

Preparing for a National Marine Research & Innovation Strategy 2017-2021

BACKGROUND
DOCUMENTS

In preparing the National Marine Research & Innovation Strategy 2017-2021 a number of discussion papers were prepared. These papers are presented in this report.

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Introduction

In developing the National Marine Research & Innovation Strategy 2017-2021 a number of discussion papers were written. The majority of these discussion documents were prepared in advance of the public consultation that was held in late 2016. Following feedback from the consultation two further papers were prepared: a Marine Pollution paper (building on the original litter paper) and an expanded Ocean Literacy and Education paper.

This background report provides information on each of the 15 research themes and offers an insight into how the National Marine Research & Innovation Strategy 2017-2021 was formed.

It is recommended that this report is read in conjunction with the published Marine Research & Innovation Strategy 2017-2021 (available on www.marine.ie).

Policy Drivers for Marine Research

In common with other European countries Ireland's economic future and the role of research and innovation in supporting growth are shaped by global forces. There are lasting concerns about the impact on society of climate change, an ageing and increasing world population, unsustainable usage patterns of natural resources and food security. These connected issues are pervasive across society, presenting many challenges but also creating opportunities to increase the contribution that Ireland's marine economy can make to the development of a sustainable society. Expanding research activity, both fundamental and applied, and the introduction of measures to stimulate innovation are crucial in developing lasting responses to the many societal challenges that face Ireland and our European partners.

Unlike the majority of European countries, Ireland has extensive marine territories, which the Government, through its marine policy, *Harnessing Our Ocean Wealth – An Integrated Marine Plan for Ireland*¹, identified as having the potential to contribute to Ireland's economic recovery. The successful implementation of Harnessing Our Ocean Wealth (HOOW) is complementary to the Government's Action Plan for Jobs and the EU's Europe Strategy 2020 in seeking to create new, sustainable and innovative approaches to deliver growth and job creation. Ireland's marine territories support diverse economic activities that are based on the sustainable use of marine natural resources and provide many attractive non-commercial benefits to citizens and visitors alike.

Ireland's ocean economy comprises the economic activity which directly or indirectly uses the marine as an input, independent of location. Examples of the diverse activity of the ocean or maritime economy include the traditional areas such as shipping and maritime transport, tourism and leisure, sea fisheries, aquaculture, seafood processing and off-shore oil and gas, as well as the new research-driven areas of marine biotechnology, marine renewable energy, advanced technology-based products and marine commerce.

The most recent data from the Socio-Economic Research Unit (SEMURU), in NUI Galway, on the performance of Ireland's marine economy describes the sector as employing close to 17,500 full-time equivalents, having a turnover of €4.3 billion and contributing 0.7 percent of GDP (€1.3 billion).

¹ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

In this period, the traditional or established marine areas of the marine economy accounted for 95 percent of total turnover (€3.96 billion) and 93 percent of total employment, with most areas reporting increased economic activity. The remaining component of the marine economy, which represents new and emerging sectors, is particularly reliant on research activity and also experienced strong economic growth.

Data from the Central Bank² point to Ireland's positive economic performance in 2015, which recorded a growth in GDP of just under 7 percent, increased employment, and a stronger than expected growth in exports and imports. As a result of increased market demand in 2015, export performance by the agri-food and tourism sectors, which are largely indigenous industries closely linked to the marine economy, was strong. Ireland's marine sector includes a multitude of manufacturing and service companies. Preliminary data from the Central Statistics Office³ shows the manufacturing sector to have grown in value terms by 14.2 percent during 2015. Over the same period growth in value terms in the distribution, transport, software and communications sectors was 8.7 percent, whilst the service sector increased by 4.3 percent.

Growth Targets

From a 2007 baseline, where turnover of the marine economy reached €3.4 billion, the Government set a target to double the value of the marine economy to reach 2.4 percent of GDP by 2030. The goal of *Harnessing Our Ocean Wealth*, to place Ireland close to the EU average of 3-5 percent contribution from the marine sector in 23 years, includes an interim target for the marine economy to generate €6.4 billion in turnover by 2020. These growth targets require the performance of established and emerging sectors of Ireland's marine economy to improve in line with projections of various national strategies. The contribution of private sector investments is a critical contribution towards reaching these economic targets.

Investments in research and development drive economic growth. The creation of new marine-related research capacity and increased research performance, as a result of *Sea Change* and other public sector investments, contribute to Ireland's significant strengths in research and development. National policy plans to build on the successes of Ireland's innovation-driven culture, that embraces science and technology, and to place Ireland on the path to becoming a leading research performer.

² Central Bank of Ireland 1st Quarterly Bulletin of 2016 16th January 2016

³ Central Statistics Office (2016) Quarter 4 2015 and Year 2015 (Preliminary)

Ireland plans to increase the intensity of research and development to 2.5 percent of GNP by 2020⁴. Business expenditure on research and development increased by 31 percent and public sector investment fell by 22 percent between 2008 and 2013. The private sector spent more than €2 billion on research and development between 2013 and 2014⁵. At a time when national policy led to research funds being prioritised and directed towards supporting national economic goals, the number of companies engaged in research and development increased.

Policy Context to the Marine Research and Innovation Strategy

Ireland's marine research and innovation strategy is designed to support knowledge-driven and value-added growth, sustain improvements in the quality of life and inform policy concerning the management and sustainable use of Ireland's marine environment. Responding to the growth and development targets in *Harnessing Our Ocean Wealth* is the driving force behind the development of the Research & Innovation strategy. A broader influence on the strategy is a range of current EU and national policies. These include:

- The Marine Strategy Framework Directive of 2008⁶ is an ecosystem-based approach to manage marine environments, designed to ensure the pressure of human activities on the marine environment is kept within levels compatible with the achievement of good environmental status by 2020.
- Launched in 2010, EUROPE 2020⁷ calls for member states to tailor national strategies to support EU goals for (a) smart growth: developing an economy based on knowledge and innovation; (b) sustainable growth: promoting a more resource efficient, greener and more competitive economy; and (c) inclusive growth: fostering a high-employment economy delivering social and territorial cohesion.
- The Limassol Declaration of 2012⁸ recognised the marine and maritime sectors as crucial drivers of growth and jobs for the EU economy – providing annual Gross Value Added of €495 billion, supporting the employment of 5.4 million Europeans, and identifying that 88

⁴ Innovation 2020 (2016)

⁵ Central Statistics Office (2015) Business Expenditure On Research And Development 2013-2014

⁶ European Commission (2008) Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)

⁷ European Commission (2010) *EUROPE 2020 A strategy for smart, sustainable and inclusive growth* COM(2010) 2020, March 2010 Brussels

⁸ Declaration of the European Ministers responsible for the Integrated Maritime Policy and the European Commission, on a Marine and Maritime Agenda for growth and jobs the "Limassol Declaration"

million Europeans work in coastal regions, where over 205 million live. The Declaration also identified Europe's seas and oceans as offering unexplored areas for innovation, sustainable growth and employment.

- “Blue Growth” is Europe’s plan for growth in the blue economy⁹ and is the maritime dimension of the Europe 2020 strategy. This plan recognises that Europe’s blue or marine economy can “contribute competitiveness, resource efficiency, job creation and offer new sources of growth whilst safeguarding biodiversity and protecting the marine environment, thus preserving the services that healthy and resilient marine and coastal ecosystems provide”. Blue Growth identifies five value chains able to deliver sustainable growth and jobs in the blue economy – blue energy, aquaculture, maritime, coastal and cruise tourism, marine mineral resources, and blue biotechnology.
- The European Commission, in its plan “EU Innovation in the Blue Economy”¹⁰ identified the need for actions to correct issues that are specific to the blue economy including – gaps in knowledge and data about the state of our oceans, seabed resources, marine life and risks to habitats and ecosystems, diffuse research efforts in marine and maritime science that hinders inter-disciplinary learning and slows the progress of technological breakthroughs in key technologies and innovative business sectors, and the lack of scientists, engineers and skilled workers able to apply new technologies in the marine environment.
- The EU strategy for the Atlantic Ocean¹¹ (2011), which supports the objective of creating sustainable jobs and growth in the area, calls for member states with Atlantic coastlines to initiate five thematic actions. These include, (1) *implementing the ecosystem approach* to the management of fisheries and aquaculture activity, promoting spatial planning as a tool for implementing the ecosystem approach in the Atlantic Ocean area and establishing sustainable observation systems, from space and at sea, to allow Europe to gain a better understanding of the Atlantic; (2) *reducing Europe's carbon footprint* by exploiting the potential of energy from wave, wind and tides, reducing the emissions from shipping by introducing more fuel-efficient ships, and moving freight from road to sea; (3) the *sustainable exploitation of the Atlantic seafloor's natural resources* through developing a better knowledge of the rich biodiversity of the ocean, and by ensuring the extraction of

⁹ European Commission (2012) Blue Growth opportunities for marine and maritime sustainable growth COM/2012/0494 final Brussels

¹⁰ European Commission (2014) *Innovation in the Blue Economy: realising the potential of our seas and oceans for jobs and growth*. COM(2014) 254 final/2 May 2014 Brussels

¹¹ European Commission (2011) Developing a Maritime Strategy for the Atlantic Ocean Area COM(2011) 782 final Brussels

mineral and biological resources for food, fuel and other uses whilst preserving its ecosystem functions; (4) *responding to threats and emergencies* by ensuring the EU is prepared for such events in the Atlantic whether they are caused by accidents, natural disasters or criminal activity, adopting legislative measures on maritime safety, and having a risk management policy linking threat and risk assessment; and (5) *achieving socially inclusive growth* by measures that help to protect coastal communities and attract high-added value jobs to coastal areas, create economic clusters and address infrastructural deficits.

- Europe’s plan for a bioeconomy, published in 2013¹², sets, inter alia, a goal to maximise the use of biomaterials by sustainable processing methods, thus minimising waste. Ireland’s marine environment supports the harvest and culture of marine biomass (fish and algae) used in various consumer and industrial products. Processing discards, resulting from these products, offers substantial potential for the recovery of value by recycling, as opposed to disposal.
- The EU Atlantic Action Plan¹³ (2013) supports the implementation of the EU Strategy for the Atlantic and aims to revitalise the marine and maritime economy in the Atlantic Ocean area and sets out priorities for research and investment to drive the ‘blue economy’ in the Atlantic area. It shows how the EU’s Atlantic Member States, national and regional agencies and the Commission can help to create sustainable growth in coastal regions and drive forward the “blue economy” while preserving the environmental and ecological stability of the Atlantic Ocean. The Plan is built around actions to encourage the promotion of entrepreneurship and innovation; protect, secure and enhance the marine and coastal environment; improve accessibility and connectivity; and create a socially inclusive and sustainable model of regional development.

Ireland’s National Research Prioritisation Exercise¹⁴ stresses the importance of enterprise driven research. Amongst the priority research areas are clusters closely connected to the marine economy. Marine ICT applications include priorities A – Future Networks & Communications, B – Data Analytics, Management, Security & Privacy, and C – Digital Platforms, Content & Applications. Food

¹² European Commission (2012) Innovating for Sustainable Growth: A Bioeconomy for Europe. 13.2.2012 COM(2012) 60 final. Brussels

¹³ European Commission (2013) Action Plan for a Maritime Strategy in the Atlantic area - Delivering smart, sustainable and inclusive growth COM/2013/0279 final. Brussels

¹⁴ Forfas (2012) Research Prioritisation Steering Group Report. Available at <https://www.djei.ie/en/Publications/Publication-files/Research-Prioritisation.pdf>

from the Sea is included in priority I – Sustainable Food Production & Processing. Marine Energy is a dedicated priority area – J; opportunities for Marine Biotechnology are reflected in Priorities E – Medical Devices, G – Synthesis, Formulation, Processing & Drug-Delivery, H – Food for Health, and M – Processing Technologies & Novel Materials.

The sustainable management of the marine environment relies on evidence-based policy. Though not within the remit of the research prioritisation exercise, the final report identified “policy research” as providing the knowledge required to develop regulations and stressed that research for enterprise, research for knowledge and research for policy are not mutually exclusive but are “collectively aimed at improving the economic and societal wellbeing of the country and the health and wellbeing of its citizens¹⁵”.

Innovation 2020¹⁶ is Ireland’s strategy for research and development, science and technology innovation. The long-term vision of Innovation 2020 is for Ireland to become a “Global Innovation Leader driving a strong, sustainable economy and a better society”. Maintaining scientific excellence in areas relevant to the economy and society is a cornerstone of the vision that also seeks to create an internationally competitive industry base within a knowledge-based innovation ecosystem. The Innovation 2020 vision mirrors the goals for the marine economy as expressed in *Harnessing Our Ocean Wealth*, including prioritising ICT, food, energy, health, manufacturing and materials, services and business processes.

Enterprise 2025¹⁷ is Ireland’s strategy for future enterprise activity. This broad plan identifies opportunities for enterprise growth and job creation for the next ten years. It describes the marine, maritime and environmental services areas as offering un-tapped potential, and calls for the full potential of the marine economy to be developed through the implementation of the *Harnessing Our Ocean Wealth* strategy.

An array of Irish industry sector development plans support the high-level goals of European and Irish research and innovation strategies. Some of these plans highlight the actions required to harness the potential contribution of the marine economy to overall industry performance.

¹⁵ Report of the Research Prioritisation Steering Group, Dublin 2015, pg. 21

¹⁶ Innovation 2020 A report by the Interdepartmental Committee on Science, Technology and Innovation; Dublin 2015

¹⁷ Enterprise 2025 Ireland’s National Enterprise Policy 2015-2025. Department of Jobs, Enterprise and Innovation, Dublin 2015

- There are strong references to the role of marine foods as supporting the growth and development of Ireland’s food sector in **FoodWise2025**, the national food research plan SHARP, and in the National Aquaculture Plan.
- National energy strategies include marine energy challenges in the **Off-shore Renewable Energy Plan** and the **Strategy for Renewable Energy 2012 to 2020**.
- The **Geosciences Research Strategy 2015-2020**, INFOMAR, and the Action Plan for Biodiversity are relevant to the use of marine materials.
- The **National Ports Policy** and the **Low Carbon Development Bill** are both relevant to marine services, whilst marine tourism features in the national tourism plan **People, Place and Policy - Tourism to 2025**. The challenge of maintaining “good environmental status” of the marine environment is at the core of Ireland’s adoption of the **Marine Strategy Framework Directive**, which was subsequently incorporated into Irish law in SI No. 249/2011 - European Communities (Marine Strategy Framework) Regulations 2011, whilst the **Climate Action Plan** is cross-cutting across all marine related activity.

The Marine Coordination Group (MCG) appointed a Development Task Force to advise on the implementation measures necessary to achieve the goals in HOOW. It identified five thematic areas for action, and three types of intervention for existing marine industries, emerging resources and potential marine markets. The task force also emphasised the role of national support programmes and the need for matching funds from the private sector in opening the way for Ireland to capture the many opportunities offered in a marine economy. The five thematic areas for new enterprise activity include Food from the Sea, Energy from the Ocean, Tourism & Business in Marine & Coastal Areas, Enterprise & Industry and Integrated Marine Capacity and Capability. The dedicated interventions are required to develop untapped resources and nascent marine industries, attract non-marine industries into marine markets, and strengthen established marine sectors. The interventions aim to address perceived and real deficits regarding research, development and innovation in the marine economy and include:

- In the *short term*, expand the talent pool available so as to attract Foreign Direct Investment and strengthen existing industry, whilst strengthening environmental, technological and governance capacity.
- In the *medium term*, investment, coupled with existing research infrastructures, can be used to demonstrate the application of products and services in new marine markets.
- In the *long term*, generate new products and services, in particular in the emerging fields of Marine ICT, Marine Bio-Resources and Offshore Renewable energy.

Based on the various policies and plans detailed in this section, the 15 research themes shown below have been identified. The thematic research areas are consistent with those in broader national strategies that plan to build on national assets and capabilities. Opportunities to draw from Ireland's wider research and innovation community in creating lasting benefits for the marine economy exist.

EU Integrated Maritime Policy	EU CFP – EMFF OP 2014-2020	JPI Oceans R&I Agenda	EU Strategy for the Atlantic & Action Plan	Harnessing Our Ocean Wealth	Our Ocean Wealth Development Task Force	Innovation 2020	National Research Prioritisation	Enterprise 2025
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A THRIVING MARITIME ECONOMY

Bioresources - Aquaculture & Biomass Production - Wild Resources - Processing for Food & Other Use - High Value Products	✓	✓	✓	✓	✓	✓	✓	✓
Advanced Technologies	✓		✓	✓	✓	✓	✓	✓
Subsea Resources	✓		✓	✓	✓	✓		✓
Renewable Energy	✓			✓	✓	✓	✓	✓
Tourism & Leisure	✓			✓	✓	✓		✓
Transport & Logistics	✓			✓	✓	✓		✓
Security & Surveillance	✓	✓		✓	✓	✓	✓	✓

HEALTHY MARINE ECOSYSTEMS

Biodiversity, Ecosystems & Food-webs	✓	✓	✓	✓	✓		✓	
Pollution & Litter	✓	✓		✓	✓			
Climate Change	✓	✓	✓	✓	✓		✓	
Ocean Observation & Seabed Mapping	✓		✓	✓	✓	✓	✓	

ENGAGEMENT WITH THE SEA

Ocean Literacy & Education	✓	✓		✓	✓			
Integrated Policy & Governance - Socio Economics - Law - Planning & Governance - Business Development	✓	✓	✓	✓	✓	✓		✓
Information & Spatial Technologies, Analytics and Modelling	✓			✓	✓	✓	✓	✓
Engineering	✓			✓	✓	✓	✓	✓

Figure 1 Cross-Cutting National and International Policy Drivers

A Capability Maturity Model for Marine Research

Introduction

The preparation of a National Marine Research & Innovation Strategy is an action in *Harnessing Our Ocean Wealth* (Government of Ireland, 2012), Ireland's Integrated Marine Plan. The action sets out a number of key parameters that the new strategy must address:

- The strategy must address “industry, policy and discovery research”. That is, the strategy must examine and support research from basic to applied research. In technology terms, the strategy must address the full range of Technology Readiness Levels (TRLs) and a similar approach is required for research related to policy and social sciences.
- It must focus on relationships and networks, including “industry/academia collaborations”. It must also enable “maximum participation in EU funding programmes” and promote “clusters/networks and in order to create critical mass...”

From the above it can be inferred that the strategy must ensure that there is sufficient human capacity to participate in collaborative research, ensure that there is adequate infrastructure to support research across the full spectrum of knowledge development (from basic to applied), and also ensure that Irish researchers are adequately connected both nationally and internationally in terms of networks & relationships.

The action also specifies that the strategy must develop and identify funding instruments in relation to marine research. In order to do so, while taking account of the dimensions outlined above, a mechanism is required to establish where funding is required and what the nature of this funding is. Furthermore, this mechanism must take account of the wide spectrum of research themes that are covered under the umbrella of marine research.

Marine research crosses a number of industry and policy related vertical themes. A review of current relevant national and European policy documents, conducted as part of the strategy preparation, identified a number of such themes, and classified them under the three goals of *Harnessing Our Ocean Wealth* (Government of Ireland, 2012). Each of these has differing national capacities with varying degrees of application and experience in the marine domain.

In order to facilitate comparisons between the themes, a generalised Research Capability Maturity Model (RCMM) has been developed by the Marine Institute. This paper outlines the basis for this model and its specific application in relation the preparation of the National Marine Research and Innovation Strategy.

Prioritisation of public research funding

There are remarkably few frameworks available for evaluating the relative strengths and weaknesses of research themes in advance of decisions on public funding. Yet, as noted by the OECD, direct funding of research and development is one of the main policy instruments used by governments to support science and innovation in priority areas (Van Steen, 2012). From a framework perspective, the emphasis tends to be on the post-expenditure establishment of benchmarks on how public funds have been spent and the achievement of metrics for spending, such as the Frascati Manual (OECD, 2002), as distinct from the pre-expenditure determination of where funding should be concentrated.

Typically, research prioritisation within themes, or across themes, is achieved through a consultative process featuring stakeholder engagement or assessment by experts. Structured techniques, such as the Delphi Method or Nominal Group Techniques (Delbecq, et al., 1975), are often used with a view towards arriving at a preferred future. There are three main difficulties with such approaches.

Firstly, the methods rely on the opinions of domain experts. Priorities arrived at will inevitably exclude potential priorities that had no advocate involved in the process, the results will depend on the quality of the experts selected, and maybe subject to the biases of the facilitator (Gupta & Clarke, 1996).

Secondly, the results are by definition a form of crowd-sourcing, and are subject to the failures of crowdsourcing, in particular where there are insufficient numbers involved in the process to mitigate against individual preferences and inter-participant dependence.

Thirdly, and perhaps most importantly, such techniques are focused toward prioritisation, as distinct to objective comparison between equally valid themes.

Given the cross-cutting nature of marine research, this third point is of particular relevance. It may not be practical, nor desirable, to attempt to prioritise the thematic areas that can be characterised as relating to marine research; as those thematic areas themselves will have their own priorities and stakeholder communities. Attempts by advocates within the horizontal cross-cutting marine community to prioritise will inevitably lead to conflict with one or more of the industry vertical groups.

The proposed alternative advocated here is to assume that each industry vertical is interested in developing the research capability within their own vertical. Funding related to marine research is prioritised across all verticals with the ambition of progressing the relative maturity of each.

Maturity Models

The concept of maturity models originated in the field of Information Systems. Mettler et al trace the origins of maturity models back to the 1970's (Mettler, et al., 2010), in particular Nolan's stage model of computing resource management (Nolan, 1973). The field of quality management also featured maturity matrices, an early example being Crosby's Quality Management Maturity Grid (Crosby, 1979). However, it was the publication of the Capability Maturity Model (CMM) for software development (Paulk, et al., 1993) that expanded the awareness of such models through its intersections with other disciplines such as project management and quality improvement.

In general terms, a Maturity Model provides a frame of reference by which the relative sophistication of two or more similar, but not identical, areas of interest can be compared. This is achieved taking a snapshot of each at a moment of time. Lasrado et al (Lasrado, et al., 2015) provide a useful, and recent, history of the evolution of maturity models and highlight the increase in academic publications on the topic from 20 in 1994 to 115 in 2008.

The topic of research capacity is particularly suited to maturity models because the process of research management is largely immutable. As noted by Mettler et al (Mettler, et al., 2010) this means that a maturity model applied to the field will not need to have its basic requirements and assumptions adjusted significantly over time. This feature allows the progression of maturity in the subject being assessed to be tracked over time.

It should be noted that the concept of Maturity Models in general, and the RCMM outlined here, differs considerably from that of a Technology Readiness Level (TRL) (European Commission, 2014), which is frequently used to indicate the progression of a technology from basic research through to commercial application. As discussed later, an immature research theme as assessed on the RCMM would only support research for a few TRLs. In contrast, a fully mature research theme would support research applicable to most, if not all, TRLs.

Model Development

In approaching the development of a Research Capability Maturity Model, a range of approaches are available. Lasrado et al (Lasrado, et al., 2015) identify three meta-models for maturity model development, of which that described by De Bruin et al (De Bruin, et al., 2005) was selected. This was a pragmatic choice - the approach described is suited to situations where there is little pre-existing consensus on what constitutes maturity amongst potential user communities. This reflects the situation described above.

The De Bruin et al approach features six phases of model design as follows:

1. Scope. Define the outer boundaries for the model
2. Design. Determine the architecture of the model
3. Populate. Identify dimensions and sub-categories describing detailed description in the form of statements
4. Test. Challenge the relevance, rigour, validity, and reliability in terms of both construct and content
5. Deploy. Deploy in phases, first among collaborators, then target audiences and finally to an entire population
6. Maintain. If acceptance is achieved, design to handle volumes

The following sections describe the actions for each of these phases in the development of the RCMM.

Phase 1 – Scope – Define the outer boundaries for the model

Mettler et al (Mettler, et al., 2010) provide a framework for maturity model characterisation, in which the concept of maturity itself provides the basis for design selection. Three archetypes of maturity are presented in the framework, namely:

1. Process maturity, i.e. the characteristics of what is done in the domain to be modelled.
2. Object maturity, i.e. the characteristics of what is produced in the domain to be modelled.
3. People capability, i.e. the characteristics of the people operating in the domain to be modelled.

In terms of research practices, the proposed RCMM does not attempt to capture the process by which research activities are carried out, eliminating the first archetype. However, the outputs, or more precisely the outcomes of research (either in the form of policy advice or product innovations), are of interest. Moreover, the capabilities of the people and the supporting environment in which they operate are of key interest.

Informed by the specific action under Harnessing Our Ocean Wealth which gives rise to the need for a Marine Research & Innovation strategy, the supporting environment was defined to be the infrastructure (be it physical such as equipment or virtual such as databases) and the networks and relationships available to researchers and in which they participate.

The maturity framework being designed is therefore concerned with: the capability of the people, the infrastructures they utilise and the networks of relationships in which they operate. These

represent the research environment on one dimension; and the nature of the outcomes which this environment produces exist on another dimension.

Phase 2 – Design – Determine the Architecture for the model

With the concept of maturity arrived at, a suitable design is required. Again, (Mettler, et al., 2010) provide three templates for model design.

1. Maturity Grids are simple illustrations of maturity relying on textual descriptions.
2. Likert-like Questionnaires are similar to maturity grids, but focus on the use of scores from questionnaires to describe good practices and typically are multi-faceted, leaving it to the user of the model output to assess relative strengths and weakness of the domain instances being assessed (e.g. through “web diagrams”).
3. CMM like models, which are based upon a formal architecture (though this may be relatively simple) specifying a number of key practices that are used to benchmark predefined levels of sophistication.

In the case of the RCMM, it was elected to develop a CMM-Like model. This was based on a number of pragmatic considerations including elimination of the two other alternatives. Maturity Grids do not provide enough detail to suggest targeted funding instruments that can be used to advance the maturity of a particular research theme. Similarly, Likert like questionnaires do not provide sufficient clarity in terms of the particular dimensions of a research theme that require attention.

By contrast, CMM like models provide an intuitive progression of maturity to which specific actions or supports can be applied in order to support progression from one level to another.

The broad design of the model is therefore a matrix type model, with the dimensions of human capacity, infrastructure and networks & relationships on one axis, with the other axis being a series of CMM like levels describing the outcomes achieved at each level.

Phase 3 – Populate – Identify dimensions and sub-categories describing detailed description in the form of statements.

A widely quoted definition of maturity in the literature is that provided in the Oxford English Dictionary, namely “the state of being complete, perfect or ready”. By this definition the highest level should reflect a fully functional research system. What constitutes a fully functional research system is a subjective determination, but from a public policy perspective, it can be defined to be:

- a) a situation where a research theme requires no intervention or support on the part of the state (beyond the commissioning of research for policy support reasons); and

- b) a situation where the research process provides a route from basic research through to commercial or policy support application.

In a sense such a level of maturity may be viewed as being largely aspirational, although it is possible to identify the practices that would characterise such a level. In the RCMM this level is termed as *translational*, that is to say where research effort has a continuous and repeatable path to being directly translated into either product development or policy formulation.

At the other end of the spectrum, an immature research system can be seen as a situation where there is little or no targeted public support for the research theme in question (or if there is, it is ineffective) and other than serendipitous or coincidental circumstances (including informal contacts or personal knowledge on the part of the consumer of the research) there is no planned route for the application of research to commercial or policy support application.

The selection of levels in between is largely arbitrary, with little guidance on the matter in the literature. In an assessment of the use of maturity models in the field of new product development, (Fraser, et al., 2002) note that the original Crosby Quality Maturity Grid featured 5, (as does the CMM) and observe that maturity models typically use between 3 and 6. Because of the need in both CMM like staged models and maturity matrix models to provide descriptions of performance at each level, the complexity of the model increases with each level as does the difficulty of its application. (Fraser, et al., 2002) speculate that the majority of maturity models use no more than 5 levels.

In the case of the RCMM, with no well-established consensus on how to determine the appropriate number of levels, five levels of maturity were selected because:

1. As noted above 5 levels are used in a number of models, in particular the Software Capability Maturity Model.
2. An odd number of levels provide a “middle” state that represents a well-established level of maturity.
3. The demonstration of progression is more than a “beginning, middle and end” representation that a 3 level model would provide, allowing for sufficient granularity in the identification of key characteristics that can be used to support progression.

Having decided that the model should describe 5 levels of maturity, these levels were then described at a high level with broad statements. The lowest (*ad-hoc*) and highest (*translational*) levels were initially described in line with the characterisation above, followed by a description of the middle level (*established*). The definition of this middle level was important as it needed to represent a mid-point in the progression from an incoherent research system to a fully functional translational

system. With this in mind, this level reflected evidence of collaboration between researchers and evidence of involvement of the users of research outputs in the framing of research themes.

The remaining two levels (*collaborative* and *defined*) were then defined in a manner that represented intermediate steps in the progression of a research themes maturity, resulting in a tangible description of the Research Capability Maturity Model as shown in Figure 2.

		Dimensions		
		Human Capacity	Infrastructures	Networks & Relationships
Maturity	“Translational”	There is evidence of a pipeline of research from basic investigation to commercial application or policy definition facilitated by dedicated national facilities		
	“Collaborative”	National level research facilities exist with international collaboration with internationally recognised research performers		
	“Established”	Dedicated research facilities exist & there is evidence of collaboration nationally & internationally, with industry or policy maker participation		
	“Defined”	Communities of interest exist with some access to facilities and active research projects		
	“Ad-hoc”	Research is based on individual research interests with no institutional support or facilities		

Figure 2 Level descriptions

The issue of the relationship between the RCMM and the TRL scale was discussed throughout the model development. The TRL scale is one which places the development of technologies on a nine-point scale ranging from basic principles being observed through to technology deployment. While there is a potential relationship between the two, the TRL scale applies to the technology itself, while the RCMM describes the state of the research environment through which a technology might be developed. Furthermore, the RCMM is intended for both technology development and the formulation of policy advice, which does not map to the TRL scale.

With these broad descriptions of the 5 levels available, the first of two workshops was held to identify key indicators that would aid identification of the level at which research themes were operating in each of the three dimensions. Those attending the workshop were experts who, while not actively engaged in research of each of the themes, were sufficiently familiar with research activity within the theme at a national level in Ireland over some years. Some of those involved also had familiarity across a number of the themes in order to ensure that the indicators could be applied

consistently across the themes. Those in attendance were also identified with the expectation that they would carry out the assessment of one or more of the themes using the model as described below in the later steps.

In defining each of the indicators, consideration had to be given to ensuring that the indicators matched the overall level description, and also to ensuring that the indicators relating to a particular dimension were consistent with the indicators in the other dimensions.

Figure 3 shows the final model with each of the indicators associated with each dimension and level.

Phase 4 – Test – Relevance, rigour, validity, reliability in terms of both construct and content

With the model and its key indicators established, a number of test themes were used as an initial validation of its application, specifically the research themes of Renewable Energy and Transport. The purpose of this exercise was twofold. In addition to validating the structure of the model, it also allowed for the creation of a guide for the assessment of the other themes.

The use of the model is a qualitative exercise based on the expert judgment and experience of the assessor. The indicators in the model were not designed to be exhaustive, but rather were intended to provide a benchmark of the type and nature of those characteristics that an assessor would expect to be associated with a particular level.

DIMENSIONS

		Human Capacity	Infrastructures	Networks & Relationships
MATURITY	<p><u>Level 5: Translational</u> There is evidence of a pipeline of research from basic investigation to commercial application or policy definition facilitated by dedicated national facilities</p>	<p>Industry based researchers involved in Product Development Lifecycles</p> <p>Researchers participating in legislatively based, or ministerial appointed, fora that inform legislation or regulation</p>	<p>Nationally funded research centres</p> <p>Postdoctoral Training</p> <p>EU "Best in class" research infrastructures</p> <p>National Test & Demonstration Facilities, including end-user population for real-world feedback</p>	<p>Networks of interest featuring high levels of industry or policy-making participation</p> <p>IP frameworks available</p> <p>Consistent leadership roles in international standard setting forums</p> <p>Consistent leadership roles in international inter-governmental mandated scientific organisations.</p>
	<p><u>Level 4: Collaborative</u> National level research facilities exist with international collaboration with internationally recognised research performers</p>	<p>International Research Awards, e.g. ERC Research Awards</p> <p>International Travel Awards, e.g. Fulbright</p> <p>International Research Contracts e.g. EU Tender Awards</p> <p>Regular development or refinement of methods, techniques or processes that inform regulation</p>	<p>Nationally available equipment or platforms (e.g. equipment pools)</p> <p>Postgraduate training</p> <p>Participation in EU infrastructure networks</p> <p>National Test and Demonstration facilities</p> <p>Postdoctoral training</p>	<p>Inter-institutional research cluster/centres</p> <p>Industry collaboration in research including industry funding</p> <p>Industry participation in research theme definition</p> <p>Funding from policy-making organisations</p>
	<p><u>Level 3: Established</u> Dedicated research facilities exist and there is evidence of collaboration nationally and internationally, with industry participation</p>	<p>Established Principal Investigator Position(s)</p> <p>PI Led Research Teams with Postdoctoral Researchers</p>	<p>Purpose build lab space/purpose bought equipment</p> <p>Dedicated data infrastructures or repositories</p> <p>Postgraduate teaching modules and/or courses</p>	<p>Multiple teams concurrently participating in Framework/H2020 projects</p> <p>Industry or sectoral policy-maker led research themes</p> <p>Regular national conferences/workshops with some international participation</p>
	<p><u>Level 2: Defined</u> Communities of interest exist with some access to facilities and active research projects</p>	<p>Multiple Project Based PI Appointments</p> <p>Active PhD Level Research Projects</p> <p>Undergraduate courses with established lecturers</p>	<p>Defined undergraduate training</p> <p>"Allocated" general purpose lab space or equipment, evidence of institutional commitment through capital spending</p>	<p>National Workshops</p> <p>Inclusion in Framework/H2020 ids</p> <p>Recognised community of interest</p>
	<p><u>Level 1: Ad-Hoc</u> Research is based on individual research interests with no institutional support or facilities</p>	<p>No dedicated facilities, general purpose equipment etc.</p> <p>No dedicated training or education associated with the field</p>	<p>No dedicated facilities or general purpose equipment etc.</p> <p>No evidence of commitment through capital spending</p>	<p>No nationally organised/hosted workshops</p> <p>No associations, networks of interest</p> <p>Collaboration is based entirely on one-to-one or personal relationships</p>

Figure 3 Key Indicators

Following this test application, a second workshop was convened with largely the same participants as the first, with a number of additional assessors to cover a number of themes that were previously unassigned (specifically in the areas of biodiversity, tourism and ocean observation).

The second workshop considered a number of issues that arose in this first application of the model. These included:

1. The granularity of the target theme. This issue related to the selection of the research themes themselves, and whether the identification of sub-themes was required. The question posed by the assessors of the test themes was whether all sub disciplines in a research theme were required to meet the standard associated with a level. More precisely, the assessors were unsure whether the failure of sub-discipline to meet the standard should result in the entire theme failing to achieve a level. For example, in the area of ocean energy, the research infrastructure associated with wave energy in Ireland was found to be quite advanced with both the “Lir” facility in UCC and the SmartBay facility in Galway supporting TRL research from basic levels through to about Level 7. However, in the case of tidal energy, the infrastructure base was not as advanced.

There were two outcomes from the discussion on this issue. Firstly, in relation to infrastructure, the model was updated to include access to infrastructure as well as infrastructure itself. In the case of the example mentioned above, this meant that research centres that have access to tidal infrastructure in Northern Ireland were considered the same as infrastructure in Ireland. Similarly, formal access to infrastructures in the EU and beyond was to be viewed as sufficient.

Secondly, it was determined that each research theme had to be judged based on a broad assessment rather than a narrow one of the capacity available. For example, the subsequent assessment of the area of Ocean Observation determined it to be at the *Established* level. A key indicator for this level is that there be “established principal investigator positions”. While there are indeed such positions in the areas of chemical and biological oceanography, the assessment notes a potential weakness in relation to physical oceanography. However, this weakness was judged to be outweighed by the breadth of expertise in the overall field, and the historically strong presence at faculty level of physical oceanography in the country.

2. Bias towards research for industry application. The initial version of the model was focused on a research path that led to the translation of research outcomes to commercial applications. During the course of the discussion it became apparent that this is not always the destination for all publically funded research, with policy advice and formulation being another valid outcome for research outputs. The model was updated to cater for this.
3. Training and academic course development versus human capacity development. A specific issue arose as to whether training courses and structured education programmes such as degree programmes formed part of the infrastructure dimension or the human capacity dimension. The discussion concluded that such education programmes represent an infrastructure that delivers potential human capacity, but that this has to be harnessed through specific research programmes before definitive human capacity advances can be made.

Phase 5 – Deploy – In phases, first among collaborators, then target audience and finally to entire population

Following the clarifications to the model outlined above, a brief guidance document was prepared for the assessors as part of the wider research theme assessment exercise. Based on this and the deliberations of the previous workshop, the assessments of the research themes were carried out.

These were published in a draft Marine Research and Innovation Strategy, together with a series of background documents on each research theme which included a rationale for the maturity assessments. These documents were made available in a public consultation to which the public were invited to comment.

The public consultation took the form of a web-based questionnaire that covered the totality of the draft strategy. Two questions were specifically aimed at the maturity model. These were:

1. Are the five levels an appropriate classification of maturity? If not, what changes would you propose and why?
 - There were 21 responses to this question.
 - 8 were unambiguously positive.
 - 1 was unambiguously negative.

- The remainder were positive in a qualified sense. Two respondents were concerned with the term “ad-hoc” and how that might be perceived, however, it was retained as it is a widely accepted term for the initial level in maturity models.
2. Do the dimensions of Human Capacity, Infrastructure and Networks & Relationships appropriately capture the kinds of supports required by a Research and Innovation (R&I) System?
- There were 21 responses to this question.
 - 12 were unambiguously positive.
 - 1 was unambiguously negative.
 - 1 conflated the levels with the Technology Readiness Level scale.
 - The remainder were positive in a qualified sense with a range of suggestions for extending the definition of the dimensions and contextualising in an Irish specific context.

Independently, one in each of the questions, two respondents queried whether a staged model was appropriate in a research system context. The specific point both respondents made was that “translational” research can take place even in a research theme that exhibits the key indicators of the “ad-hoc” level. For instance, a single researcher can produce results that impact on policy.

A related issue raised by three respondents to the first question was whether the model adequately captures the concept of research excellence, as sometimes measured by metrics such as citation rates etc.

These are valid concerns; however, they are mitigated in two ways. Firstly, the model is designed to provide a classification of maturity across a particular domain, in this case marine research in Ireland. It is not intended to comment on the excellence of individual researchers, research groups or indeed institutions. At such lower levels of granularity excellence will no doubt occur, and will be reflected in both publication rates and the use of research outputs in translational activities. However, whether such excellence and outputs occur in a systematic manner is left to chance unless there is a framework in which to determine where research funding is required.

Secondly, it is an underlying assumption of the model that funding in research activity will result in both research excellence and societal good as argued by Graham Reid (Reid, 2014).

The model therefore indirectly supports scientific excellence and a focus on the utilisation of scientific outputs.

Phase 6 – Maintain – If acceptance is achieved to handle volumes

This phase represents the current state of the model's development, and represents the next opportunity for its further development. Potentially the model could be applied to any research domain, not just marine related research. Such application would provide an opportunity for further validation and could address some of the weaknesses discussed below.

Weaknesses in the model

The Research Maturity Model described in this document is guilty of many of the main criticisms of such models as listed by (Lasrado, et al., 2015), that is to say the model:

- Lacks theoretical foundation. In line with the maturity models examined by (Fraser, et al., 2002), the RCMM is structured according to our notions of good practice using experience-based principals.
- Lacks statistical basis. Again in common with those models examined by (Fraser, et al., 2002), the RCMM has been tested exclusively by means of qualitative and informal approaches such as interview and experience, with no quantitative or statistical analysis. The range and quantity of the responses received in the public consultation are not sufficient to adequately test the model in a quantitative sense.

The issue of research theme granularity, identified during the early deployment of the model remains an issue. Further use of the model in the marine research or any other context requires careful consideration of the scope to which is to be applied. Some basis for the selection of research themes needs to be identified. In the case of the preparation of the research strategy for which the RCMM was initially described, this was on the basis of established European topics referenced in policies and industry strategies.

Finally, an obvious failing of the model is that it is framed in the context of European Union research framework programmes. An abstraction to more generalised Transnational research cooperation mechanisms would be warranted.

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A Thriving Maritime Economy

The first goal of Harnessing Our Ocean Wealth is “A Thriving Maritime Economy”, which focuses on the market opportunities to achieve economic recovery with socially inclusive and sustainable growth.

This document considers seven broad themes under this heading, namely:

Bioresources

- Aquaculture and Biomass Production
- Wild Resources
- Processing for Food and Other Use
- Value Added Products

Advanced Technologies

Subsea Resources

Renewable Energy

Tourism

Transport

Security & Surveillance

Bioresources – An Overview

Introduction

Marine bioresources comprise species that exist naturally in the marine environment and those marine species that can be cultured, whether at sea or on land; they form the basis of food and non-food products and remain largely under-exploited compared to terrestrial biological resources despite the high-growth potential that they offer. The majority of Ireland's marine bioresources, principally harvested from wild fisheries and supplemented by aquaculture, are used as food products and food ingredients; with a minority contributing to cosmetic, horticultural, animal feed and health, chemical and nutritional supplement products.

Irish interest in the sustainable exploitation of marine bioresources is rising in line with international activity, which targeted marine environments as sources of biological, genetic and chemical diversity as the basis for novel compounds offering a wide range of applications across many industry sectors.

Oceans cover 70% of the planet's surface area. The marine and coastal environments contain diverse habitats and environmental niches, which in turn support an immense diversity of biological species. Oceans are recognised together with tropical rainforests as the greatest source of biodiversity on Earth. The marine environment hosts most of the known 34 phyla of animals on Earth, and 20 phyla that are unique to the marine. A further illustration of the complexity and biodiversity of the marine environment is that algae, a marine bioresource of increasing commercial interest, span four kingdoms: Plantae, Chromista, Protista, and Bacteria.

The oceans have an important role in maintaining the global environment; they produce up to 80 percent of our oxygen and act as a sink for carbon dioxide – absorbing large amounts generated by human activities, in addition to having a key role in maintaining Earth's climate as a result of the movement of water by ocean gyres and other ocean currents. Though the oceans are one of the remaining sources of wild food on the planet they provide only 129 million tonnes per annum or 1.46 percent of the total global food supply. This is at a time when demand for food is set to continue to increase, and when agriculture is seen as the prime driver of climate change and major contributor to loss of biodiversity.

Ireland's marine bioresources comprise many forms, e.g. whole fish, aquaculture products, macro-algae (seaweed) – both wild and cultured, micro algae, marine invertebrates and

marine micro-organisms. Ireland's marine territories offer a natural competitive advantage, providing opportunities to support a myriad of enterprise activity based on the sustainable use of marine bioresources in connected industry sectors such as food, health and emerging bio-based industries.

