; R – Requires Strengthening; G – Gap Area.

Considerable strengths exist in the competencies required to meet Objective 1. However, research capabilities need to be strengthened in the areas of power take-off technologies and wave forecasting. Many of the R&D competencies required in support of the objectives to have operational prototype devices also require strengthening. Additionally, infra-structural support, in the form of near-coast and open-ocean test sites, is required to meet this objective.

Research competencies to address the issue of power quality require strengthening. Although one dedicated research centre is active in this field, several of the main third-level institutions have core competencies in the general area of electrical engineering and could contribute to future requirements through accurately targeted research programmes. Finally, a major issue facing ocean energy devices is that of energy storage. This issue is being addressed by the wider renewable energy industry, specifically in relation to onshore and offshore wind energy. A gap exists within the research community with respect to the application of existing and/or novel energy storage solutions for ocean energy devices.

The competencies required to achieve the final objective, access to environmental data, are generic to many of the programme areas and specific to the Knowledge & Information Management programme of the Strategy and are not considered here.

Current Strengths	Require Strengthening	Gaps
> Model testing and performance validation > Hydrodynamics and modelling > Mooring design > Wave climate modelling > Data acquisition and performance validation > Economic modelling	> Power Take-off (PTO) technologies > Wave forecasting > Prototype design, specification and construction > Operational and deployment strategies > Power quality and conditioning technologies > Electrical connection design and specification	> Application of energy storage methodologies

Figure 3.8 Research Competencies Required to Meet 2013 Objectives for Renewable Ocean Energy

3.4.8 Prerequisites for Achieving Objectives

Internationally, as well as in Ireland, the critical factor both for device technology and for emerging business models for the sector is the demonstration of full-scale prototypes in operational, open-sea environments. In view of the competitive international environment that exists for wave energy technology, the following general prerequisites for the successful delivery of the objectives for the renewable ocean energy research programme are suggested:

> Policy

A national commitment to maximising energy generation from renewable sources and, particularly, to supporting the development of indigenous technical and industrial capabilities in respect to the technologies involved.

> Support

Close collaboration between the agencies with relevant responsibilities and the establishment of an executive implementation mechanism.

> Funding

A commitment to a sustained programme of funding support, addressing the range of RTD and capital and price support measures necessary to provide a climate of confidence within which the private sector can raise and commit the significant funds necessary to create industrial offshore energy power arrays.