Marine Bioresources – Positioned to respond to global challenges

European and Irish policy converges in generally agreeing on global factors that should be taken into account when deciding on future actions concerning marine bioresources and other areas; including actions that can galvanise Ireland against possible adverse global issues, as well as stimulate Irish activities designed to allow the country to capitalise on the social and economic opportunities, which global change in the broadest sense will create.

These factors include:

- **Globalisation:** Global issues have already affected trade and the effect of globalisation is set to continue by way of new entrants into enlarged global markets, in turn bringing innovation and changes in value chains.
- **Demographics:** Point to a growing divide between countries with youthful and aging populations, global skills shortages, expanded middle classes in developing economies.
- **Global economic uncertainty/public debt:** The recent financial crisis continues to affect the capacity of many countries to respond to major social, economic and environmental challenges, with knock-on consequences for businesses.
- **Geo-political volatility:** Where local issues lead to difficult relationships between nation states, economic sanctions and conflict including loss of human life.
- **Technological advances:** Transform life, business and the global economy resulting in opportunities for the creation of new products and services, business models, organisational structures, manufacturing processes and value chains, in a more connected world.
- **Individual empowerment:** The adoption of new technological advances, better health, and wider provision and adoption of education globally is a significant driver of change in the global economy and society.
- **Climate change:** Climate will test the resilience of natural and built systems globally, with food production and ecosystems being particularly vulnerable. Environmental-related rules and regulations can be a driver of innovation in the longer term, but they also place significant cost and administrative burdens on individual firms,

particularly those in manufacturing. Environmental factors are increasingly taken into account by consumers when making purchasing decisions.

- **Water, energy, and food nexus:** The demand for water, energy and food resources (the WEF nexus) is anticipated to increase at a rapid rate over coming decades; exacerbated by climate change.

Developing the economic value of Ireland's marine bioresources needs research to help solve the sustainability and efficiency issues of existing harvesting activity, add value to both harvested and cultured marine bioresources and manage the impact of these activities. This research will have to be undertaken in the context of the global challenges outlined above; to address the domestic challenges of marine spatial planning and to balance the competing needs of economic development and environmental protection.

Research is also required in fields related to existing ones which offer significant interdisciplinary research potential, especially in marine biotechnology, to ensure Ireland can benefit from the myriad of opportunities it offers in support of environmental, economic and societal sustainability.

Ireland's ability to engage in research that supports the development of our marine bioresources is strengthened by a cohort of principal investigators with proven capabilities in relevant areas. The availability of Marine Institute ocean-going research vessels, equipped with an array of mapping and sample retrieval systems, including remotely operated vehicles, enable researchers to access the full extent of Ireland's marine territories.

A policy context to the sustainable use of marine bioresources

Marine bioresources will contribute to the continued growth and competitiveness of Irish agri-food and play a pivotal role in Ireland's economic recovery. Targeted research and development, partnerships between industry and the scientific community, and the development of innovative, value-added products are common themes emphasised by national policy as fundamental to achieving industry sector growth targets.

At the core of marine bioresources related policy is the role that these resources have in contributing to the growth of Ireland's largest indigenous industry sector – food production and processing, whilst also offering considerable scope to contribute to growth in other emerging areas of Ireland's economy.

Food Harvest 2020¹⁸ and more recently, FoodWise2025¹⁹ each point to growth opportunities for Ireland’s marine bioresources sector in food – primarily as a source of food and food ingredients, but also including other areas. FoodWise2025 is clear in highlighting these opportunities:

In addition to food production, there is a growing opportunity for Ireland to achieve a strategic advantage in the marine biotechnology field. Our strengths in this area lie in our extensive and high quality marine resources, a recognised capacity in marine biological sciences R & D and strong technological capabilities in the food, pharmaceutical, medical devices and nutraceutical spheres. The importance and market potential of this emerging area has been recognised by the EU and domestically under the National Research Prioritisation Exercise and the integrated marine plan “Harnessing our Ocean Wealth”.

The National Strategic Plan for Sustainable Aquaculture Development²⁰ outlines a number of specific research actions to support the competitiveness and sustainability of the finfish, shellfish and seaweed cultivation industries. The plan reflects Ireland’s ambitions under the Common Fisheries Policy and informs investment priorities for aquaculture under the European Maritime and Fisheries Fund.

The raft of European policy relevant to the role and opportunities for marine bioresources reflects a focus on their contribution to the development of the European Bioeconomy. With clear priorities for the bioeconomy to develop on the back of the conversion of renewable resources from terrestrial and marine environments there are clear opportunities for marine bioresources to contribute to food, animal feed and other bio-based products and in doing so support Europe to meet the so-called grand challenges for the 21st century.

Europe expects that additional growth will result from sustainable primary production, food processing, industrial scale biotechnology, and enhanced bio-refining activities, leading to new bio-based industries and to transform existing ones to meet new market opportunities

¹⁸ Food Harvest 2020 (Executive Summary) (available at <https://www.agriculture.gov.ie/media/migration/foodindustrydevelopmenttrademarkets/foodharvest2020/2020FoodHarvestExeSummary240810.pdf>)

¹⁹ <https://www.agriculture.gov.ie/media/migration/foodindustrydevelopmenttrademarkets/foodwise2025/report/FoodWise2025.pdf>

²⁰ <https://www.agriculture.gov.ie/media/migration/seafood/marineagenciesandprogrammes/nspa/NationalStrategicPlanSusAquaDevel181215.pdf>

for bio-based products. The EU estimated that every euro invested into biotechnology related R&D would generate a ten-fold return on investment.

The EU's dedicated marine strategy, "Blue Growth"²¹, is to the fore in identifying actions and opportunity areas related to marine bioresources, including aquaculture, and the use of biotechnology to unlock high-value compounds from marine bioresources for use by health, cosmetic, industrial bio-materials, food, feed and chemical industries. The EU common fisheries policy (CFP)²² aims to continue to influence change in the harvesting and management of wild fish stocks. Blue Growth and the CFP each stress the importance of safeguarding biodiversity and protecting the marine environment in capturing or cultivating marine bioresources.

Research areas included in the EU Horizon 2020 challenges provide insights to growth opportunities for the marine bioresources sector, which are common with national goals. Particularly relevant in an Irish context are the challenges that relate to:

- Improved health and wellbeing
- Sustainable primary production and processing systems for food and other bio-based products
- The sustainable management and exploitation of marine bioresources, food and feed security and safety, the competitiveness of the agri-food industry and the sustainability of food production processing
- Transforming industrial processes and products into environmentally friendly bio-based ones, developing integrated bio-refineries and new markets for bio-based products
- Understanding the impact of climate change and other environmental changes on the marine environment

Marine Bioresources – Sector driven research

Sector driven research plans make research connections between the marine and industries unconnected with the marine. This multi-sector approach to the use of marine bioresources is currently reflected in national and European research policy, which focuses on harnessing

²¹ European Commission (2012) Blue Growth opportunities for marine and maritime sustainable growth COM/2012/0494 final Brussels

²² http://ec.europa.eu/fisheries/cfp_en

an array of research competencies to create value from the use of marine bioresources in multiple market areas.

Activities that offer growth and employment linked to marine bioresources, whilst at the same time addressing a range of societal, economic and environmental challenges by supporting excellence in research, include primary production areas of aquaculture and fisheries; the processing of marine bioresources; creating value-added products from marine bioresources; and the optimised management of marine resources and the marine environment.

Conditions required to develop Ireland's marine bioresources research activities

Exploring marine environments and converting marine biomass into new products and processes requires contributions from diverse scientific and engineering disciplines. The many, and at times, cross-cutting opportunities for marine biotechnology and related research in the food, health and materials sectors, and within the established marine origin food sector, demand inputs from multiple sources to realise them. A concerted approach involving researchers, industry and policy working closely to create the conditions required to realise the promise of the marine bioresources sector is required. A relatively few "imperatives" have to be met in creating the environment in which Irish marine bioresources related research can flourish. The principal elements are to:

- Retain a focus on scientific and engineering excellence in all aspects of and at all stages in the evolution and application of knowledge
- Implement marine bioresources related actions identified in national policy, such as those identified in the National Strategic Plan for Sustainable Aquaculture Development
- Continue efforts to establish a greater level of visibility and recognition for marine bioresources research in national and EU policy
- Employ greater precision in the application of research effort towards the "low-hanging fruit" to secure early successes that will contribute to Ireland's ability to be globally competitive in food, health and materials related activity
- Commit to the long-term funding of research designed to unlock the potential of marine organisms to contribute novel compounds to address human health conditions
- Enhance the available research infrastructures by providing access to dedicated "state of the art" facilities and technologies to collect, screen, assess and develop

novel products and processes from marine bioresources and enable the continuous development of new research capacity

- Reinforce the deployment of a sustainable approach to the exploitation of marine bioresources
- Provide a focal point for marine bioresources research as a means of integrating leading and relevant related capabilities to perform internationally competitive research with commercial outcomes

Research Themes

Future marine bioresources research is driven by the need to support primary production from fisheries and aquaculture activities, to identify opportunities to maximise the use of marine origin materials in the creation of food and novel bio-based products and to develop capabilities to process marine bioresources for food and other bio-based products. At the same time, such research must be informed by the need to protect and preserve Ireland's marine environments and marine biodiversity. These themes and associated drivers are described in the following sections together with assessments of research capabilities for each theme.

Bioresources – Aquaculture and Biomass Production

Aquaculture has a key role as a sustainable source of supply of materials for use as food and other products. Traditionally the focus of Ireland’s aquaculture activity was the production of finfish and shellfish for food use, an area that continues to be identified as offering significant growth opportunities coupled to the increased demand for the sustainable production of animal protein. To take advantage of the increased demand requires increases in the output from aquaculture, with an emphasis on high-value species. Research to support culturing marine species for food will continue and be expanded to include culturing species for use in areas other than food. The production of biomass by culturing macro- and micro-algae provides an additional source of raw materials for use in a variety of market areas.

Prioritised Research Areas

Breeding and species selection

New breeding programmes, including programmes to support the introduction of new high-value species, are required to provide farmers with access to improved stock. The impact of selective breeding programmes is likely to be seen in improved performance at the farm level. Such programmes will target increased growth rate, reduced mortality and greater resistance to disease in finfish, shellfish and seaweeds. Long-term genetic gains are expected as a result of improved breeding programmes, in addition to improving the cost competitiveness of production. Diversifying the range of species and the introduction of new species should be supported by appropriate breeding programmes.

Disease and stock health

The health of animals used in the human food chain is a global priority. Steps are required to continuously improve the health status and welfare of farmed species at all stages in their life cycle. New management strategies and other approaches are required to minimise disease and control parasites that have a negative effect on the cost of production and to improve animal welfare. Early warning systems of health threats and improved diagnosis are required. Research is also required to identify measures to minimise the use of treatments and increase the understanding of factors that have led to tolerance/resistance to treatments. Novel approaches to enhance biosecurity and bio-containment, thus minimising the spread of disease between wild and farmed stock, are required.

Feed

The reliance on traditional sources of feed for fed-finish is not sustainable. Alternative, sustainable sources of protein are required to support the expansion of fed-finish activity and ensure balanced nutrition throughout the life cycle. Novel feed sources and the potential of using functional ingredients should be investigated. Knowledge about the interaction between genetics and nutrition will allow developments that lead to improved feed efficiency. Existing practices of in-feed medication, particularly antibiotics, should be examined from the perspective of their contribution to the improved health of and/or possible risk to the consumer.

Production and production systems

The global demand for marine biomass for food and other use is set to increase and methods that allow Ireland to increase aquaculture output are required. Production systems have to be sustainable and enable new species and new culturing regimes to be introduced. These systems should support the anticipated expansion of cultured biomass for food, non-food use, and as new sources of feed. Increasing output from sustainable sources requires the role of aquaculture in creating new marine biomass supply-chains to be examined. Producers require knowledge concerning sustainable aquaculture production systems that are focused on improving overall competitiveness, are suitable for different species, improve fish welfare and health, and minimise biosecurity risks. In this context there is a need for insights to better understand the economic and environmental impact of alternative/contrasting production systems for aquaculture; particularly regarding the large scale culturing of algae and the scope that exists to introduce integrated multitrophic production systems and where such aquaculture activities might be optimally located.

Aquaculture Research Capability Assessment

Ireland’s aquaculture activity includes finfish, shellfish and algae (macro- and micro-algae) production and is the source of all cultivated biomass used in the creation of food and other bio-based products. Whilst common competencies are required in developing products from marine biomass, the scientific research capabilities required to maximise the yields from cultivated fish, shellfish and algal resources differ.

A common research profile exists across each aquaculture area reflecting the need to expand capacity in what are priority research areas for the bioeconomy. On-going research is mostly led by institutional based PIs funded from national and international sources but with little apparent collaboration nationally. With the exception of algae, undergraduates have little or no exposure to aquaculture.

Algal Cultivation	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 6: Irish Research Maturity in Algal Cultivation showing the different levels of maturity for human capacity, infrastructure and networks

Finfish Aquaculture	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 4: Irish Research Maturity in Finfish Aquaculture showing the different levels of maturity for human capacity, infrastructure and networks

Shellfish Aquaculture	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 5: Irish Research Maturity in Shellfish Aquaculture showing the different levels of maturity for human capacity, infrastructure and networks

Bioresources – Wild Resources

Producing food for an expanding global population is a challenge faced by all food producing nations and one that is already attracting a wide range of expertise seeking technical and other resolutions to match demand with supply. Already providing 16 percent of all animal protein consumed globally, scope exists to increase the contribution of fish in resolving food security issues. To do so requires the sustainable exploitation of wild fisheries; providing fish whilst maintaining natural resources and without damaging or destabilising the marine environment. This is a challenge recognised by European and Irish actions in implementing the common fisheries policy. Research related to the capture of species from wild resources under this heading includes all “wild” resources – fish, algae, sponges and other invertebrates harvested for food or other uses.

Prioritised Research Areas

Knowledge of wild resources

Expanding the range of species for food and other use relies on knowledge regarding multi species interactions, maximum sustainable yields (MSY) and setting management targets. The modalities and execution of wild marine harvesting has to be informed by accurate assessments and feedback from monitoring systems designed to provide knowledge about stocks and the sustainability of harvesting. As demand for algal biomass increases, research conducted at the level of individual species, to quantify available biomass and to support the definition and introduction of sustainable harvesting regimes for species of commercial interest is required.

Management of resources

Factors that influence the capacity of wild stocks of marine species to continue to meet the demands from the processing sector have to be understood in greater detail. The development of prediction and modelling tools which can function at a higher level than the species is required to support an integrated approach in decision making relating to the exploitation of all wild species and to enable the implementation of an ecosystems approach to the management of all wild resources. Methods to support greater selectivity in the modalities and execution of the harvesting of marine biomass are required, so as to manage the impact of wild harvesting on the marine environment. The introduction of revised licensing regulations for seaweed harvesting, which are linked to sustainable harvesting regimes for species of commercial interest, are required to preserve stocks.

Optimal use of resources

Adding value to wild caught/harvested species is a challenge for Ireland’s bioresources sector, which also seeks to maximise the potential to increase wild catch fisheries and harvested seaweeds without threatening long-term sustainability of natural production of all marine species. Ireland currently exploits its marine fisheries resources to the full extent of harvesting permitted under the CFP. There may, however, be potential in commercialising species which are not currently harvested and developing higher value added products from those which are.

Wild Marine Bioresources Research Capability Assessment

The wild capture of fish and shellfish from waters around Ireland is the largest source of marine biomass with close to 290,000 tonnes landed in Ireland during 2014. The wild fisheries sector is managed in accordance with EC regulations under a common fisheries policy and capture is limited by the imposition of quotas and most is used as human food. The majority of the 40,000 tonnes of seaweed reported as harvested in Ireland is from wild sources and is dominated by the harvest of one species *Ascophyllum nodosum* (approx. 25,000 tonnes) used in the production of alginates and other polysaccharides. Other uses for wild harvested seaweed include animal feeds and animal health, horticulture, cosmetics, food and food ingredients.

Research capabilities in fisheries and seaweeds are based around a small number of PIs in three institutions, some of whom are internationally renowned experts in their areas reflected in them having secured European and national research funds. Undergraduate teaching programmes in Marine

Fisheries	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 7: Irish Research Maturity in Fisheries showing the different levels of maturity for human capacity, infrastructure and networks

Seaweeds	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 8: Irish Research Maturity in Seaweeds showing the different levels of maturity for human capacity, infrastructure and networks

Sciences include modules in phycology, and marine biology, including fisheries. Whilst there are no large scale harvesting of species other than fish and seaweeds, there is an increased interest in other marine organisms, such as bacteria, sponges, jellyfish, sea squirts, sea cucumbers, starfish and micro-algae as sources of novel compounds.

Bioresources – Processing for Food and Other Use

Ireland's seafood sector is comprised of finfish, shellfish, smoked, pelagic and whitefish producers. There are also a small number of firms harvesting seaweeds for food and other use. Whether originating from wild harvested or cultured sources marine bioresources, sometimes described as marine biomass, are processed as a step in the value-chain. In the case of fish used for food, the majority of processing is primary in nature and typically involves filleting, preservation and packaging. Processing of algal resources, or the co-products of fish processing, typically involves a transformation of the raw materials using thermal, chemical, enzymatic or other processing technique, and subsequent bio refining. The potential exists to shorten the supply chain by a closer integration of culturing processes with transformation and bio refining. This supports expanding the use of cultured marine biomass for more than just food use. Ireland is largely reliant on equipment suppliers for innovations in processing equipment. Other than as a research topic, there is no processing of the range of wild species used in discovery related activity.

Prioritised Research Areas

Supply chain development

Sensory and other changes in bioresources are initiated on harvesting. Methods to minimise delay between individual processing steps, including time to market or end use, are needed to secure maximum value from all species. These measures include steps to enhance the storage and transport of in-process and final products that focus on enhancing the safety, quality and the stability of nutrients and bioactive compounds. The capacity to demonstrate the provenance and authenticity of food, food ingredients and materials with applications in human health demands reliable and efficient traceability systems.

Sustainable processing technologies

Novel technologies are needed to provide sustainable and competitive processes at all stages in the harvesting or culture, transformation and refining of marine bioresources. The availability of such processes is essential in supporting the production of SMART food and other bio-based products. A key aspect of all future processing technologies is their ability to minimise waste and to maximise the recovery of value from previously discarded, under-utilised and processing co-products. Novel processing technologies are identified as key to providing efficient production processes for bioactive, technical and functional products and ingredients and minimally processed marine origin food products. Goals to expand the use of marine bioresources as the source of high-value ingredients and in health, cosmetic, chemical biomaterial products and in other applications have to

be supported by processes that ensure continuity of supply, meet exacting safety and product quality requirements and offer processors flexible, adaptive production systems.

Integrated bio refining

As the complexity of end-use applications for marine derived materials increase, new concepts of bio refining marine biomass are required. Customised products based on novel culturing processes and bioprocessing that stimulate organisms to produce specific compounds require greater integration of processing steps. Significant scope exists to adapt technologies such as those used to support the production of new products. Integrated, multi-stream bio refining can enhance sustainability and bring about improvements in production output and overall competitiveness, as a result of closer interaction between production and processing steps, including refining multiple species or sources of biomass into specific fractions. The concept of integrated bio refining can include using biological resources to create biomass. Marine micro-organisms offer scope to become future bioprocessing “factories”. Of particular interest is exploring the scope to use biological resources in the form of micro- and other production organisms to create new more sustainable biotechnological production methods.

Marine Biomass Processing Research Capability Assessment

A variety of processes are used in the conversion of fish and seaweeds into food and other products. Typically biomass processing has become more complex and includes methods to ensure maximum use of raw materials thus minimising waste. Strong linkages exist between sustainability and processing, where efforts to minimise any adverse effects of processing on environmental status is a priority. Ireland’s fish processing sector relies greatly on processing innovations developed by suppliers; and product development activities are supported by various semi-state agencies. The increasing importance of non-traditional sources of marine biomass – principally macro- and micro-algae, although industrial fin fish and crustacean species may also play a role, provides Ireland’s research providers with opportunities to develop a bio refining approach to transform raw materials into specific compounds. In doing so new opportunities for collaboration involving biologists and engineering expertise are being created in what is generally seen as an emerging area of research.

Bioresource Processing	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 9: Irish Research Maturity in Bioresource Processing showing the different levels of maturity for human capacity, infrastructure and networks

Bioresources – Value Added Products

Major opportunities exist to create high-value products, in addition to food from marine bioresources. The success of developing food ingredients derived from fish and macro-algae is widely known, with such ingredients providing food products with enhanced stability, flavours, colour and used as edible films and food coatings. In addition to providing foods with important techno-functional properties, marine bioresources have become established as ingredients used in functional foods, food supplements and nutraceuticals. Compounds derived from species of fish, macro- and micro-algae include lipids, proteins, polysaccharides, pigments, fibre, and minerals all of which are linked to providing nutritional and other benefits to humans and animals. There are also new pharmaceuticals derived from marine organisms to treat pain, some cancers and to reduce levels of triglycerides that are associated with atherosclerosis. However, it is not only food and health areas that offer opportunities for marine derived compounds. Marine organisms are known sources of enzymes, biomaterials, industrial chemicals, cosmetics, and personal care products and with known applications in the horticulture and feed sector.

Prioritised Research Areas

Bioprospecting and discovery

Bioprospecting relies on collaborative research and technologies developed outside the marine biological area. The search for new approaches to locate, collect and assess the potential of marine organisms as sources of novel materials remains a major challenge. Extreme marine environments are not the only source of novelty, with much to discover in more accessible locations and from activities that already process marine organisms. Expanding the scope and increasing the intensity of bioprospecting expands the supply of new organisms to screen for novel compounds and bioactive materials. New tools and methodologies are required to enhance the bio discovery process. Data mining techniques target areas of high marine biodiversity; remote sensing can be used to assess abundance of some resources; and metagenomics allows DNA to be recovered from microorganisms that are not easily cultured. Developing greater capacity for bioprospecting and discovery is a way of attracting new expertise and capabilities to engage in marine bioresources research. The biodiversity of the marine environment is recognised as a rich source of natural compounds. Increasing the rate of the discovery, identification, extraction, and targeted delivery and incorporation of novel bioactive compounds is fundamental in supporting the development of a wide range of value-added products.

Food, feed and food ingredients

Marine bioresources are proven sources of food, feed and food ingredients. New opportunities exist to expand the use of these resources for higher value products and foods that are inherently healthy. High on the research agenda are functional ingredients derived from marine bioresources for specific dietary needs. Target organisms include fish and algae, where early work confirmed their potential to contribute more than basic nutritional components. The recovery of compounds from materials discarded during processing is an immediate opportunity to add value by using them in food related applications. Options also exist for research to support the development of products that target animal feed and ingredients and which are based on marine bioresources, particularly marine derived proteins, lipids and minerals. Opportunities also exist to add value to traditional fish products by the development and adoption of new processing methods to enhance shelf-life, food safety, and convenience in ways that meet consumer demands.

Health and biomaterials

The marine environment is recognised as a major source of compounds with pharmaceutical potential. The health sector has targeted marine derived molecules as new pharmaceutical entities and in doing so continues to emphasise the potential of marine origin materials in drug discovery. Marine compounds demonstrate a range of anti-tumour, anti-inflammatory, analgesia, immunomodulation, allergy, and anti-viral properties in bioassays; and several approved drugs are derived from marine sources. Improvements in gut health and cognitive development are also being targeted by marine compounds. Pharmaceutical firms recognise a role for marine derived enzymes in supporting bioprocessing methods to produce new drugs. Several medical devices are based on materials derived from algae; and together with marine origin biocompatible materials, for use in medical devices, for drug delivery or in the repair, replacement or regeneration of tissue are expanding research areas. There are signs of convergence between food and pharma that offer scope for marine compounds to fill needs for specialised diets to provide nutrition for specific cohorts; e.g. the very young, older persons and persons unable to consume “normal diets”.

Other bio-based products

Marine bioactives and other marine derived compounds offer potential to support a wide range of bio-based and other products, providing scope to expand the use of marine bioresources and stimulate culturing activity. Target markets for such materials include industrial chemicals, cosmetics, personal care, agriculture and horticulture applications and in the fish aquaculture sector, where there is an increased demand for alternative feedstock to replace traditional fishmeal. Marine derived enzymes can support the expansion of industrial bioprocessing. Amongst the opportunities for these products are the so called “low-hanging fruit”, these offer researchers few barriers by way

of regulatory compliance, market/customer acceptance or the availability of bioresources as the source of novelty.

Marine Biomass Discovery and Characterisation Research Capability Assessment

There is a wide level of acceptance that most marine biological resources remain largely undiscovered; and the opportunity for the sustainable exploitation of marine biodiversity remains to be fully grasped. These views coincide with an increased policy awareness regarding the potential role of marine bioresources as sources of novel medical molecules, bio-plastics, enzymes and biocides, in addition to food. European policy concerning the bioeconomy highlights not only the need for food production systems to be more sustainable, but also identifies marine bioresources as a

source of novel processes and products. National research funds created research critical mass and stimulated collaborative research in a range of related areas supportive of the exploration and discovery of novel compounds from marine bioresources. A solid foundation of internationally recognised research involving a cohesive group of PIs from Irish universities and research institutions exists to generate knowledge that supports the creation of high-value marine origin products.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 10: Irish Research Maturity in Bio Prospecting & Bio Discovery showing the different levels of maturity for human capacity, infrastructure and networks

Advanced Technologies

Overview

Ireland's existing capabilities in ICT and engineering provide a solid foundation to tap into emerging global markets for marine technology products and services in areas such as sensors, platforms, advanced materials, subsea communications, robotics, computer vision, simulation, observation, forecasting, informatics and modelling.

This was initially recognised through Sea Change (2007-2014)²³ and the associated Discovery Research Measure, which aimed to bring together knowledge and expertise from non-marine areas and focus it on marine applications. It recognised the opportunity to stimulate areas of basic and applied research in areas that offer high growth potential such as marine technology, marine biodiscovery and Ocean Energy.

Subsequent investments included the Beaufort Marine Research Awards in ICT and Sensors, the development of National Test and Demonstration Infrastructure such as SmartBay, and the elaboration of the SmartOcean strategy (SmartOcean, 2010²⁴). Clusters of activity and world-class infrastructure have emerged through the national SmartOcean network, the Irish Maritime and Energy Resource Cluster (IMERC) and state investments in ICT centres of excellence and infrastructure. This provides a solid foundation to establish Ireland as a centre of excellence in the development, test, demonstration, commercialisation and delivery to market of the next generation of innovative marine technologies and technology based services.

Marine Technology is an emerging sector with significant market potential in a growing global blue economy. In its recent Ocean Economy Report, SEMRU reports an increased turnover of 27% to €71 million, superseding the initial target set out in Harnessing Our Ocean Wealth of > €61 million. Exports almost doubled in this time period. Recent figures also suggest further market opportunities in this domain. For example, a recent study reported that business activity from companies across the US in ocean measurement, observation and forecasting produces annual revenue of \$7 billion (US IOOS, 2016)²⁵.

Expertise across the ICT research and enterprise sector is also recognised as a key enabler for the achievement of developmental and management objectives across the entire marine sector. It

²³ SEA CHANGE – A Marine Knowledge, Research & Innovation Strategy for Ireland 2007–2013 (available at <http://oar.marine.ie/bitstream/10793/69/1/Sea%20change%20part%20I.pdf>)

²⁴ Harnessing Ireland's Potential as a European and Global Centre for Ocean Technologies, 2010 (available at http://www.smartocean.ie/sites/default/files/img/SmartOcean_Consultation_Document.pdf)

²⁵ https://ioos.noaa.gov/wp-content/uploads/2016/04/oceanenterprise_feb2016_Secure.pdf

supports the growth and competitiveness of established sectors such as oil and gas, transport and shipping, and fisheries and aquaculture, which are facing increasing global challenges. It also enables the potential of emerging marine sectors such as marine renewable energy, marine environmental monitoring, marine surveillance and marine biotechnology.

Research in ICT continues to be a priority area for Ireland (Innovation 2020)²⁶ and the advanced marine technology opportunity is aligned with the national enterprise policy (Enterprise 2025)²⁷ that sets out to build on our comparative strengths and core competencies in our main exporting sectors and to realise untapped potential of sectors that present opportunity for growth. This is also recognised in the report from the Our Ocean Wealth Development Task Force (Development Task Force, 2015)²⁸ that sets out a strategic framework, which includes the ‘marinising’ of existing sectors where Ireland already has internationally recognised competence and capacity, such as ICT.

Context

Ireland has a robust and highly successful home-grown ICT sector, built on the substantial knowledge and research base of numerous Irish universities and ICT research institutes. Research in ICT continues to be a priority area and it is one of the six broad enterprise themes in **Innovation 2020**, covering the 14 areas from the **National Research Prioritisation Exercise**. The national enterprise policy **Enterprise 2025** sets out to build on the comparative strengths and core competencies in our main exporting sectors and to realise untapped potential of sectors that present opportunity for growth. It clearly identified ICT as a strength and Marine & Maritime as an area of untapped potential.

Harnessing Our Ocean Wealth (2012)²⁹ outlines marine ICT as an emerging sector of the marine economy with potential for growth. The subsequent report from the Development Task Force (2015)³⁰ recognises the need to ‘marinise’ our existing ICT sector, building on existing investments and the recognised competence and capacity across indigenous and FDI enterprises, to leverage additional opportunities in marine related markets. In addition to having significant export potential

²⁶ Innovation 2020 (2016) (available at <https://www.djei.ie/en/Publications/Publication-files/Innovation-2020.pdf>)

²⁷ Enterprise 2025 Ireland’s National Enterprise Policy 2015-2025. Department of Jobs, Enterprise and Innovation, Dublin 2015

²⁸ Our Ocean Wealth Development Task Force - report to the inter-departmental marine coordination group (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/news/Final%20Our%20Ocean%20Wealth%20Development%20Task%20Force%20Report.pdf>)

²⁹ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

³⁰

<http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/news/Final%20Our%20Ocean%20Wealth%20Development%20Task%20Force%20Report.pdf>

in a growing global blue economy, it also acts as an enabler for enhancing the growth, competitiveness and sustainability of a number of established and emerging marine sectors earmarked for growth in *Harnessing Our Ocean Wealth* (2012).

From a European policy context, the role of technology in creating an opportunity for the development of the blue economy is recognised in **Blue Growth (2012)**³¹ – an initiative to harness the untapped potential of Europe’s oceans, seas and coasts for jobs and growth. The **European Strategy for Marine and Maritime Research (2008)**³² had previously highlighted the importance of science and technology development for reconciling promotion of sustainable economic growth in sea-based activities with environmental conservation. European policy measures, set out to form the bedrock for blue growth, also reinforce the importance of R&D in marine technology. **Marine Knowledge 2020**³³ presents a strategy on improving marine knowledge as a “key element to achieve smart growth in the European Union in line with the Europe 2020 Strategy”. A conservative estimate of the benefits of creating an integrated marine data network to replace the current fragmented network, is €300 million per annum. This will also open up new opportunities for innovation and growth. Similarly, the **EU Strategy for the Atlantic (2012)**³⁴ and the **Atlantic Action Plan (2013)**³⁵ highlight a number of priority areas for research and investment to drive blue growth in the Atlantic area. A number of these areas are directly underpinned by developments in marine ICT.

Overall, the Digital Agenda forms one of the seven pillars of the **Europe 2020 Strategy**³⁶ and proposes to better exploit the potential of Information and Communication Technologies (ICTs) to foster innovation, economic growth and progress. In **Horizon 2020**³⁷, ICT-related topics can be found in all priorities, including 'Excellence Science', 'Industrial Leadership', and 'Societal Challenges'. Horizon 2020 will be a key support to the implementation of the **EU Atlantic Action Plan (2014 – 2020)**³⁸ which has an objective to develop *a European Atlantic ocean observing and predictive capability*. Observing systems, data sharing and technology development are also priority areas

³¹ European Commission (2012) Blue Growth opportunities for marine and maritime sustainable growth COM/2012/0494 final Brussels

³² [https://ec.europa.eu/research/participants/portal/doc/call/fp7/fp7-ocean-2011/30283-com\(2008\)534-a_european_strategy_for_marine_and_maritime_research_en.pdf](https://ec.europa.eu/research/participants/portal/doc/call/fp7/fp7-ocean-2011/30283-com(2008)534-a_european_strategy_for_marine_and_maritime_research_en.pdf)

³³ http://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020/index_en.htm

³⁴ ECO/306 EESC-2012-1298

³⁵ European Commission (2013) Action Plan for a Maritime Strategy in the Atlantic area - Delivering smart, sustainable and inclusive growth COM/2013/0279 final. Brussels

³⁶ European Commission (2010) *EUROPE 2020 A strategy for smart, sustainable and inclusive growth* COM(2010) 2020, March 2010 Brussels

³⁷ <http://www.horizon2020.ie/>

³⁸ EU Atlantic Action Plan (2014 – 2020) & Inter Regional Funding Opportunities <http://oar.marine.ie/bitstream/10793/962/1/EU%20Atlantic%20Action%20Plan%202014-2020%20and%20InterRegional%20Funding%20Opportunities.pdf>

identified in the process of developing the **Galway Statement on Trans-Atlantic Ocean Co-operation**.

Relevant Documents / Sectoral Plans

Harnessing Our Ocean Wealth (2012) targets a number of sectors for growth, noting that we can achieve substantially more from our marine economy given existing expertise and our extensive marine assets. The application of expertise in marine ICT can help realise these ambitions through facilitating exploration and research, identifying and fulfilling new opportunities for innovation and growth, and enabling appropriate monitoring, planning and regulation.

Harnessing Our Ocean Wealth (2012) further outlines a number of key enablers and associated actions to realise this vision. Thematic areas that can be readily supported through a national capacity in marine ICT include:

- marine spatial planning
- licensing and regulation (Action 2)
- maritime safety, security and surveillance (Action 3, Action 8)
- ocean observation and seabed mapping (Action 9, Action 23)
- coastal protection, food risk and disaster management (Action 35)
- aquaculture and fisheries (Action 10)
- marine data integration and management (Action 9, Action 33)

From an enterprise and business development perspective, a national R&D capacity will also underpin Action 1, Develop an integrated enterprise strategy to generate momentum in specific emerging market opportunities, prepared across development agencies, (e.g. ICT and sensors), and Action 20, Progress a number of targeted emerging business development opportunities e.g. offshore renewables, maritime security and safety, ICT and sensors etc. The importance of test-beds/facilities for demonstration and commercialisation purposes that promote Ireland as a test-bed for renewable energy technologies and ICT is also outlined as part of Action 25.

Recommendations for the progression of these actions have been outlined as part of the report from the **Development Task Force (2015)**, with the ‘marinising’ of our existing ICT sector recommended as part of the three categories of intervention (‘marinising’, ‘strengthening’, ‘developing’). Specific recommendations around marine technology research and innovation include:

- In the short term, increase the talent pool available so as to attract FDI and strengthen existing industry whilst strengthening environmental, technological and governance capacity.
- In the medium term, investment, coupled with existing research infrastructures, can be used to demonstrate the application of products and services in new marine markets.
- In the long term, generate new products and services, in particular in the emerging fields of Marine ICT, Marine Bioresources and Offshore Renewable Energy.

Demonstrator projects recommended in this area include, the Integrated Digital Ocean, Marine Technologies for Safety and Security, and Marine Clusters.

Development of capacity in marine technology also contributes to national objectives in a number of related policy areas – e.g. Government Policy Statement on **Growth and Employment in the Green Economy (2012)**³⁹, **FoodWise 2025**⁴⁰, **National Ports Policy**⁴¹, **National Strategic Plan for Sustainable Aquaculture Development**⁴² and **The White Paper 'Ireland's Transition to a Low Carbon Energy Future 2015-2030'**⁴³. For example, one of the areas highlighted in the development of the green economy is Ireland's exceptional renewable energy resources, which provide a distinct advantage compared to other European countries. Expertise across ICT and engineering is one of the strengths that can support the development of these areas. For example, to leverage one of the greatest resources of renewable energy in the world, which is strategically located off the West Coast of Ireland, the development of offshore wind and wave will require innovation in relation to mooring structures, data management systems, operation and management processes, licensing frameworks and environmental impact assessments.

The growth and development of advanced marine technologies is directly aligned with the recommendations in **Enterprise 2025**⁴⁴, particularly in relation to “building on strengths” and “realising un-tapped potential”.

³⁹ Delivering our Green Potential, the Government's Policy Statement on Growth and Employment in the Green Economy in Ireland. <https://www.djei.ie/en/What-We-Do/Business-Sectoral-Initiatives/Green-Economy/Green-Economy-Policy-in-Ireland/>

⁴⁰ <https://www.agriculture.gov.ie/media/migration/foodindustrydevelopmenttrademarkets/foodwise2025/report/FoodWise2025.pdf>

⁴¹ <http://www.dttas.ie/sites/default/files/node/add/content-publication/National%20Ports%20Policy%202013.PDF>

⁴² <https://www.agriculture.gov.ie/media/migration/customerservice/publicconsultation/sustainableaquaculturedevelopment/NatStratPlanSustAquaculDevelopdraftconsult100615.pdf>

⁴³ <http://www.dccae.gov.ie/energy/en-ie/Energy-Initiatives/pages/white-paper-on-energy-policy-in-ireland-.aspx>

⁴⁴ Enterprise 2025 Ireland's National Enterprise Policy 2015-2025. Department of Jobs, Enterprise and Innovation, Dublin 2015

Enterprise 2025 identified areas of emerging opportunities, which are directly related to the marine sector, where building on existing capabilities in ICT are an evolution of existing sectors and/or a combination of areas in which we have capability. These include:

- **Aquaculture** – where Ireland’s reputation in ICT can also reinforce trust in the Irish aquaculture stock, through the development of traceability systems to support food safety and trade
- **Big Data** – where real-time data and predictive analytics is relevant for a vast range of sectors and activities and informs effective decision making, increased efficiencies, reduced risk, spot business and consumer trends, facilitate the delivery of targeted and customised services and solutions
- **Geosciences** – where building on strengths in internet technologies, mobile technologies and data analytics/Software can help achieve the aim of the new iCRAG⁴⁵ centre to transform geoscience research in Ireland, and help deliver economic impact for a broad range of application areas and industries, in Ireland and overseas

The aim of **Enterprise 2025** to “embed innovativeness” is particularly relevant to the advanced marine technology sector and aligns with the plans to set out grand challenges and partner with enterprises and the research community to deliver innovative solutions that address issues of national priority. The key elements of innovation policy over the coming decade will include:

- Exploring the options for a cross government ‘grand challenges’ approach that ‘creates’ a market for innovative products and services and addresses specific national priorities
- Using the State’s circa €8.5 billion procurement budget to stimulate innovation in SMEs to develop solutions to meet the needs of the public sector including, through rolling-out further Small Business Innovation Research (SBIR) initiatives

The new Strategy for Science, Technology and Innovation, **Innovation 2020**, identifies how we respond to the grand challenges as a major determinant of economic and societal development in the years ahead. Interdisciplinary research is key to addressing such challenges, recognised in the selection of the 14 priority areas under Research Prioritisation and in Horizon 2020.

The advanced marine technology sector cuts across several of these priority areas, including Marine Renewable Energy and Sustainable Food Production and Processing (Marine fisheries and seafood). It also links the broad enterprise themes of ICT, Energy and Food.

⁴⁵ Irish Centre for Research in Applied Geosciences

Nationally-funded research in these areas has the potential to further address national and global challenges and to provide economic opportunities for researchers and industrial partners to leverage further funding from the Horizon 2020 programme and develop products and services for global markets.

From a European policy context, the priority areas in the **EU Atlantic Action Plan** identified a number of topics where advanced marine technology R&D is required including, improving maritime safety and security, exploring and protecting marine waters and coastal zones through developing a European Atlantic ocean observing and predictive capability, and considering ways to accelerate the deployment of sustainable offshore renewable energy. Supporting these topics would align with and demonstrate commitment to “the full potential of the Marine economy through the implementation of the Harnessing Our Ocean Wealth strategy”, which is a key action in **Enterprise2025**.

A number of position papers also reinforce the need for marine technology R&D. The report from the European Marine Board ‘Navigating the Future IV – Position Paper 20’⁴⁶ highlights a number of important areas for development in the advancement of ‘blue technologies’ and the need for an ‘integrated and sustained European Ocean Observing System’. It is outlined how the latest marine technology developments have resulted in cost-effective applications for marine sectors, with these technologies being developed in fields such as robotics, ICT, and other areas of engineering research and development.

A number of blue technologies that are set to revolutionise marine research and societal applications outlined include:

- Robotics and autonomous systems
- Miniaturised solutions to marine monitoring
- Nature inspired design
- Acoustics to enhance marine ecosystem management
- Nano-biotechnology
- Renewable energy harvesting including wave energy and algae biofuels
- High performance computing and ICT innovations

⁴⁶ European Marine Board (2013). Navigating the Future IV. Position Paper 20 of the European Marine Board, Ostend, Belgium. ISBN: 9789082093100

The need for multi-sector partnerships, stakeholder collaboration and knowledge transfer between publically funded research and industry is highlighted in order to fast track innovation and product commercialisation in this area.

In terms of in-situ observations, new smart sensors for ocean observation, techniques and platforms to provide automated solutions to multidisciplinary marine monitoring with improvements to sensitivity, accuracy, stability, resistance to oceanic conditions and depth are outlined as all being key. Routine autonomous in-situ and biological and chemical measurements of marine biodiversity etc. will also require a technological leap (e.g. the application of molecular methodologies using genomics). Other work is focused on minimising power requirements, reducing the size of sensors, enabling multi-parametric observation from single platforms, and also developing micro-sensors to be fitted to marine organisms, which can often provide vital profile information. The need for marine data management in order to leverage its economic and societal application is repeatedly reinforced throughout the various policy, strategy and discussion documents. For example, **Marine Knowledge 2020** states that marine knowledge is critical to sustainably managing the changing seas and oceans, while also offering new opportunities for growth and employment. The need for marine data is also increased through environmental data Directives and Regulations e.g. MSFD for monitoring, INSPIRE which obliges public authorities of member states to adopt measures for the sharing of datasets, the Data Collection Framework for fisheries data collection and management, etc.

The Green Paper published by the European Commission '**Marine Knowledge 2020: From seabed mapping to ocean forecasting**' (2012) reinforces the importance of developing capacity in marine monitoring platforms, informatics and modelling, data management and decision support tools for the sustainable expansion of the blue economy.

Recognising the importance of blue technologies, a selection of **FP7 Ocean of Tomorrow** and **Horizon 2020** topics have focused on this area. For example the FP7 Oceans of Tomorrow call in 2013 was dedicated to the development of innovative new sensor technologies. In the most recent Horizon 2020 work programme for SC2, the BG-05-2016 topic is a call for an ERA-NET Cofund on marine technologies where proposals should focus on '*reducing underwater noise and emissions, reducing environmental impacts, minimising the carbon footprint, recycling, novel materials, advanced manufacturing technologies, sensors for navigation, observation, monitoring and the deep-sea environment*'.⁴⁷ Participation from Ireland in a proposal related to this call means that Irish researchers and SMEs would have an opportunity to respond to emerging calls. Additionally, the

⁴⁷ http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-food_en.pdf

European Commission recently announced funding of over €7.5m to boost innovation and create jobs in the marine and maritime sectors through the European Maritime and Fisheries Fund. Under the Blue Technology element of this call, over €2.5 million will be used to ‘encourage public-private partnerships that will support the transfer of new technologies and research results into commercial applications and coordinate strategic investment at sea-basin level’.

Research Capabilities (Maturity Assessment)

The research capability of Advanced Marine Technology is assessed as “Established”. This reflects the success in recent years in applying a range of skills that Ireland possesses in technology to the marine area, coupled with a number of now well-established research centres specifically focused on water and the marine.

Human Capacity: “Established”

Ireland has a robust and highly successful home-grown ICT sector, built on the substantial knowledge and research base of numerous Irish universities and ICT research institutes. It is recognised as being at the heart of European ICT and has established research centres and strategic research clusters.

In recent years many of these centres have been consolidated into centres of scale through the SFI Research Centres Programme so that they can readily compete, with critical mass, on an international level, thus generating excellent science and both economic and societal impact. Significant expertise also exists within Enterprise Ireland/IDA Technology Centres, Enterprise Ireland Technology Gateways and internationally recognised Higher Education Institutions research centres. Expertise crosses a number of relevant areas to the marine including Software, Data Management and Data Analytics, Communications, Sensors and Devices, Advanced Materials/Composites, and Energy. Two of the SFI Centres have elements that are directly related to marine and marine technology – the Centre for Marine and Renewable Energy (MaREI) and the Irish Centre for Research in Applied Geosciences (iCRAG).

However, there exist a number of other centres that have expertise in a range of key enabling technologies for the development of marine technology products and services. These include: ADAPT, AMBER, CeADAR, CONNECT, IC4, ICHEC, iCOMP, INSIGHT, IPIC, MCCI, SEES and Centres of

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established	■	■	■
Defined	■	■	■
Ad-hoc	■	■	■

Figure 11: Irish Research Maturity in Advanced Technology showing the different levels of maturity for human capacity, infrastructure and networks

excellence such as Tyndall National Institute (UCC), the National Centre for Sensor Research (DCU) and TSSG (WIT). A number of Technology Gateways also provide substantial expertise for companies that are considering operating in the sector. These include CAPP, TEC-NIMBUS, WiSAR Lab and others.

Some of these centres are already engaged in marine related projects. However, it is ad-hoc in nature, with no dedicated centre of excellence of critical mass to marine technology R&D. Significant opportunity exists to leverage existing competencies and capabilities across a number of enabling technologies drawing on expertise in the research centres, and to drive new forms of marine ICT innovation from existing investments. Currently, the low number of marine-related research projects does not reflect the prioritisation of the marine sector as an emerging opportunity.

However, there are a small number of Principal Investigator (PI) teams with marine-related ICT expertise, some of which are linked into the research centres outlined. A selection of these includes:

The **Mobile & Marine Robotics Research Centre (MMRRC)** in the **University of Limerick** is the only research centre focused on the application and development of marine robotics within the island of Ireland. This research centre consists of a mix of postdoctoral researchers and PhD students from various disciplines including electronics, computer science, and mechanical and aeronautical engineering. The MMRRC is a partner in the MaREI centre and most of its research funding has come through renewable energy related projects. Similarly research centres at **NUI Galway**, in particular at the **Ryan Institute**, have a selection of marine technology related expertise and also play a lead role in the SFI MaREI research centre. NUI Galway operates the HF Radar network off the Irish coast and has research teams with expertise in numerical modelling.

The **National Centre for Sensor Research at Dublin City University** was awarded the Beaufort Marine Research Award in ICT and Sensors and has since established MESTECH (Marine and Environmental Sensing Technology Hub) and the DCU Water Institute. PIs, Postdoctoral Researchers and PhDs are also involved in SFI Research Centres including INSIGHT. Expertise lies in the area of biosensors, low cost sensor technologies, biofouling, materials, visual sensing and data analytics.

There exists a selection of PIs, Postdoctoral researchers and PhD students within the **IMERC** research partners (**CIT and the constituent college NMCI (Halpin, Nimbus), UCC, Irish Naval Service**) that also have expertise in Marine ICT in areas such as informatics, sensing, communications, simulation, GIS, ocean observation etc. Additional expertise also lies within other HEIs – for example the **National Geocomputation Centre in Maynooth University, UCD Earth Institute** and the **Dublin Institute of Advanced Studies (DIAS)** also have Professors, Postdoctoral Research Fellows and PhD students with

relevant expertise but that cross-cut into a number of related areas such as climate, earth observation and energy.

Irish researchers have been involved in a number of marine technology-related research projects funded through FP7 research and innovation programmes and Horizon 2020. For example a major focus of the FP7 Oceans of Tomorrow 2013 call was to develop innovative marine technologies for a wide range of applications. Irish partners are involved in 4 of these projects – BRAAVOO, MariaBox, CommonSense and SenseOcean.

Irish researchers are involved in the interdisciplinary European Research Council (ERC) project MULTIWAVE⁴⁸. The Irish research team is led by Prof Frederic Dias from UCD School of Mathematics and Statistics, who focuses on the hydrodynamic research part of the project. The research on optical systems is led by Professor Dudley from the University of Franche-Comté. Ireland's ICT and advanced technology research capacity has the ability to undertake similar research though has not yet won ERC grants for marine related projects.

There are recent examples of collaborative approaches between research centres that have been mainly facilitated through national and EU funding calls, and collaborations through the SFI and EI/IDA centres. However, dedicated cross-institutional PI teams, working on marine technology-related projects is an area that will need to be significantly strengthened to underpin a mature industry base and to compete at international scale. Ireland's ICT research centres have the ability to compete in this field, though capacity would have to be focused or directed towards these areas as the underdeveloped marine sector in Ireland becomes better established and the untapped potential identified in **Enterprise2025** is realised.

Infrastructures: "Established"

Ireland has nationally available test beds and research platforms that could be used for ICT research in the marine & maritime fields. For example:

A national marine technology test and demonstration facility is located at **SmartBay** in Galway Bay. The research infrastructure and services support the test and development of marine technology products and services. A quarter-scale ocean energy test site is also located at the site. Up until the end of 2015, a number of small scale projects were funded through the SmartBay National Infrastructure Access Programme funded by Dublin City University. In 2015, the infrastructure saw a major upgrade with the deployment of a sub-sea cabled observatory in Galway Bay. This is a

⁴⁸ <http://www.ercmultiwave.eu/>

collaborative initiative between the Marine Institute, SEAI, MaREI (UCC) and SmartBay, to further develop the national test and demonstration facility for marine energy and technology. The total cost of the cable project is circa €3.6 million, funded through grant-aid from SFI.

Additionally, a number of the research centres operate research infrastructure that can support capacity build in the area of marine technology:

- The **NCSR** at DCU and **Tyndall National Institute** have research labs and fabrication facilities that support sensor development.
- DCU operates a number of marine sensor deployments through the Marine and Environment Sensing Technology Hub and the Water Institute.
- **Tyndall National Institute** hosts the only full CMOS (metal oxide semiconductor) integrated circuit construction, Micro Electronic Mechanical systems (MEMS) and III-V Wafer Semiconductor fabrication facilities and services in Ireland. This infrastructure supports the prototyping of new product opportunities for its target industries – electronics, medical devices, energy and communication.
- The **MMRRC** operate a test tank, a simulator, and a selection of both off-the-shelf and customised unmanned underwater vehicles (UUVs) and airborne platforms for the test and development of new technologies.
- The **NCG** at Maynooth University has an unmanned aircraft system for testing novel sensors and associated data aggregation, data interrogation and GIS tools for the test and development of geospatial computational methods.
- ICHEC operate the **Fionn Supercomputer** as part of the nationally available High-Performance Computing (HPC) Systems infrastructure and this has been used on marine related research projects.
- **NUIG** operate two sets of HF Radar systems off the west coast.

At the end of 2015, SFI announced further funding for marine technology-related infrastructure, which included:

- In situ Marine Laboratory for Geosystems Research (IMARL) – €2.86 million
- Marine Renewable Energy Remote Operation Vehicle for Challenging Conditions (Wave, Wind, Tidal) – €1.96 million
- Open ocean Emulator for Grid Integrated next generation Marine Renewable Energy Systems – €2.23 million

There is additional opportunity to develop marine-related demonstrators from Internet of Things (IoT) test-beds that have been funded e.g. the **SFI Connect** Pervasive Nation test-bed.

The Marine Institute provides access to a national equipment pool. The national research vessels, RV *Celtic Explorer* and RV *Celtic Voyager* and the deep-water Remotely Operated Vehicle, ROV *Holland 1*, are core research infrastructure that Ireland's researchers in the advanced marine technology and marine ICT fields can access. Additionally, the national weather buoy network and the national tide gauge network provide data to support marine related test and demonstration applications. The Marine Institute also operates the national marine data centre. The **Irish Digital Ocean** platform provides access to a diverse range of services including online maps, data dashboards, data access, data search and publications. It enables Irish digital marine resources to be leveraged for research and aims to promote marine-related research by improving access to data and analytical tools.

There is the potential to become part of a global research infrastructure around ocean observation systems, supported by a national research centre with fully-functioning, inter-institutional research collaborations and nationally available ICT research infrastructure. The Marine Institute is currently a partner in a number of European large-scale marine research infrastructure initiatives e.g. Fix03, EuroFleets, Jerico, AtlantOS etc. and has recently signed agreements to become members of the EMSO and EuroArgo ERICs. However, in some cases the role could be more prominent if certain facilities were more advanced e.g. Ireland currently does not manage any deep sea observatory.

Additionally there are test beds in relation to Smart Cities, Energy, Security and Shipping that could also be leveraged for marine technology testing purposes. These include the facilities located on the **IMERC** campus in Ringaskiddy e.g. the LIR National Ocean Test Facility, the simulation facilities in the National Maritime College of Ireland and the Naval test bed. **NUIG** have a tidal basin and wave flume test tank and there also exists a wave tank facility at **Maynooth University**. The **Nimbus Centre** in CIT also operates the Litmus technology trialling infrastructure for the development of technologies in areas such as energy and water.

Additional infrastructure is also operated off the coast. For example the **Commissioners of Irish Lights (CIL)** operate a buoy network that has been used in the past for testing new technologies (e.g. by MESTECH in Dublin Bay). They also operate a shore-based network of AIS base stations and are upgrading their coastal communication networks to provide higher speed. CIL are collaborators in the MaREI research centre and their lighthouses have also been used for the deployment of infrastructure by the marine technology research and innovation community e.g. HF Radars operated by NUIG.

Publically available infrastructure such as that operated by the **Irish Defence Forces**, in particular the Irish Naval Service, and increasingly by the Air Corps, can also provide unique advantages if coordinated into a national infrastructure network. This can be furthered through the **Defence Enterprise Initiative** as outlined in the White Paper on Defence (2015)⁴⁹. Additionally, the Service Level Agreement (SLA) between the Marine Institute and the Department of Defence was recently updated to include services relating to the Air Corps, in addition to the Irish Naval Service. Other developments, including the development of the Atlantic Marine Energy Test Site (AMETS) by **SEAI**, which is a grid-connected full scale ocean energy test site, may provide an opportunity for dual purpose test and demonstration facilities. The Irish Coast Guard have also made available infrastructure and end-user expertise for the development of R&D projects that support the delivery of their services. Finally, a selection of Irish ports and harbours have demonstrated intent to use their facilities to support the test and demonstration of marine technologies e.g. coastal broadband, UAV test and development, renewable energy etc.

A significantly greater impact could be achieved if a coordinated programme for investment and structured programmes of engagement, test and development were established across available digital and physical infrastructures; similar to what has been achieved for the ocean energy sector through MAREI. This joined-up approach would also provide a unique competitive advantage, positioning Ireland as a global centre of excellence, helping to attract inward investment in this domain.

Networks (Industry engagement): “Established”

The Marine Institute’s “*National Marine Technology Programme*” facilitates a range of research and development activities in areas such as sensors, advanced communication systems, robotics, engineering, advanced materials, data management and informatics – for marine related applications . This programme aims to broker national and international relationships between technology developers in industry and academic centres of excellence for application driven technology development in marine ICT. It has led to the development of the SmartOcean initiative, to develop a cluster of companies and academic partners with marine technology-related expertise and to establish an internationally recognised brand of expertise. However, this programme would benefit from a dedicated cluster programme, along with marketing and communications investment, to profile the cluster’s expertise, attract additional national and international stakeholders and broker partnerships. There is also a selection of regional cluster initiatives emerging which could add significant value to the network, if supported e.g. the Galway Marine Innovation cluster, and

⁴⁹ Ireland's White Paper on Defence (2015) <http://www.defence.ie/WebSite.nsf/WP2015E>

clustering initiatives involving UL and Limerick docks. This is in addition to more established clustering activities at IMERC which has significant importance in creating the required ecosystem to drive innovation across a number of areas of the marine in particular energy, security and surveillance and maritime related activities.

The Marine Institute has hosted a number of SmartOcean workshops and jointly sponsored a conference with InvestNI on how to establish Northern Ireland and Ireland as leaders in the development of ICT products and services for global marine sectors. For the last number of years, the Marine Institute has sponsored an Ireland Pavilion at the biennial Oceanology International conference and trade show and has also participated in a number of international events to promote the expertise of the cluster. Most recently the Marine Institute also joined the IRDG⁵⁰ innovation network in order to profile marine opportunities among a number of its industry members including ICT companies.

IMERC is also making significant progress in promoting networks amongst research, industry and the public sector agencies. It recently launched 'The Entrepreneur Ship' which provides a touch-down space for companies on the campus and provides access to the expertise and infrastructure of its co-located partners. Funding has also been secured for the development of an innovation building on the campus.

Ireland has internationally recognised research centres established in the ICT field. However, it lacks a dedicated research centre, of scale, in marine ICT, which would help to further develop industry-industry and industry-academic relationships in this field. Given the strengths Ireland has in marine data, associated marine research activities and its ICT sector, it should be possible for Ireland's research base to become a leading player in advanced marine technology themes in the Horizon 2020 programme – including coordinating major projects across the challenge areas linked to the marine sector.

Research Topics

Given existing competencies and investments across ICT, engineering and marine, research topics in the area of marine technology should centre around the development of capabilities in the area of advanced sensors, in-situ and airborne monitoring platforms, data acquisition and communications, data processing, cataloguing and management, informatics, visualisation, virtual/augmented reality forecasting and prediction, robotics and autonomous systems, and materials and systems that can

⁵⁰ Industry R&D Group is a non-profit, business-led Innovation Network of member companies and colleges, working together to drive excellence in Innovation within Ireland's industry to create growth, jobs and prosperity (available at <http://www.irdg.ie/>)

survive harsh environments. This requires expertise across a number of areas, which include big data, machine learning, artificial intelligence, computer vision, remote sensing, streaming data, high performance computing, cloud computing, nanotechnology, materials science, photonics, wireless networks, acoustics, microelectronics, analytical chemistry, modelling, and simulation. Relevant expertise in engineering and energy harvesting will also play a critical role.

There exists expertise in these areas through the research centres previously mentioned. However, there is a real need to invest in ‘marinising’ these existing competencies and capabilities. Doing so would equip Ireland with the capabilities to further develop its marine resource while also responding to both European and global market and R&D opportunities.

SFI Centres with the required expertise include:

MaREI – Areas of relevance include marine renewable energy informatics tools; cost reduction for marine renewable energy; novel materials for MRE systems, operations support engineering; MRE decision support and data management, environmental monitoring, modelling.

iCRAG – Projects in the marine geosciences spoke and platform projects in enabling technologies such as geophysical sensing, data and imaging.

INSIGHT – Machine learning and statistics; semantic web; linked data; optimisation and decision analytics; sensing.

IPIC – Advancing and miniaturising photonic integration science to produce micro and nanoscale optoelectronic systems to produce innovative and disruptive solutions in areas such as communications and sensing.

CONNECT – Internet of Things (IoT) technologies – smart sensors, network technologies (i.e. service aware networks/network aware services), integration and testbeds, security and privacy.

AMBER – 2-D nanomaterials, heterostructures and network interfaces supporting targeted projects in areas of manufacturing, process technologies and novel materials and ICT.

ADAPT – Digital platforms and the extraction of actionable knowledge from all forms of digital content and user interaction.

LERO – Software research in areas such as high integrity systems, autonomous and adaptive systems, security and privacy already underpinning application areas such as Smart Cities.

As part of the development of capacity in marine technology it will be necessary to promote an interdisciplinary research culture that can build on existing capacity and develop synergies. Central to this approach is the recognition that there has already been significant investment in Ireland to develop world-class capabilities in other areas of research that can be of benefit to the marine sector. Ireland has world-class expertise in areas of software engineering (e.g. LERO), data analytics (e.g. INSIGHT) and networks and communications (e.g. CONNECT). The facility to develop new collaborative and interdisciplinary research initiatives exists through mechanisms such as the SFI spokes programme.

SOFTWARE, DATA MANAGEMENT, DATA ANALYTICS
CeADAR – Centre for Applied Data Analytics Research
ICHEC – Irish Centre for High End Computing
INSIGHT – Centre for Data Analytics
MaREI – Marine Renewable Energy Ireland
LERO – Irish Software Engineering Research Centre
TSSG – Telecommunications Software and Systems Group

COMMUNICATIONS
CONNECT – The Centre for Future Networks & Communication
IPIC – Irish Photonic Integration Centre
TSSG – Telecommunications Software and Systems Group

SENSORS & DEVICES
AMBER – Advanced Materials and Bioengineering Research
CCAN – Collaborative Centre for Applied Nanotechnology
IPIC – Irish Photonic Integration Centre
MCCI – Microelectronic Circuits Centre Ireland
TYNDALL – Tyndall National Institute
NCSR – National Centre for Sensor Research

ADVANCED MATERIALS AND COMPOSITES
AMBER – Advanced Materials and Bioengineering Research
ICOMP – The Irish Centre for Composites Research

ENERGY
MaREI – Marine Renewable Energy Ireland
iCRAG – The Irish Centre for Research in Applied Geosciences
SEES – Sustainable Electrical Energy Systems

The national marine technology research and innovation strategy should promote collaborative and interdisciplinary research across these areas, identify opportunities to build a critical mass of research expertise that leverages and combines existing expertise from previous investments in ICT

and engineering, recruit scientific leaders to build indigenous research capacity, both sustain and further develop existing research infrastructures that will underpin the development of capacity in this area, develop coordinated access programmes for technologies of various Technology Readiness Level (TRL) building on existing test-beds and public infrastructure, and build on these infrastructures to develop high profile test-beds to grow our international reputation.

Focus of Funding

To summarise, in order to transition from an “Established” to “Translational” maturity level for research in advanced marine technologies, the key focus areas for funding include:

- Supporting and incentivising collaborative research between ICT and marine-focused research centres – including effective and sustainable inter-institutional research collaborations.
- Establishing a research programme of scale in Ireland in the Marine ICT field that will attract international interest from researchers and industry to utilise Ireland’s research infrastructures for joint marine and ICT research.
- Centring the large-scale research programme around a world leading research infrastructure that can provide Ireland with a competitive advantage that could secure further international investment, for example in maritime surveillance or ocean observation-systems.

The need to incentivise and foster inter-institutional and cross-sectoral collaboration which would also make optimal use of public investments in marine research infrastructures could be achieved through formulating a “Grand Challenge” in the advanced marine technology sector.

In addition to the specific value to Ireland, and the wider global community, of the solutions developed, this would have the added benefits of stimulating collaboration between Ireland’s higher education institutions and enterprises, both local and international.

Innovative approaches to funding such projects, in particular the use of the SBIR, would engage the public sector in the “Grand Challenge” and also foster collaboration across Government departments and agencies.

Subsea Resources

Overview

Ireland has proven conventional gas reserves and there is strong technical evidence that conventional oil resources may exist in Ireland's offshore basins. However, there is no oil production to date. Additionally, research studies indicate that methane gas hydrate resources could exist offshore (Mac Aodha, Brown, & Johnson, 2005)⁵¹. These yet to be proven hydrocarbon resources could generate clean gas as a transition fuel that complements intermittent renewable energy resources as Ireland decarbonises its energy generation to meet GHG emission targets. Gas reserves offshore Ireland would provide Europe with an alternative sustainable and secure energy supply to current sources from a depleting North Sea and politically unstable North Africa and Russia.

There are also offshore marine aggregate resources that may be economic to develop in the future (Sutton, 2008)⁵². The potential for deep sea mining offshore Ireland is currently unknown but is thought to be limited (GSI, 2016)⁵³.

The development of Ireland's indigenous subsea hydrocarbon and mineral resources has the potential to deliver significant and sustained benefits, particularly in terms of enhanced security of supply, import substitution, fiscal return, national and local economic development and technology learning. A significant societal challenge is the public belief that consumption of the existing reserves of fossil fuel will have a detrimental impact on global climate and therefore further exploration should be reduced or perhaps stopped. This is reflected in government energy policy to curtail and in the longer term eliminate oil and gas from Ireland's energy mix (Department of Communications, Energy & Natural Resources, 2015)⁵⁴.

Over the last 20 years, Ireland has developed internationally competitive research capacity in hydrocarbon exploration, primarily through the Petroleum Infrastructure Programme, as evidenced by significant success in winning direct oil company financial support for research groups (Fault Analysis Group, Geophysics, Marine & Petroleum Geology UCD) and lectureships (Tullow Chair and Tullow Lectureships UCD). Research in natural resource development is also funded by the Geological Survey of Ireland's Geoscience Research Calls and by INFOMAR Research Calls. The new

⁵¹ Mac Aodha, P; Brown, C; Johnson (2005), *A Methane Hydrate Resource Assessment Offshore Western Ireland*, ISPSG Report IS05/02, Dublin

⁵² Sutton, G (ed) (2008), *Irish Sea Marine Aggregates Initiative-IMAGIN*, Marine Institute, Galway

⁵³ www.emodnet-geology.eu

⁵⁴ Department of Communications, Energy & Natural Resources (2015), *Ireland's Transition to a Low Carbon Energy Future 2015-2030*, DCENR, Dublin

applied geoscience centre iCrag consolidates the research capacity of a number of third level institutes into a coherent structure to deliver the practical application of creative ideas in natural resource development (including subsea resources) supported by significant geophysical, geochemical and big data research infrastructure. The outreach component of iCrag will research the current public perception of natural resource development and the social science elements of obtaining a licence to operate.

The development of subsea natural resources is supported by research in a diverse range of disciplines including geology, physics, chemistry, engineering and mathematics. Dublin City University, University of Limerick, Queens University Belfast, Galway Mayo Institute of Technology and the Irish Centre for High-End Computing (ICHEC) are all currently funded to provide research that supports subsea resource development.

This research capability is well established and collaborative with respect to its human capacity, infrastructures, network and relationships.

Context

The goals of energy policy, as stated in the White Paper on Ireland's Energy Policy "Ireland's Transition to a Low Carbon Energy Future 2015-2030"⁵⁵, are to maintain a secure energy supply; deliver energy at minimum cost to consumers; and reduce greenhouse gas emissions. The White Paper identifies geosciences as an important component of energy research. The aim of SFI's Irish Centre for Research in Applied Geosciences (iCrag) is to de-risk exploration for subsea natural resources by improved understanding of the geology and related processes; by innovative techniques for predicting the location of subsea resources and by improved methods for optimising the production of resources. The development of subsea hydrocarbon resources will contribute to Ireland's security of energy supply.

Relevant Documents / Sectoral Plans

Ireland's strategy for research and development, science and technology, "Innovation 2020"⁵⁶, commits to implement research related actions in the Energy White Paper and Energy Research Strategy. It also commits to building on existing research capacity and infrastructure; to stimulating innovation in SMEs through rolling-out further Small Business Innovation research (SBIR) initiatives; and to ensuring that Ireland's Intellectual Property (IP) framework remains fit for purpose. There are no direct references to offshore oil & gas or minerals research in the Research Prioritisation Exercise

⁵⁵ <http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Energy-Initiatives/Energy%20White%20Paper%20-%20Dec%202015.pdf>

⁵⁶ Innovation 2020 A report by the Interdepartmental Committee on Science, Technology and Innovation; Dublin 2015

(RPE), which predated the establishment of SFI Centres such as iCRAG where sustainable economic benefit can be demonstrated. However, energy related areas such as geosciences are identified as important components in the RPE. There is also a commitment to implement actions identified in the “Geoscience Research Strategy 2015–2020” and “Harnessing Our Ocean Wealth-An Integrated Marine Plan for Ireland”⁵⁷. A key action of “Harnessing our Ocean Wealth” is to continue to implement research supporting increased hydrocarbon prospectivity through government-industry collaboration. This research is ongoing under the Petroleum Infrastructure Programme which was set up in 1997 by the Department of Communications, Energy and Natural Resources.

Submissions to a government consultation document on “Harnessing Our Ocean Wealth – An Integrated Marine Plan for Ireland” suggested that existing patented technology could be put to use in extracting minerals, metals and gas hydrates from offshore Ireland and identified the need to invest in research to take advantage of this potential. The subsequent Development Task Force Report⁵⁸ recommended continued investment in baseline data collection, and related infrastructure and knowledge development, to ensure that Ireland’s natural subsea resources are managed in compliance with European and Irish environmental law whilst supporting the exploration and discovery of oil and gas in Irish waters.

The European Marine Board Policy Brief No.2 (Larkin, 2015)⁵⁹ identifies knowledge gaps in marine mining and oil and gas in resource evaluation of ore and gas hydrates, and baseline knowledge to support development of appropriate environmental impact assessments and effective regulation. These baseline gaps are being addressed by iCRAG and ObSERVE, a programme of targeted acoustic and aerial surveys of cetaceans and seabirds in the Irish offshore.

The **Integrated Strategic Energy Technology Plan (SET Plan)** is one of the three strands, along with the Strategic Transport Research and Innovation Agenda and the Global Technology and Innovation Leadership Initiative, that will be brought together to give impetus to the Energy Union technology and innovation agenda. The **European Energy Research Alliance** is the research pillar of the SET-Plan and has “Joint Programmes” that join institutions in other European countries to work on shared priority setting and research projects that are aligned with the priorities for low carbon technologies

⁵⁷ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

⁵⁸ Marine Development Task Force (2015), *Our Ocean Wealth Development Task Force - Report to the Interdepartmental Marine Coordination Group*

⁵⁹ Larkin, K.E., Donaldson, K., McDonough, N., Rogers, A., (2015), *Delving Deeper: How can we achieve sustainable management of our deep sea through integrated research*, European Marine Board, Ostend

defined in the SET-Plan. There are no joint programmes related to subsea resources in the EERA SET Plan.

In the UK, offshore oil & gas is a mature industry. The Scottish Government's "Oil & Gas Strategy 2012 – 2020 Maximising Our Future"⁶⁰ highlights the role of innovation in achieving security of supply, and the long-term transition towards a lower-carbon economy. For example, recent research published by Scottish Enterprise suggests the skills, knowledge and expertise of the oil and gas supply chain could help reduce the costs of offshore wind operations. Priorities identified for innovation reflect the mature nature of the sector and include enhanced oil recovery, ageing infrastructure, subsea development, and development of non-conventional hydrocarbons.

An approach to technology and innovation which will help to develop new finds at a lower cost needs to be adopted. OTM Consulting provides insights on oil and gas industry research and development needs that improve safety, optimise operations and reduce associated costs. They have identified embedding automation and robotics into operations (including technology transfer from other industries), enabling real time condition monitoring using innovative sensors and algorithms, improving water treatment through innovative materials and chemistry, and investigating novel subsurface imaging techniques as the top technology areas for R&D. The UK-based Industry Technology Facilitator is a not for profit organisation, focused on the commercial needs of its international oil and gas operating and service companies, that identifies collaborative R&D initiatives to address shared technology challenges. Their recent calls for proposal have been on the themes of characterisation and simulation of carbonate reservoirs, hybrid enhanced oil recovery, mooring integrity, and subsea produced water quality for re-injection.

⁶⁰ (available at <https://www.scottish-enterprise.com/knowledge-hub/articles/publication/oil-and-gas-industry-strategy>)

Research Capabilities (Maturity Assessment)

The Irish research capability in subsea resources is collaborative with nationally available equipment pools and industry collaboration including industry funding.

Human Capacity: “Established”

There are several Principal Investigator- (PI) led research teams in the field of geosciences established in Ireland. University College Dublin, Trinity College Dublin, Dublin Institute of Advanced Studies, National University of Ireland Galway, National University of Ireland Maynooth and University College Cork are members of the new iCrag Centre.

Between them they have nine principal investigators with a track record of working with industry to deliver real impact, and have attracted more than €7M industry funding from 1998 to 2014. The iCrag centre represents a major investment from SFI in subsea natural resource development, which can leverage additional industry funding and continue to produce PhD graduates.

The UCD School of Earth Sciences includes a dedicated Marine and Petroleum Geology Research Group, which is currently staffed by two academic staff, one postdoctoral researcher and seven PhD students. Funding comes from a range of sources including industry, the EU and state funding agencies. There are two lecture positions and a professorship sponsored by industry partners through Tullow Oil; and Woodside Energy sponsor a scholarship programme for students pursuing an MSc in Petroleum Geoscience.

In addition to applied geology, other third-level institutes provide support to subsea resource research in the fields of physics, chemistry, engineering and mathematics. These include Dublin City University, University of Limerick, Queens University Belfast, Galway Mayo Institute of Technology and the Irish Centre for High-End Computing (ICHEC). They are all currently funded to provide research that supports subsea resource development.

Infrastructures: “Defined – Established”

There are nationally available equipment pools for subsea resource research including the Irish Centre for High-End Computing (ICHEC) for computational and modelling; the national research vessels, RV *Celtic Explorer* and RV *Celtic Voyager* and the deep-water Remotely Operated Vehicle

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 12: Irish Research Maturity in Subsea Resources showing the different levels of maturity for human capacity, infrastructure and networks

(ROV *Holland 1*) for data acquisition; the sub-sea cabled observatory in Galway Bay to test environmental sensors and corrosion testing; the In situ Marine Laboratory for Geosystems Research (iMARL) comprising ocean bottom seismographs, temperature and acoustic recorders; and laboratory equipment such as the electron beam mineral analyser at Trinity College Dublin. Through EC funded programmes transnational access is provided to some of this infrastructure.

Networks (Industry engagement): “Defined – Established”

The Petroleum Infrastructure Programme (PIP) was setup in 1997 and is Ireland's joint Government-Industry petroleum research programme, with the aim of promoting hydrocarbon exploration and development activities by funding research and data gathering offshore Ireland. PIP collaborates with Nalcor Energy, the Newfoundland and Labrador provincial energy corporation, in a transatlantic research initiative called the North Atlantic Petroleum Systems Assessment (NAPSA). The objective of NAPSA is to foster research collaboration between Irish and Atlantic Canadian researchers that will lead to the establishment of funded scientific projects to enhance our understanding of the petroleum geology and prospectivity of the North Atlantic basins. The long term goal is to promote research that leads to increased petroleum exploration and development, with projects also fostering basic research to enhance the growth of scientific knowledge. A national conference “Atlantic Ireland” with international participation is held each year in Dublin to promote this research and define research themes for the future.

Ireland's geoscience research base has a track record of industry engagement. The integrated approach of iCRAG provides scope for industry led themes for research as well as increasing the level of industry funding. The level to which iCRAG achieves these ambitions will determine whether Ireland's research base in the area of marine geoscience, hydrocarbons and raw materials can reach the highest level of research maturity.

Research Topics

An objective of iCRAG is to unlock Ireland's natural resources, including subsea resources, by de-risking exploration. The priority research topics to achieve this are:

1. Improved understanding and models of the geology and related processes.
2. Innovative techniques for predicting the location and nature of resources.
3. Improved methods for optimising the production of resources.

These research topics, specific to Ireland but with global applications, are guided by the industry partners that sit on Technical Advisory Committees. The research capacity exists in Ireland to meet priority research topic 1. For innovative techniques, priority research topic 2, stronger links with

industry R&D departments are required. The innovative techniques may originate from research topics in material science, nanotechnology, physics, ICT etc. These industry links are usually introduced by the enterprise agencies IDA or Enterprise Ireland (e.g. Cathx Ocean introduction to R&D partner Subsea 7 by Enterprise Ireland). These introductions can be delivered by expanding the existing commercialisation support from the enterprise agencies. Priority research topic 3 is primarily an engineering topic with an element of big data and high end computational capacity.

Other research priorities identified by the global oil and gas industry at, for instance, the Industry Technology Facilitator Technology Showcase Exhibition and Conference 2016 include:

- Inspection technologies that can be transferred from other industries such as, for example, aerospace, nuclear, marine, medical and automotive using robotics, autonomous underwater vehicles and drone technologies
- Use of Big Data technologies for subsurface imaging, asset integrity, logistics, condition monitoring and production efficiency
- Efficient treatment and transportation of offshore drilling cuttings
- Automation and robotics for drilling for cost efficiency and improved health, safety and the work environment

Existing capabilities in Ireland in cross-cutting areas of research, such as the Mobile & Marine Robotics Research Centre from the Department of Electronic and Computer Engineering at the University of Limerick, could contribute to this global research agenda and through this enhance Ireland's credentials for becoming a European hub for energy innovation.

Focus of Funding

The focus of funding for subsea resources research should be to:

- Improve and increase access to research infrastructure, both the national and international marine research vessels and associated infrastructure, and the Defence Forces naval patrol vessels and aircraft, through funded open access programmes
- Expand the high end computing capacity in Ireland or negotiate access to international high end computing capacity for Irish researchers
- Increase the non-technical financial and legal support for spin out companies to enable them to identify and negotiate commercialisation agreements to develop research technology to a commercial technology readiness level and get access to market

The success of the iCrag centre in relation to fully realising its inter-institutional research capacity, with industry engaged in promoting and funding specific research agendas, will play a key role in

delivering ambitions for the research and innovation strategy in the offshore Oil & Gas and Marine Minerals areas.

It is recommended that funding should be targeted towards extending the capacity and infrastructures underpinning iCrag to attain a “translational” maturity level which would be evidenced by winning significant ERC awards and international research contracts. This includes cross-cutting areas such as research vessels and ocean observation systems.

Funding to support “Networks & Relationships” should be focused on promoting the commercialisation opportunities generated by Irish research to venture capital funds and technology companies servicing the international oil and gas and mining sectors. The significant advantage to industry of participation in targeted projects connected to SFI Research Centre spokes needs to be promoted and new industry partners found.

The global search for new subsea sources of clean gas and raw materials provides opportunities for the commercialisation of Irish cross cutting research in geoscience, engineering, information and communication technology, and nanotechnology, in partnership with industry.

Renewable Energy

Overview

Ireland has exemplary natural resources of offshore wind, tidal and wave energy that can be tapped to generate clean, sustainable and secure energy to meet Europe’s energy and climate change goals.

The main opportunity for Ireland is to capitalise on these abundant resources to create new enterprise and FDI opportunities in the knowledge intensive, scientific and engineering sectors needed to harness these resources.

Over the last 15 years Ireland has developed internationally competitive research capacity, primarily through the Hydraulic & Maritime Research Centre at UCC, as evidenced by significant success in FP7 programme. The new National test facilities, LIR, co-located with the MaREI centre in Cork, along with the Galway Bay test site provide state-of-the-art research infrastructure that covers low to medium range “Technology Readiness Levels”. The development of the Atlantic Marine Energy Test Site (AMETS), and opportunities for offshore wind demonstration sites, can cater for the higher TRL stages, providing Ireland with capabilities across the test bed spectrum.

The ocean energy research group at Queens University Belfast has equally impressive research credentials with industry-led research programmes on near-shore wave energy in their wave tank test facilities, a tidal energy test site in Strangford Lough and the pre-commercial tidal demonstration project, Seagen, operating in Strangford Lough since 2008. QUB already collaborates with UCC, UL and Maynooth on an MSc course and there is an internationally competitive “All-Ireland” research capability that could be developed.

The MaREI centre represents a major investment from SFI in this sector, which can leverage additional industry funding and continue to produce PhD graduates. However, staff turnover at director level and limited mobility among our national researcher base presents risks to establishing internationally recognised research leadership in this area.

As identified in **Enterprise 2025**⁶¹, challenges in relation to access to finance for the development of new technologies is particularly prevalent in the clean technologies sector, where development times and capital requirements limit the sources of funding that can be obtained – in particular for start-ups and spinouts utilising the IP generated by the existing research base. The Spanish and Scottish governments have recently awarded contracts under SBIR programmes that have

⁶¹ Enterprise 2025 Ireland’s National Enterprise Policy 2015-2025. Department of Jobs, Enterprise and Innovation, Dublin 2015

stimulated significant international industry collaboration to compete in tender competitions, with the added benefit of promoting and increasing the utilisation of the research and test bed infrastructure in these countries. A similar approach would ensure that the existing facilities at LIR in Cork and Galway Bay are leveraged to kick-start enterprise growth and support FDI in Ireland for this high potential sector.

Context

Ireland's new enterprise policy **Enterprise 2025: Innovative, Agile, Connected** identifies "Marine" and "Green technologies" as sectors where untapped potential can be realised to contribute to job creation and sustainable economic growth targets. Investments in RD&I remain below comparator countries, and the proportion of enterprises engaging in research and innovation is too low. To enhance innovation in enterprise, government has adopted a new Strategy for Science, Technology and Innovation. Key elements of innovation policy include:

- Building on existing research capacity and infrastructure
- Exploring the options for a cross government 'grand challenges' approach
- Stimulating innovation in SMEs through rolling-out further Small Business Innovation Research (SBIR) initiatives
- Ensuring that Ireland's Intellectual Property (IP) framework remains fit for purpose
- Ensuring supply of researchers and human capital
- Promoting greater collaboration between enterprise and HEIs including increased mobility between industry and academia

The **Strategy for Science, Technology and Innovation** is built around five core strategic policies:

- Prioritisation of public funds into areas of research that offer most potential for economic recovery and social progress
- Consolidation of resources in units of scale with scientific excellence
- Increased collaboration between academia and industry and between academic and research-performing institutions
- International collaboration, to maximise return on investment and to optimise success under EU Framework programmes
- Facilitating the translation of knowledge and the transfer of technology into jobs

Ireland will develop the full potential of the Marine economy through the implementation of the **Harnessing Our Ocean Wealth** strategy⁶² and, through a whole of government approach, will leverage our natural resources to enhance our RD&I capabilities and stimulate start-ups and growth in green/clean technology enterprises. This will link with meeting EU commitments to lower greenhouse gas emissions and reach a share of renewables of 20% by 2020 and at least 27% by 2030, where generating electricity from offshore wind and wave & tidal energy resources was included in Ireland's **National Renewable Energy Action Plan (NREAP)**⁶³, within the overall objective of Ireland's energy policy, which is to ensure secure and sustainable supplies of competitively priced energy to all consumers.

Europe has also identified Ocean Energy as a sector that has high potential for sustainable jobs and growth in its **Blue Growth** strategy⁶⁴, which is the maritime contribution to achieving the goals of the Europe 2020 strategy for smart, sustainable and inclusive growth.

EU energy policy is focused on the **2030 Climate-Energy Package** and **Energy Union** that incorporates:

- Energy security, solidarity and trust
- A fully integrated internal energy market
- Energy efficiency first
- Transition to a low-carbon society
- An Energy Union for Research, Innovation and Competitiveness

The **Integrated Strategic Energy Technology Plan (SET Plan)** is one of the three strands, along with the Strategic Transport Research and Innovation Agenda and the Global Technology and Innovation Leadership Initiative, that has been brought together to give impetus to the Energy Union technology and innovation agenda.

The **European Energy Research Alliance** is the research pillar of the SET-Plan and has "Joint Programmes" that join institutions in other European countries to work on shared priority setting and research projects that are aligned with the priorities for low carbon technologies defined in the SET-Plan. The EERA Joint Programme for Wind Energy was launched in 2010 and has an Offshore

⁶² HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

⁶³ [http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Renewable-Energy/The%20National%20Renewable%20Energy%20Action%20Plan%20\(PDF\).pdf](http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Renewable-Energy/The%20National%20Renewable%20Energy%20Action%20Plan%20(PDF).pdf)

⁶⁴ European Commission (2012) Blue Growth opportunities for marine and maritime sustainable growth COM/2012/0494 final Brussels

Wind sub-programme in which University College Dublin is a participant. There is also an EERA Ocean Energy JP, in which the MaREI Centre participates.

The **Strategy for Renewable Energy: 2012-2020**⁶⁵ identified the opportunity for Ireland to become a world leader in the testing and development of next generation offshore renewable energy technology. The **National Research Prioritisation Exercise (NRPE)**, through the priority area on “Marine Renewable Energy”, is focused on promoting the green economy by positioning Ireland as a research, development and innovation hub to drive the deployment of marine renewable energy technologies and services.

The **Offshore Renewable Energy Development Plan (OREDPP)** sets out policy to take full account of the energy and economic development opportunities, and environmental issues, associated with the exploitation of our national offshore wind and ocean resources. This includes increased exchequer support for Research, Development and Demonstration, with a fund focused on stimulating industry-led projects for the development and deployment of Ocean Energy devices and systems.

Other countries, including Scotland, France, Spain and the US, are also pursuing the economic opportunities in this sector.

The Offshore Renewable Energy Catapult centre established in the UK is focused on enabling and supporting technology innovation to drive down the cost of offshore renewable energy by accelerating the development, testing, commercialisation and deployment of offshore renewable energy technologies.

Scotland and Spain have recently awarded contracts worth €15m through SBRI type programmes for the development of wave energy technology at early stage TRLs. The Department of Energy in the US is running its “Wave Energy Prize” competition, with seed funding to build and test 1/20th scale models on offer to ten finalists and an overall prize of \$1m for the winning technology team.

In addition to the immediate enterprise and FDI opportunities from Ireland becoming a test bed for the development of new technologies, the production of renewable energy from indigenous resources can support energy security in the longer term, when efficient and cost competitive technologies emerge from the major research agenda being driven by Europe and evidenced by the Technology Platforms for Offshore Wind and Ocean energy.

⁶⁵ https://www.teagasc.ie/media/website/crops/crops/RenewableEnergy_Strategy2012-2020.pdf

Relevant Documents / Sectoral Plans

The increased exchequer support for Ocean Research, Development and Demonstration outlined in the OREDP is targeting:

- Development and provision of support services at test facilities
- A “Prototype Development Fund” focused on stimulating industry-led projects for the development and deployment of Ocean Energy devices and systems

There are also plans for a market support scheme based on a feed-in tariff for the generation of electricity that is aimed at attracting early deployments and the associated jobs.

Environmental monitoring will also be addressed, specifically the collection and dissemination of data and the monitoring of potential significant environmental impacts arising from the development of offshore renewable energy installations.

SEAI are responsible for the “Prototype Development Fund” and the current call invites applications for:

- Industry-led projects to develop and test wave and tidal energy capture devices and systems
- Independent monitoring of projects/technologies
- Industry-led R&D aimed at the integration of ocean energy into the electricity market and the national electricity grid (and network)
- Data monitoring, forecasting, communications and control of OE systems

SEAI is also a member of OCEANERA-NET, a network of 16 national and regional funders and managers of research and innovation programmes, which is coordinating funding programmes between European countries and regions to support research and innovation in the ocean energy sector. The contracts for the first call, launched in in 2014, have been awarded and further calls are planned for 2016.

The specific challenges selected were based on reports from the OCEANERA-NET project, Funding Organisations priorities, recommendations from the SI Ocean project, the European Energy Research Alliance for ocean energy technologies and the SEAS-ERA Marine Research Plan for the European Atlantic Sea Basin. The research topics were:

1. Develop standardised approaches/methods/tools for ocean energy site characterisation and project and array/park planning.
2. Modelling and design of components, systems, sub-systems and devices for ocean energy technologies taking into account manufacturing, installation, operation, maintenance and environment requirements.
3. Development and testing of critical components for delivering reliable, sustainable and high-performance ocean energy generation, particularly:
 - i) Device structure and materials
 - ii) Foundations and moorings
 - iii) Power take off
 - iv) Intelligent predictive maintenance, condition monitoring systems
 - v) Control and power electronics
 - vi) Electrical systems
 - vii) Mechanical systems
 - viii) Sub-sea systems
 - ix) Energy storage systems
4. Demonstration and validation of technological developments in a real sea environment.
5. Design and development of tools and solutions for the technological advancement and optimisation of components, devices, and arrays/parks.

The European technology and Innovation Platform for Ocean Energy (TP Ocean) published its Strategic Research Agenda in 2016. The draft SRA has identified the following priority areas across basic research, applied research and market uptake areas:

- Testing and Modelling
 - Elaborate bespoke ocean energy testing and demonstration guidelines and standards
 - Mitigate the “scaling-up” effect by improving research into the different behaviours of small-scale and full-scale devices
 - Validate numerical models replicating the real marine environment
 - Improve long-term durability testing and prediction with numerical models
 - Develop reliable monitoring systems to assess the resource in real time and analysis tools to interpret the data, including short to medium term forecasting
 - Ensure funding for demonstration of ocean energy technologies, arrays and family of technologies (near shore, deep sea, floating, subsea etc.)

- Installation and Logistics
 - Develop remote operating systems and at sea operations planning tools to optimise weather windows
 - Optimise methods for installation and decommissioning to reduce operation offshore and develop quick release and recovery systems for foundation and anchoring systems
 - Offshore Health & Safety
- Reliability and Survivability
 - Increase understanding of load effects on ocean energy devices to improve control systems and dynamic response
 - Development of sensors and fault detection systems for accurate condition monitoring, enabling predictive and preventive O&M processes
 - Develop robust and performant components with improved specifications to mitigate fatigue
 - Develop modular/Commercial Off-The-Shelf (COTS) components
 - Improve wave energy converter PTO, demonstration reliability and performance
- Power Generation and Grid
 - Develop “wet-mate” cable coupling and decoupling systems
 - Develop reliable grid conditioning components and methods for ocean energy
 - Optimise cable installation and maintenance
- Materials and Manufacturing

For Offshore Wind, the Strategic Research Agenda/Market Deployment Strategy⁶⁶ published by the European Wind Energy Technology Platform (TPWind), published in March 2014, identifies six priority areas that are focused on reducing the LCOE and “Safety, environment and education”; they are:

- Sub-structures
- Logistics, assembly and decommissioning
- Electrical infrastructure
- Wind turbines and farms
- Operations and maintenance
- External conditions

⁶⁶ http://www.windplatform.eu/fileadmin/ewetp_docs/Documents/reports/TPWind_SRA.pdf

These research priorities are supported by the Horizon2020⁶⁷ programme for 2015/16 that has specific calls for Ocean Energy. The rationales for the Horizon2020 calls are:

- European industries are leading the emergence of the technologies
- Many devices developed and prototypes tested, but market potential yet to be realised
- Demonstration of reliable and survivable systems essential
- Environmental, social and public impacts to be addressed

The calls cover the range of research areas and are as follows:

Basic research:

- Up-scaling technologies currently at lab-scale-LCE-6-2017

Advanced research:

- Increased performance and reliability of ocean energy sub-systems–LCE-7-2016
- Innovative power take-off systems and control strategies–LCE-7-2017

Demonstration:

- Scaling up in the ocean energy sector to arrays–LCE-15-2016 (€15 million)
- Design tools for ocean energy devices and arrays development/deployment–LCE-16-2017 (€7 million)

Market uptake:

- Multi-use of the oceans' marine space, offshore and near-shore: compatibility, regulations, environmental and legal issues (CSA), BG-3-2016, Budget: €2 million

There will be a significant proportion of the funding assigned to Horizon2020 remaining for the 2018/20 programme and the commission is indicating that the focus will be on larger scale projects.

The funding topics for offshore wind in the same Horizon2020 calls are:

- Improved understanding of the physics of wind as a primary resource and wind energy technology (LCE-6-2017)
- Advanced control of large scale wind turbines and farms (LCE-7-2016)
- Reduction of environmental impact of wind energy (LCE-7-2017)

⁶⁷ <http://www.horizon2020.ie/>

- Solutions for reduced maintenance, increased reliability and extended life-time of off-shore wind turbines/farms (LCE-13-2016)
- Demonstration of large >10MW wind turbine (LCE-14-2017)

Research Capabilities (Maturity Assessment)

The renewable energy research field is close to being at the Established level overall, and is clearly so in relation to Infrastructures and Networks & Relationships. There is a strong human capacity base with relevant research centres in place. However, the extent to which this base is applied to the marine field, as distinct from the wider renewable energy field, is an issue, with a need for an increase in dedicated focus on the marine.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 13: Irish Research Maturity in Renewable Energy showing the different levels of maturity for human capacity, infrastructure and networks

Human Capacity: “Defined – Established”

There are PI led research teams working across a wide range of topics associated with offshore wind, wave & tidal energy.

Following on from the Beaufort awards that increased the number of PhD graduates in this area, the MaREI SFI-funded centre has plans to recruit over 70 PhDs over the next 3 years.

However, the MaREI centre currently has an interim director and the turnover in this key position indicates that leadership issues will need to be addressed.

Infrastructures: “Established – Collaborative”

Ireland has a range of lab facilities and test sites that span the TRLs for research in this area, as shown in the Table below. There are also facilities for monitoring and other related support areas, for example the Coastal and Marine Research Centre (CMRC) at UCC and Wave Energy Simulation Tools at NUIM.

Most of the facilities in Ireland are focused on wave energy research. N. Ireland, however, has developed a tidal energy test site in Portaferry following on from the deployment of the commercial demonstration projects, Seagen – a world first, in Strangford Lough in 2008.

There are no dedicated test facilities for offshore wind technology. However, the wave test tanks have been used to test floating wind turbine designs and other test facilities could potentially cater for testing and field trials of next-generation foundation solutions for offshore wind.

There are also plans to develop an offshore wind test site in the Irish Sea, focused on demonstration of next generation fixed foundations, where new solutions for deeper water sites are at TRL6/7 and ready for pre-commercial deployment.

Researchers and industry, nationally and internationally, can hire existing test facilities. The Hydraulic & Maritime Research Centre, now relocated to the new LIR Centre in Ringaskiddy, coordinated the MARINET FP7 project that provided funded access to international researchers and businesses wishing to undertake tank testing projects at European facilities. Irish companies could not use the MARINET project to access facilities in Cork, though they were able to utilise the facilities operated by Queens University Belfast in Northern Ireland.

Work is on-going to bring Ireland’s established test facilities into a pan-European research infrastructure through the ESFRI roadmap; however, a well-defined national access programme is not currently in operation.

Table 1: National facilities for OE research

MRE Technology development:	Engineering:	In N. Ireland:
1. LIR National Ocean test facility, Ringaskiddy, Cork A. Ocean Basin: TRL4 B. Wave & Current Flume: TRL2 C. Wave Watch Flume: TRL1	7. Rotating test Rig, UCC: TRL3/4 8. Structural Research Laboratory, NUIG: TRL 4 9. Mobile & Marine Robotics Research Centre (MRRC), UL: TRL3/4	12. Belfast Wave Tank (QUB): TRL3/4 13. Portaferry Wave Tank (QUB): TRL3/4 14. Tidal Test Site (QUB): TRL5/6 15. Wave test site (QUB): TRL4/5
2. Tidal Basin, NUIG: TRL 2/3 3. Wave Flume, NUIG: TRL1/2 4. COER Wave tank facility, NUIM: TRL1/2 5. Galway Bay, Wave Test site: TRL5/6 6. AMETS: TRL8/9	10. Dublin Bay Digital Diamond Testbed (CIL): TRL 5/6 11. Galway Bay Subsea Cable Observatory: TRL5/6	16. SeaGen Demonstration site – Strangford Lough (MCT – Atlantis): TRL6/7 17. Minesto – Strangford Lough Demonstration site (Minesto): TRL5/6
		Proposed: 18. North Irish Sea Array – NISA (Oriel & Gaelectric): TRL8/9

Networks (Industry engagement): “Established – Collaborative”

The SFI MaREI research centre was established in 2014 and the model is based on inter-institutional research clusters to bring together Ireland’s marine energy research capacity to undertake core research and industry-led research projects. In-kind and cash funding is provided by businesses to part-fund the work undertaken. It is too soon to assess the functionality and performance of the centre, although two directors have moved on, to date, and sustained leadership will need to be addressed.

A technology centre, CASE, has been established in N. Ireland and several industry partners from Ireland have been involved in some of their projects, which cover the research areas of turbines, integration & storage, energy efficiency and energy from biomass. The centre is funded by £5m from InvestNI (£1m per year over 5 years). No Irish partners have been involved in any of the tidal turbine projects yet, although projects have included international partners from Germany and Scotland who can contribute cash or in-kind to avail of the research capacity on offer from the NI partners (QUB, UU and AFBI), which is supported at a 75% level from the InvestNI core funding.

Ireland has had a strong track record of success in the EU FP7 programme, in particular through the Hydraulic & Maritime Research Centre at UCC. UCC were the coordinator on several bids to the first set of calls involving Ocean Energy 2014/15. Success, however, has been minimal for the new Horizon2020 programme.

Ireland is due to host The European Wave & Tidal Energy Conference (EWTEC) in 2017 and continues to be recognised as being among the leading countries on Marine renewable energy research.

Indicators of industry engagement and impact of research remains low. There are low numbers of spinouts and no evidence of venture capital investment in the sector in Ireland in recent years. A national IP protocol was published in 2012. Protracted negotiations with universities, however, are an issue that has been raised in relation to the functionality of the IP protocols.

The complementarity of the Republic's Wave resource and research facilities and those of Northern Ireland in respect to Tidal resource and facilities provides a base on which to enhance collaboration in the MRE field.

Research Topics

Ireland’s existing strengths in test facilities for wave energy at lab scale (TRL3/4) at LIR, and field trials (TRL5/6) at Galway Bay, fit well with the need for testing and modelling identified in TP Ocean’s draft Strategic Research Agenda.

The Horizon2020 calls for 2015/16 include both the development of new technologies and increased performance and reliability of ocean energy subsystems, which would utilise test facilities like LIR and Galway Bay.

Support for Irish research projects in these areas will enable opportunities to compete for the Horizon2020 funding to be developed. Research in wave and tidal energy will continue to focus on reducing the levelised costs for energy and associated uncertainties, until the technology can attract sustained investment from private sector sources.

Recent research completed on geotechnical conditions in the Irish Sea, and opportunities to develop a site for demonstrating new foundation systems and larger turbines, provides opportunities for Irish researchers to establish a niche area of expertise in the offshore wind sector.

Focus of Funding

The instability in research leadership that could result from staff turnover in key senior positions at the SFI MaREI centre needs to be addressed. Focusing funding on a research project of significant scale, with wide ranging research themes, could support programmes designed to bring world-leading Research Professors and Future Research Leaders to Ireland.

Access to finance remains a challenge for the SMEs in the ocean energy sector, which also impacts on the ability for these research-orientated businesses to access test facilities.

A national access programme, similar to the MARINET FP7 project coordinated by UCC, could help increase the level of engagement of industry with the HEIs.

The SBIR programme launched by the Scottish government appears to have attracted significant interest from international businesses, has prompted business to collaborate with expertise in the research centres and will have the benefit of increasing the utilisation of existing test facilities in Scotland.

A suitably designed SBIR initiative, leveraging the LIR and Galway Bay facilities, could attract inward investment and potentially position Ireland as a world-leading hub for the deployment of marine renewable energy technologies and services.

Attracting demonstration projects could be achieved with a flexible approach to capital grants and feed-in tariffs that avail of opportunities in this area as they emerge.

Given the rapid advances, internationally, in the development of floating offshore wind technologies, and the very large resource identified for this technology in Ireland's strategic

Environmental Assessment, a specific new focus of funding should be designed to attract leading developers to test and demonstrate technologies in Irish waters.

Tourism

Overview

Global and Irish Tourism is in a period of unprecedented growth. More than **7.9m** overseas visitors came to Ireland in 2015, which represents an increase of **11%** on the year before. In terms of spending by international tourists, overseas revenue increased by **13%** to **€4.1 billion** and total tourism revenue for the year is expected to be **€7.3 billion**, an increase of 11% compared to 2014. **The Annual Tourism Industry Review in December 2015**⁶⁸ stated that Irish tourism is well placed to deliver significant employment and foreign earnings growth to 2020 and beyond provided the industry maintains competitiveness. The research on travel and tourism patterns within Ireland indicates that 70% of visitors are concentrated in areas representing 30% of the country. That area hugs the coastline from Malin to Mizen right around to Carlingford. Therefore, development of tourism in coastal and marine areas is essential to the development and growth of Irish tourism.

International consumer research conducted by the United Nations World Tourism Organisation (UNWTO) and Fáilte Ireland highlights that a growing number of consumers want to engage fully in what a destination has to offer; they seek a unique and authentic experience and therefore the development focus is shifting from product development to experience development. Fáilte Ireland's strategic development approach is based on identifying and defining those international consumers who are our best prospects. This new way of targeting growth is based on global and domestic consumer segmentation models and is embedded in current policies and plans.

The '**Wild Atlantic Way**' (WAW) is one of the biggest tourism initiatives ever undertaken in Ireland; developed by Fáilte Ireland it is designed to highlight Ireland's unique geographical positioning along the Atlantic Ocean. The objective is to develop a world leading destination brand that will attract more visitors and revenue from international markets and support the national tourism sustainable growth strategy for the next five years. In addition to the Wild Atlantic Way proposition, the emerging **Ireland's Ancient East (IAE)** and **Dublin, "A Breath of Fresh Air"** propositions plan to harness and use the marine asset and maritime heritage as a key point of differentiation.

Whilst still a niche area in the context of Irish tourism, global cruise tourism is growing at a significant rate and Ireland is attracting an increasing share of this market. Over 245 ships visited Irish ports in 2014 and the recent report "**Shared Strategy to maximise the economic growth of Cruise Tourism across the Island of Ireland**" has recommended a number of actions to deliver further growth for the Island.

⁶⁸ <http://www.failteireland.ie/Utility/News-Features/News-Library/Failte-Ireland-Annual-Review-and-Forecase.aspx#top>

The **Harnessing Our Ocean Wealth**⁶⁹ plan has set ambitious targets for Ireland’s ocean economy. The targets for Marine and Coastal Tourism, and Leisure including Cruise Tourism are demanding but considered achievable given recent performance and the national tourism development policy proposals in **People, Place and Policy Growing Tourism To 2025**⁷⁰. There are significant synergies between the **Wild Atlantic Way Operational programme**⁷¹ and **Harnessing Our Ocean Wealth** with regard to the development priorities in marine and coastal areas, which include investment in coastal infrastructure, amenities, towns and villages, management and sustainability actions, community engagement and supports, and addressing barriers to business development and growth.

There is evidence to suggest that marine tourism research is not being addressed amongst the academic community. The majority of research that contributes to the development agenda for tourism is commissioned by Fáilte Ireland and informed by international and national statistics from CSO, Eurostate, UNWTO and SEMRU. The number of academic researchers specialising in tourism is relatively small and whilst some Universities and Institutes of Technology are engaged in hospitality and tourism research activity it is considered that there is a gap between the needs of the development plans and policies and contributions. There is, however, interest in collaboration and recognition and a desire to build partnerships and networks that will support national tourism development strategies and innovative coastal development and experiences.

Context

There are many policies and strategies that have the ambition and/or potential to develop and grow tourism in our coastal areas and deliver revenue and local employment. The challenges and need for cross-cutting policies, engaged communities, and sensitive development are demanding. The **Harnessing Our Ocean Wealth** vision, goals and enabling actions provides the framework to support the development of the sector. **The Development Task Force** identified coastal and marine tourism as a cornerstone of its coastal and marine business theme; as the contribution from the Marine and Coastal Tourism Sector to the revenue targets for 2020 (€1,500 million) is ranked as the second most important contributor following Maritime Commerce and Ship Leasing (€2,600). Therefore, the importance of building a robust measurement system has been recognised and SEMRU is continuing

⁶⁹ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

⁷⁰ <http://www.dttas.ie/sites/default/files/publications/tourism/english/people-place-and-policy-growing-tourism-2025/people-place-and-policy-growing-tourism-2025.pdf>

⁷¹ http://www.failteireland.ie/FailteIreland/media/WebsiteStructure/Documents/2_Develop_Your_Business/Key%20Projects/Wild-Atlantic-Way-Operational-Programme_1.pdf

to collect reliable and comparable marine socio-economic data across all marine sectors including marine tourism and leisure. Its work can be further supported by the policy proposals in **People, Place And Policy Growing Tourism To 2025**, launched in March 2015, which includes support for innovation and continual improvement in the competitiveness and sustainability of our tourism offering, in order to most effectively meet the needs of future visitors. The Department of Transport, Tourism and Sport will, with the CSO, tourism agencies and third level institutions, establish a forum to identify key areas and ways in which additional sources of data can be harnessed to provide enhanced understanding of tourism performance and its economic contribution, including the possibility of developing a Tourism Satellite Account for Ireland.

Tourism Action Plan for the period 2016-2018⁷² launched on 28th January 2016 (FI and TI) and identified 23 actions to be addressed in the period between 2016 and 2018 aimed at securing continued growth in overseas tourism revenue and employment. The actions address a range of key issues, including the marketing of Ireland as a visitor destination overseas; visitor access to and within Ireland; the effective presentation of Irish culture, sport, and events to visitors; the role of Local Authorities in supporting tourism; visitor accommodation capacity; and skills development in the tourism sector.

The Programme for Government – published in 2016 – has restated commitments for rural development that support marine and coastal tourism development and includes actions to support development of Blueways, Coastal Walks and Greenways.

There are a number of additional national plans and policies that may inform a future research strategy and these include:

- CEDRA – Report of the Commission for the Economic Development of Rural Areas (CEDRA) “Energising Ireland’s Rural Economy”
- Priorities identified in the EU Atlantic Action Plan
- Shared Strategy to maximise the economic growth of Cruise Tourism across the Island of Ireland
- Commissioners of Irish Lights – Great Lighthouses of Ireland development plan
- Dublin Port Master plan
- Dublin Bay Biosphere Plan
- Leader Development plans LCDC’s – due to be submitted and evaluated in the latter part of 2016

⁷² <http://www.dttas.ie/sites/default/files/tourism/Tourism%20Action%20Plan%20-%20Final.pdf>

- New Visitor Experience Development plans commissioned by Fáilte Ireland – targeting areas such as Skelligs Coast, Burren and Connemara
- Development plans for Cork City and Harbour

Relevant Plans and Policies

People, Place and Policy Growing Tourism To 2025, launched in March 2015, highlights that although the number of academic researchers specialising in Irish tourism research is small, the high quality of the published research continues to provide valuable insight into the ongoing development of the sector.

The Government will support innovation and continual improvement in the competitiveness and sustainability of our tourism offering, in order to most effectively meet the needs of future visitors. The innovative developments that are undertaken in tourism, by the public and private sectors, will be complemented by high quality research that facilitates understanding of changing patterns in visitor needs and emerging solutions to meet those needs.

The Central Statistics Office (CSO) has a lead role in the collection and publication of statistics on overseas and domestic tourism activity. The Department of Transport, Tourism and Sport will establish and chair a forum to identify key areas and ways in which additional sources of data can be harnessed to provide enhanced understanding of tourism performance and its economic contribution. The Department will invite the CSO, tourism agencies, universities and institutes of technology to contribute to the forum. A multi-annual framework of research on tourism will be agreed between the parties. This may include the development of a Tourism Satellite Account for Ireland.

Fáilte Ireland, Tourism Ireland Action Plan 2016 – 2018

Action 13 – Fáilte Ireland and Bord Bia will collaborate on the development of food-related experiences for tourists, including the promotion of food, beverages and marine trails that highlight the very high quality of Irish food and beverages for visitors. The food experiences will align closely with the three tourism experience brands (Wild Atlantic Way, Ireland’s Ancient East, and Dublin – A Breath of Fresh Air).

Action 18 – The provision of Wi-Fi connectivity at outdoor locations, particularly at the signature points along the experience brands, will be encouraged to support visitors in sharing their images of Ireland through social media.

Action 21 – In recognition of the importance of tourism to local economies and the contribution of Local Authorities to tourism development:

- Local Authorities will, under the auspices of the County and City Management Association, convene a Tourism Strategy Sub-group, whose primary objective will be to facilitate the sharing of best practice on developing tourism.
- Guidelines, including a draft template for Local Authority tourism strategies, consistent with the policy objectives in 'People, Place and Policy - Growing Tourism to 2025', will be developed.
- Following approval of the template, each Local Authority will be required to produce a tourism strategy (or update its existing strategy) within this common template.
- The tourism agencies will engage with individual Local Authorities that have developed/are developing links with the diaspora from their respective counties in order to examine the opportunities for collaboration.
- A conference addressing best practice in the Local Authority/Community tourism field will be organised in 2016 in order to bring together the varied stakeholders in local tourism to exchange best practice.

Action 22 – A review of the effectiveness of existing supports available to new tourism enterprises will be undertaken, including the potential to establish a start-up fund to support innovative tourism projects, involving collaborative approaches at Local Authority and community levels.

Action 23 – The Fáilte Ireland Visitor Attitudes Survey will be updated to reflect the wider range of factors influencing visitor satisfaction. The findings of this research will inform future public investment decision.

The **Wild Atlantic Way Operational Programme 2015 - 2019**, sets out a strategy and an implementation framework and programme for the sustainable implementation of the Wild Atlantic Way over the period.

Action #50 – *Explore opportunities for collaboration both nationally and with other EU states on research and funding projects at an inter-regional level* relates to the objective to implement the Operational Programme through a range of effective partnerships at community, county, regional and national level. A Partnership Strategy is to be devised with stakeholders and partners identified as being central to the implementation of the Operational Programme and critical to ensuring an integrated national co-ordinated approach to implementation of the programme and protection of the environmental resources along the route.

Tourism as a driver in rural economies and the report of the **Commission For The Economic Development Of Rural Areas (CEDRA)** “Energising Ireland’s Rural Economy” included a number of

recommendations in the tourism area including the preparation of a national plan for the development of tourism in rural areas as a distinct part of the national tourism planning process.

The Department of Transport, Tourism and Sport is participating in the inter-Departmental Group tasked with the implementation of the recommendations of the CEDRA report. The recent Programme for Government has restated the Government's commitment to the report findings.

Harnessing Our Ocean wealth, as the key driver for the strategy, has highlighted tourism in the Enablers of "Clean – Green – Marine" and "Business Development, Marketing & Promotion" along with specific actions for tourism on "Infrastructure" and "International and North/South Cooperation". Feedback from the consultation also highlighted the importance of actions in the "Capacity, Education, Training & Awareness" enabler.

- Clean – Green – Marine: Reputation for a clean, green marine environment, which benefits many of our marine enterprises (e.g. seafood, tourism and leisure).
- Business Development, Marketing & Promotion: The vision of Ireland as a clean, green, high-quality, innovative producer of excellent food is being branded at home and abroad. The food industry is embracing this concept, contributing to economic recovery with its ability to grow and export. This image is also being promoted as an essential component of Ireland's tourism product.
- Infrastructure: Action 34 – Carry out national, regional and local initiatives aimed at tapping into the potential of new and existing coastal infrastructure to develop sustainable products, services and jobs.
- International and North/South Cooperation: North/South and East/West cooperation in the marine area is traditionally strong. Areas of common interest include shipping, energy, tourism, aquaculture and research. Action 38 – Continue to foster a North/South and East/West approach in developing/enabling the marine sector (e.g. grid/all-island energy strategy, marine tourism and leisure) through existing structures and bodies.
- Capacity, Education, Training & Awareness: Feedback from Consultations – Communities were encouraged to become more involved with our marine potential and be supportive of the development of the sector. Local coastal communities were identified as key players in certain marine sectors e.g. tourism and leisure. The need to promote engagement with the sea at a recreational level and strengthen our awareness and identity of our ocean wealth was highlighted.
- Action 34d: Utilising existing built and natural assets (e.g. lighthouses and offshore islands) to develop tourism products and services.

The strategic framework from the **Development Task Force** includes “Tourism & Business in Marine & Coastal Areas”, aimed at providing employment to rural coastal communities by capitalising on and adding value to initiatives such as the Wild Atlantic Way, as well as other tourism related initiatives such as Cruise Ship Tourism.

Priorities are identified in the **EU Atlantic Action Plan**⁷³ to combat seasonality and improve prospects for SMEs through diversification of maritime and coastal tourism products and development of niche markets by investing in:

- Marine sport, marinas and nautical leisure activities
- Port services, including those for cruise passengers
- Identifying and promoting cultural and natural attractions of the Atlantic seaboard such as artisanal fishing, local cuisine and maritime heritage
- Protecting and restoring tourist attractions, including coastal and underwater cultural attractions, and maritime heritage sites with archaeological, ecological or historical value

The Great Lighthouses of Ireland project⁷⁴ designed and developed by the Commissioners of Irish Lights and funded by INTERREG, includes the development of five new tourism experiences and branding and marketing of 12 lighthouse tourism sites around the Irish coast. Fáilte Ireland, Tourism Northern Ireland, Tourism Ireland, Local Authorities, the Royal Society for the Protection of Birds, and community groups are all partnered in this project. The project links closely with the Wild Atlantic Way, Causeway Coastal route, the Mourne Coastal Driving Route and Ireland’s Ancient East and is expected to attract a significant number of additional domestic and overseas visitors to the coastal periphery. Irish Lights are also in the process of developing projects to increase awareness of maritime heritage and support the protection of heritage assets within their remit.

⁷³ EU Atlantic Action Plan (2014 – 2020) & Inter Regional Funding Opportunities <http://oar.marine.ie/bitstream/10793/962/1/EU%20Atlantic%20Action%20Plan%202014-2020%20and%20InterRegional%20Funding%20Opportunities.pdf>

⁷⁴ <http://www.irishlights.ie/tourism/great-lighthouses-of-ireland.aspx>

Research Capabilities (Maturity Assessment)

Overall, the Marine & Coastal Tourism research theme is assessed to be at “Ad-hoc”. There is considerable scope to progress this research theme to “Defined”. In contrast to the overall lack of active academic research in the field, it has an active community of interest, which is something of an anomaly when set beside the capacity and infrastructure dimensions. A likely explanation of this is that the research theme is of interest to a considerable community of research, but is not their primary focus of research.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 14: Irish Research Maturity in Marine & Coastal Tourism showing the different levels of maturity for human capacity, infrastructure and networks

Human Capacity: “Ad-hoc”

The majority of existing research is directed by government agencies, in particular Fáilte Ireland who has invested in global consumer research to inform their development and investment agenda. The capability at academic level is currently concentrated in small numbers of academic researchers specialising in Irish tourism research at University of Limerick, Dublin Institute of Technology, Galway Mayo Institute of Technology and Sligo Institute of Technology and there is little evidence of research in “Marine” themes. Additional posts and projects are being considered within the Institute of Technology network and a number of collaborative projects are underway.

Infrastructures: “Ad-hoc”

In addition to the centres mentioned above, there are a number of undergraduate training programmes with direct and indirect relevance to the research theme. However, there is a lack of evidence of HEI commitment to the topic in the form of capital spending.

A National Innovation Centre for Tourism is proposed in current tourism development strategies and the University of Limerick has endeavoured to lead in this area; its National Centre has supported eight PhD projects since 1997.

Networks (Industry engagement): “Ad-hoc – Defined”

There is considerable evidence of an active community of interest in this field. This includes the number of annual (and in some instances long running) workshops and conferences. The Kemmy Business School at the University of Limerick lead and host the Annual Tourism Policy Workshop at Dromoland Castle – now in its seventh year it has attracted high-level national and international

speakers. Themes have included Tourism Performance and Competiveness, Consumer Trends, Insights and Innovation, Best Practice and Destination Development. The opportunity exists to influence the agenda and request for papers in 2016, as this is hosted in November each year.

The annual Tourism and Hospitality Research in Ireland Conference (THRIC) has included papers on the “Wild Atlantic Way”. Three papers (out of 33) with a marine theme related to the “Wild Atlantic Way” were presented at the 11th annual Tourism and Hospitality Researchers in Ireland Conference (THRIC) in 2015 – this network could be targeted to present and consider Marine Tourism Research needs.

There is also evidence of research networks such as that supported by the Connacht-Ulster Alliances (GMIT, IT Sligo and Letterkenny IT). The initiative of the Wild Atlantic Way (WAW) was deemed by the cluster group as an appropriate research theme due to its current impact on the region. It was recognized that this research theme is multifaceted and would therefore benefit from an inter-institutional and an interdisciplinary research approach. Researchers from the four institutions have identified and agreed a number of themes for future research that include:

- The development of creative tourism on the WAW (bundling, knowledge sharing)
- Investigating the gaps in infrastructure for marine tourism on the WAW
- The development of renewable energy technology tourism on the WAW
- The development of cultural tourism trails on the WAW e.g. food, literary, folklore etc.
- The tourist experience on the WAW (movement, slow tourism)
- The intrinsic value of the WAW on the regions
- The development of genealogical and diasporic tourism on the WAW (maritime history)
- Under-utilised marine food ingredient development

Nationally, a number of entities such as Waterford institute of Technology have been successful in leading INTERREG funded consortia, and while these are not directly research related, they have included the application of research and best practice such as Green Innovation and Future Technology (GIFT), supported SME clusters and action learning. WIT was a lead partner in the Fáilte Ireland Tourism Learning Networks and this model could inform a Marine Tourism Cluster approach.

There are very effective Marine networks in place such as Cork Maritime College and Malin Waters’ group – the opportunity exists to network them with Tourism academic groups and networks.

Finally, there are a range of trade networks, community networks and destination groups, which appear to interact regularly with the research community. The Burren Geo Group has recently won national and international awards. The Irish Responsible Tourism Awards and Leave No Trace Ireland

each have a network that collaborates with universities and IOTs that could be leveraged to support research and innovation activity. The Wild Atlantic Way and Adventure Tourism networks are established and could be supported to target international and EU research funds. An emerging Pan-European Armada Heritage and Tourism Network is an example of maritime heritage research that may support a number of future programmes.

Research and Funding Focus

Research in this area should act as a catalyst to build partnerships and networks that can support innovation in delivering new visitor experiences, performance and destination development benchmarking, consumer research and trends, citizen engagement and awareness, and a national maritime interpretation strategy. The research should be closely aligned to the topics identified under the Integrated Policy & Governance theme.

Proposed Focus of Funding / Instruments

Consideration should be given to funding interventions at three levels, national, community and institutional:

1. Support an annual National Marine Tourism Research Forum to align existing expertise and resources amongst the academic and agency community. This would act as a catalyst to harnessing existing expertise and resources and encourage Marine Tourism research and papers for more conferences and events. Consideration should also be given to a Research Award.
2. Fund a Marine Tourism Innovation scheme that supports coastal community / academic partnership research and develop new visitor experiences harnessing marine resources and maritime heritage, technology and links with other marine disciplines.
3. Fund PhD positions to support the preparation of EU and Funding applications that will add to the national tourism and maritime development agenda.

Transport

Overview

The maritime transport sector can be divided into three main areas:

- Ports & Maritime Logistics
- International Maritime Services
- Seafaring (which covers the training and certification of seagoing crew)

There is a very low level of functioning R&D capacity in ports and maritime transport sector, which, given its role in supporting export led growth, would appear to be a fundamental weakness in the sector's ability to plan for and add long term strategic value to the domestic economy.

There are opportunities for **Ireland's Ports infrastructure** to participate as "test beds" for the deployment of 'e-Maritime' services. The 'e-maritime' concept aims at promoting the competitiveness of the European maritime transport sector and a more efficient use of resources through better use of Information and Communication Technology (ICT) tools.

The planned development of the **International Shipping Services Centre (ISSC)** will create a global centre of excellence for integrated shipping services, with potential to attract more international shipping companies to come to Ireland, where the favourable tax regime, which includes an R&D tax credit, would promote increased investment in this area.

The **National Maritime College of Ireland (NMCI)** is a purpose built facility that serves the training requirements of the School of Nautical Studies, Cork Institute of Technology and the Irish Naval Service. Facilities are focused on providing training and education for the Merchant Marine and the non-military needs of the Irish Naval Service, though NMCI is involved in a European FP7 research project where the simulation facilities are being utilised.

The **Halpin Centre** for Research & Innovation at the NMCI is the maritime research and innovation centre for the Cork Institute of Technology and the research and innovation arm of the Irish Naval Service. The centre undertakes research and innovation in the areas of Maritime Safety & Security, Shipping Transport & Logistics and Maritime Education & Training.

Ireland's capacity for specific maritime transport research is low, though researchers from other cross-cutting areas are active in maritime networks and EU Collaborative research projects, for example the Centre for Innovative Human Systems, Irish Centre for Composites Research (IComp) and the SFI MaREI Centre. The main transport research capacity in Ireland is through the Transport &

Infrastructure research cluster at UCD and the **Centre for Transport Research and Innovation for People (TRIP)**, which is a multidisciplinary centre based at TCD with links to UCC.

The **Irish Transport Research Network** was formed in late 2009 by a group of University based researchers. It hosts an annual conference with some maritime themes, though transport research in Ireland is predominantly on land-based transport and few research projects into maritime transport have been undertaken by Irish research groups.

Ireland's Maritime Transport sector has considerable growth opportunities, as identified in the recent report from the **Development Task Force (DTF)** established as part of "Harnessing Our Ocean Wealth – An Integrated Marine Plan for Ireland"⁷⁵. These opportunities span across the full marine sector and include cross-cutting opportunities in ICT, and clean, efficient energy for the maritime transport industry.

These areas are included in the prioritisation that underpins Ireland's strategy for research and development, science and technology – **Innovation 2020**⁷⁶, for example:

- "Data Analytics, Management, Security & Privacy" that has applications for shipping services
- "Smart Grids and Smart Cities" for "Intelligent Ports" and meeting the objective for the EU's "Motorways of the Sea" to reconcile all the key elements involved in maritime transport – ports, ships, human element and organisational systems and procedures
- "Future Networks & Communications" for the EU's E-maritime concept

The cross-cutting research capacity in Ireland provides an opportunity to participate in the HORIZON 2020 Work Programme "**Smart, green and integrated transport**"⁷⁷, which has specific maritime transport calls where sustainability in all of its three dimensions (economic, environmental and social) remains a key challenge for waterborne transport. Equally important is a continued focus on improving maritime safety.

In parallel to continued support for cross-cutting research on maritime transport, the capacity for direct transport related research could be improved by strengthening the existing transport research centres in maritime related fields.

⁷⁵ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

⁷⁶ Innovation 2020 (2016) (available at <https://www.djei.ie/en/Publications/Publication-files/Innovation-2020.pdf>)

⁷⁷ <https://ec.europa.eu/programmes/horizon2020/en/h2020-section/smart-green-and-integrated-transport>

The need to stimulate industry collaboration in research could be achieved through a targeted SBIR programme that could also enable the utilisation of existing infrastructures in ports as “test-beds” for new enabling technologies that contribute to national research priorities in ICT, Data Analytics & Renewable Energy.

Increased interaction with leading maritime transport centres in Europe, in particular through exchange programmes to attract researchers to Ireland, would help improve capacity in the short term and provide scope for future development of Ireland’s research capacity.

Context

Ireland’s **National Ports Policy 2013**⁷⁸ is focused on facilitating a competitive and effective market for maritime transport services. It introduces clear categorisation of the ports sector and the transfer of smaller State commercial port companies to relevant local authority control. There are no actions directly referencing research & innovation needs, however, there are opportunities for Ireland’s Ports infrastructure to participate as “test beds” for the deployment of ‘e-Maritime’ services at European and global level, which will be one of the main priorities for the EU Commission in terms of practical implementation of RTD efforts in the field of maritime transport.

The opportunities for cross-cutting research & innovation for Ireland’s Maritime Transport sector were identified in the recent report from the **Development Task Force (DTF)** established as part of “Harnessing Our Ocean Wealth - An Integrated Marine Plan for Ireland”. These opportunities span across the full marine sector and include cross-cutting opportunities in ICT and clean, efficient energy for the maritime transport industry.

These cross-cutting areas are included in the sector prioritisation that underpins Ireland’s strategy for research and development, science and technology **Innovation 2020**. For example, priority areas from the **National Research Prioritisation Exercise (NRPE)** applicable to the maritime transport research agenda are:

- “Data Analytics, Management, Security & Privacy” for shipping services
- “Smart Grids and Smart Cities” would cover ‘Intelligent Ports’ and meeting the objective for the EU’s “Motorways of the Sea”: to reconcile all the key elements involved in maritime transport – ports, ships, human element and organisational systems and procedures
- “Future Networks & Communications” for the EU’s E-maritime concept

⁷⁸ <http://www.dttas.ie/sites/default/files/node/add/content-publication/National%20Ports%20Policy%202013.PDF>

Sectors identified in the new enterprise policy **Enterprise 2025**⁷⁹: **Innovative, Agile, Connected** are also relevant, for example the untapped potential of “Marine” and “Green technologies” could contribute to economic growth in the maritime transport sector. The overall low level of investments in RD&I in Ireland that needs to be addressed across all sectors has a particular resonance to the maritime transport sector, where no or very low levels of functioning R&D capacity present a fundamental weakness in the sectors ability to plan for and add long term strategic value to the domestic economy given the crucial role the maritime transport sector has in supporting export led growth.

The main strategic objectives for the **European maritime transport system up to 2018** concludes that “The European Union and its Member States have a strong common interest in promoting safe, secure and efficient intra-European and international shipping on clean oceans and seas, the long-term competitiveness of European shipping and related maritime industries in world markets, and the adaptation of the entire seaborne transport system to the challenges of the 21st century” and that Europe should be a world leader in maritime research and innovation.

The **EU Atlantic Action Plan** sets out priorities for research and investment to drive the ‘blue economy’ forwards in the Atlantic area. Priorities for implementation through to 2020 have been identified and the 2014-2020 Partnership Agreements for the ESIF are an important funding channel that Member States can use to implement these priorities.

Leading member states in this area have innovation and associated financing for transport at the heart of their maritime strategies. The **Dutch Maritime Strategy 2015 – 2025**⁸⁰ was presented at the “Maritime and Innovation Brokerage Event 2015” hosted by The Netherlands. Key points are:

- Innovation is focused on clean, smart and safe shipping, social innovation and integration of the maritime transport in the logistical chain
- Continue the intensive cooperation within the Netherland’s maritime cluster but also look for cross industry innovations
- Government will facilitate the maritime cluster to seize business opportunities, for example, eliminating barriers to innovation through fast processes of approval and government plans to adjust or even delete legislation in order to offer greater scope for experimentation, to encourage innovative types of vessels and, where possible, to act as launching customer

⁷⁹ Enterprise 2025 Ireland’s National Enterprise Policy 2015-2025. Department of Jobs, Enterprise and Innovation, Dublin 2015

⁸⁰ https://www.noordzeeloket.nl/images/The%20Dutch%20Maritime%20Strategy%202015-2025_4995.pdf

- The Netherlands, in cooperation with the European Commission, EIB and shipping sector (KVNVR) is developing a **Shipping Financing Tool**

The Commission aims for EU wide roll-out of this type of innovative financing, not only for EU shipping, but also infrastructure, alternative fuels and inland shipping. The Netherlands is a front-runner; Sweden, Finland and France are on track.

The UK has a **Transport Systems Catapult**, which participated in the SISTALS ("Solutions for Integrated Seamless Transport Across Land and Sea") feasibility study that helped demonstrate the value of a fully integrated vehicle and freight tracking system that could be used to increase fuel efficiencies and reduce the impact of congestion, whether at sea, in ports or on the road – with the scope to also consider rail freight issues in the future. Project partners included AB Ports, General Lighthouse Authorities (GLA), UK Hydrographic Office, Universities and ICT & data specialists.

The Research and Radio-navigation Directorate (R&RNAV) work for the General Lighthouse Authorities (including the Commissioners of Irish Lights) and are leading a proposed INTERREG project SeaSHIFT (Sea Sustainable Harmonised Integrated Freight Transport).

Ireland's ports and research capabilities in cross-cutting sectors, for example ICT, could get involved in similar research activities; however, there appears to be a lack of coordination on research projects in the maritime transport sector.

Relevant Documents / Sectoral Plans

The priorities identified in the EU Atlantic action plan, with relevant maritime transport references include:

- Priority 1: Promote entrepreneurship and innovation
 - Increasing the capacity of the Atlantic area to innovate through research and technology by encouraging:
 - a) Networking and co-operative research between research centres, higher education and business in the Member States
 - b) Transferring knowledge and insights, as well as skills between higher education, business and research, including through regional, national and cross-border maritime clusters and technology platforms
- Priority 2: Protect, secure and develop the potential of the Atlantic marine and coastal environment
 - Reinforcing the safety and security of seafarers, coastal populations, property and ecosystems

- Priority 3: Improve accessibility and connectivity
 - Facilitating the development of ports as hubs of the blue economy
- Priority 4: Create a socially inclusive and sustainable model of regional development
 - development of niche markets by investing in port services, including those for cruise passengers

In addition to the funding available through the ESIF Partnership Agreements, these research priorities for Europe are supported by several funding programmes that include:

- Connecting Europe Facility (CEF)
- Horizon2020
- INTERREG

Connecting Europe Facility (CEF) finances projects which fill in the ‘missing links’ in Europe’s transport, energy and digital network – and there’s a total of €26.2bn available over the next seven years.

The Motorways of the Sea project continues under the auspices of CEF, with emphasis on connectivity within Europe. Eligibility is usually based on projects involving two or more European partners.

A more direct route for funding is available through the Horizon 2020. In addition to collaborating on research activities, opportunities for Irish companies or ports would also include being the test bed or deployment area for something new and innovative.

Other EU funding opportunities include the INTERREG programme, for example the INTERREG North-West Europe Programme 2014-2020.

Research Capabilities (Maturity Assessment)

Human Capacity: “Ad-hoc”

There are few researchers dedicated to Maritime transport in Ireland. However, researchers from other cross-cutting areas, such as the Centre for Innovative Human Systems, the Irish Centre for Composites Research (IComp) and the SFI MaREI Centre, are active in maritime networks and EU Collaborative research projects with transport themes. The main transport research capacity in Ireland is located at the Transport & Infrastructure research cluster at UCD and the Centre for Transport Research and Innovation for People (TRIP), which is a multidisciplinary centre based at TCD with links to UCC.

Transport research in Ireland is predominantly on land-based transport and few research projects into maritime transport have been undertaken by Irish research groups. For example, The National Institute for Transport & Logistics (NITL) is managed by the School of Transport Engineering, Environment & Planning at Dublin Institute of Technology.

Infrastructures: “Ad-hoc”

The IMDO publishes an annual statistical bulletin, the Irish Maritime Transport Economist, which is a comprehensive reference guide to maritime transport statistics, including trade, traffic, international shipping markets and economic data. The archive of the Irish Maritime Transport Economist carries annual statistics and analysis from 2004 onwards, which provides valuable data sets for a range of maritime transport research areas. However, outside of relatively small and focused research studies undertaken by companies and public sector bodies involved in the maritime transport sector there is little evidence that these data sets have been utilised for large scale research projects.

There are no direct testing infrastructures for maritime transport, though ports and lighthouses could be “test beds” and there is evidence that this is happening on other sectors. The facilities at the NMCI are being used as part of the FP7 research project LEANWIND, which is linked to investigating some transport issues in relation to cost reduction for offshore wind.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 15: Irish Research Maturity in Maritime Transport showing the different levels of maturity for human capacity, infrastructure and networks

Networks (Industry engagement): “Ad-hoc – Defined”

The **Irish Transport Research Network** was formed in late 2009 by a group of University based researchers. It hosts an annual conference with some maritime themes, however, only two out of the 55 papers presented at the 2014 and 2015 conferences had links to maritime transport.

There is some involvement in EU networks. The European Technology Platform WATERBORNE is a forum where all stakeholders from the waterborne sector define and share a common Vision & Strategic Research Agenda, driving the necessary innovation efforts forward. There are 29 members and Ireland is represented through the National Maritime College of Ireland.

The Halpin centre is involved in collaborate research projects with other EU partners, including as lead partner in the INTERREG funded project “Small Craft Emergency Response and Survival Training for Arctic Conditions” (SMACS) completed in 2014. Relevant projects to transport have been focused on:

- Improving maritime safety and Atlantic Regions coastal pollution response through technology transfer, training and innovation
- Improving competitiveness of the naval ancillary industry by implementing activities to enhance innovation capacity
- Providing unmanned platforms for search and rescue operations
- Promoting the results of a number of completed maritime vocational education and training (MVET) projects which directly address particular problems or deficiencies in MVET throughout Europe, and represent innovative use of ICT in lifelong learning
- Demonstrating, evaluating and disseminating new robotic systems, sensors and networking technologies in maritime incidents endangering human life, the environment and economic activities
- Building and demonstrating an EU maritime surveillance system integrating existing national and communitarian installations and enhancing them with innovative technologies
- Providing an empirically-informed, multi-stakeholder understanding of how the impact, legitimacy and effectiveness of European security legislation might be best measured and understood

Ireland’s research or industry base has minimal involvement in large collaborative research projects with a direct relevance to maritime transport; however, Ireland’s researchers are involved in projects that have some maritime transport themes. For example UCC are coordinating the LEANWIND FP7 project which is focused on reducing the cost of offshore wind and includes work

packages on developing new concepts for installation vessels. The National Maritime College of Ireland is also a participant on the LEANWIND project.

Research Topics

Research topics relevant to Ireland are largely driven by the EU research agenda for Maritime Transport.

INTERREG North-West Europe Programme 2014-2020⁸¹ has themes on Innovation, Low Carbon and Resource and materials efficiency that could have application in Ireland's maritime transport sector, for example, a particular "Specific Objective" is "To facilitate the implementation of transnational low-carbon solutions in transport systems to reduce GHG-emissions in NWE". This Programme will co-finance cooperation projects with €370 million of the European Regional Development Fund (ERDF).

The 2016/17 calls in the HORIZON 2020 Work Programme "Smart, green and integrated transport" include relevant calls under "Mobility for Growth" that will address:

- Mode-specific challenges in areas of waterborne transport
- Cross-modal and/or transport integration specific challenges, for example on Safety, Logistics, Intelligent Transport Systems & Infrastructure
- Cross-cutting issues on socio-economic and behavioural research and forward looking activities for policy making

The Waterborne calls include:

- MG-2.1-2017: Innovations for energy efficiency and emission control in waterborne transport
- MG-2.2-2016: Development, production and use of high performance and lightweight materials for vessels and equipment
- MG-2.3-2016: New and improved transport concepts in waterborne transport
- MG-2.4-2017: Complex and value-added specialised vessels

Infrastructure calls include:

- MG-7.3-2017: The Port of the future

⁸¹ http://www.nweurope.eu/media/1225/nwe-programme-manual_v3-call3.pdf

Other calls on other Horizon 2020 programmes and INTERREG programmes, for example calls on cross-cutting focus areas of Blue Growth and Energy Efficiency, which links with the “Matrix of Opportunity” identified in the DTF report, include:

- Boosting Innovation for emerging Blue Growth activities
 - BG-2-2016/2017: High value-added specialised vessel concepts enabling more efficient servicing of emerging coastal and offshore activities
- Low Carbon Energy
 - LCE 19 – 2016/2017: Demonstration of the most promising advanced biofuel pathways
 - LCE 8 – 2016/2017 Development of next generation biofuel technologies

Focus of Funding

Continued support for cross-cutting research on maritime transport needs to be leveraged to establish capacity for direct transport related research. This could be improved by strengthening and adding maritime fields to existing transport research centres. A focus on incentivising and supporting participation in Horizon2020 or INTERREG bids could act as a stimulus to this.

The need to stimulate industry collaboration in research could be achieved through a targeted SBIR programme that could also enable the utilisation of existing infrastructures in ports as “test-beds” for new enabling technologies that contribute to national research priorities in ICT, data and renewable energy.

Industry players in Ireland doing R&D on maritime transport that is relevant to Ireland with potential to export new solutions to others, could be stimulated though the range of research and innovation support available from Enterprise Ireland, for example Innovation Vouchers.

Exchange programmes that could attract leading maritime transport researchers to Ireland would help address capacity in the short term and could be used as a stepping stone to building a more sustainable research capacity in this area.

Developing an Innovative Financing Tool and running a pilot scheme for maritime transport to catch up with front runners like The Netherlands, Sweden, Finland and France on the EU Commission’s roll out plans.

Security & Surveillance

Overview

Ireland's unique location as an island on the western periphery of Europe, and a gateway to the Atlantic, provides opportunities to develop and test smart maritime safety, security and surveillance products and services for an expanding global market. Capacity, networks and expertise in this domain are mostly cross-cutting in nature, in particular with links to Advanced Technologies. However, particular specialist expertise will need to be developed through leveraging existing domain knowledge and test beds available through the Irish Defence Forces and other agencies and organisations such as the Coast Guard, the Marine Institute and the Commissioner of Irish Lights.

Maritime safety, security and surveillance are key to achieving the vision and goals of Harnessing our Ocean Wealth (2012)⁸². The creation of the conditions needed for economic growth, investment and job creation depend on a safe, secure and protected environment consistent with best international standards. In addition, there is significant opportunity to develop a centre of excellence for marine surveillance products and services that can be exported internationally given our geographical location and existing expertise in the ICT and engineering sector. These factors positively lend themselves to a unique value proposition in this domain in addition to other factors. These include existing collaborations and relationships between public agencies such as the Irish Naval Service, the Coast Guard and the Air Corps and the national research and innovation community.

There exists a selection of PI led groups working on aspects of this domain. However, creating opportunities for further collaboration between research teams and industry with expertise relevant to this sector in light of emerging opportunities could increase the maturity level in this area. In particular, the enterprise base is at a low but emerging level and incentivising linkages between the emerging enterprise bases could help create the platform for more industry funded research in the medium to long term. Additionally there exists research and industry not currently operating in this environment, which have expertise that is transferable to meet future demands in this emerging sector. Building on existing partnerships of agencies operating in this sector could help further engagement with additional EU/International partners.

Infrastructure already exists that can also support developments in this sector and there is much potential for the further integration of these facilities. For example the Marine Institute Research Vessels, the Irish Naval Vessels, Air Corps and Coast Guard platforms are already being used to

⁸² HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

support research and innovation at varying levels in areas of technology development that are relevant to this sector. Agencies such as the Marine Institute and Commissioner of Irish Lights (CIL) operate a network of fixed and moving data collection platforms off the Irish Coast. CIL also operate e-navigation services and networks which include an extensive AIS Aids to Navigation (AtoN) service. In particular, the collaboration between the Irish Naval Service with UCC and CIT as part of the Irish Maritime and Energy Research Cluster has provided a significant platform to expedite the dedicated use of publically available infrastructure to provide real test environments for technology. Most recently, the SLA between the Department of Defence and the Marine Institute has been updated to include services relating to the Air Corps, in addition to the Irish Naval Service. However, there also exists further opportunity to develop purpose built facilities. Purpose built platforms to support research in maritime security could help to attract interest from EU & international researchers as a stepping stone to creating a National Research Centre for the sector. Additionally, test beds and platforms being deployed for other sectors, including use of and engagement with the ports sector, could help to form part of a multi-platform offering that would support various elements of the value chain required to further develop this sector.

Researchers are involved in EU funded projects and initiatives such as the Defence Enterprise Initiative and the Irish Maritime and Energy Resource Cluster (IMERC) have helped to support the development of a recognised research community in the maritime security sector. The maturity level is rated as “Defined”.

The development of a cross-institutional interdisciplinary research team that further builds on existing capacity, infrastructure and relationships with industry will help to advance the networks in this domain. Additionally, the opportunity to use SBIR initiatives to accelerate local and international collaborations, as well as supporting the enterprise base as it becomes established in Ireland, would help increase the maturity level. Capacity across the research and enterprise sector has been mapped across the general thematic area of security by Dr. Michael Murphy, the National Delegate and Contact Point for Security. This will help to facilitate future collaborations (Murphy, 2015).

Context

Maritime safety, security and surveillance is outlined as one of the key enablers of Harnessing Our Ocean Wealth (2012). The associated actions promote the development of research and development in this sector. The subsequent report from the Development Task Force proposed a demonstrator initiative in Marine Technologies for Security and Safety.

The significance of this domain in the development of our marine economy is due to a number of factors. Firstly ensuring a safe, secure and protected maritime environment is critical for economic

growth, investment and the general prosperity of our maritime sector. Additionally, given the levels of growth envisaged for the offshore economy both nationally and internationally e.g. Blue Growth (2012), the future development of the offshore economy will require technologies to support offshore operations in challenging environments and for safety at sea.

The European Council adopted a **Maritime Security Strategy (EUMSS)**⁸³ in 2014. One of the five work strands in its action plan is dedicated to “Maritime Security Research and Innovation, Education and Training”. The objective is to promote research and the development of innovative technologies that contribute to the improved efficiency and effectiveness of operations and information sharing, through coordinated and enhanced research and knowledge development.

Ireland's **White Paper on Defence** (2015)⁸⁴ highlighted that many of the risks and threats listed in the EU Maritime Security Strategy are relevant to Ireland's maritime domain. Ireland has a very significant stake in the matters comprehended by the EUMSS. The White Paper confirms Ireland's strong support for the EUMSS and its Action Plan. Ireland will continue to support the internal as well as the external dimension of maritime security and will continue to stress the importance of the global aspect of the Action Plan.

Additionally, in the context of the EU's **Blue Growth**⁸⁵ strategy, **Integrated Maritime Surveillance** is outlined as one of the essential components to provide knowledge, legal certainty and security in the blue economy. In this context a **Common Information Sharing Environment (CISE)** is being developed jointly by the European Commission and the EU/EEA Member States. A draft roadmap was published by the European Commission in 2010 to develop the CISE so that data and information can be exchanged easily and to create better situational awareness by enhanced cooperation across maritime surveillance authorities. A follow up document was published in 2014 around next steps within the development of CISE. Similarly, one of the priorities of the **EU Atlantic Action Plan**⁸⁶ is to “Protect, secure and develop the potential of the Atlantic marine and coastal environment”, with specific objectives on *improving maritime safety and exploring and protecting marine waters and coastal zones*.

⁸³ <http://register.consilium.europa.eu/doc/srv?l=EN&f=ST%2011205%202014%20INIT>

⁸⁴ <http://www.defence.ie/WebSite.nsf/WP2015E>

⁸⁵ European Commission (2012) Blue Growth opportunities for marine and maritime sustainable growth COM/2012/0494 final Brussels

⁸⁶ EU Atlantic Action Plan (2014 – 2020) & Inter Regional Funding Opportunities <http://oar.marine.ie/bitstream/10793/962/1/EU%20Atlantic%20Action%20Plan%202014-2020%20and%20InterRegional%20Funding%20Opportunities.pdf>

Relevant Documents / Sectoral Plans

In the context of the Harnessing Our Ocean Wealth enabler ‘Maritime Safety, Security and Surveillance’, the following actions support the need to develop a national research and innovation capacity in this domain:

- Action 3 – Develop and implement systems to provide real-time operating, surveillance and monitoring information on activity within Ireland’s maritime domain
- Action 8 – Collaborate with industry and R&D institutes to deliver leading edge technology that supports more effective and efficient maritime surveillance capacity

The White Paper on Defence highlights the responsibilities across departments for security and responsibilities for maritime-related security including the following – Revenue has responsibilities to combat the smuggling of illicit narcotics and other contraband; The Department of Transport, Tourism and Sport has responsibilities relating to port and airport security; The Department of Communications, Energy and Natural Resources has lead responsibilities relating to cyber security; The Department of Agriculture, Food and the Marine and the Sea Fisheries Protection Authority have certain responsibilities relating to the security of maritime resources.

The Department of Transport also have a particular remit across safety related policy areas and operates the Irish Maritime Administration, which includes the Marine Survey Office and the Irish Coast Guard. The Irish Coast Guard’s objective is to reduce the loss of life on Ireland’s seas, lakes, waterways and rivers, coastal and remote areas; to provide assistance to persons in dangers at sea, and the coast or remote inland areas; to coordinate searches for missing persons at sea or on the coast; to provide support on request to statutory bodies or agencies particularly in emergency response; to intervene as necessary in marine casualties; to monitor maritime traffic within our EEZ; to prevent or minimise damage to the marine environment within the Irish Exclusive Economic Zone, harbours and maritime local authority areas; and to preserve property when possible (Irish Coast Guard, 2016)⁸⁷. The Coast Guard operates a selection of platforms, technology and international partnerships to assist in meeting these objectives.

In addition to contributing to national security, military organisations are typically required to provide a range of non-security services to Government departments and agencies. The White Paper on Defence outlines that there is an ongoing need to examine new and innovative (novel ways to get additional utility for the State, with minimal additional costs) means of improving capabilities in

⁸⁷ <http://www.dttas.ie/maritime/english/irish-coast-guard-ircg>

security and defence so that the Defence Forces are in a position to undertake these roles. In this context, it is outlined that the Department of Defence will assess opportunities arising from EU funding and will also identify opportunities for cooperative-collaborative engagement between the Defence Forces and Irish-based enterprise and research institutes including third level colleges. The primary purpose is to support the Defence Forces' capability development while also leveraging opportunities to support innovation, growth and jobs.

The ***Defence Enterprise Initiative*** will be developed further over the course of the White Paper. This will include the establishment of a Security and Defence Enterprise Group bringing together enterprise, industry, research and practitioners in the field of security and defence to identify areas of common endeavour and collaboration. Through the Security and Defence Enterprise Group, the Department of Defence and the Defence Forces, with Enterprise Ireland, will also seek to support Irish based enterprise in their engagement with the European Defence Agency (EDA) and in accessing EDA and Horizon 2020 programmes. As the State's principal sea-going agency, the Naval Service provides a unique sea-going capability. The Air Corps also has an effective maritime surveillance capacity.

From a European Policy perspective, the actions in the **EUMSS** action plan on "Maritime Security Research and Innovation, Education and Training" include:

- Establish new and develop further existing networks for knowledge and competence development in the field of maritime security for civilian and military educational institutes, centres and academies
- Establish a civil-military agenda for research and innovation in support of maritime security including the development of dual-use and multipurpose capabilities in support of Member State capabilities
 - Promote public-private partnerships to accelerate technology development.
 - Create a network of global research and development partners.
 - Identify capability gaps requiring technological solutions and also promising innovative technologies that will have dual-use or cross-sectoral benefit. These may relate to maritime surveillance and situation awareness, information sharing, unmanned systems, environmental and energy aspects and innovative sensors.
 - Explore innovative sensors applications to improve the early detection and continuous tracking of small vessels, with a focus on (a) advanced technologies to independently verify self-reporting systems and help detect non-reporting ships, and (b) novel platforms to improve the highly-needed continuous surveillance.

- Promote the conduct of inter-agency, joined-up exercises

The need to maximise synergies and cross-fertilization in the field of maritime cyber security, in particular between the maritime sector, the ICT industry and other industry sectors, as well as academia is also highlighted. A Draft Roadmap towards establishing the **Common Information Sharing Environment (CISE)** for the surveillance of the EU maritime domain was published in 2010. CISE is being developed jointly by the European Commission and EU/EEA member states and will integrate existing surveillance systems and networks and give all concerned authorities access to the information they need for their missions at sea.

The specific objectives from the **EU Atlantic Action Plan** on the priority area of “Protect, secure and develop the potential of the Atlantic” include:

- Supporting investments in state-of-the-art equipment that contribute appropriately to enhancing coordinated preparedness and responses to marine threats, natural disasters, marine accidents, spills of oil and hazardous material or trafficking.
- Developing, testing and deploying new technologies to improve the inspection of vessels and enhance the safety and security of ports and shipping by better integrating data from satellites and from air, sea and land-based surveillance facilities and innovative in-situ instruments to improve situational awareness in the maritime domain.
- Helping to deliver regional sea-basin-related information services within the Common Information Sharing Environment (CISE), based on agreed EU-wide standards and experience gained by Member States in pilot projects.
- Developing a **European Atlantic ocean observing and predictive capability**, based on existing structures, platforms and mechanisms to support the implementation of EU policies; reduce costs for industry, public authorities and research institutions; stimulate innovation and reduce uncertainty in the behaviour of the Atlantic ocean and the impact of climate change by developing new instruments and platforms for ocean observation and ecosystem monitoring (including seabed mapping) that increase the number of parameters that can be measured automatically; lower the costs of observation; and accelerate the dissemination of data to users.

The importance of this domain in European policy is reflected through the inclusion of marine specific topics in the Horizon2020 challenge on **“Secure societies – Protecting freedom and security of Europe and its citizens”**⁸⁸. These include:

- SEC-20-BES-2016: Border Security: autonomous systems and control systems
Low levels of situational awareness on the EU borders, high at sea and on unpopulated or scarcely populated land areas, are important factors of cost of border surveillance. This could improve if the different prototypes of unmanned vehicles tested today to perform automatically a very limited set of functions and routines could be transformed into autonomous, long-enduring agents able to operate in complex maritime and land environments.
- SEC-01-DRS-2016: Integrated tools for response planning and scenario building
Enhanced cooperation between autonomous systems entities: satellite-, sea-, land- and air-based systems, including but not limited to the Copernicus, Galileo and EGNOS systems, from different agencies and of a large variety of capabilities and costs.

Security is also referenced in the 'Secure, Clean and Efficient Energy'⁸⁹ challenge where “Support to the initiative on sustainable energy in the defence and security sector” is listed under other actions.

Ocean Observation & Surveillance is covered in **“Advanced Technologies”** and is linked to the combination of Ireland's ICT strengths and existing marine research test beds and infrastructure.

By way of international comparisons, **“The UK National Strategy for Maritime Security”**⁹⁰ published in 2014 has innovation as one of its key priorities where it will “continue to monitor the latest innovative technological developments in security screening and detection equipment with a view to sponsoring joint trials with UK industry and our European and international partners. This will allow us to exploit the latest research and development activity and deliver effective and low cost solutions to future maritime threats”.

⁸⁸ http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-security_en.pdf

⁸⁹ http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-energy_en.pdf

⁹⁰

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/310323/National_Strategy_for_Maritime_Security_2014.pdf

Research Capabilities (Maturity Assessment)

Despite being a relatively newly defined area for marine related research, the Security and Surveillance theme is at the Defined stage in terms of Human Capacity, Infrastructures and Networks & Relationships.

Human Capacity: “Defined – Established”

There exists a selection of PI led groups working on aspects of this domain. However, some of these teams are not focused uniquely on the security and surveillance sector but have expertise that is applicable to this domain in addition to others. In this context there are significant links with the ‘Advanced Technologies’ section of this strategy. Research teams with a high level of focus on this sector include the following:

The **Halpin Centre for Research and Innovation** (Cork Institute of Technology) based at the National Maritime College of Ireland (NMCI) on the IMERC campus delivers and supports Maritime Operations Research and Innovation in Ireland and internationally. A small team, including PhD students are involved in collaborative research projects, including those with other EU partners. Examples of projects related to the safety and security sector include:

- Lead partner in the INTERREG funded project “Small Craft Emergency Response and Survival Training for Arctic Conditions (SMACS) completed in 2014.
- Improving maritime safety and Atlantic Regions coastal pollution response through technology transfer, training and innovation.
- Improving competitiveness of the naval ancillary industry by implementing activities to enhance innovation capacity.
- Providing unmanned platforms for search and rescue operations.

The **Mobile & Marine Robotics Research Centre (MMRRC)** at the University of Limerick has undertaken research projects in the areas of Marine Incident Response, Marine Intervention and Maritime Security. The research has focused on development of advanced robotic platforms, airborne platforms, novel communications and sensor solutions to address these challenging areas.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 16: Irish Research Maturity in Maritime Security & Surveillance showing the different levels of maturity for human capacity, infrastructure and networks

MMRRC are partners in the SFI Centre MaREI. They are involved in number of national and international projects which include the following:

- Aeolus – over the horizon surveillance (radar, camera, multispectral), collaborative project with NMCI, CIT, supported by the Irish Naval Service for ship access, funded by EI.
- AWESCO – H2020 International Training Network on Airborne Wind Energy.
- NATO Science for Peace project **MORUS** – Unmanned system for maritime security and environmental monitoring.
- MaREI – Observation & Monitoring Spoke projects with industry partners: Real-time high-bandwidth radio communications in marine facilitating remote monitoring and real-time control of platforms; Development of marinised UAV system for inspection and SAR off shore.
- GSI INFOMAR 2015 – Auto launch and recovery with moving pilot – base station.
- IRC – Remote and auto flight control of tethered parafoil kites for airborne wind energy and aerial sensor/communications platforms.
- NETMar Project and Exercise Cathach – Emergency response exercise planning and coordination. UAVs deployed in segregated airspace over three day exercise. Key partners: Irish Aviation Authority, Irish Naval Service, Irish Coast Guard, Commissioner of Irish Lights.
- FP 7 Project Darius – Marine incident demonstrator/training project involving at sea lost vessel and ship collision incidents.
- DAHG supported survey of UC42 sub marine wreck – where ROV *Latis* was deployed from LE *Eithne*.
- Sensored telemetry streaming from fixed wing aircraft, system identification, and controller design.
- Long Range High Bandwidth Secure Comms – Remote Presence, live interaction with distant robotic vehicles and sensor platforms independent of existing infrastructure.
- Ocean sensing platforms – for persistent remote presence offshore with extended horizon communications and satellite communications (controlled and monitored from anywhere).
- Ocean RINGS environment developed for subsea operations – extended to airborne maritime operations environment, unmanned aerial vehicles and remotely operated vehicle smart systems i.e. fault tolerant control, auto tuning, one-click auto survey, augmented reality visualisations (transparent ocean).

The **National Centre for Geocomputation** and the broader **Geocomputation and Earth Observation** cluster at Maynooth University has specific expertise around the area of drones and is a leading centre of excellence in the field of geocomputation, applying computational methods to large spatial

datasets addressing areas such as data acquisition, analysis, modelling and visualisation. In the marine, there is focused expertise around multi-sensor mapping and monitoring systems. The NCG are leading a Petroleum Infrastructure-Funded (PIP) project in the area of oil spill detection and have carried out a marine incident demonstrator with multiple organisations in the context of the project. They also hold a Funded Investigator role as part of the SFI Centre iCrag in mapping marine surface features. In the context of this project, they are developing systems and software for mapping and monitoring marine slick features.

The **Coastal & Marine Research Centre (CMRC)**, now part of the **SFI MaREI research centre** at the Beaufort building in UCC has expertise in working with end users regarding requirements for remotely sensed data in the environment and security fields and has worked closely with the Irish Naval Service in providing advice regarding the use of SAR image information for their operational requirements in fisheries monitoring and maritime surveillance. The Applied Remote Sensing & GIS group now based at MaREI-UCC has been a partner on several internationally funded research projects relating to maritime security and surveillance, including:

- Development of a Decision Support Environmental Tool for the Irish Coast Guard – funded by the Irish Coast Guard, Department of Transport.
- Addressing New challenges in Satellite Based Maritime Surveillance and Arctic Monitoring (ANISTIAMO) – a project funded by the European Space Agency (ESA) and coordinated by Kongsberg Satellite Services in Norway. CMRC tasks centre on collation of user requirements and incorporating user preferences into the design of satellite-based services and products, and the development of ship detection and tracking capabilities based on interpretation of radar (SAR) imagery. Skytec and National Space Centre are the Irish Industry partners.
- Next Generation Maritime Picture (RMP) project is funded through ESA's Integrated Applications Programme. It aims to enhance the recognised maritime picture for the Irish Naval Service through the addition of supplementary data sources such as satellite AIS. In addition, state of the art data mining, data analysis and simulations are used for early identification of unusual behaviour of vessels. Skytek, National Space Centre, UCC, and the Irish Naval Service are the Irish partners on the project.
- The CMRC also has a good working relationship with Qinetiq with whom they have been working for over two years on the application of remotely sensed imagery for maritime security issues.

An example of a project emerging through the Defence Enterprise Initiative is the Aeolus project, which involves collaboration between the naval service, the Halpin Research Centre, Nimbus (CIT),

SEAI and the MMRRRC (UL). The project received funding from Enterprise Ireland to develop a kite system for increased surveillance and also opportunities for increased energy efficiency. This will also result in opportunities for commercialisation and the development of a spin out company.

Overall there exists a good baseline of capacity in the research community to build on. Further leveraging the capacity outlined in the area of Advanced Technologies and creating opportunities for collaboration between research teams and industry with expertise relevant to this sector in light of emerging opportunities would increase the maturity level in this area.

Infrastructures: “Defined”

The infrastructures available for research in the safety, security and surveillance sector include:

- The resources and expertise available from the Defence Forces through the Defence Enterprise Initiative
- Simulators and UUVs developed/upgraded by MMRRRC at UL for trialling new technological developments
- The Irish research vessels, Irish naval vessels, Irish Air Corps platforms and access to international vessels in Irish waters
- The Irish Coast Guard have made available infrastructure and end-user expertise for the development of R&D projects that support the delivery of their services
- The NCG at Maynooth University has an unmanned aircraft system for testing novel sensors and geospatial computational methods
- ICT infrastructure available at the ICHEC for accessing near real time satellite remote sensing data
- Data aggregation platforms and data interrogation and GIS tools operated by research centres such as MaREI, NCG, NUIG (e.g. HF Radars) and national agencies including the Irish Naval Service, the Irish Air Corps, the Coast Guard, the Marine Institute and the Commissioner of Irish Lights
- The Commissioner of Irish Lights also operates a shore based network of AIS base stations and an extensive AIS Aids to Navigation (AtoN) service. They are currently upgrading their coastal communication networks to provide higher speed. Additionally they provide e-navigation services including communication, data transfer, and exact positioning verification which can also support real time monitoring and historic data
- A teleport facility is operated by National Space Centre Ltd

Over the last number of years, the Naval Service has developed subsurface technological capability with a suite of ROVs and ROV related equipment. A commercial industry aligned ROV pilot technician

course developed for military personnel has also enabled the development of substantial knowledge around the use of this equipment. Additionally SkyTec Ltd. has developed an Unmanned Aerial System (UAS) school at the NMCI with IAA authorisation. Infrastructure outlined as part of the ‘Advanced Technologies’ and ‘Renewable Energy’ components of this strategy are also relevant here e.g. SmartBay for testing AUVs.

Additionally there exists much potential to develop dedicated infrastructure for the test and development of technologies in this domain. There are existing facilities with direct water access, nearby port infrastructure and relevant expertise to develop a multiplatform offering for a national centre of excellence for training and testing. Additional types of infrastructure could also support the development of expertise e.g. coastal radar and Wi-Fi systems along the coast.

Networks (Industry engagement): “Defined”

The development of networks in this space is advanced through initiatives such as the **Irish Maritime and Energy Resource Cluster** and the ***Defence Enterprise Initiative***.

The **Irish Maritime and Energy Resource Cluster** (IMERC) is an alliance between the Naval Service, Cork Institute of Technology (CIT) and University College Cork (UCC), which brings together expertise in the fields of energy engineering, maritime operations, maritime technology and ecosystem governance. This research and commercial cluster aims to realise Ireland’s economic potential in the global, maritime and energy markets. The IMERC strategy includes addressing technology challenges in a wide range of areas including network integration, autonomous vehicles and underwater operations. As the Naval Service has significant technological end user knowledge, it can bring this valuable knowledge to researchers and foreign direct investment clients and small and medium enterprises. The MMRRC has also collaborated with the Naval Service, the Naval Training College and IMERC on numerous projects and has some notable ongoing active collaboration from the projects outlined in the ‘Capacity’ section. The Commissioner of Irish Lights is a collaborator in the SFI MaREI Centre. Agencies such as the Irish Naval Service and the Irish Coast Guard are partners in a selection of European security and surveillance related projects.

The ***Defence Enterprise Initiative*** is a joint initiative of the Department of Defence and Enterprise Ireland, where the Defence Forces make available resources and expertise, including advice and information etc., to Enterprise Ireland supported companies and other companies and institutions engaged in research, innovation and product/service development in the security and defence arena. The support offered by the Defence Forces includes the evaluation of technology research and innovation, provision of information on military requirements and the Defence Forces considered views on trends in specific capability development requirements. This initiative will be

developed over the course of the White Paper on Defence and will include the establishment of a Security and Defence Enterprise Group that will bring together enterprise, industry, research and practitioners in the field of security and defence to identify areas of common endeavour and collaboration. An example project that has emerged is Aeolus, which was described in the section on Research Capacity. There are plans in place to develop an inter-agency working group for the development of a single state national maritime picture, which will include relevant agencies across Government departments e.g. Air Corps, Naval Service, Coast Guard, Marine Institute, etc.

Further development of these initiatives and the strengthening of an interdisciplinary industry focused research team operating in this space that leverages existing capacity and infrastructure will help to advance the networks in this domain. Capacity across the research and enterprise sector has been mapped across the general thematic area of security, which will help to facilitate future collaborations (Murphy, 2015).

Research Topics

Given existing expertise and the recommendations and actions outlined in the various policy documents and sectoral plans, research topics that focus on the development and implementation of systems that provide real time operating, surveillance and monitoring information on activity in the maritime domain, along with the delivery of cutting edge technologies that can deliver this information from harsh and remote environments in a real-time manner should be the focus of future investment. In addition to the development of capacity, this will also require further investment in dedicated infrastructure or the ability to leverage existing infrastructure into purpose built facilities and develop the appropriate partnerships between enterprise, research and public sector development and defence agencies.

In this context, research topics should include areas related to:

- Development and testing of Autonomous vehicles e.g. Unmanned Aerial Systems (UAS), Unmanned Surface Systems (USS), Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs)
- Related to the above, the development of advanced communications, sensor technologies and platforms to support maritime surveillance
- Development of geospatial technologies and decision support tools for mapping, monitoring, tracking and decisions support

Focus of Funding

Capacity:

Overall there exists a good baseline of capacity in the research community to build on. Further leveraging capacity outlined in the area of Advanced Technologies and creating opportunities for collaboration between research teams and industry with expertise relevant to this sector in light of emerging opportunities would increase the maturity level in this area.

Infrastructures:

Additionally there exists much potential to develop dedicated infrastructure for the test and development of technologies in this domain. There are existing facilities with direct water access, nearby port infrastructure, communications infrastructure and relevant expertise to develop an internationally recognised centre of excellence for training and testing in this domain.

Other test beds and platforms being deployed for other sectors could help form part of a multi-platform offering that would include this sector. Purpose built platforms to support research in maritime security could help to attract interest from EU and international researchers as a stepping stone to creating a National Research Centre for the sector.

Networks:

The opportunity to use SBIR initiatives to accelerate local and international collaborations, as well as supporting the enterprise base as it becomes established in Ireland, would help to increase the maturity level. Full engagement of the relevant agencies in the objectives of the Defence Enterprise Initiative and further development of industry oriented research collaborations will be necessary. Additionally, the development of a cross-institutional interdisciplinary research team that further builds on existing capacity, infrastructure and relationships with industry will help to advance the networks in this domain. Capacity across the research and enterprise sector has been mapped across the general thematic area of security and a similar exercise with a more refined focus on the maritime domain may help to further facilitate collaborations. However, the ability to leverage capacity from other sectors will also be critical.

The enterprise base is at a low but emerging level and incentivising research linkages with the emerging enterprise base could help create the platform for more industry funded research in the medium to long term.

Healthy Marine Ecosystems

The second goal of Ireland's Integrated Marine Plan, *Harnessing Our Ocean Wealth*, is to protect, preserve and, where possible, restore Ireland's rich biological diversity and ecosystems. To do this, a deep understanding of the functioning of the ecosystems that are at work in our expansive maritime territory is required.

Key areas of research cover:

Biodiversity, Ecosystems & Food Webs

Litter

Marine Pollution

Climate Change

Ocean Observation

Biodiversity, Ecosystems & Food Webs

Overview

A healthy, functioning environment is essential for economic growth and activity. Biological diversity and the functioning of ecosystems are critical for the sustainability of any environment.

Ireland has a unique geographical position, which influences the physical properties of the ocean around us. These features combine to give us a network of independent ecosystems whose productivity is driven by the biologically diverse food webs they support. Thus, biological diversity and productive, high functioning food webs are the essential component of healthy ecosystems in the Irish marine space. The goods and services that we derive from the biological marine resources are built upon these elements. Approximately 50% of the most recent Gross Value Added (GVA) estimates for Ireland's ocean economy, €1.3bn, (SEMUR 2012 report on Ireland's Ocean Economy⁹¹) rely on the biological productivity derived from these food webs.

The intrinsic value of biodiversity itself cannot be underestimated. Its economic value is being increasingly realised in the form of ecosystem goods and services. Economic values are considered to be both tangible and intangible. The intangible elements, such as human well-being, while difficult to quantify, also contribute to economic growth and wealth. On the other hand, tangible benefits which can be directly measured, e.g. healthy fish stocks, need to be managed sustainably to ensure their economic benefits continue to support economic growth while at the same time conserving their intrinsic value. The report on the Economics of Ecosystems and Biodiversity⁹² (TEEB) estimates that global business opportunities from investing in biodiversity could be worth US\$ 2-6 trillion by 2050.

Research is fundamental to understanding how to utilise our biodiversity and ecosystems in a sustainable manner so that the ecosystem goods and service derived from them can be managed and utilised into the future. Monitoring forms a critical component of research, allowing us not only to assess impacts and measure change, but as an essential data resource for other researchers within the field of biodiversity, ecosystems dynamics and function, and in other related disciplines (e.g. climate change research).

We cannot conserve what we do not know. Therefore, research is critical to ensure the benefits of biodiversity and functioning ecosystems are available to drive economic growth into the future. This

⁹¹ Ireland's Ocean Economy, 2012 (available at http://www.nuigalway.ie/semru/documents/semru_irelands_ocean_economy_web_final.pdf)

⁹² TEEB – The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers (2010)

will allow policy decisions to be based on a thorough knowledge of the various problems, interactions and dependencies involved.

Biodiversity research in Ireland has largely focused on the research required to implement various EU nature and environment Directives, resulting in a lack of funding for blue skies or fundamental research. This has led to gaps in our knowledge base, which hamper our understanding of biodiversity and ability to conserve it. Nationally, biodiversity research support across different government departments is fragmented, scattered and largely uncoordinated. This has led to a lack of coherence between departments attempting to implement the various Nature Conservation Directives and conduct the necessary research required for their implementation. It has resulted in an overlap of research projects and a lack of awareness across departments of where the knowledge gaps actually lie. There is currently a lack of understanding and knowledge regarding biological diversity⁹³ and an urgent need to develop scientific, technical and institutional capacities to provide the basic understanding upon which to plan and improve appropriate conservation measures. This lack of hard scientific data has been highlighted by the Convention on Biological Diversity (CBD) and by various other national, European and international regulations and by the Irish National Biodiversity Plan. In recent years, economic recession and a lack of understanding of the intrinsic and extrinsic benefits of biodiversity, has compounded the underfunding of marine biodiversity research.

Marine food web and ecosystem research in Ireland has focused on small scale primary research. National research on biological marine productivity has focused either on components at the bottom of the food web in terms of biological oceanography, or on the population dynamics of individual commercially exploited species, which is used to provide advice on fisheries management in support of the CFP. There is a gap in the knowledge and understanding of food web structure and function, and on the detail of ecosystem level productivity in Irish waters. This lack of knowledge needs to be addressed in order that Ireland can fully implement a suite of international imperatives ranging from Ecosystem based fisheries management (as espoused in the CFP), to marine spatial planning (MSP), and the implementation of the Convention on Biological Diversity (CBD). Funding of food web and marine ecosystem research has been ad-hoc and lacking co-ordinated objectives that would assist this research impacting appropriately on national policy objectives.

⁹³ Waldren, S., Scally, L., Atalah, J., Brown, M., Byrne, C., Crowe, T., Cunningham, C., Davies, A., Eschmann, C., Fitch, J., Fitzgerald, H., Galley, C., Gittings, T., Grennan, J., Guiry, M., Higgins, T., Harrison, S., Irvine, K., Kavanagh, R., Kelly-Quinn, D.L., Long, M.P., McCarthy, T.K., Milbau, A., O'Callaghan, E., O'Halloran, J., O'Mahony, L., Osborne, B., O'Toole, C., Parnell, J.A.N., Rodríguez Tuñón, A., Stengel, D. & Stout, J. (2011). Biochange. Biodiversity and Environmental Change: An Integrated Study Encompassing a Range of Scales, Taxa and Habitats. Synthesis Report. STRIVE Report Series No. 68. Environmental Protection Agency, Wexford.

Context

Global concern over widespread loss of biodiversity has resulted in regulations and policies in favour of environmentally sound development and biodiversity conservation (UNEP, 1992⁹⁴). In Ireland, the majority of legislation that aims to halt biodiversity loss and protect ecosystems is EU driven (Habitats Directive, Birds Directive, Marine Strategy Framework Directive, Water Framework Directive, Environmental Liability Directive, and the Planning and Development (Amendment) Regulations 2011). Despite these legislative instruments the status of Ireland's biodiversity remains poor or bad (NPWS, 2008⁹⁵). While the legislative drivers have helped to encourage and foster research, this research is directed at applied research, and fundamental or blue skies research remains poorly funded and underrepresented. National legislation on the protection and sustainable use of the marine bio-resource is also substantially focused on the impacts of human activity rather than the natural biological mechanisms that support the derivation of economic value. Implementation of such legislation is largely driven by EU directives.

It is thus not surprising that research in this area, which is not co-ordinated at a national level, is undertaken by Ireland generally within traditional schools of science (e.g. biological oceanography, zoology) in universities and Technology Institutes; or through one off programmes aimed at addressing knowledge gaps in support of specific policies (e.g. Beaufort EAFM project in support of the CFP).

The impacts of increased anthropogenic activity in the marine space (e.g. through increased marine tourism and transport, the establishment of marine renewable energy sites and the increased utilization of both traditional and non-traditional marine biota in biotechnological applications) will require a system level understanding of ecosystem level productivity, which is driven by marine food webs, in order to manage that increasing marine activity in a sustainable fashion. Thus, research to understand food web structure and function in marine ecosystems is fundamental to managing the impact of Ireland's aspiration for increased activity across all sectors as aspired to in Harnessing Our Ocean Wealth.

At an International level, the United Nations **Convention on Biological Diversity (CBD)**, to which Ireland is a signatory, provides the framework for the conservation and sustainable use of global biodiversity through the use of the Ecosystem Approach. It sets out commitments to which each contracting party must adhere, in order to maintain the diversity and functionality of the world's

⁹⁴ United Nations Environment Programme. www.unep.org

⁹⁵ Bullock, C., Kretsch, C. and Candon, E., 2008. *The Economic and Social Aspects of Biodiversity. Benefits and Costs of Biodiversity in Ireland*. Department of Environment, Heritage and Local Government, Dublin.

ecosystems, in tandem with economic development. It also details the obligations that each contracting party has towards identification and monitoring the components of biodiversity and both *in-situ* and *ex-situ* conservation of these components. Specifically, Article 12 of the CBD details a requirement for research and training to develop methods for conservation and sustainable use of biological resources. The ultimate outcome of which would be halting the loss of biodiversity on a global scale.

In October 2010 **The Strategic Plan for Biodiversity 2011-2020** was adopted at the Conference of the Parties (COP) 10. This Plan was designed to promote effective implementation of the CBD through a strategic approach, which includes five goals and 20 Aichi Biodiversity Targets. These focus on the conservation and sustainable use of biodiversity, and safeguarding ecosystems, species and genetic diversity. Support mechanisms for research, monitoring and assessment are detailed in the plan and are fundamental to ensuring its effective implementation.

At a European level, the **EU Biodiversity Strategy**⁹⁶, published in 2011, aims to halt the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020. It identifies six overarching target areas containing twenty actions designed to halt the loss of biodiversity and maintain and restore ecosystem services in the EU by 2020, as well as highlight the requirement to understand food webs and ecosystem level productivity. The EU Nature Conservation Directives form an integral part of implementing the Strategy.

The **EU Nature Conservation Directives**⁹⁷ (**Birds and Habitats Directives**) remain the overarching driver for biodiversity research throughout Europe. While the aim of both Directives is to contribute towards ensuring biodiversity through the conservation of natural habitats and of wild fauna and flora, the need for research to fully implement the Directives is specified also.

Regulation 1143/2014 on Invasive Alien Species (IAS)⁹⁸ (2015) – The spread of Invasive Alien Species (IAS) has been identified as one of the four main drivers of anthropogenically driven biodiversity loss⁹⁹. The issue of IAS and its implications for biodiversity has been addressed at International, European and National level both through Directives and legislation. However, In January 2015 a stand-alone regulation on the control of invasive species came into force. This

⁹⁶The EU Biodiversity Strategy to 2020 (available at <http://ec.europa.eu/environment/nature/info/pubs/docs/brochures/2020%20Biod%20brochure%20final%20lowres.pdf>)

⁹⁷ http://ec.europa.eu/environment/nature/natura2000/index_en.htm

⁹⁸ Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the prevention and management of the introduction and spread of invasive alien species, 2015 (available at <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014R1143>)

⁹⁹ Millennium Ecosystem Assessment (2005) Living beyond our Means: Natural Assets and Human Well Being. Statement by the Millennium Ecosystem Assessment Board. 25pp.

regulation deals with measures (including research) for the control of IAS to protect native biodiversity and ecosystem services as well as ecosystem food web structures.

The **Marine Strategy Framework Directive**¹⁰⁰, which came into force in 2008, aims to protect the marine environment across Europe. The focus of the Directive is on achieving Good Environmental Status (GES) of the EU's marine waters by 2020. It is the first EU legislative instrument to propose a framework for the protection and maintenance of marine biodiversity and marine food webs. This framework is based on the implementation of an ecosystem-based approach to the management of anthropogenic activities as they relate to the protection of the marine environment. The Directive notes that programmes of measures executed under marine strategies will only be effective if they are based on informed knowledge of the marine environment and allied to the waters relevant to each Member State. In this regard it makes provision for national level preparation of an appropriate framework to include marine research and monitoring operations, for informed policymaking.

Both the **European Marine Board** and the **European Platform for Biodiversity Research (EPBR)**, which are pan-European science/policy platforms, have provided recommendations for the most urgent priorities for research.

At a National level **Actions for biodiversity 2011-2016**¹⁰¹ is Ireland's second National biodiversity plan. It was developed with cognisance of the EU Biodiversity Strategy and the CBD strategic plan and provides a strategy for the restoration and conservation of Ireland's biodiversity. The plan is built around a series of seven strategic objectives. Objective 2 of the plan aims to substantially strengthen the knowledge base for conservation, management and sustainable use of biodiversity. In this respect it notes that *"Up to date scientific knowledge is essential for an informed assessment of the status of biodiversity, for insight into the causes of biodiversity loss and for developing the means to halt or reverse losses"*. It notes that programmes of inventory and research detailed in the first National Biodiversity Plan, which have not yet been completed, should be addressed. It also notes the research recommendations of the NPBR, which include a programme of prioritised marine research, and aims to address them.

¹⁰⁰ DIRECTIVE 2008/56/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), 2008 (available at <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056>)

¹⁰¹ ACTIONS FOR BIODIVERSITY 2011-2016 IRELAND'S NATIONAL BIODIVERSITY PLAN, 2011 (available at <https://www.npws.ie/sites/default/files/general/national-biodiversity-plan-english.pdf>)

The Biodiversity Knowledge Programme for Ireland¹⁰², produced by the National Platform for Biodiversity Research and published by the EPA in 2006, was one of the first attempts to assess biodiversity knowledge gaps in Ireland and the research required to address them. This programme identified four priority areas for biodiversity research, including the enabling actions required to implement them. While considering biodiversity research needs as a whole, many of the specific research themes identified in this programme related to the need for marine research.

Research recommendations of the Marine Working Group of the NPBR – A review of the Biodiversity knowledge Programme by the National Platform for Biodiversity Research was undertaken in 2012 and concluded with the publication of five sectoral plans for biodiversity research needs, including marine research in Ireland. This document identified the enabling actions and urgent research priorities under the guidance of an expert working group and wider consultation with those involved in marine research and policy in Ireland.

Ireland's biodiversity in 2010: knowledge gaps¹⁰³ noted that a huge body of work remains to document Ireland's marine biodiversity resource. It further noted that it will be a challenge to make a significant contribution to improving this within the next decade, to 2020 unless significant resources are dedicated to it.

The **Strategy for Science, Technology and Innovation**¹⁰⁴ provides a framework to foster excellence in Irish research. It aims to achieve this through implementing increases in the 4th level public research system to increase research capacity and provide a better management of the research and innovation environments. It notes that *"meeting international environmental obligations will demand continued engagement in such areas as climate change, biodiversity loss, environment and health, the urban environment, air pollution, waste management and water quality"*.

Harnessing Our Ocean Wealth¹⁰⁵ is an integrated marine plan that provides a framework for high-level goals and integrated actions across policy, governance and business to enable Ireland's marine potential to be realised. It is designed around three high level goals that focus on developing a

¹⁰² Biodiversity Knowledge Programme for Ireland, Report by the National Platform for Biodiversity Research 2006 (available at http://www.epa.ie/pubs/reports/research/biodiversity/EPA_biodiversity_knowledge_programme.pdf)

¹⁰³ National Biodiversity Data Centre (2010). Ireland's Biodiversity in 2010: Knowledge Gaps. National Biodiversity Data Centre, Waterford.

¹⁰⁴

<https://www.agriculture.gov.ie/media/migration/research/Strategy%20for%20Science%20Technology%20and%20Innovation%202006%202013.pdf>

¹⁰⁵ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at

<http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

thriving marine economy, ensuring healthy ecosystems and increasing Ireland's engagement with the sea. The plan recognises the importance of biodiversity to ensuring a healthy ecosystem and supports measures, including research, to achieve this aim.

At a sectoral level, numerous Acts and Statutory Instruments directly provide for the protection of Ireland's biodiversity. However, without relevant research to inform such legislation it will become outdated. For example, new technologies such as wave and tidal energy devices and the technology used to install them, can have impacts on our biodiversity that are not known. Therefore, for legislation to be fit for purpose, new research to inform both policy and legislation is essential.

The **Offshore Renewable Energy Development Plan**¹⁰⁶ acknowledges that we must improve our understanding of the impact offshore renewable energy developments may have on Ireland's marine environment. It also identifies the extensive monitoring and research that will be required in order to provide the evidence that a particular development would not have a significant adverse effect on the integrity of that site.

Strategic Environmental Assessment (SEA) of Offshore Renewable Energy Development Plan¹⁰⁷ (**ORED**P) – This document identifies where knowledge gaps exist relative to offshore renewable energy developments. It concludes that further research is required on a number of aspects of marine biodiversity knowledge. It notes that should a particular site be proposed for further development, extensive monitoring and research to provide sufficient evidence that a particular development would not have a significant adverse effect on the integrity of that site would be required.

OREDP **Natura Impact Statement**¹⁰⁸ – In tandem with the SEA the OREDP NIS outlines areas where research is required. Specifically, it notes the requirement for further research on the impacts of offshore renewable energy projects (noise and collision risk in particular) on marine mammals. It also addresses the levels of uncertainty and need for research on the interactions between birds and offshore renewable energy developments and limitations in information and data on the location of offshore habitats.

¹⁰⁶ Offshore Renewable Energy Development Plan A Framework for the Sustainable Development of Ireland's Offshore Renewable Energy Resource, February 2014 (available at <http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Renewable-Energy/20140204%20DCENR%20-%20Offshore%20Renewable%20Energy%20Development%20Plan.pdf>)

¹⁰⁷ (available at <http://www.dccae.gov.ie/energy/en-ie/Renewable-Energy/Pages/ORED-P-Landing-Page.aspx>)

¹⁰⁸ (available at <http://www.dccae.gov.ie/energy/en-ie/Renewable-Energy/Pages/ORED-P-Landing-Page.aspx>)

Relevant Plans and Policies

The following section describes the specific actions called for under the various Directives and policies described above. It should be noted that unless otherwise specified, mention of the term “biodiversity” in these documents includes marine biodiversity.

Convention on Biological Diversity (CBD)

- Establish and maintain programmes for scientific and technical education and training in measures for the identification, conservation and sustainable use of biological diversity and its components and provide support for education and training for the specific needs of developing countries
- Promote and encourage research that contributes to the conservation and sustainable use of biological diversity, particularly in developing countries, *inter alia*, in accordance with decisions of the Conference of the Parties taken in consequence of recommendations of the Subsidiary Body on Scientific, Technical and Technological Advice
- In keeping with the provisions of Articles 16, 13 and 20 of the CBD, promote and cooperate in the use of scientific advances in biological diversity research in developing methods for conservation and sustainable use of biological resources

The Strategic Plan for Biodiversity 2011-2020¹⁰⁹

Support mechanisms for research, monitoring and assessment

The following key elements, relevant to biodiversity & ecosystems research, to ensure effective implementation of the Strategic Plan are:

- Global monitoring of biodiversity: work is needed to monitor the status and trends of biodiversity and ecosystem services, maintain and share data, and develop and use indicators and agreed measures of biodiversity and ecosystem change
- Ongoing research on biodiversity and ecosystem function and services and their relationship to human well-being
- The contributions of knowledge, innovations and practices of indigenous and local communities relevant to the conservation and sustainable use of biodiversity to all the above

Strategy for science, technology and innovation

Specific marine biodiversity research measures detailed in this strategy include:

¹⁰⁹ <https://www.cbd.int/doc/strategic-plan/2011-2020/Aichi-Targets-EN.pdf>

- Conducting a survey of marine research and researchers on an all-island basis with particular emphasis on research underway outside of the Marine Institute (2006)
- Developing a research discovery programme in Marine Biotechnology; Marine Biodiversity; Marine Technologies (2007-2013)

Two separate cross-cutting areas relevant to marine biodiversity include the following measures:

- Develop Ireland as a global monitoring centre for climate change assessments in the context of the North Atlantic Gulf Stream, unique marine and other ecosystems and SMARTBAY system (2007-2012)
- Use the data derived from the Irish seabed survey and the new Infomar programme to place Ireland in a position of competitive advantage in a range of areas including participation in International research programmes (2006 –2013)

Actions for biodiversity 2011-2016

The current plan notes that programmes of inventory and research detailed in the first National Biodiversity Plan have yet to be completed. These include:

- Enhance research and progress assessments on status, trends and distribution of all habitats and species of community interest and of additional habitats and species of national and regional importance
- Carry out further and more detailed research on the economic value of ecosystems and biodiversity in Ireland
- Continue and complete national measures to research and reduce adverse effects on marine fisheries, aquaculture, etc. on biodiversity in particular within Natura 2000 areas

The Biodiversity Knowledge Programme for Ireland

The biodiversity knowledge programme for Ireland detailed 3 overarching research themes and a series of actions to support them. These include research in support of biodiversity policy, research to improve knowledge and skills and research to support economic, social and educational needs.

The following research themes are specified:

- Taxonomic and systematics research
- Long-term studies on biodiversity
- Research to improve basic understanding of biodiversity and eco-system services
- Research on variation in ecological patterns and processes across different spatial and temporal scales
- Research on the management of biological resources

Research recommendations of the Marine Working Group of the NPBR¹¹⁰

This document described the main thematic areas where research was required, and the enabling actions required to ensure adequate and policy driven research was conducted. The recommendations of the NPBR were concluded following lengthy deliberations by an expert working group on marine biodiversity and a consultation process involving the main actors at both policy and the scientific community levels.

These are:

- The identification and conservation of areas of high biodiversity value
- The establishment of long-term study sites and a programme of research to be conducted within these sites
- Invasive non-native (alien) species

Harnessing our Ocean Wealth

This plan has, at its core, the goal of achieving healthy ecosystems that provide the intrinsic and extrinsic benefits of biodiversity (e.g. food, climate, health and well-being). A specific action of the plan is to:

- Promote further research into economic values of marine biodiversity and ecosystem services to ensure best practice planning and management of the ocean resource

A number of Directives and policies identify a need for biodiversity research to fill knowledge gaps and therefore facilitate the implementation of the Directives. While many of these, including the **EU Biodiversity Strategy, the Birds and Habitats Directives, Regulation 1143/2014 on Invasive Alien Species** and the **Marine Strategy Framework Directive** do not identify specific research needs, they recognise the need for biodiversity research and research of ecosystems function to fill knowledge gaps. For example, the need for this research is frequently seen in the implementation of Articles 6(3) and 6(4) of the EU Habitats Directive where marine research may be required to assess the impact of a project or plan on marine biodiversity, thereby ensuring it remains at favourable conservation status.

Other sectoral areas such as The **Offshore Renewable Energy Development Plan¹¹¹**, the **Strategic Environmental Assessment (SEA) of Offshore Renewable Energy Development Plan (OREDPP)¹¹²** and

¹¹⁰ http://www.botanicalevironmental.com/wp-content/uploads/2014/02/NPBR_recomm_combined.pdf

¹¹¹ Offshore Renewable Energy Development Plan A Framework for the Sustainable Development of Ireland's Offshore Renewable Energy Resource, February 2014 (available at

the **OREDP Natura Impact statement**¹¹³ address the issue that significant knowledge gaps exist and that research will be required to address them. They acknowledge that we must improve our understanding of the impact offshore renewable energy developments may have on Ireland’s marine environment. The general theme that emerges from all of these documents is:

- The need for research to assess the impact of new developments and novel technologies on marine mammals and birds

Research Capabilities (Maturity Assessment)

Human Capacity: “Established”

The study of marine biodiversity, marine food webs and ecosystems are very varied fields with a requirement for specialists in a wide range of disciplines from taxonomy to chemistry and mathematical modelling. While specialist teams with the required capacity for certain aspects of research exist in a number of areas, capacity in others is severely lacking.

The areas where capacity for biodiversity research is low is partially as a result of the costly infrastructural cost associated with field based research in the marine environment. As concluded by Ireland’s Biodiversity in 2010: capacity building is central to filling knowledge gaps of many aspects of biodiversity. To date, much of the research of Ireland’s marine biodiversity deals with conspicuous groups and enormous gaps exist in the current capacity to deal with less conspicuous, but fundamentally important taxa.

In general, marine biodiversity research expertise is centered on a number of third level institutes where a number of small PI led research teams operate. Capacity among state organisations is low. Due to the cross-cutting nature of marine biodiversity research, additional capacity, focused on impacts on biodiversity, exists at the Marine Institute. Currently this research is largely driven by legislative requirements, but the capacity for greater collaborative research is available. At a

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 17: Irish Research Maturity in Biodiversity, Ecosystems & Food Webs showing the different levels of maturity for human capacity, infrastructure and networks

<http://www.dccae.gov.ie/energy/SiteCollectionDocuments/Renewable-Energy/20140204%20DCENR%20-%20Offshore%20Renewable%20Energy%20Development%20Plan.pdf>

¹¹² https://www.seai.ie/Renewables/Ocean-Energy/The-Offshore-Renewable-Energy-Development-Plan-OREDP/Environmental_Report/SEA_ER_Final.pdf

¹¹³ [http://files.dcenr.gov.ie/Decarbonisation/OREDP%20Natura%20Impact%20Statement%20\(NIS\).pdf](http://files.dcenr.gov.ie/Decarbonisation/OREDP%20Natura%20Impact%20Statement%20(NIS).pdf)

translational level, a number of researchers have been actively involved in legislatively based fora to assist in informing legislation. This includes the members of the expert working groups of the National Platform for Biodiversity Research (NPBR) and participation by Irish experts in the European Platform for Biodiversity Research (EPBR) and the UN Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES).

Much of the existing research on ecosystems is based on the traditional disciplines of ecology, but there have been some cross disciplinary approaches. There has been a limited capacity at post grad and post doc levels resulting in a critical skill gap in marine food web modelling itself. Research is engaged in by PI's at several HEI's where the human capacity exists at the senior researcher level (MI, QUB, UCC, TCD). Some food web modelling expertise exist as well as PhD and postgraduate level research projects within these institutions but training is often sourced from international institutions such as Ecopath with Ecosim (EwE) training from SAMS. There is some activity at translational level where individual researchers engage in IGO's (i.e. ICES) who inform policy at an EU level.

Infrastructures: "Established – Collaborative"

The infrastructural requirements for research vary considerably depending on the specific field of study. Many areas of research have a low infrastructural requirement while others require vast resources. Laboratory facilities exist within the third level institutes but are limited in scope and capital requirements. Access to the required field-based technology required for some fields of research is costly and for some areas of study is only available through external outsourcing to private companies. On a national basis, the facilities made available by the Marine Institute research vessels and their associated equipment provide the scope and needs required for a number of disciplines and provide the opportunities that research groups could not be expected to fund themselves.

The scale of the requirement for marine ecosystem field sampling is currently only met for large scale offshore studies by the Marine Institute's research vessels and associated equipment. However, the MI Research vessels are currently in high demand, are oversubscribed (in relation to the competition for ship time) and do not have the capacity to expand the current amount of work undertaken to support primary research. This is, however, not a barrier to increased research activity as existing activity on the RV's can be adapted to provide sampling opportunity. Storage of biological samples is more of an issue and there is no national infrastructure available to fulfil the need that would arise under increased sampling activity. Equipment on board the vessels such as the CTD, Multibeam Echo Sounder and the Remotely Operated Underwater Vehicle, ROV *Holland 1*,

provide the facility to detect biodiversity and enable scientists to better understand ecosystems functioning.

The Coastal and Marine Research Centre (CMRC) is currently in the process of amalgamating with the Hydraulics and Maritime Research Centre (HMRC) under the banner of Beaufort. This organisation focuses on specific key marine thematic areas, which include biodiversity and the application of the ecosystem approach to fisheries and marine management. The Ryan Institute at NUI Galway focuses on a number of areas related to marine and environmental research, including biodiversity; and The Marine Biodiversity Ecology and Evolution (MarBEE) researchers of UCD focus on areas of study relating to biodiversity, ecosystem functioning and food web dynamics with facilities such as state of the art molecular biology facilities available for research.

Other existing infrastructures include the national databases maintained by the Biodiversity Data Centre, the Global Biodiversity Information Facility (GBIF), of which Ireland is a participant, and the Marine Irish Digital Atlas (MIDA).

Networks (Industry engagement): “Established – Collaborative”

The EU has identified food chains and conservation of biological diversity as key elements of research under SC2 in the context of food security and sustainability. However, as of yet, there is no specific call for marine ecosystem or food web research as this is seen as a cross cutting theme. Similarly at national level the 2015 DAFM FIRM call covered some aspect of ecosystem and food web research, but these topics would be secondary to the research areas identified.

Ireland participates in Seventh Framework Programme for Research and Technological Development (FP7) projects such as ECOKNOWS and OPERAS, which focus on use of marine ecosystems and ecosystem services.

As well as networks initiated through FP7, collaborative networks are operative for current H2020 projects such as AQUASPACE, AQUACROSS, ResponSEable and BENTHIS with International participants. INTERREG Atlantic Area Programmes also offer opportunities for international collaboration.

The EU has implemented specific marine biodiversity funding calls that provided opportunities for collaborative networks across Europe in previous RTD Framework Programmes and a number of Irish PI's have participated in such networks. Biodiversity, however, is not a standalone topic in Horizon 2020 and this may hinder collaboration in the field at a European level in the future. Specific marine biodiversity options for funding and networking are now currently limited to cross-cutting themes, for example under the water JPI, and through the Life programme.

INFOMAR, the joint Marine Institute/Geological Survey of Ireland initiative provides a platform for collaborative biodiversity and ecosystems research by identifying a variety of different biodiverse seafloor ecosystems when undertaking surveys. While concentrating on seabed mapping the network and infrastructure developed by this programme could be extended to facilitate more focused research.

Formal national networks have not been established but the research community is relatively small and the majority of actors in the field collaborate on an *Ad hoc* basis as required, particularly in response to funding calls.

Research Themes

The research themes identified below were developed through the work of the expert working group on marine biodiversity of the NPBR in 2012¹¹⁴. Captured in the list of 4 overarching themes are the recommendations of the research priorities identified by the EU Marine Board¹¹⁵ and occasional recommendations from the European Platform for Biodiversity Research. Specific topics related to each overarching theme are detailed in the relevant documents.

1. The identification and conservation of areas of high biodiversity value

This theme includes the evaluation of threats to these areas and the production of effective conservation management strategies to protect their conservation interests.

The main policy drivers in support of this research theme include the Habitats Directive, the Birds Directive, the Marine Strategy Framework Directive and the Convention on Biological Diversity. Each of these directives is implicit in its requirements for research to enable the objectives of the various Directives to be reached. With due cognisance of these policy drivers the NPBR recommended this theme as a priority area of research.

2. The establishment of long-term study sites and a programme of research to be conducted within these sites

The establishment of a programme of long-term ecosystem research, through the establishment of a network of long-term study sites, is an essential mechanism to better understand ecosystem structure and function, and respond to environmental, societal and economic drivers.

¹¹⁴ Research recommendations of the Marine Working Group of the National Platform for Biodiversity Research (2012) National Platform for Biodiversity research.

¹¹⁵ Heip, C and Mc Donough, N. (2012). Marine Biodiversity: A Science Roadmap for Europe. (Marine board future science brief #1). European Marine Board, Ostend, Belgium.

The main policy drivers in support of this research theme are the same as those listed under Topic 1, i.e., the Habitats Directive, the Birds Directive, the Marine Strategy Framework Directive and the Convention on Biological Diversity. As outlined above, each of these directives is implicit in its requirements for research to enable the various Directives to be reached. With due cognisance of these policy drivers the NPBR recommended this theme as a priority area of research.

3. Invasive non-native (alien) species

The Development of an early warning system for the identification and detection of non-native invasive marine species is an essential step in protecting marine biodiversity, marine ecosystems and the sustainable development of aquaculture.

Globally, IAS are one of the five major threats to ecosystem functioning, human health, and biodiversity. The annual global economic impact of IAS is estimated to be 1.4 trillion USD. For Europe one of the key findings of a recent study was the overall negative impact of IAS, including widespread ecological degradation to ecosystem services that are vital for economic development, tourism and human health.

The main policy driver in support of this theme is the Regulation 1143/2014 on invasive alien species. In line with the previous two themes it is also a priority area of research recommended by the NPBR.

4. Research in support of assessing the impacts of new and novel technologies

As the development of the marine economy grows, pressures on biodiversity and ecosystems will increase. This has been stressed in a number of recent strategies, as outlined in section 3, which have indicated the knowledge gaps in marine biodiversity and ecosystems functioning. Research to address the identified knowledge gaps is urgently required so that development of the marine economy can proceed on an informed basis.

The main policy drivers in support of this theme include the Birds and Habitats Directives and the EU guidelines for “Biodiversity proofing” the EU budget.

Research themes to better understand the complex dynamics of ecosystems i.e. their system function, food webs and trophic level interactions would include:

- Marine food web modelling for marine ecosystems in Ireland – Currently this activity is not being conducted; and there is a need to begin to develop this area in order to provide estimates at ecosystem level of potential productivity.

- Primary diet data analysis and research – Any modelling activity needs to be supported by empirical data. This empirical data will need to be gathered from the traditional sources such as stomach contents, but it will also be important to gather empirical data on genetics and stable isotopes, which will become incorporated in future models.

Focus of Funding

It is important that a distinction be made between funding research to inform existing policy needs i.e. to better inform legislative requirements, and funding for basic (blue skies) research. Biodiversity and marine ecosystems are cross-cutting areas within topics aimed at sustainable development or impact mitigation. While frameworks such as the Common Framework for Biodiversity Proofing the European Maritime and Fisheries Fund¹¹⁶ do not include specific funding for biodiversity and marine ecosystems research they may contribute to the impetus for funding applied research to inform policy needs. However, dedicated funding mechanisms to support basic research are lacking at EU and National level and are, at best, available on an ad-hoc basis through EU funding such as LIFE and occasional nationally funded calls such as STRIVE. A dedicated funding mechanism is required to fund basic marine biodiversity research, marine food webs and ecosystem function research and maintain a dynamic marine biodiversity research community in Ireland.

The BioChange project¹¹⁷, funded under the STRIVE programme resulted in the type of dynamic functional research network required to build institutional and human capacity and create a vibrant biodiversity research network addressing concerns such as the Impacts of Invasive Species on Ecosystems. However, the lack of follow up funding to maintain this network has resulted in its demise.

It is recommended that a future funding mechanism be established to support research networks to build on existing human capacity and better enable basic, as well as applied, research. It is recommended that this mechanism should facilitate:

- The creation of human capacity with the necessary skill sets and experience to engage in the next generation of marine food web and ecosystem research. These skill sets include expert level knowledge in mathematics, statistics and coding to support modelling activities; as well as the engagement of PI's conducting cutting edge research in the fields of isotope analyses and genetics in marine food web and ecosystem productivity research.

¹¹⁶ Newman, S, Medarova-Bergstrom, K, Rayment, M, Skinner, I and Tucker, G (2014) Common Framework for Biodiversity-Proofing of the EU budget: Guidance for the European Maritime and Fisheries Fund. Report to the European Commission, Institute for European Environmental Policy, London.

¹¹⁷ https://www.epa.ie/pubs/reports/research/biodiversity/STRIVE_68_web.pdf

- The support of a national research group who would act as a catalyst and support network for satellite researchers to successfully compete for and win EU funds. This capacity to win EU resources would be vital to address the transient nature of the human capacity within the research area.

Further, there is a requirement for the identification of a funding mechanism which has the capacity to manage competitive research calls for marine research on the themes identified in section 5 across all government departments.

To reiterate the recommendations made by the NPBR on marine biodiversity research and to facilitate the coordination of inter-departmental systems, there is an urgent need to establish an interdepartmental working group, including the relevant key technical experts to:

- Ensure coordinated research effort and knowledge sharing between departments and agencies to maximise efficiencies and research effort of direct relevance to the implementation of legislative requirements.
- Evaluate impacts, compatibilities and conflicts between government policies and biodiversity objectives and economic practice. This review should be based around the relevant sectors.
- Identify policy blind spots and suggest methods that might be used to resolve policy conflicts. This should also include developing the actions required from research recommendations e.g. responsibility for dealing with invasive non-native species.
- Identify more effective ways of integrating existing knowledge from both fundamental and applied research thereby facilitating evidence-based policy making.

Litter

Overview

A highly visible change in the marine environment is the abundance of litter. Marine litter is a persistent problem affecting all regions of the world. The extent of the world's marine litter is attributed to increased human pressures on the oceans and the failure to implement and enforce regional and international regulations and standards. Expansions in the level of economic and social activities that take place on the oceans and along coastal areas generate waste. With much of the waste finding its way into the marine environment, the effects can be noticed far from where the waste entered the water, possibly remaining in the seas for centuries.

Marine litter is defined “as any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment. Litter consists of items that have been made or used by people and deliberately discarded or unintentionally lost in the sea or on beaches, including materials transported from land into the marine environment by rivers, run-offs, sewage systems or winds.”¹¹⁸

Marine litter constitutes a vast and growing threat to the marine and coastal environment with negative impacts on animal and human life. There is a constant build-up of marine litter because most of it is made from materials that are slow to degrade naturally or just don't degrade at all. The need for proper and efficient waste management is recognised internationally as an issue that must be addressed worldwide.

Relevant to Ireland, and to the definition of research related activity concerning marine litter, are various initiatives of the United Nations Environment Programme (UNEP), Convention on Biological Diversity (CBD), Oslo and Paris Conventions for the Protection of the Marine Environment of the North-East Atlantic (OSOPAR) and the EU Marine Strategy Framework Directive (MSFW), all of which seek to increase knowledge of the scale and impact of marine litter and define actions that can help to alleviate the problem.

Context

Acknowledging the extent of the global marine litter problem, Ireland's attention to marine litter focuses on obligations to implement measures to address the problem in the broader context of the Marine Strategy Framework Directive (MSFD). All EU countries are obliged to take actions to

¹¹⁸ Galgani, F. Hanke, G. Werner, S. De Vrees, L. (2013) Marine Litter within the European Marine Strategy Framework Directive. *ICES Journal of Marine Science*. Vol 70 Issue 6 September.

implement the Marine Strategy Framework Directive (MSFD) by 2020. Ireland's responsibilities under the MSFD are to:

- Protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected
- Prevent and reduce inputs in the marine environment, with a view to phasing out pollution, so as to ensure that there are no significant impacts on, or risks to, marine biodiversity, marine ecosystems, human health or legitimate uses of the sea

The implementation process for achieving Good Environmental Status (GES) with reference to a number of descriptors commenced in 2011 with the incorporation of the Directive into Irish Law. Subsequently, an initial assessment was completed in 2014, followed by the creation of a monitoring programme in 2015 and the launch of a consultation process aimed at supporting the development of measures – any action on a National, Regional, European or International level that is intended to help achieve or maintain Good Environmental Status and to achieve the environmental targets – a process requiring measures to be operational by December, 2016.

Under the MSFD, the descriptor applicable to marine litter is that *“Properties and quantities of marine litter do not cause harm to the coastal and marine environment.”*¹¹⁹ Final indicators associated with the descriptor are needed, notably those relating to biological impacts and to micro-particles, as well as for the enhanced assessment of their potential toxicity.¹²⁰ Agreed indicators for litter in the marine environment and the impact of litter on marine life include:

- Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source
- Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source
- Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics)
- Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis)

¹¹⁹ http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/index_en.htm

¹²⁰ European Commission (2010) *On criteria and methodological standards on good environmental status of marine waters*. Commission Decision 2010/477/EU

From what was largely an aesthetic problem, the impact of marine litter is wide-ranging, expanding and one in which there remain significant knowledge gaps. Amongst the impacts highlighted are the entanglement of species in marine litter; ingestion of litter by marine species; alteration, damage and degradation of benthic habitats; reduced recreational, aesthetic and educational value of marine areas; and economic harm as a result of marine litter interfering with aquaculture, fishing, transport, tourism and leisure, and power generation. There is a particular concern regarding the impact of micro-particles mostly, though not exclusively, originating from plastic materials. Knowledge of these micro-plastics is scant, with major concerns that these particles have adverse effects on marine organisms.

There are many sources of marine litter; a survey of beach litter in Ireland identified tourism, sanitation, fishing and shipping as the source of 75 percent of litter.¹²¹

National policy

Ireland's policies concerning marine litter have been developed in the context of European policies. S.I. No. 249/2011 – European Communities (Marine Strategy Framework) Regulations 2011 brings the EC Marine Strategy Framework Directive into force.

In the Irish EPA report, Ireland's Environment 2012 – An Assessment, "marine litter" is mentioned as one of the pressing issues, together with overfishing, acidification, and loss of biodiversity.¹²² Marine litter was identified by the EPA as a research topic falling within the scope of the MSFD during the definition of the EPA research strategy.¹²³

Responsibility for implementing the MSFD resides with Department of Housing, Planning, and Local Government (DHPCLG) as the designated Competent Authority. However, the implementation process is recognised as requiring support from other government departments and agencies including the Department of Agriculture, Food and the Marine; Department of Arts, Heritage, Regional, Rural & Gaeltacht Affairs; Department of Transport, Tourism and Sport; Department of Communications, Climate Action & Environment; Marine Institute; Environmental Protection Agency; Bord Iascaigh Mhara; Seafood Fisheries Protection Authority; Petroleum Affairs Division;

¹²¹ Department of Environment Community and Local Government - Marine Institute (2013) *Ireland's Marine Strategy Framework Directive Article 19 Summary Report Initial Assessment, GES and Target and Indicators*.

¹²² Environmental Protection Agency (2012) *Ireland's Environment 2012 An Assessment*. Environmental Protection Agency, Ireland. Available at: http://www.epa.ie/pubs/reports/indicators/00061_EPA_SoE_2012.pdf

¹²³ Environmental Protection Agency (2014) *EPA Research Strategy 2014-2020 - Using knowledge to protect and improve our natural environment and human health* Available at: <http://www.epa.ie/pubs/reports/research/eparesearchstrategy2014-2020/EPA%20Research%20Strategy%202014-2020.pdf>

Food Safety Authority of Ireland; Health and Safety Authority; Department of Jobs, Enterprise and Innovation; Inland Fisheries Ireland; and the Marine Survey Office.

Closely linked to future policy concerning the marine environment is the report from the Task Force for Marine Spatial Planning (MSP); this task force set out to recommend a framework for implementing MSP in Ireland as set out in *Harnessing Our Ocean Wealth – An Integrated Marine Plan for Ireland*. A range of Directives are associated with the introduction of such a planning process, notably the MSFD where it is recognised from an assessment and data collection perspective that there are potential synergies between implementation of the MSFD and other directives relevant to marine litter including:

- **Strategic Environmental Assessment (SEA) Directive 2001** – The SEA Directive (2001/42/EC) requires most spatial plans or programmes to be assessed to determine whether implementation would be likely to have significant effects on the environment.
- The **Habitats Directive** (92/43/EEC) – This placed an obligation on Member States of the EU to establish the Natura 2000 network. The network is made up of Special Protection Areas, established under the **Birds Directive** (79/409/EEC), and Special Areas of Conservation (SACs), established under the Habitats Directive.
- The **Water Framework Directive** (WFD) – The WFD (2000/60/EC) is a key initiative aimed at improving water quality throughout the EU. It applies to rivers, lakes, groundwater and coastal waters.

Harnessing our Ocean wealth does not refer directly to marine litter but in common with the broad national position highlights the MSFD and actions to implement it, including those to:

- Carry out an initial assessment and related works required under the MSFD in order to provide an accurate picture of the environmental status of our marine waters.
- Set appropriate targets in the pursuit of good environmental status.
- Develop an Atlas of the Irish Marine Environment, which will include the collation of all relevant information into a central GIS. This will be an important tool underpinning decisions on policies and actions and to protect biodiversity and act as a stepping-stone to future, long-term measures (e.g. in the development of a National Marine Habitat Map and a Maritime Spatial Plan).

European and international policy

A raft of European policy is relevant to the MSFW and through it related to marine litter:

- Water Framework Directive (WFD; 2000/60/EEC)
- Natura Directives (i.e. Habitats Directive [HD; 2009/147/EC] and Birds Directive [BD; 92/43/EEC])
- Marine Planning/Licensing (e.g. Environmental Impact Assessment [EIA; E5/337/EEC])
- Strategic Environmental Assessment [SEA; 2001/42/EC])
- Fisheries management (e.g. Common Fisheries Policy [CFP; 1380/2013])
- Waste Framework Directive (2008/98/EC)
- Urban Waste-Water Treatment Directive (1991/271/EEC)
- Integrated Pollution Prevention and Control Directive (Directive 96/61/EC)
- Port Reception Facilities for Ship-generated Waste and Cargo Residues Directive (2000/59/EC)
- Waste Management (Waste Electrical and Electronic Equipment (WEEE) Directive (2012/19/EU)
- Restriction of Hazardous Substances (RoHS) Directive (2002/95/EC); Environmental Liability Directive (2004/35/EC) (as amended); Safety of Offshore Oil and Gas Operations Directive (2013/30/EU); Batteries and Accumulators Directive (2006/66/EC)
- End-of-life vehicles Directive (2000/53/EC)

The EU 7th Environment Action Programme (EAP)¹²⁴ is designed to guide European environment policy until 2020. This programme draws attention to the issue of marine litter and identifies the MSFD as a key measure in *“combating pollution and establishing a Union-wide quantitative reduction headline target for marine litter supported by source-based measures and taking into account the marine strategies established by Member States.”*

With marine litter accepted as being a global issue, several international organisations have developed policy recommendations and called for concerted effort in all maritime regions. OSPAR, whose aim is the protection of the north-east Atlantic, developed three indicators for marine litter and is engaged in the development of further indicators. UNCLOS imposes a number of general obligations on States to protect the marine environment in seas under their jurisdiction, including measures to protect ecosystems and habitats. The Convention on Biological Diversity (CBD)

¹²⁴ European Commission (2013) *General Union Environment Action Programme to 2020 - Living well, within the limits of our planet* DECISION No 1386/2013/. Available at: <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN>

highlights marine litter as a factor affecting biodiversity. Similarly, the United Nations Environment Programme draws attention to the need to address marine litter.

European and international policy documents draw attention to the need to develop a greater understanding of marine litter including sources, nature and amount of litter; the impact of marine litter on marine environments, coastal areas and on animal as well as human populations; assessment and monitoring methods; and the need for strategies to address the challenge of marine litter.

The accumulation and effect of micro-plastics in the oceans has attracted the attention of all major agencies and organisations involved with matters associated with the marine environment. The United Nations supported Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection describe how micro-plastics originate and the effect of these materials on the marine environment, including when ingested by marine organisms.¹²⁵ In doing so the report makes specific recommendations for further research to fill knowledge-gaps about micro-plastics in the marine environment.

The G7 wants more action on marine litter and resource efficiency and called for “an action plan to combat marine litter, in particular actions to combat land and sea-based plastic litter pollution, as well as removal actions and the need for education, research and outreach to other countries and stake - holders on this issue.”¹²⁶

The Honolulu Strategy, published by UNEP and the NOAA Marine Debris Program¹²⁷, is a framework for a global response to reduce the ecological, human health, and economic impacts of marine debris. It is also intended to be used as a planning tool for developing or refining spatially or sector-specific marine debris programs and projects; a common frame of reference for collaboration and sharing of best practices and lessons learned; and as a monitoring tool to measure progress across multiple programs and projects.

¹²⁵ GESAMP (2015). *Sources, fate and effects of microplastics in the marine environment: a global assessment*. (Kershaw, P. J., ed.). (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90

¹²⁶ G7/G20 Sherpa office of the Federal Chancellery (2016) *Final Report by the Federal Government on the G7 Presidency 2015*. Press and Information Office of the Federal Government, Berlin. Available at: https://www.g7germany.de/Content/EN/Anlagen/G7/2016-01-20-g7-abschluss-eng_en.pdf?blob=publicationFile&v=3

¹²⁷ United Nations Environment Programme (2011) *The Honolulu Strategy a global framework for prevention and management of marine debris*. UNEP/NOAA Available at: <http://www.unep.org/gpa/documents/publications/honolulustrategy.pdf>

Relevant Documents / Sectoral Plans

In relation to the development of Ireland’s marine research and innovation strategy, the MSFD is by far the most influential document concerning marine litter. Other national initiatives that reference litter in the marine environment each point to the implementation of the MSFD and the achievement of GES as mechanisms to address the litter issue.

Marine litter is absent in the priorities of the Research Prioritisation Exercise despite being relevant to the Sustainable Food Production and Processing priority area. Nor does the Enterprise 2025 strategy mention marine litter. Innovation 2020 stresses that one of Ireland’s goals is to ensure that our development is sustainable environmentally, socially and economically. It also identifies increasing our understanding of the environment and the environmental consequences of human activities, and changing attitudes towards environmental issues. Environmental research can have a profound and long-lasting effect on our society and economy.

Other documents relevant to the definition of an Irish strategic research agenda to improve knowledge about marine litter are mentioned earlier in this document and referenced in footnotes.

Research Capabilities (Maturity Assessment)

The research capability of marine litter research in Ireland is assessed as “Ad-hoc – Defined”. Despite a number of active research projects, and some limited laboratory space, the field is relatively young in terms of development in Ireland. A number of Institutions are collaborating internationally, however, in the main these projects are at an early stage.

Capability and Capacity

Reviewing national funding for research that targeted marine litter is one way of developing insights to Ireland’s capacity to engage in future research concerning marine litter. Few references to national funds supporting such research have emerged. The environmental status in Ireland's coastal areas and surrounding seas were examined in a Quality Status Report, published by the Marine Institute in 1999. Amongst the findings was that these regions suffered from the impact of human activities and coastal development.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 18: Irish Research Maturity in Marine Litter showing the different levels of maturity for human capacity, infrastructure and networks

The Marine Institute does not appear to have specifically funded research where marine litter was the theme. The EPA a main funding agency for environmental related research also appears not to have funded research specifically concerning marine litter, but had funded research on nanoparticles in the marine environment.

In a bibliometric study of research publications on marine micro-plastics conducted by Science-Metrix¹²⁸ on behalf of JPI Oceans and using the metadata from 24 million scientific papers published between 1996 and 2012, Ireland did not appear in the list of countries identified as producing more than 20 publications on micro-plastic topics over that period.¹²⁹

Of the four funded projects totalling €7.5m funded in a recent call by JPI Oceans,¹³⁰ three have an Irish involvement, with GMIT, NUI Galway and UCC named as collaborators in PLASTOX, EPHEMARE and BASEMAN. These projects are summarised below:

- BASEMAN – Defining the baselines and standards for micro-plastics analyses in European waters
- EPHEMARE – Ecotoxicological effects of micro-plastics in marine ecosystems
- PLASTOX – Direct and indirect ecotoxicological impacts of micro-plastics on marine organisms
- WEATHER-MIC – How micro-plastic weathering changes its transport, fate and toxicity in the marine environment

UCC was involved in the 2010 FP7 marine litter project as partners in MARLISCO¹³¹. This project was designed to facilitate dialogue and promote co-responsibility among the different actors towards a joint vision for the sustainable management of marine litter across all European seas. Though the project ended in May 2015, two UCC based researchers from MARLISCO now collaborate in two different JPI Oceans micro-plastics projects. The UCC based CMRC appears to be the only research group with critical mass and multi-disciplinary expertise required to engage in marine litter related research.

¹²⁸ <http://www.science-metrix.com>

¹²⁹ <http://jpi-oceans.eu/sites/jpi-oceans.eu/files/public/news->

[images/Bibliometric%20assessment%20of%20research%20activities%20related%20to%20microplastics%20marine%20pollution.pdf](http://jpi-oceans.eu/sites/jpi-oceans.eu/files/public/news-images/Bibliometric%20assessment%20of%20research%20activities%20related%20to%20microplastics%20marine%20pollution.pdf)

¹³⁰ <http://www.jpi-oceans.eu/news-events/news/results-€75-million-call-microplastics-published>

¹³¹ MARine Litter in Europe Seas: Social Awareness and CO-Responsibility

Through BIM, Ireland was involved in the European “Fishing for Litter” project. This pilot project sought to develop methods to support the removal of marine litter from Europe’s four regional seas – Baltic Sea, North East Atlantic, Mediterranean Sea and the Black Sea. The project delivered “tool-kits” highlighting best practices and guidance on the removal of marine litter. The project commenced in 2013 and produced its final report¹³² in February 2015.

Research Topics

The only marine litter project identified in either the 2014/15 or 2016/17 Horizon 2020 work programme for Challenge 5 Climate Action, Environment, Resource Efficiency and Raw Materials was an inducement prize for achieving a plastic-free water environment (i.e. in rivers, lakes, seas and/or oceans). The most innovative and effective solution will be rewarded, e.g. for avoiding, collecting or destroying plastic litter, adopting the more appropriate solution. There was little evidence pointing to support for major marine litter projects in Europe. The FP7 project MESMA focused on marine spatial planning and aimed to produce integrated management tools (concepts, models and guidelines) for Monitoring, Evaluation and Implementation of Spatially Managed marine areas, based on European collaboration and it referenced marine litter. Through AquaTT, Ireland participated in the STAGES project, a European Coordination and Support Action in the "The Ocean of Tomorrow" programme that aimed to improve the scientific knowledge base to support the implementation of the Marine Strategy Framework Directive (MSFD). Examples of other FP7 projects which included reference to marine litter are:

- LIFE SMILE – Strategies for Marine Litter and Environmental prevention of sea pollution in coastal areas LIFE12 ENV/IT/000289
- LIFE - AMMOS – Integrated information campaign for the reduction of smoking related litter on beaches LIFE12 INF/GR/000985
- INTERREG MARLIN Baltic Marine Litter
- Ocean of Tomorrow CLEANSEA Towards a Clean, Litter-Free European Marine Environment through Scientific Evidence, Innovative Tools and Good Governance ENV.2012.6.2-4

Marine litter appears not to have a significant profile in recent EU funding programmes.

A review of marine litter within the MSFD identified the following research needs:

¹³² Van Breusegem W, O’Brien S, van der Burgt N, Oulès L, McGuinn, L (2015) **Pilot project: Removal of marine litter from Europe’s four regional seas**. Milieu Ltd (Belgium). Available at: <http://www.marelitt.eu/files/14261483060.pdf>

- Evaluate the behaviour (floatability, density, effects of wind, biofouling, degradation rates) and factors affecting the fate of litter (weather, sea state, temperature driven variations, slopes, canyons, bays, etc.) and affecting the transport of litter
- Use comprehensive models to define source and destination regions of litter (especially accumulation areas, permanent gyres, deep sea zones), estimate residence times, consider the average drift times and Tran boundary transport from and to MSFD region/sub regions
- Evaluate the rates of degradation of the different types of litter, quantify the degradation products (to nanoparticles) and evaluate the environmental impact of litter-related chemicals (Phthalates, bisphenol A, flames retardants, etc.) on marine organisms
- Identify sources for direct inputs of micro-particles of litter
- Establish the environmental impacts of micro-litter, in particular in relation to the potential physical and chemical impacts on wildlife, resources and the food chain
- Evaluate biological impacts (on metabolism, physiology, survival, reproductive performance and ultimately on populations or communities)
- Evaluate the risk of the introduction of invasive non-indigenous species
- Study dose/response relationships in relation to the types and quantities of marine litter in order to enable science-based definitions of threshold levels for GES
- Evaluate direct costs of marine litter to the maritime industry, fishing industry, local authorities and governments and in terms of impact on ecosystem goods and services

Global research needs concerning marine micro-plastics identified by the GESAMP study included:

- Generate data on weathering-induced fragmentation of at least the PE, PP and EPS plastics in the marine environment
- Examine the influence of weathering on particle sorption characteristics
- Establish improved and validated methods for sampling at the sea surface in sediments and in biota
- Organize inter-calibration exercises and harmonise reporting units to make future data comparable around the world
- Design sampling strategies to establish time trends and spatial trends in selected marine areas
- Conduct additional sampling of sub-tidal and in particular deep-sea sediment
- Investigate nano-sized plastic particles in marine organisms as a critical input for future risk assessments

- Develop more realistic transport models, to incorporate variable particle properties, 3D circulation and sources of plastics and micro-plastics

The Department of Environment and Local Government public consultation document on the Marine Strategy Framework Directive Article 11¹³³ identifies the need for on-going research and developments at national, Regional Seas and European levels to inform the Monitoring Programme, and identifies the following in relation to research on marine litter:

- Ireland is investigating the applicability of the European Environment Agency’s Marine LitterWatch App for its OSPAR18 beach litter surveys. An Taisce Clean Coast voluntary groups have participated in a Europe-wide test run of the App, the results of which are yet to be released.
- Ireland is investigating the applicability of a surveillance indicator for seabed litter. Research is currently underway in relation to the monitoring of micro-plastics in the Irish marine environment. The research will include investigation of survey methodologies and the extent of the pressure in Irish waters. This is part of a Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI-Oceans) project.
- A proposal for an international pilot project which will consider the eco-toxicological effects of micro-plastics, the mechanism of toxic action as well as the impact of chronic exposure is currently under discussion by research funding bodies within JPI Oceans.
- Ireland is contributing to the development of a low cost and effective methodology for measuring riverine inputs for marine litter under the Working Group on Marine Litter (WG ML), coordinated by the Commission.

Focus of Funding

References in Irish policy documents to environmental sustainability and the green economy are drivers of research activity, providing scope for actions to support research on marine litter. Similarly, research priorities for advanced materials provide scope to consider the impact of these materials on the marine environment. Major research themes associated with marine litter include understanding the nature and amount of litter; the impact of marine litter on marine environments, on coastal areas and on animal and human populations; assessment and monitoring methods; and strategies to address the challenge of marine litter. A specific research theme and one likely to present major opportunities is marine micro-plastics/nano-particles.

¹³³ Department of Environment, Community and Local Government (2014) Marine Strategy Framework Directive Article 11 Monitoring Programmes – Public Consultation. Available at: <http://www.environ.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownload%2C38589%2Cen.PDF>

Ireland's contributions to the JPI Oceans micro-plastics research call enabled Irish participation and contributed to the development of research capabilities. However, the scale of funding is insufficient to build critical mass. This participation is an opportunity to build upon. Many research areas exist; these could be used, provided funds are made available, as the basis to attract competencies from related areas (e.g. remote sensing, seabed mapping, oceanography, toxicology etc.) to work on marine litter research priorities. To do so requires a strategic research agenda to be defined. This should justify why Ireland needs to develop research in areas where there is little evidence of research critical mass. And such an agenda could address specific Irish needs in ways that also contribute knowledge to support global research activity.

Ireland's immediate research needs appear to be those required to reach GES within the implementation of the MSFD. Provided justification in the context of a strategic research agenda, these needs could be met whilst also providing funds that will furnish Ireland with a greater capacity to engage in marine litter research. It is unlikely that such capacity will be built without active management designed to build research links and collaboration within Ireland and further engagement with international research groups.

Marine Pollution

Overview

Pollution of the marine environment is a growing cause for concern. As pressures on the marine environment increase and intensify from a variety of anthropogenic sources, it is widely recognised that swift action must be taken to halt and reduce marine pollution at the source/pathway level prior to interaction with receptors.

The United Nations Convention on the Law of the Sea (UNCLOS), ratified by Ireland on the 21st June 1996¹³⁴, defines pollution of the marine environment as “...*the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities*”¹³⁵.

Adverse or potentially adverse effects can occur when chemicals, particles, industrial, agricultural, commercial and domestic waste, noise, litter and non-indigenous species (NIS¹³⁶) gain entry into or spread in the marine environment. The vast majority (approximately 80%¹³⁷) of marine pollution is caused as a result of land based human activity.

It is commonly acknowledged that the implementation of existing controls would contribute significantly towards addressing marine pollution and its wide range of effects that impact negatively on the goal of healthy marine ecosystems. The knowledge, know-how and plans to protect, preserve and restore our rich biological diversity and ecosystems, for the most part, exist and are in place. However, the difficulty is in implementing actions and coordinating the management required to implement actions.

Apart from the fundamental issue of implementing existing plans, measures and controls, the other areas that have huge potential to combat marine pollution are through:

- Developing a deeper understanding of the scale, nature, location and transport processes of pollutants.

¹³⁴ <https://www.dfa.ie/media/dfa/alldfawebstemedi/treatyseries/uploads/documents/treaties/docs/199801.pdf>

¹³⁵ http://www.un.org/depts/los/convention_agreements/texts/unclos/part1.htm

¹³⁶ A review of the MRIS Biodiversity, Ecosystems and Food-webs research theme has indicated that NIS have been included within the summary and background analysis document related to this theme. However, NIS has been screened in to this analysis also given the interlinkages with other aspects of the theme.

¹³⁷ <http://oceanservice.noaa.gov/facts/pollution.html>

- Research and development of innovative solutions that prevent, detect, quantify and treat marine pollution.

Research related activity concerning marine pollution in Ireland is driven by various initiatives at International, EU and National level. The **JPI Oceans Strategic Research and Innovation Agenda 2015 – 2020** is an important driver for research. In addition the **EU Marine Strategy Framework Directive (MSFD)**, **EU Water Framework Directive (WFD)** and **OSPAR** (Oslo and Paris Conventions for the Protection of the Marine Environment of the North-East Atlantic) all seek to protect the marine environment, and through monitoring and assessment identify key environmental issues which require attention. At national level, **Innovation 2020** promotes innovation in the marine and environmental sectors while ensuring development is environmentally, socially and economically sustainable. While marine pollution is not identified in the document *per se*, increasing the understanding of the environment and the environmental consequences of human activities, and changing attitudes towards environmental issues is promoted. The **EPA Research Strategy 2014-2020**¹³⁸ is another key driver for marine research under its water theme.

The Clean-Green-Marine enabler¹³⁹ of Ireland’s **Harnessing Our Ocean Wealth – An Integrated Marine Plan for Ireland**¹⁴⁰, states that the future sustainability and growth of Ireland’s marine industries depends on protecting the credibility of the clean, green image that Ireland enjoys. Compliance with national and international environmental legislation is an essential component of this image, and compliance is stated as a “*competitive advantage*”. With targets to double the value of Ireland’s ocean wealth to 2.4% of GDP by 2030 and to increase the turnover from our ocean economy to exceed €6.4bn by 2020¹⁴¹, the MSFD and the WFD (actions under the Clean-Green-Marine enabler), are valuable methods whereby Ireland can ensure that development strategies and management practices do not impair the capacity of ecosystems.

There are areas that require targeted research and innovative solutions to the problems that marine pollution creates. These, as well as other areas of focus, are presented in the following sections as well as the plans, policies and other relevant documents that communicate and highlight research priorities relevant to the area of marine pollution.

¹³⁸ <http://www.epa.ie/pubs/reports/research/eparesearchstrategy2014-2020/eparesearchstrategy2014-2020.html>

¹³⁹ An enabler is an area that is vital for creating the conditions for growth and investment for a sustainable future for a thriving maritime economy.

¹⁴⁰

<http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Publications/2012/HarnessingOurOceanWealthReport.pdf>

¹⁴¹ <https://www.djei.ie/en/Publications/Publication-files/Innovation-2020.pdf>

Context

The key instrument that Ireland and other EU Member States will use to address marine pollution and pressures on the marine environment is the EU's MSFD. The MSFD requires EU Member States to develop a strategy to achieve or maintain Good Environmental Status (GES) in marine waters by 2020 at the latest. The aim of the MSFD is to more effectively protect Europe's marine waters by applying an ecosystem-based approach to the management of human activities while promoting the sustainable use of the marine environment for present and future generations.

The MSFD encapsulates several other important EU legislative instruments including: Water Framework Directive, Urban Waste Water Treatment Directive, Bathing Waters Directive, Birds & Habitats Directives, Common Fishery Policy, Environmental Quality Standards Directive, Nitrates Directive, and international conventions [e.g. International Convention for the Prevention of Pollution from Ships (MARPOL)]. Various requirements under the above mentioned Directives can and will contribute towards the achievement of GES and wider objectives of the MSFD and vice versa. In addition, the WFD sets a goal of achieving Good Ecological Status and Good Chemical Status for all EU ground and surface waters (including intertidal, transitional and coastal waters out to one nautical mile), which directly complements the goal of GES under the MSFD. All quality elements included in WFD assessments are subject to management measures to protect ecosystems in coastal and transitional waters and will collectively positively contribute to achieving GES.

Measures proposed under the MSFD to address marine pollution will only be effective if they are based on a deep understanding of marine ecosystem functioning. Therefore this requirement should ideally translate into provisions being made for marine research to improve knowledge, monitoring and assessment operations. A strong evidence base for the effectiveness of management measures is also crucial. This will inform policymaking and positively contribute to the cyclical revision of MSFD measures by adjusting, adding to and refining them every six years.

More specifically, Ireland's responsibilities under the MSFD are to:

- Protect and preserve the marine environment, prevent its deterioration or, where practicable, restore marine ecosystems in areas where they have been adversely affected.
- Prevent and reduce inputs in the marine environment, with a view to phasing out pollution, so as to ensure that there are no significant impacts on, or risks to, marine biodiversity, marine ecosystems, human health or legitimate uses of the sea.

The implementation process for achieving GES with reference to a number of descriptors commenced in 2011 with the incorporation of the MSFD into Irish Law¹⁴². Subsequently, an initial assessment was completed in 2013¹⁴³, followed by the development of a monitoring programme in 2015¹⁴⁴ and a programme of measures which was published in 2016¹⁴⁵ and came into effect in December 2016.

Under the MSFD, the main descriptors applicable to marine pollution are:

- **Descriptor 2** Non-Indigenous Species (NIS) introduced by human activities are at levels that do not adversely alter the ecosystem.
- **Descriptor 5** Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.
- **Descriptor 8** Concentrations of contaminants are at levels not giving rise to pollution effects.
- **Descriptor 9** Contaminants in fish and other seafood for human consumption do not exceed levels established by Community legislation or other relevant standards.
- **Descriptor 10** Properties and quantities of marine litter do not cause harm to the coastal and marine environment.
- **Descriptor 11** Introduction of energy, including underwater noise, is at levels that does not adversely affect the marine environment.

NIS in the context of Descriptor 2 are species that are either deliberately or unintentionally introduced by human activities outside of their natural range. NIS that become established and cause damage to the environment, or result in economic losses or health issues are typically referred to as invasive NIS. These species may cause unpredictable and irreversible changes to marine ecosystems through predation or competition with indigenous species, or by the modification of habitats and changes to food webs.

¹⁴² <http://www.irishstatutebook.ie/eli/2011/si/249/made/en/print>

¹⁴³ <http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownload%2C34365%2Cen.pdf>, and <http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownload%2C34366%2Cen.pdf>

¹⁴⁴ <http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownload%2C43583%2Cen.pdf>

¹⁴⁵ http://www.housing.gov.ie/sites/default/files/public-consultation/files/outcome/msfd_poms_summary_report.pdf

Eutrophication is the process of nutrient enrichment of waters that leads to increased growth, primary production and biomass of algae, changes in the balance of organisms and water quality degradation. Excess nutrients, commonly nitrogen and phosphorus, introduced into the sea by human activities can disturb the natural balance between nutrient availability and marine plant and animal growth. Increased availability of nutrients can cause the proliferation of rapidly reproducing opportunistic species of marine plants and animals, some of which can adversely affect ecosystems.

Contamination is the presence of a substance where it should not be or at concentrations above background. Pollution is contamination that results in or can result in adverse biological effects to resident communities. All pollutants are contaminants, but not all contaminants are pollutants.¹⁴⁶ A variety of polluting substances enter the seas around Ireland. These pollutants can cause damage to the marine environment, can affect humans through the consumption of contaminated seafood and can cause harmful algal blooms (HABs), closing bathing areas and sometimes causing fish/shellfish/marine mammal/seabird poisoning.

Chemical substances form an essential part of our everyday life. They can be naturally occurring (non-synthetic) with natural background levels in the marine environment or man-made (synthetic) products with no natural background levels. Examples of non-synthetic contaminants include trace metals found in the earth's crust or polyaromatic hydrocarbons which predominantly result from the combustion of fossil fuels and organic materials, while synthetic contaminants include polychlorinated biphenyls (PCBs), pesticides, organotins (e.g. tributyltin – TBT) and many brominated flame retardants. Once released to the environment, these substances can end up in the marine environment and be accessible for uptake by living organisms. The unwanted effects of this include harm to organisms at lower levels of the food chain (e.g. plankton and invertebrates) and a magnification of concentrations through food webs, resulting in higher concentrations and potential impacts at the top of the food chain, affecting species groups such as seabirds, marine mammals and seafood consumers.

Marine litter can occur on the seabed, in the water column / floating and on the coastline, with direct impacts ranging from aesthetic degradation, damage to equipment and vessels, through to risks to human health. It can pose a risk to a wide range of marine organisms such as seabirds, marine mammals, fish and turtles, through ingestion and entanglement. Marine litter, in the form of micro-plastics, can carry and release chemical contaminants into the marine environment or transfer them directly to marine organisms after ingestion.

¹⁴⁶ <http://www.sciencedirect.com/science/article/pii/S016041200600136X>

Energy in the marine environment refers to the introduction of light, electricity, heat, noise, electromagnetic radiation, radio waves or vibrations. Under MSFD Descriptor 11, the primary energy source of concern in an Irish context is underwater noise, which is categorised as either impulsive or continuous. Impulsive noise is defined as *“One or more sound pulses, each of short duration and with long gaps of no significant sound emission between pulses”*. Continuous or ambient noise is commonly defined as *“Background noise without distinguishable sources”*. Understanding and monitoring the level of noise in the marine environment is becoming an area in which more research and attention is being given in recent years.

Relevant Documents / Sectoral Plans

JPI Oceans Strategic Research and Innovation Agenda 2015 – 2020

The vision of the Joint Programming Initiative (JPI) Healthy and Productive Seas and Oceans (JPI Oceans) is to enable Blue Growth and jobs, whilst fostering the health and productivity of seas and oceans and addressing the pressures of climate change and human impacts on the oceans. Ten Strategic Areas are identified in the JPI Strategic Research and Innovation Agenda (SRIA) 2015 - 2020. A number of areas are relevant in the context of marine pollution:

Strategic Area 3 – Science Support to Coastal and Maritime Planning and Management

Three activities are promoted under this theme: development of a common strategy for sustained long-term monitoring of human impacts and climate change in coastal areas; research to understand marine ecosystems goods and services; and research on the land-sea interface. The first and third themes in particular are highly relevant in terms of the marine pollution theme. This Strategic Area highlighted the need to develop a transnational network of scientific institutions responsible for providing advice to policy needs in relation to spatial planning (MSP, CFP, MSFD, WFD) in the short term, with longer term goals of development and implementation of an integrated monitoring strategy for coastal observation; enhanced research on the land-sea interface (increased use of models and ecosystems goods and services), and building of an efficient interdisciplinary scientific community for industry and policy-relevant knowledge.

Strategic Area 4 – Linking Oceans, Human Health and Wellbeing

Again three activities are promoted. Of particular relevance to marine pollution is investigating the processes involved in the transport and transmission of toxins (biogenic) and toxicants (man-made) from the marine environment to humans. This includes the impact of consumption of contaminated seafood or toxins produced by the phytoplankton species involved in harmful algal blooms (HABs).

Expertise from a diverse range of disciplines across natural, social and economic sciences, including public health and medicine is required.

Strategic Area 5 – Interdisciplinary Research for Good Environmental Status

The rationale for the activities proposed under this theme is based on analysis of the first phase of implementation of the MSFD which showed that progress was needed in how we can monitor and assess GES more efficiently. Three activities are proposed: Promotion of the exchange of knowledge, best practices and cooperation among different countries and networks; act as a hub to address acute risks (including emergencies) and disasters inside and outside the EU by putting in place temporary panels of experts; and research to address gaps in knowledge relating to harmful algal blooms on marine ecosystems, maritime economy and human health. In the short term, enhancing the networks of research institutions to address current barriers to a common understanding and coherent assessment of GES in European waters is required. Long term goals are research to address effects of eutrophication and HABs, and research on critical pollutants in the marine environment to inform future GES assessments.

Strategic Area 6 – Observing, Modelling and Predicting Ocean State and Processes

Activities proposed under this theme include supporting the set-up of a European Ocean Observing System; promotion of common standards and open access to data and the harmonisation of data requirements in particular for the MSFD, and supporting e-infrastructures for computing, modelling, forecasting and early warning systems. A long term plan for observing technologies is proposed, supported by actions to improve access to existing high performance computing facilities, to ocean modelling frameworks, allowing several ocean related components of the earth system to work together or separately, and to forecasting capacities. A world class network of marine data centre adopting common standards is another long term goal.

Other Strategic Areas propose cross cutting themes, for example:

- Relationship between and combined impacts of climate change and human pressures (Strategic Area 8)
- Development of a better understanding of multiple pressures on food-webs and how they impact on fisheries and aquaculture such as the effects of eutrophication and harmful algal blooms (HABs)

Marine Strategy Framework Directive

Ireland's MSFD Initial Assessment, GES, Targets and Indicators Report published in October 2013¹⁴⁷ identified information gaps in relation to each descriptor and provides a useful guide for where research may be required:

Descriptor 2 Non-Indigenous Species (NIS)

- There is a high degree of uncertainty around the abundance estimates and associated trends in existing NIS data for Irish waters which is exacerbated by the disparate data sources.
- The determination of trends is further complicated by conflicting views on what constitutes a cosmopolitan, cryptogenic or NIS. In many cases, there is a high degree of uncertainty on how a NIS arrived in Irish waters and their subsequent dispersal once established.

Descriptor 5 Eutrophication

- Atmospheric deposition of nitrogen is assessed based on a single Irish station (along with other stations in Northern Ireland and the United Kingdom, to derive modelled estimates). This resolution does not allow for conclusions to be drawn for Irish waters on this pressure and modelled estimates are only indicative.

Descriptor 8 Contaminants

- Synthetic and non-synthetic contaminant monitoring datasets are currently spatially and temporally limited.
- Internationally agreed assessment methodologies and criteria requires further development for assessing Good Environmental Status with respect to a range of hazardous substances.
- The Radiological Protection Institute of Ireland's monitoring of marine biota (i.e. mussels, prawns and oysters) is primarily directed towards the assessment of containment risk in relation to human exposure and does not presently address the question of whether radionuclide activity concentrations in the marine environment have an adverse impact on marine biota.
- The specific or overall adverse effects of any particular spill / acute pollution event remains largely unknown.
- The projections of future trends in marine acidification are based on global predictions and not specific to Irish waters. There is a need to understand the natural variability of oceanic

¹⁴⁷<http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownload%2C34365%2Cen.pdf>

pH and the marine carbonate system in order to be able to distinguish long term trends from natural fluctuations. There is no available information on current impacts directly attributable to acidification in Irish waters and agreed indicators and monitoring are not in place.

Descriptor 9 Fish and Shellfish Contamination

- Current arrangements for assessing pressures under the Shellfish Waters Directive are limited because of the low sampling frequency preventing robust and reliable temporal trend analysis.
- The magnitude and distribution of microbial contamination in the marine environment is variable and can be strongly influence by weather and environmental condition (OSPAR, 2009) which needs careful evaluation when considering temporal differences in microbial occurrence.
- The assessment of microbial pathogens in Irish waters is based on bathing water and shellfish water monitoring which is only representative of microbial pathogen populations in near-shore waters. Microbial pathogen occurrence, interactions and impacts in open (marine) waters remains unknown.

Descriptor 10 Marine Litter

- There has been no assessment of the environmental impacts of marine litter in Irish waters and there is little quantitative or qualitative information on the possible adverse effects on marine organisms at the population and community level. Impacts from ingestion and entanglement are known to be a source of mortality among a range of marine species, which includes marine mammals, seabirds and benthic crustaceans, but there are no data beyond observations of mortality of individuals and some limited studies examining the impact of ghost fishing.
- Both the OSPAR beach monitoring and the IGFS data sets are inadequate to determine trends in litter concentration or distribution and provide little indication of the variability, in litter movement and distribution. From the perspective of scale, the Irish coastline is approximately 10,139 km in length, but only 4 km of coastline is presently being monitored for beach litter as part of OSPAR beach litter surveys (An Taisce, 2012).
- Surveys of litter loads on the seabed have been conducted using the IGFS. This method is recognised as an acceptable sampling technique, but is nonetheless designed to catch demersal fish over a range of seabed types and is highly likely to vary in its efficiency at recovering certain types of litter, resulting in an underestimate of the true quantity of litter

present on the sea floor. For this reason the IGFS results are most appropriately used as an estimate of relative rather than absolute densities of seabed litter.

- To date, there have been no assessments of litter in the water column or on the open sea surface in Irish waters. Floating litter has the potential to exert adverse impacts at all levels of the marine environment. Harm is caused by direct ingestion or by entanglement, but a process of degradation may give rise to the conversion to micro-litter particles, of which the impacts are little understood. In addition, floating litter could potentially, act as a vector for the translocation of alien (invasive) species.

Descriptor 11 Energy (including Underwater Noise)

- Information on the sources, magnitude, distribution and impacts of continuous sound in the Irish marine environment is limited. Research currently being undertaken is intended to support the development of ‘risk-based’ noise monitoring programmes, incorporating the establishment of baselines and the determination of trends. Further research is required.

Ireland also published its *MSFD Article 11 Monitoring Programme Report* in April 2015¹⁴⁸. The adequacy of the monitoring programmes proposed is commented upon as part of the “Programme Level Questions” 5g / 5h and 6e / 6f. The following observations were made:

Descriptor 2 Non-Indigenous Species (NIS)

- The development of a consistent approach towards the development of a national NIS monitoring programme to meet the needs of the MSFD was identified as a knowledge gap. A desk study was undertaken to identify relevant sites and pathways and to prioritise sites/pathways based on relative risks (high to low), characteristic environmental conditions, arrival pathways and patterns of previous invasion. Further work is needed to establish a monitoring programme and to investigate pathways for arrival.

Descriptor 5 Eutrophication

- While the monitoring programme for eutrophication is considered adequate, the programme is continuously being reviewed and improved. The methodologies for the analysis of Total Nitrogen and Total Phosphorus are, for example, currently undergoing development.

¹⁴⁸<http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/Environment/Water/FileDownload%2C43582%2Cen.pdf>

Descriptor 6 Contaminants

- Potential gaps in Descriptor 8 monitoring to be considered for inclusion [during the review of the WFD, MSFD D8 and OSPAR JAMP programme] could be: concentration of bio-accumulating contaminants at higher trophic levels e.g. seabird eggs; offshore monitoring: while concentrations are expected to be low, limited offshore monitoring, for example using passive sampling, would be warranted.

Descriptor 9 Fish and Shellfish Contamination

- None identified.

Descriptor 10 Marine Litter

- Work is underway to assess the riverine inputs of floating litter (UCC – CMRC research project).
- Research work is proposed at GMIT to assess the feasibility of adopting the OSPAR fulmar indicator for litter in biota.
- GMIT are running a research project on the occurrence of micro-plastics in seas around Ireland. The project is also assessing the accumulation of pollutants on micro-plastics.
- GMIT are also investigating marine micro-plastics and the inter-relationships between sources, receiving environment and fauna. This includes survey of micro-plastics in sediments of inshore areas.
- Further work is required to elucidate the factors influencing the observed distribution and abundance of micro-plastics. The results of this research will not be available to contribute to the MSFD in 2014, but are expected to contribute to the next MSFD cycle commencing in 2018.

Descriptor 11 Energy (including Underwater Noise)

- Ireland plans to establish an ambient noise monitoring programme based on modelling with model calibration. This will build on research work undertaken in Ireland through two EPA STRIVE projects including the UCC – CMRC project – mapping the spatio-temporal distribution of underwater noise in Irish waters.
- Future potential developments in monitoring platform technology (more reliable and more cost effective) will inform and may change this approach.

Water Framework Directive

Ireland has just published a Public Consultation document on the River Basin Management Plan for Ireland¹⁴⁹ (2018 – 2021). This is the second cycle of River Basin Management Planning for Ireland, with a single river basin district approach being brought forward together with an improved evidence base to underpin measures implementation at national and local level. The 2013 – 2015 water quality status information found that 32% of transitional waters and 76% of coastal water are achieving good or high status. 93% of bathing waters met the required standard in 2015 and 75% of shellfish waters meet microbiological guide values. Therefore, our transitional waters in particular are well below required WFD ecological status objectives.

The characterisation of water bodies found that agriculture and urban waste water were the significant pressures on river and lake water bodies. Characterisation of transitional and coastal waters is on-going. Priorities have been identified for the next phase of implementation of the WFD in Ireland and these include full compliance with relevant EU legislation; prevention of deterioration; meeting the objectives for designated protected areas; protecting high status waters; and targeted actions and pilot schemes in focus sub-catchments. Key measures will include compliance with the Good Agricultural Practice Regulations and planned investment in urban waste water collection and treatment infrastructure.

A number of Government Departments including the Department of Housing, Planning, Community and Local Government and the Department of Agriculture, Food and the Marine sit on the Water Policy Advisory Committee for the WFD, while the Marine Institute play a significant role in monitoring of WFD transitional and coastal water quality monitoring. Improvements in assessment methods are being trialled by the EPA, in particular for hydromorphological pressures assessment.

The success of measures implemented under the WFD will have knock-on positive effects for the success of the MSFD implementation in Ireland also. Where possible, targets, indicators, monitoring programmes and measures have been aligned, in particular for Descriptor 5 Eutrophication and Descriptor 8 Contaminants. There is further work required to align biological water quality element monitoring (fish species, benthic communities, macro-algae and angiosperms (seagrass) under the WFD with Descriptor 1 Biodiversity monitoring under the MSFD.

¹⁴⁹ http://www.housing.gov.ie/sites/default/files/public-consultation/files/draft_river_basin_management_plan_1.pdf

OSPAR Quality Status Report 2010

OSPAR produce a Quality Status Report (QSR) every 10 years, the latest from 2010¹⁵⁰. While due to be updated in the coming years, it provides a condensed overview of knowledge on trends in pressures and impacts and the quality status of the North-East Atlantic and its Regions covering the period 1998 – 2008, some aspects of which are still current in 2017.

Eutrophication

- Reductions in phosphorus discharges were recorded; however, nitrogen discharges are still the main problem, especially those from agriculture.
- Concern about atmospheric nitrogen inputs is increasing (sources include power plants, industry and industrial processes, agriculture, transport, international shipping etc.). Evaluation of the contribution of atmospheric nitrogen emissions in marine eutrophication assessments is required.
- More rain and increased flooding as a result of climate change are expected to enhance nutrient enrichment through increased freshwater inputs and run-off from land. Rising sea temperature and prolonged stratification are likely to lead to increased incidence of harmful algal blooms and changing phytoplankton composition. Ocean acidification may also promote changes in the plankton.
- New observational tools such as instrumented buoys, ferry boxes, airborne surveillance and remote sensing, have the potential to complement traditional sampling and to help design cost effective monitoring programmes to enhance the evidence base for future eutrophication assessments through better spatial and temporal coverage.
- Future monitoring and assessment should be supported by refinement of the methodologies of the Common Procedure; coordinated use of new observational tools and continued cooperation on evaluating transboundary nutrient transport and improved knowledge through modelling.

Hazardous Substances

- Efforts on biological effects must continue: It is not yet possible in most cases to link chemical monitoring with observations of effects in species in such a way that conclusions can be drawn about the impact of contaminants on the functioning of ecosystems at a regional level.

¹⁵⁰ <http://qsr2010.ospar.org/en/index.html>

- Understanding of endocrine disrupting effects must improve: Since the QSR 2000, there has been little improvement in knowledge about concentrations of potentially endocrine disrupting chemicals released to the marine environment.
- Emerging problems from substitute chemicals: In many cases when a hazardous substance is phased out, its uses are filled by other chemicals. There is clear need to keep environmental levels of chemicals used as substitutes under review as these could also pose environmental risks.
- The OSPAR Coordinated Environmental Monitoring Programme (CEMP) should be further developed for future monitoring and assessment, supported by the following:
 - Improved understanding of the effects of hazardous substances, particularly cumulative effects and endocrine disruption.
 - Improved biological effects monitoring, integrated where appropriate, with chemical monitoring.
 - Extended datasets further offshore beyond the densely populated and industrialised coasts.
 - Improved information collections on the production, uses and pathways to the marine environment, especially for substances which are not deemed suitable candidates for marine monitoring.
 - Use of research results on concentrations and effects of hazardous substances on deep-sea species and ecosystems.
- There is increasing evidence that climate change may alter pathways of hazardous substances to the North-East Atlantic – this requires future monitoring and assessment.

Radioactive Substances

- Discharges from the sector have fallen, and environmental concentrations and exposure of humans and biota to some monitored radionuclides from the nuclear sector is low. Offshore oils and gas extraction is a substantial source of inputs of naturally occurring radionuclides to the sea.
- OSPAR should continue to improve the evidence base and assessment tools for evaluating progress towards objectives. This should be achieved by:

- Continued systematic collection of data on discharges and concentrations of the indicator radionuclides.
- Further development of tools to estimate and assess doses to evaluate impacts of discharges on the environment.
- Further develop statistical trend analysis techniques, taking advantage of experience gained in other contexts.
- Develop environmental quality criteria for the protection of the marine environment against adverse effects of radioactive substances.

Other Human Uses and Impacts

- Improved detection of pathogens in seawater and seafood and the assessment of associated risks through expanded monitoring, modelling and development of suitable molecular tools should be promoted.
- Further reductions in faecal inputs to coastal waters are needed, such as through better sewage collection and treatment and best practices for agricultural uses of sewage and manures.
- Levels of underwater noise are thought to be increasing internationally. Studies show that noise does affect marine organisms, but so far there is a lack of knowledge on specific effects and possible cumulative effects, which makes understanding of dose-response relationships difficult.
- Research is needed on the propagation and effects of underwater sound on marine life, as well as behavioural and auditory studies, programmes to monitor the distribution of sound sources and the relevant marine species, and anthropogenic sound budgets.
- Marine litter is a persistent problem affecting the seabed, the water column and coastlines. There are limited data on seabed and floating litter. OSPAR should support the implementation of international and EU legislation, initiatives such as UNEP's (Regional Seas Programme) work on marine litter, and ongoing research into litter in the deep sea and the ecological effects of microplastics.

EPAs Ireland's Environment – An Assessment 2016

In this sixth State of the Environment report published by the Environmental Protection Agency (EPA¹⁵¹) in 2016, very clear messages are presented in terms of inland and marine water quality. Ireland's location in the Atlantic Ocean on the edge of the European continent has meant that, in comparison with many other European countries, its marine environment has remained relatively unpolluted. Ireland's water quality is good in comparison with many of our European neighbours, however, there are many impacts that need to be addressed to bring all waters up to a satisfactory standard and to protect waters already in good condition.

In recent years, the level of environmental stress, from both internal and external sources, has increased. Coastal development and industrialisation, particularly during the 1990s, has resulted in an increase in the range and magnitude of pressures that have the potential to impact negatively on the quality of Ireland's tidal waters. Pressures have also come from the intensification of agriculture and commercial fishing. The application of inorganic fertilisers and changing farming practices have caused nutrient enrichment of inshore surface waters, and, in the fishing sector, the use of new technologies and larger modern trawlers has allowed the capture of unsustainable quantities of fish. The continued release of untreated sewage into the marine environment from several large towns is a major cause of concern for coastal communities and ecosystems. In addition, the impacts of climate change pose a significant and not yet fully understood threat to this environment.

Preliminary results from a full 6-year ecological status assessment under the Water Framework Directive (WFD) covering the period between 2010 and 2015 indicate little change in the quality of Ireland's transitional (estuarine) and coastal waters. A preliminary assessment using information from all transitional and coastal monitored water bodies was used to extrapolate the results to unmonitored ones. For coastal waters, the number of water bodies at High or Good status has increased from 68% in 2012 to 76% in 2015 due to the recovery of certain water bodies from algal bloom impacts. In terms of surface area assessed there has been no change with 93% of coastal water area at high or good status. In transitional waters, 47% of water bodies remain at moderate or worse status which is the same as was found during the last assessment.

Elevated nutrient concentrations (phosphorus and nitrogen) continue to be the most widespread water quality problems in Ireland, arising primarily from human activities such as agriculture and waste water discharges to water from human settlements, including towns, villages and rural houses. Concentrations of both nitrate and phosphorus tend to be elevated in the north-east, south-

¹⁵¹ http://www.epa.ie/pubs/reports/indicators/SoE_Report_2016.pdf

east and south of the country and lower towards the west, north-west and south-west. There is a clear correlation between the areas with the highest nitrate and phosphorus concentrations in waters and areas with the most intensive agriculture and highest human population densities. The level of pollution from hazardous substances is low. In 35% of designated shellfish waters with elevated faecal contamination, additional measures to improve quality and achieve higher objectives are required.

The Drivers and Pressures identified by the EPA relevant to the marine environment were:

- Eutrophication.
- Threats to improving water quality e.g. ongoing and planned expansion of the agricultural sector under Food Harvest 2020 and Food Wise 2025.
- Urban Waste Water.
- Marine Litter.
- Dredging of Marine Harbours and Marinas.
- Marine Fisheries and Aquaculture.
- Impacts of Commercial Fishing.
- Sea fishing by-catch.
- Impacts of Marine Aquaculture.

Responses proposed to deal with the identified pressures and drivers are presented and include:

- River Catchment Planning.
- Tackling Diffuse Pollution (agriculture, Rural Development Programmes, Domestic Waste Water Treatment Systems).
- Tackling Point Source Pollution (Urban Waste Water Treatment).
- EPA Water Research Programme.

The key outlook messages are:

- The slow progress in improving the ecological status of surface waters means that new approaches are needed. This is being progressed with the establishment of new water governance structures and by using the integrated catchment management approach supported by better evidence and science.
- It is doubtful whether current agricultural initiatives will offer the solutions needed unless adjustments are made. While the reform of the Common Agricultural Policy, and the greening aspect and link to payments was welcomed, there was criticism expressed that the

policy proposals from the Commission were weakened during negotiations and therefore do not effectively meet the standards necessary to prevent environmental degradation by the agricultural sector. Monitoring of the reform is needed.

- Community involvement has the potential to contribute significantly towards effect catchment management.
- Initiatives to improve the stock of septic tanks and sludge management need to continue.
- Investment and operational improvements in urban waste water are needed.
- Targeted investigative monitoring is needed to detect hazardous substances which may be of concern in the aquatic environment.
- Key developments for the protection of marine waters include the implementation of the Marine Strategy Framework Directive. A reformed Common Fisheries Policy and new legislation for Maritime Spatial Planning are seen as key drivers for the restoration and maintenance of harvested stocks and the promotion of sustainable development respectively.
- Rising sea temperatures, ocean acidification, ocean deoxygenation and rising sea levels have been identified as four of the key stressors impacting on the world's oceans and coastal environments.
- The proposals for large-scale seaweed harvesting will require scrutiny and regulation to prevent damage to intertidal biodiversity, to maintain sustainability and to protect the marine environment.
- Raising awareness of the benefits and services to society from water catchments will assist in their management.
- Economic policy instruments can play a role in achieving water policy goals.

EPA Research Strategy 2014 – 2020

The EPA's Research Strategy 2014 – 2020 (EPA, 2014¹⁵²) has as its theme – *“Using knowledge to protect and improve our natural environment and human health”*.

Priority areas requiring consorted national effort identified were:

- Supporting water protection, conservation and management obligations under the Water Framework Directive, Marine Strategy Framework Directive and Floods Directive.

¹⁵² <http://www.epa.ie/pubs/reports/research/eparesearchstrategy2014-2020/eparesearchstrategy2014-2020.html>

- Understanding environment–health interactions, including risks from emerging chemicals and novel materials, while highlighting the benefits to human health of a clean and well managed environment.
- Furthering the knowledge base on the role of the natural environment, its resources and ecological limits, and our understanding and protection of ecosystems and their role in sustaining the economy and human wellbeing.
- Developing integrated approaches and growth opportunities through management of the challenges that arise from climate change, water quality and other environmental issues.

Under the Water Pillar of the EPA Research Strategy, groundwater, surface water, transitional and coastal water; as well as waste water, drinking, bathing and shellfish waters are covered. The water pillar will support the emerging policy and implementation research needs in relation to the implementation of the Water Framework Directive (WFD), as well as marine research considerations to support to the formulation and implementation of policies. The document acknowledges that technology and innovation have a significant role to play in meeting environmental challenges, and that behavioural change is another key area that requires focus.

Five thematic areas have been included in the 2014 – 2020 Water Pillar:

1. Safe Water.
2. Ecosystem Services and Sustainability.
3. Innovative Water Technologies.
4. Understanding, Managing and Conserving our Water Resources.
5. Emerging and Cross-cutting Issues.

Multi- and inter-disciplinary teams will be required to advance the themes, with expected social, economic, technology, environment and policy impacts. The themes selected also sought to align with the international Strategic Research Agenda launched by the Water Joint Programming Initiative¹⁵³.

Harnessing Our Ocean Wealth

Harnessing Our Ocean Wealth (HOOW) is an integrated marine plan that provides a framework for high-level goals and integrated actions across policy, governance and business to enable Ireland's

¹⁵³ <http://www.epa.ie/researchandeducation/research/internationallinkages/jointprogramminginitiatives/waterjpi/>

marine potential to be realised. Three high level goals, of equal importance, have been included within the plan, including Goal 2 Healthy Ecosystems. To support the vision and goals of the plan, eight enablers to create the conditions for growth and investment are identified, one being Clean-Green-Marine. The ethos of the enablers is to protect and conserve marine ecosystems, ensuring development strategies and management practices do not impair the capacity of ecosystems to deliver market and non-market goods and services. Twelve actions are identified under this enabler, one of which is the implementation of the MSFD and a second, to continue to implement the EU Water Framework Directive through the River Basin Management Plans.

Research Capabilities (Maturity Assessment)

A review of current research being funded by the following funding bodies¹⁵⁴ was undertaken to inform the maturity assessment for marine pollution. The funding bodies included were:

- JPI Oceans.
- Horizon 2020 EU Seventh Framework Programme (FP7).
- EU LIFE Programme.
- European Regional Development Fund, INTERREG and European Structural and Investment Funds.
- Science Foundation Ireland.
- Marine Institute.
- Environmental Protection Agency.
- Other Funding.

JPI Oceans

In terms of joint actions and projects for interdisciplinary research for Good Environmental Status, Ireland is involved in three projects – all related to marine litter. The pilot action *Ecological Aspects of Microplastics* was proposed in February 2013, with Ireland as a participating country and the Marine Institute as a funding partner. This resulted in a joint call in 2015 of €7.7 million, with four projects selected for funding in January 2016:

- BASEMAN – defining the baselines and standards for microplastics analysis in European waters. GMIT are the Irish organisation involved in this interdisciplinary and international collaborative research project.

¹⁵⁴ The top funding bodies as evidenced by the projects on-going within Ireland are listed here. This section does not provide a complete inventory of funding bodies, or indeed current research on-going in Ireland of relevance to marine pollution, but provides a high level overview of where research funding has been targeted in the past decade.

- EPHEMARE – ecotoxicological effects of microplastics in marine ecosystems. UCC are the Irish organisation involved in this project.
- PLASTOX – direct and indirect ecotoxicological impacts of microplastics on marine organisms. NUI Galway are the Irish organisation involved in this project.
- WEATHER-MIC – how microplastic weathering changes its transport, fate and toxicity in the marine environment. There is no Irish involvement in this project.

A second pilot action – Intercalibration for the EU WFD, has a number of objectives including testing a mechanism for joint funding from environmental authorities of nine member countries, surpassing the traditional model of joint calls, to obtain performance improvements. Ireland have signed a memorandum of understanding and committed budgets to the pilot action. No funding has been made available to date under this pilot action for specific projects.

Horizon 2020

Horizon 2020 is the largest EU Research and Innovation programme with a budget of approximately €80 billion over 7 years (2014 – 2020). It succeeded the 7th EU Framework Programme (FP7) in 2014. It is the financial instrument of the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe’s global competitiveness. It has three key pillars, excellent science, industrial leadership and societal challenges. 18 thematic sections are included in the Horizon 2020 work programme, including Societal Challenge 5 “*Climate Action, Environment, Resource Efficiency and Raw Materials*”¹⁵⁵. This theme includes as part of its activities to “.....assure environmental integrity, resilience and sustainability”. Ireland has performed strongly, winning €350+million in funding to date. 472 projects have been awarded to Ireland in the first two years of Horizon 2020, with 164 of those projects under the “excellent science” pillar¹⁵⁶.

Successful Irish SC5 projects as a result of the 2nd Stage H2020 SC5-2015 call¹⁵⁷ which have some linkage to marine pollution (although not directly targeted towards this area) were:

- AQUACROSS. UCC. AQUACROSS seeks to advance the application of ecosystem-based management for aquatic ecosystems in an effort to support the timely achievement of the EU 2020 Biodiversity Strategy and other international conservation targets. In this regard,

¹⁵⁵ The Environmental Protection Agency and Enterprise Ireland are the national delegates for this challenge.

¹⁵⁶ <https://www.djei.ie/en/Publications/Publication-files/Interim-evaluation-of-Ireland%E2%80%99s-Participation-in-Horizon-2020.pdf>

¹⁵⁷

<http://www.epa.ie/researchandeducation/research/internationallinkages/horizon2020/horizon2020sc5/h2020sc5irishresults/>

AQUACROSS aims to develop and test an assessment framework which considers the full array of interactions, *including human activities*, within aquatic ecosystems.

- ATLANTOS. Marine Institute/NUI Galway. The overarching objective of AtlantOS is to achieve a transition from a loosely-coordinated set of existing ocean observing activities producing fragmented, often monodisciplinary data, to a sustainable, efficient, and fit for-purpose Integrated Atlantic Ocean Observing System (IAOOS).
- MERCES: Marine Ecosystem Restoration in changing European Seas. NUI Galway. The overall goal is to enhance the EU capacity to restore degraded and/or damaged marine ecosystems and habitats and the services they provide to human well-being. This will be achieved by offering policy makers and stakeholders new solutions for marine restoration, creating the knowledge base for new professions in the field of marine environmental services, and creating new job opportunities in both the private and public sectors associated with (economic) interests in the remediation of degraded/damaged marine ecosystems. It will also involve the analysis of the effects of restoration on the recovery of ecosystem services and societal benefits and the provision of a cost-benefit analysis of restoration activities.

EU Seventh Framework Programme (FP7)

Ireland has had involvement in the following EU Seventh Framework Programme (FP7) funded projects that have relevance to the Marine Pollution theme:

- BRAAVOO¹⁵⁸ – Biosensors for real time monitoring of marine contaminants. This project developed innovative solutions for real-time in-situ measurement of high impact and difficult to measure marine pollutants. The concept was based on a unique combination of three types of biosensors (nano-immuno, bacterial, and algal biosensors) which will enable both the detection of a number of specific marine priority pollutants as well as of general biological effects that can be used for early warning. IDS Monitoring was the sole Irish participant in this project and a report of field trials carried out in Ireland is available from the BRAAVOO website¹⁵⁹.
- MariaBox¹⁶⁰ – MARINE environmental in-situ Assessment and monitoring tool BOX. This project developed a wireless marine environment analysis device for monitoring chemical and biological pollutants while installed into a buoy, a maritime means of transport or a mooring. Dublin City University was the Irish partner involved in the project.

¹⁵⁸ <http://www.braavoo.org/#slide-1>

¹⁵⁹ http://www.braavoo.org/BRAAVOO_MissionReport_Ireland.pdf

¹⁶⁰ <http://www.mariabox.net/wordpress/>

- Micro B3¹⁶¹ – Marine Microbial Biodiversity, Bioinformatics and Biotechnology. This project develops innovative bioinformatic approaches and a legal framework to make large-scale data on marine viral, bacterial, archaeal and protists genomes and metagenomes accessible for marine ecosystems biology and to define new targets for biotechnological applications. UCC was the Irish partner involved in the project.
- ECsafeSEAFOOD¹⁶² – Priority environmental contaminants in seafood: safety assessment, impact and public perception. This project assessed food safety issues related to priority contaminants present in seafood as a result of environmental contamination (including those originating from harmful algal blooms and those associated with marine litter) and evaluate their impact on public health. AquaTT was the Irish partner involved in this project.

EU LIFE Programme

The LIFE (the Financial Instrument for the Environment) Regulation, which was published on 20 December 2013, sets a budget for the next funding period, 2014 – 2020 of €3.4 billion. There were four complete phases of funding prior to the new call publication¹⁶³. The LIFE programme is the EU's funding instrument for the environment and climate action. There has been no recent marine related projects funded within Ireland, with successful projects in recent times related the terrestrial and freshwater protected habitats and species themes.

European Regional Development Fund, INTERREG and European Structural and Investment Funds

The European Regional Development Fund (ERDF) is one of the main financial instruments of the EU's cohesion policy. European Territorial Cooperation (ETC), better known as Interreg, provides a framework for the implementation of joint actions and policy exchanges between national, regional and local actors from different Member States. ETC is funded by the ERDF and is one of the five funds of the European Union under European Structural and Investment Funds. A project that has recently secured funding in March 2017 is the Acclimatize Project¹⁶⁴.

- Acclimatize will close the knowledge gap in relation to the faecal pollution of 'at-risk' urban and rural bathing waters in Ireland and Wales by identifying and quantifying pollution streams and determining their impact on these waters through a dynamic period of climate change. The project is an ETC backed Ireland-Wales cooperation initiative¹⁶⁵ being led by

¹⁶¹ <https://www.microb3.eu/>

¹⁶² <http://www.ecsafeseafood.eu/>

¹⁶³ <http://ec.europa.eu/environment/life/about/index.htm>

¹⁶⁴ <http://irelandwales.eu/projects/acclimatize>

¹⁶⁵ The Ireland Wales programme is one of a family of European Territorial Co-operation (ETC) programmes which provide opportunities for regions in the EU to work together to address common social, economic and environmental challenges.

University College Dublin (UCD)¹⁶⁶. The ultimate aim is to improve the quality of the marine environment and in turn help boost tourism and supporting marine activities.

Science Foundation Ireland

SFI has established twelve Research Centres focussing on strategic areas of importance to Ireland. The centres aim to deliver scientific excellence with economic and societal impact in the areas of – Pharma, Big Data, Medical Devices, Nanotechnology/Materials, Marine Renewable Energy, Food for Health/Functional Foods, Perinatal Research, Applied Geosciences, Software, Digital Content and Telecommunications. The most relevant research centre to the Marine Pollution theme is MaREI, Centre for Marine and Renewable Energy. There are several research areas of focus in MaREI with a small number being relevant to the Marine Pollution theme. Relevant projects that are currently ongoing at MaREI include:

- Acoustic monitoring station for MSFD.
- Common Sense – Cost-Effective Sensors, Interoperable with International Existing Ocean Observing Systems, to Meet EU Policies Requirements.
- EPHEMARE – Eco-toxicological effects of micro-plastics in marine ecosystems.

Marine Institute

The Marine Institute provides funding for marine research in a range of areas via competitive marine research funding programmes (e.g. Cullen Fellowship, Shiptime Programme and the Networking & Travel Initiative). Examples of recent Shiptime Programme funded projects relevant to marine pollution include:

- DINO16¹⁶⁷ – Investigate the origins of populations of the harmful dinoflagellate Dinophysis on the continental shelf. Dinophysis is responsible for over half of the toxic harmful algal events that occur in the eastern Celtic Sea. Data collected is essential to parameterise models and forecasts for harmful algal events in economically important areas.
- AZBO (The Biological Oceanography of Azadinium)¹⁶⁸ – The objectives are to deliver data to the Irish Harmful Algal Bloom (HAB) modelling effort, to map the extent of known Azaspiracid (AZA) biotoxins producers in Irish waters and to map the physical and phytoplankton characteristics of the Coastal current, Bantry Bay and Killary Harbour. Data collected will be used to assess the validity of bay mouth water flux models in order to

¹⁶⁶ <http://www.ucd.ie/innovation/newsevents/news/2017/march/67macclimatizeprojecttoimprovewaterquality/>

¹⁶⁷ <https://www.marine.ie/Home/site-area/research-funding/marine-research-ireland/research-database>

¹⁶⁸ <https://www.marine.ie/Home/site-area/research-funding/marine-research-ireland/research-database>

assess the accuracy of predicted movements of potentially toxic blooms into aquaculture areas.

Other projects that were supported by the Marine Institute in the form of PhD and Post-doctoral research include:

- Biogeochemical Cycling of Carbon and Nutrients in Irish Marine and Coastal Waters (NUIG and funded by the Marine National Development Plan).
- The Role of Passive Sampling in Screening and Monitoring of New and Emerging Chemicals (DCU and funded by the EPA).
- Investigating the Contaminant Concentration in Various Tissues of Crustaceans Fished and Landed in Ireland (GMIT, supported by FSAI).
- New Analytical Methodologies for Chemical Analysis of Pollutants and Residues (DIT).

Environmental Protection Agency

The EPA has a statutory role in coordinating environmental research. The focus of their national environmental research programme is on policy and is driven by national regulations and EU Directives. Research calls are made which are consistent with the EPA Research Strategy, the current one covering the period 2014 – 2020. A review of the latest research call from 2016, found that 11 Water Pillar projects were awarded. Those with relevance to marine pollution, including those with relevance in terms of transport of pollutants from the freshwater to the marine environment were:

- Impacts of microplastics on the Irish Freshwater environment, UCC.
- Sources, pathways and environmental fate of microplastics, GMIT.
- DiffuseTools: Catchment Models and Management Tools for Diffuse Contaminants (Sediment, Phosphorus and Pesticides), UCD.

Previous research calls under the EPA's STRIVE Programme (2007 – 2013) and further research funded and published since 2014 (up to 22nd March 2017) includes the following relevant projects:

- STRIVE 30: SmartCoast Project – Smart Water Quality Monitoring System, DCU, UCC, Marine Institute & SME industry partners.
- STRIVE 42: Macroalgal Biomonitoring – Applying Phenolic Compounds as biomarkers for metal uptake characteristics in Irish Coastal Waters, NUI Galway.
- STRIVE 96: Assessment and Monitoring of Ocean Noise in Irish Waters, GMIT.

- STRIVE 105: Ecosystems indicators¹⁶⁹ for the MSFD, GMIT.
- STRIVE 117: Monitoring of priority substances in waste water effluents, DCU, Cork County Council, CIT.
- STRIVE 120: Assessment and Monitoring of Ocean Noise in Irish Waters, GMIT.
- STRIVE 121: Mapping the spatio-temporal distribution of underwater noise in Irish waters, CMRC – UCC & Quiet Oceans.
- Research 134: Biological effects and chemical measurements in Irish Marine Waters, TCD, Marine Institute, Shannon Aquatic Toxicity Laboratory, DIT.
- Research 142: Pharmaceuticals in the Aquatic Environment, Kings College London, University of Exeter and University of the West of Scotland.
- Research 143: Pharmaceuticals in the Aquatic Environment, GMIT.
- Research 150: Assessment of exposure to metallic nanoparticles, focusing on silver on marine and freshwater model organisms at a cellular and genetic level, NUI Galway.
- Research 165: Contaminant movement and attenuation along pathways from the land surface to aquatic receptors: the Pathways Project, QUB, TCD & UCD.
- Research 184: Assessing recent trends in nutrient inputs to estuarine waters and their ecological effects, NUI Galway.
- Research 185: Investigation of the implications for Ireland of emerging standards on pharmaceuticals in receiving waters, Athlone IT.

The projects supported ranged from desk studies to large scale projects and covered themes such as underwater noise monitoring, priority substances/pharmaceuticals in the aquatic environment, monitoring technologies, biological effects and chemical measurements, contaminant movement/pathways, trends in nutrient inputs, examination of OSPAR Ecological Quality Objectives and investigation of emerging standards for pharmaceuticals. A wide range of academic institutions are evident from the projects – DCU, UCC, NUI Galway, GMIT, TCD, DIT, QUB and Athlone IT.

The trend emerging from the above research is that GMIT have established human capacity in both underwater noise and microplastics research; UCC in underwater noise; NUI Galway in metallic uptake/impacts and nutrient inputs/trends, TCD/DIT in biological effects/chemical measurements, and DCU in monitoring systems and priority substances. Athlone IT have a unique capacity for the

¹⁶⁹ Includes examination of eutrophication indicators.

examination of pharmaceuticals standards (2016 report), while earlier projects (2015 reports) in the field was undertaken from the UK¹⁷⁰.

Other Funding

The Department of Agriculture, Food and the Marine (DAFM) published the document titled “Protecting and Enhancing Water for Sustainable Agriculture – Water-related measures for the agri-food, forestry and marine sectors” in March 2017¹⁷¹. This is a first communication from the Water Network and provides a ‘stock-take’ of the water-related activities of DAFM and its agencies within the context of the national Food Wise 2025 strategy and EU water policy. In this document DAFM communicate that they promote and support water-related research through research funding programmes. Agencies under the aegis of DAFM include Teagasc, the Marine Institute, the Sea Fisheries Protection Authority and Bord Bia. The water-related activities of these agencies are included under monitoring, research, food safety regulation and marketing measures. All of these activities contribute to further strengthening the compatibility between increased food production in accordance with Food Wise 2025, and achieving and maintaining WFD good water quality status.

Research Capabilities (Maturity Assessment)

The research capability of marine pollution research in Ireland is assessed as “**Ad-hoc – Defined**”. Despite a number of active or completed projects across several of the policy driven research topics identified, there appears to be a lack of inter-institutional collaboration within Ireland and a lack of research centre establishment (other than MaREI). More specific components of the marine pollution theme like microplastics however do have a good degree of collaborative input into European funded projects (JPI Oceans) and also there has been national activity funded by Marine Institute and EPA mechanisms.

Human Capacity: “Ad-hoc – Defined”

Capacity in marine pollution research is assessed to be between “Ad-hoc” and “Defined” because communities of interest exist with some access to facilities and there are active research projects taking place. There is scope now and in the future for much more research within the marine pollution theme because of the presence of strong policy drivers (e.g. MSFD) and continuing pattern of increased pressures on the marine environment. This assessment can move up a level to “Established” with relative ease if a moderate amount of support is provided.

¹⁷⁰ Principal Investigator Dr Brian Quinn was formerly with GMIT and now with the University of the West of Scotland.

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<https://www.agriculture.gov.ie/media/migration/ruralenvironment/waternetwork/ProtectingEnhancingWaterSustainableAgriculture010317.pdf>

The study of marine pollution is a broad field covering several distinct and interconnected research areas from eutrophication to contaminants, underwater noise to marine litter and non-indigenous species. Specialists are required in acoustics, water chemistry, taxonomy, modelling, ocean observation, detection and response technology. A review of national and EU funding for research targeted at marine pollution has shown that research has been largely driven by EPA Research calls for traditional research on eutrophication and contaminants, while there has been an upturn in recent times in securing both national and EU funding for emerging research topics such as microplastics, biological effects monitoring, HABs, faecal pollution and ocean observing facilities.

Research capacity is centred in several third level institutes (NUI Galway, GMIT, UCC, UCD, TCD, DIT, DCU and AIT), while the Marine Institute are both funding and undertaking research. There is little observed follow through between consecutive projects with the exception of GMIT, NUI Galway and UCC although rarely are the same researchers involved. The exception is UCC where researchers who were involved in the FP7 MARLISCO project (completed in May 2015) are now collaborating in two difference JPI Oceans micro-plastics projects.

There is evidence of collaboration nationally and internationally, with some industry participation. However, the ad-hoc nature of research funding makes it difficult to retain capacity and expertise. To continue to develop capacity and proficiency in marine pollution research, it is necessary to further promote and encourage strong collaborations between individuals and groups at the national level (this would contribute towards moving human capacity from “Ad-hoc – Defined” to “Established”), the exact mechanism to achieve this is not absolutely clear, however, coordinated and coherent research should be an overarching principle to research funding that is allocated (especially on the national level) and be part of a larger well thought long term programme.

Infrastructures: “Ad-hoc – Defined”

Infrastructure requirements for marine pollution research vary considerably and are determined by the specific type and field of research activity. Many areas of research have low infrastructure requirements while others require significant resources. Laboratory facilities exist within the third level institutes; however, they are limited in scope and capital requirements for contaminants, microbiological and HAB research. The Marine Institute and EPA laboratories are the best equipped at present for contaminant and eutrophication assessment, however, their ability to adapt to emerging contaminants analysis is uncertain. The Marine Institute is the National Reference Laboratory under EU legislation for shellfish safety. It provides wide-ranging analytical and research services in support of the marine biotoxins monitoring programme.

The national research vessels, the RV *Celtic Explorer* and RV *Celtic Voyager* are very active research infrastructures that Ireland's researchers in the marine pollution field utilise and access through a variety of mechanisms; participation on annual monitoring programme surveys; grant aided ship time calls; EU funded research and international cooperation programmes. However, it is well known that the Marine Institute research vessels are in high demand, oversubscribed (in relation to competition for ship time) and do not have the capacity to expand the current amount of work undertaken to support primary research.

NUI Galway facilities include the Ryan Institute and the Mace Head Atmospheric Research Station in Carna, Co. Galway. Marine and coastal processes research within the institute includes research on coastal biogeochemical processes, ecosystems and human health, marine pathways and the changing coast. The Centre for Marine and Renewable Energy (MaREI) is supported by Science Foundation Ireland, and has a significant number of researchers working across 6 academic institutes with collaborations with industry partners. The focus of research is primarily on renewable energy technologies and corresponding challenges which include underwater noise impacts of wind, wave and tidal devices.

A formal infrastructure network has not been defined, however, the research community is relatively small and the majority of marine pollution researchers do collaborate on an "Ad-hoc" basis as required especially when research funding is advertised and multi-disciplinary teams are required to qualify and cooperate towards research funding calls.

Networks (Industry engagement): "Ad-hoc – Defined"

The research theme of marine pollution in relation to networks is currently defined as "Ad-hoc – Defined". However, some collaborative networks have been established in this theme, as demonstrated by participation of Irish researchers in the H2020 project, Acclimatize, being led by researchers from UCD. Acclimatize aims to improve the quality of the marine environment and contribute towards supporting marine activities.

Networks have also been established in the case of microplastics research (funded by JPI Oceans) between Irish research institutes and European institutes (e.g. BASEMAN, EPHEMARE and PLASTOX). Individuals and small research teams have demonstrated success in gaining FP7 and H2020 funding in the marine pollution field. However, and possibly as a result of the very diverse nature of the marine pollution research theme, expertise is sporadically distributed in third level institutions and agencies with limited coordination and inter-institutional research.

Research Topics

A review of the International, EU and National level policy drivers, related strategies, legislation and implementation reports (see **Section 3.3**) has revealed a wide range of areas from applied research and policy requirements (that cross-cut with element of other themes e.g. climate change, human health, ecosystem goods and services, modelling and advanced technology) that have merit for focus of funding mechanisms:

- Methods for the long-term monitoring of human impacts and climate change in coastal areas.
- Research on the land-sea interface (increased use of models and ecosystem goods and services).
- Development of a transnational network of scientific institutions for providing advice to policy on spatial planning (MSP, CFP, MSFD, WFD); improved detection of pathogens in seawater and seafood and assessment of risks (monitoring, modelling and molecular tools).
- National coordination of researchers working on microplastics in Ireland through a defined mechanism.
- Transport and transmission of toxins (biogenic) and toxicants (man-made) from the marine environment to humans (contaminated seafood, HABs).
- Research to address gaps in knowledge relating to harmful algal blooms on marine ecosystems, maritime economy and human health.
- Promotion of common standards and open access to data and the harmonisation of data requirements in particular for the MSFD.
- e-infrastructures for computing, modelling, forecasting and early warning systems.
- Cumulative effects (and cumulative impact assessment methods) e.g. development of a better understanding of multiple pressures on food-webs and how they impact on the marine environment (including fisheries and aquaculture) such as the effects of eutrophication and harmful algal blooms (HABs).
- Increased resolution and assessment of atmospheric deposition of nitrogen. Evaluation of the contribution of atmospheric nitrogen emissions in marine pollution assessments.
- Improved spatial and temporal monitoring of contaminants.
- Internationally agreed assessment methodologies and criteria for hazardous substances.
- Radionuclide impacts on marine biota.
- Impacts of acute pollution events on marine ecosystems.

- Impacts of marine acidification on Irish waters – natural variability of ocean pH and the marine carbonate system, long term trends from natural fluctuations, direct impacts and agreed indicators.
- Increased frequency and reliable temporal trend analysis for assessing pressures on shellfish waters.
- Weather and environmental influences on the assessment of microbial contamination in the marine environment.
- Microbial pathogen occurrence, interactions and impacts in open (marine) waters remains unknown.
- Environmental impacts of marine litter on marine organisms.
- Improved assessment methods for seabed litter.
- Assessment methodologies for floating marine litter.
- Development of a risk based noise monitoring programme for Ireland (monitoring/modelling).
- Noise monitoring platform technologies.
- Effects of underwater noise on marine organisms, understanding dose-response relationships.
- Offshore marine contaminant levels.
- Concentration of bio-accumulating contaminants at higher trophic levels and biological effects understanding.
- Effects of endocrine disrupting contaminants.
- New or improved observational tools for improved spatial and temporal marine eutrophication assessments.
- Emerging contaminants.
- Improved understanding of the pathways for marine contaminants/hazardous substances from the freshwater environment and altered pathways as a result of climate change in the North-East Atlantic.
- Extent of naturally occurring radionuclide increases as a result of offshore oil and gas extraction, trend analysis, evaluation of impacts on the environment and development of quality criteria.
- Further reductions in faecal inputs to coastal waters are needed, such as through better sewage collection and treatment and best practices for agricultural uses of sewage and manures.

- Evaluate source, pathways and effects of non-indigenous species (NIS) in order to develop mitigation methods to prevent and reduce the entry, spread and impacts of NIS.
- Ship-sourced pollution from illegal discharge and ship casualties.
- Assessment of risk and preparedness for large scale pollution incidents (involving oil, hazardous and noxious substances) and analysis of operational response capability at national, local and port authority level.

Focus of Funding

With Harnessing Our Ocean Wealth, the future sustainability and growth of Ireland’s marine industries depends on protecting the credibility of the clean, green image that Ireland enjoys. Compliance with national and international environmental legislation is an essential component of this image, and compliance is stated as a “*competitive advantage*”. The MSFD and WFD are importance legislative instruments in this regard, given the theme of Marine Pollution.

Major research areas have been proposed by JPI Oceans SRIA 2015 – 2020, the OSPAR Quality Status Report, successive stages of MSFD implementation in Ireland and the EPA Research Strategy 2014 – 2020. Specifically, emerging contaminants, underwater noise, microplastics/nanoparticles, microbiological inputs, HABs and NIS research are all significant areas with gaps in current knowledge. There is little evidence of significant human capacity, infrastructures and networks and relationships within the theme of Marine Pollution above the “Ad-Hoc” – “Defined” levels, presumably largely because of the broad topics and themes which are included and are in and of themselves, significant areas for research. Therefore, a strategic research agenda needs to be defined, to justify research needs and to identify priority areas to build research capacity. This strategic agenda should maximise opportunities for cross cutting agendas e.g. human impacts on biodiversity, climate change implications for contaminant pathways, research at the land-sea interface to establish linkages between MSFD and WFD and Marine Spatial Planning Directive, transport and transmission of toxins and impacts on human health. Of perhaps critical importance is the establishment of improved spatial and temporal monitoring equipment for several areas within the Marine Pollution theme such as contaminants and eutrophication.

Climate Change

Overview

Ireland's current capabilities in marine climate change research provide a foundation for an area that is now a priority globally, following on from the 2015 United Nations Climate Change Conference, COP 21, and the subsequent Paris Agreement. The health of the ocean is such a crucial economic development issue that it has warranted an explicit UN sustainable development goal (SDG 14)¹⁷² to “*conserve and sustainably use the oceans, seas and marine resources for sustainable development*” and the IPCC recently committed to preparing a special report on ‘Oceans and Cryosphere’¹⁷³ in light of gaps and emerging literature.

While it is now commonly accepted in scientific fields that human-induced climate change poses one of the main challenges faced by society in the coming decades, there is a constant need to ensure that policy makers are fully briefed and aware of the breadth of potential impacts from climate change on their policy portfolios. Navigating the Future IV¹⁷⁴, published by the European Marine Board, suggests that global warming and high CO₂ levels are driving changes in sea-level, patterns of air temperature, precipitation and extreme weather events. In addition, changes in sea temperatures, ocean circulation and ocean chemistry (e.g. acidification) are expected to affect the species composition in the open ocean and, in turn, the removal of atmospheric CO₂ by the ocean, with unknown consequences. Although the overall impact of ocean acidification on marine life and ecosystems remains uncertain, there is growing international concern that key species, especially calcifying organisms, and habitats are threatened. This includes important components of the food web in Irish waters such as primary producers, cold water coral reefs, shellfish and crustaceans. This could have profound consequences for entire marine ecosystems and their functioning with additional obvious economic and societal impacts, as explored in a 2011 study on the impacts of increased atmospheric CO₂ on ocean chemistry and ecosystems.

This area of research was previously recognised through the Sea Change Discovery Research Measure (2007-2014)¹⁷⁵ which set out the objectives of a climate change research programme; in particular the need to increase our understanding of the drivers and regulators of climate so as to improve the accuracy and reliability of predictive models, and to downscale global climate model predictions to the regional/local level in order to refine local impact scenarios. The objective in

¹⁷² <http://www.un.org/sustainabledevelopment/oceans/>

¹⁷³ <https://www.ipcc.ch/report/srocc/>

¹⁷⁴ European Marine Board (2013). Navigating the Future IV. Position Paper 20 of the European Marine Board, Ostend, Belgium. ISBN: 9789082093100

¹⁷⁵ A programme undertaken by the Marine Institute aimed at addressing the objectives of the Marine Climate Change Research Programme of Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland (2007-2014)

taking these steps was to strengthen our ability to develop knowledge-based scenarios of climate change impacts on the various marine sectors and include these in all major social, economic and environmental strategies. Investments at that time included the SSTI funded Marine Climate Change Research Programme (2007-2009)¹⁷⁶, with the subsequent publication of the Irish Ocean Climate and Ecosystem Report (2009)¹⁷⁷. In 2009 the Marine Climate Change programme was discontinued due to funding issues and therefore the planned objectives were not fully realised. During the period, clusters of centres and research activity with significant specialised expertise have developed within the HEIs (MU, NUIG, UCD, UCC, TCD).

There has been a lack of sustained funding for national climate monitoring networks and programmes as evidenced by the EPA's 2013 report on the current status and required actions for national climate observing systems. Increased inter-institutional collaborations could significantly amend national capacity in this area. A requirement also exists to engage with European and international research infrastructures, programmes and networks to maximise the impact of national investments in this area.

Context

As is set out in the Ocean-Climate Nexus Consensus Statement, the earth's climate and the ocean are fundamentally linked in ways we still do not fully understand. The ocean plays a key role as a climate regulator and in buffering the damaging effects of climate change. But the human activities that cause climate change, predominantly greenhouse gas emissions, are also affecting the health of the ocean, making it increasingly warmer and causing ocean acidification. We are damaging the very system that is fundamental to our wellbeing. Ocean scientists are at the front line in the quest for knowledge to understand the role of the ocean in the earth and climate systems, and the implications of changing oceans for our environment and wellbeing. Hence, ocean research and ocean observation must be at the heart of our global response to climate change.

COP21 – In December 2015, all parties to the UNFCCC agreed an ambitious new legally-binding, global agreement on climate change (**The Paris Agreement**). The agreement provides an international framework for a global response on climate change to hold the increase in global temperature to well below 2 degrees Celsius above pre-industrial levels and to keep the more stringent target of below 1.5 degrees in sight.

¹⁷⁶ A programme undertaken by the Marine Institute aimed at addressing the objectives of the Marine Climate Change Research Programme of Sea Change – A Marine Knowledge, Research & Innovation Strategy for Ireland (2007)

¹⁷⁷ IRISH OCEAN CLIMATE AND ECOSYSTEM STATUS REPORT 2009, September 2009 (available at <https://www.marine.ie/Home/sites/default/files/MIFiles/Docs/MarineEnvironment/Irish%20Ocean%20Climate%20%26%20Ecosystem%20Status%20Report%202009.pdf>)

A range of international organisations are involved in advocating, coordinating and supporting climate change research. These include **CLIVAR** (Climate and Ocean: Variability, Predictability and Change) and the Intergovernmental Oceanographic Commission of UNESCO (**IOC**). IOC acts as an umbrella body for a number of key programmes – the **Global Ocean Observing System (GOOS)** is a permanent global system for observations, modelling and analysis of marine and ocean variables to support operational ocean services worldwide. GOOS provides accurate descriptions of the present state of the oceans, including living resources; continuous forecasts of the future conditions of the sea for as far ahead as possible; and the basis for forecasts of climate change. **Euro-GOOS** is the European regional component. The **Global Climate Observing System (GCOS)** goal is to provide comprehensive information on the total climate system, involving a multidisciplinary range of physical, chemical and biological properties, and atmospheric, oceanic, hydrological, cryospheric and terrestrial processes.

Copernicus, previously known as GMES (Global Monitoring for Environment and Security), is the European Programme for the establishment of a European capacity for Earth Observation. The **Copernicus Climate Change Service** responds to environmental and societal challenges associated with human-induced climate changes. The service, which is undergoing implementation, will give access to information for monitoring and predicting climate change and will, therefore, help to support adaptation and mitigation.

The Galway Statement on Atlantic Ocean Cooperation, which launched the new **Transatlantic Ocean Research Alliance**, was signed in May 2013 by the EU, Canada and the United States. This cooperation is resulting in mutual benefits including better ecosystem and forecasts and deeper understanding of risks and vulnerabilities, including those relating to the global climate system and climate change impacts.

The **Atlantic Action Plan (2013)**¹⁷⁸ makes specific reference to ocean observation, in that mapping and forecasting are critical for the sustainable growth of economic activity in the Atlantic area and furthering our understanding of the oceanic processes in the Atlantic which play an important role in determining our climate. It goes on to state that making this information widely available is critical in developing a *European Atlantic ocean observing and predictive capability*. Specific objectives also include contributing to the development of tools and strategies to address global climate change issues, including mitigation and adaptation strategies by:

¹⁷⁸ http://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean/index_en.htm

- a) Supporting an assessment of the carbon footprint of the blue economy in the Atlantic area.
- b) Developing a platform for exchanging best practice on emissions reduction and energy efficiency.
- c) Developing co-operative partnerships to identify and monitor the impacts of global climate change on marine activities, ecosystems and coastal communities in the Atlantic area, including developing better predictive and risk assessment capabilities.

The **EU strategy on adaptation to climate change (2013)**¹⁷⁹ has three main objectives – promoting action by Member States; promoting better informed decision-making by addressing gaps in knowledge about adaptation; and lastly, promoting adaptation in key vulnerable sectors through agriculture, fisheries and cohesion policy, ensuring that Europe’s infrastructure is made more resilient, and encouraging the use of insurance against natural and man-made disasters.

In the UK, the **Marine Climate Change Impacts Partnership (MCCIP)** plays a key role in translating scientific evidence for a wide audience. MCCIP produces annual report cards which provide up-to-date information on more than 30 marine climate change topics (air and sea temperature, sea-level rise, ocean acidification, etc.). Short summary report cards provide simple headline statements on ‘what is already happening’ and ‘what could happen in the future’ for all 30 topics, along with confidence ratings.

The **Environmental Protection Agency** is an independent public body established under the Environmental Protection Agency Act, 1992. It has a statutory role in coordinating environmental research. The EPA also host the Advisory Council on Climate Change, which is tasked to provide independent advice to Government Departments and Agencies on the actions required to decarbonise the Irish economy by 2050. The EPA is also the IPCC National Contact Point.

Relevant Documents / Sectoral Plans

The **Fifth Assessment Report (AR5)** of the United Nations **Intergovernmental Panel on Climate Change (IPCC)** was completed in 2014 and contained extensive discussion and analysis of ocean warming, CO₂ emissions and related ocean acidification impacts. In April 2016, IPCC decided in the context of the Paris Agreement, to provide a **Special Report in 2018 on climate change and oceans and the cryosphere**.

¹⁷⁹ The EU strategy on adaptation to climate change, 2013 (available at http://ec.europa.eu/clima/publications/docs/eu_strategy_en.pdf)

The G7 Ministers of Science and Technology issued the **Tsukuba Communiqué (2016)**¹⁸⁰ in support of the achievement of the SDG14 and other relevant goals and of the objectives of related conventions, and support taking the following actions:

1. Support the development of an initiative for enhanced global sea and ocean observation required to monitor inter alia climate change and marine biodiversity, e.g. through the Global Argo Network and other observation platforms, while fully sustaining and coordinating with ongoing observation.
2. Support an enhanced system of ocean assessment through the UN Regular Process to develop a consensus view on the state of the oceans, working to a regular timescale which would enable sustainable management strategies to be developed and implemented across the G7 group and beyond.
3. Promote open science and the improvement of the global data sharing infrastructure to ensure the discoverability, accessibility, and interoperability of a wide range of ocean and marine data.
4. Strengthen collaborative approaches to encourage the development of regional observing capabilities and knowledge networks in a coordinated and coherent way, including supporting the capacity building of developing countries.
5. Promote increased G7 political-cooperation by identifying additional actions needed to enhance future routine ocean observations.

In November 2015, the **Ocean-Climate Nexus statement (2015)**¹⁸¹ was drafted by a joint Europe-US group of experts nominated by the European Marine Board and Consortium for Ocean Leadership. Our current knowledge of how to link climate to changes in marine systems is limited. Advanced data and models are required on a wide range of spatial and temporal scales in order to improve climate predictions. The following elements are required in order to close this knowledge deficit:

- *Ocean Observing* – Investments in observing infrastructure (including both in situ and remote observing hardware and e-infrastructures), coupled with new sensor and platform technologies, allow for greater spatial and temporal coverage and the measurement of an increasing array of parameters.
- *Addressing Parameter Gaps* – There is a need to complete and sustain the initial global physical and carbon ocean observing systems designed more than 10 years ago, extend

¹⁸⁰ [https://www.bmbf.de/files/01_Tsukuba%20communiqu%C3%A9_\(SET\).pdf](https://www.bmbf.de/files/01_Tsukuba%20communiqu%C3%A9_(SET).pdf)

¹⁸¹ <http://www.marineboard.eu/ocean-climate-nexus/sites/marineboard.eu.ocean-climate-nexus/files/public/The%20Ocean-Climate%20Nexus%20Consensus%20Statement.pdf>

these to include a larger suite of essential biogeochemical, biodiversity and ecosystem variables, and build more integrated systems that combine information from satellites, in situ observations, process modelling, and integrated models.

- *Long-term time series* – Long-term observations of the ocean are needed to understand its role in the global oceanic heat and carbon budget. Improved understanding of the physical and biological dynamics of the ocean is vital for assessing how much, and how fast, the earth will warm due to increased greenhouse-gas concentrations and for enhancing the quality of projections for future decades.
- *Projecting the future by understanding the past* – Historical ocean observations and natural archives (e.g. sediment cores) when coupled with current high-quality observations, form a basis for developing estimates of previous ocean states. These provide powerful constraint and verification for modelling systems developed for making projections of climate states. However, many of the historical data sets require data rescue and data reprocessing activities.
- *Combining advanced models with observations* – Advanced modelling frameworks that link the ocean, climate, and human systems, using the comprehensive data sets outlined above, can provide essential tools for planning and responding to climate change. Estimates of current state are pivotal to the development of predictions. The best possible analysis of present conditions can only be achieved by combining information from model results and observations. This requires stronger interactions between relevant research communities, projects and infrastructures.
- *e-Infrastructures and data access* – The use for research and management of ocean observations will only progress if underpinned by advanced e-infrastructures, supporting data exchange, management, archival and making data openly available for research and downstream products and services.
- *International cooperation* – Because most of the ocean lies beyond the jurisdiction of individual nations, and because of the high cost of building and operating observing infrastructures, coordinated international collaborations are essential for developing and operating ocean observing systems and for their integration into modelling activities.

A Joint programming initiative, **JPI Climate**, provides a dedicated platform to connect climate research and knowledge across Europe to better support and respond to the needs for societal innovation and sustainable development. They have also developed a Strategic Research Agenda (SRA) that sets out policy-relevant research priorities for the short, medium and long-term on climate in Europe. This agenda (2011-2015) focuses on four interconnected work modules:

1. Moving towards reliable decadal climate predictions
2. Researching and advancing climate services development
3. Sustainable transformations of society in the face of climate change
4. Improving tools for decision-making under climate change

A draft **JPI Climate Strategic Research Agenda, 2016-2025 (2016)**¹⁸² identifies three overarching challenges and a strategic mechanism. The challenges are:

1. Understanding the processes and consequences of climate change
2. Improving knowledge on climate-related decision-making processes and measures
3. Researching sustainable societal transformation in the context of climate change

The **JPI Oceans Strategic Research and Innovation Action 2015-2020 (2015)**¹⁸³ presents ten Strategic Areas, developed and agreed by JPI Oceans, as strategic priorities for marine and maritime research in Europe. A number of these relate to climate change research. The priority areas include some relevant to climate change – Observing, Modelling and Predicting Oceans State and Processes; Climate Change Impact on Physical and Biological Ocean Processes and Effects of Ocean Acidification on Marine Ecosystems.

JPI Oceans uses a range of tools to solve the challenges outlined in the Strategic Research and Innovation Agenda. One of these tools is a Joint Action where resources from multiple Member States are brought together to fund joint calls. The size and scope of each action is tailored; the research needs and the method used will depend upon the objective. For example, another mechanism is being employed for the SRAI priority area 6 (Observing, Modelling and Predicting Oceans State and Processes). This is being advanced through collaboration between EuroGOOS, the EMB and JPI Oceans on scoping a European Ocean Observing System.

JPIs are likely to see increased inter-collaborations and opportunities for cooperation in the next phase, e.g. joint JPI Oceans, JPI Climate and JPI Water calls.

The **European Marine Board (EMB) Navigating the Future** series provides regular pan-European summaries of the current status of marine research, priority recommendations and future scientific

¹⁸² Joint Programming Initiative (JPI) Connecting Climate Knowledge for Europe (JPI Climate) Strategic Research & Innovation Agenda, 2016-2025 (available at http://www.jpi-climate.eu/media/default.aspx/emma/org/10871632/JPI_Climate_SRIA.pdf)

¹⁸³ JPI Oceans Strategic Research and Innovation Agenda 2015-2020 (available at https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/JPI%20Oceans%20SRIA_0.pdf)

challenges in the context of European societal needs. **Navigating the Future IV (2013)**¹⁸⁴ was designed to inform the Commission calls under the forthcoming Horizon 2020 programme. The paper is organized around the framework of key societal challenges in the areas of climate, human health, food security, energy, and safe and sustainable use of marine space. Navigating the Future IV also addresses strategic and enabling issues such as European Ocean Observing System (EOOS), training, the science-policy interface and ocean literacy.

Navigating the Future IV summarised key research priorities according to the major categories of climate change effects and impacts in coasts, seas and oceans. These included research on sea-level changes, coastal erosion, temperature and salinity changes, ice melting, storm frequency and intensity, changing stratification, thermohaline circulation changes, riverine discharge and nutrient loads, ocean acidification, ocean deoxygenation and coastal hypoxia, impacts of climate change on marine eutrophication, and biological impacts. Planning is underway for Navigating the Future V where the horizon scanning for this document would be extended to a 10-50 year timescale.

Recognising the importance of climate change from a research perspective, a selection of **FP7** the Ocean of Tomorrow topics and projects were funded from 2010-2013. Within **Horizon 2020**, seven priority societal challenges have been identified, where funding in research and innovation may have a real impact for Europe's citizens. Societal Challenge 5, *Climate action, environment, resource efficiency and raw materials* is particularly relevant. Activities in this Challenge aim to increase European competitiveness and raw materials security and improve wellbeing. At the same time they aim to assure environmental integrity, resilience and sustainability with the aim of keeping average global warming below 2°C and enabling ecosystems and society to adapt to climate change and other environmental changes. The EC closed a stakeholder consultation to prepare the next Work Programme for Societal Challenge 5 in early April 2016. A budget of about €1 billion is to be allocated to this Societal Challenge in the years 2018-2020.

In **Innovation 2020**¹⁸⁵, it states that "Addressing climate change and linked challenges, such as ocean acidification, will require major transitions in technologies, systems and practices across key sectors in Ireland and at global level, including in energy, agriculture, transport and the built environment. Achieving Ireland's 2020 greenhouse gas emissions reductions target and the longer-term goals to 2050 will require radical change, including radical technological, societal and organisational innovations. Adaption to future climate conditions will also be required. Deeper understanding of

¹⁸⁴ European Marine Board (2013). Navigating the Future IV. Position Paper 20 of the European Marine Board, Ostend, Belgium. ISBN: 9789082093100

¹⁸⁵ Innovation 2020 (2016) (available at <https://www.djei.ie/en/Publications/Publication-files/Innovation-2020.pdf>)

terrestrial, atmospheric and oceanic systems, the relationships between them, and human impacts on them is essential.”

The **EPA Research Strategy 2014-2020**¹⁸⁶ is organised around three pillars: climate, water and environmental sustainability. It aims to identify pressures, inform policy and develop solutions to facilitate and inform a credible knowledge base underpinned by evidence-based research. The strategy recognises that the environment must be protected and proactively managed to ensure it forms the basis for a healthy society and economic well-being. Key priorities of the EPA research programme include:

- Developing integrated approaches to addressing the challenges that arise from climate change, air and water quality and other environmental issues, and identifying growth opportunities arising from them
- Deepening our understanding of the role of the natural environment in sustaining well-being and the economy
- Reducing waste generation and treating waste as a resource
- Identifying and informing cost-effective transition pathways to a carbon-neutral and climate resilient Ireland, and understanding how individual and collective behaviour can influence this transition

The outcomes of the research programme will help support effective and efficient policy development and decision-making (for example, significant infrastructure investment may be required for climate change adaptation and river basin management).

The **Climate Action and Low Carbon Development Bill** (2015)¹⁸⁷ provides for the approval of plans by the Government in relation to climate change for the purpose of pursuing the transition to a low carbon, climate resilient and environmentally sustainable economy; and to establish a body known as the National Expert Advisory Council on Climate Change. The Bill sets out the manner in which the transition towards a low carbon economy will be achieved –through a National Mitigation Plan (to lower Ireland’s level of greenhouse emissions) and a National Adaptation Framework (to provide for

¹⁸⁶ Environmental Protection Agency (2014) *EPA Research Strategy 2014-2020 - Using knowledge to protect and improve our natural environment and human health* (available at <http://www.epa.ie/pubs/reports/research/eparesearchstrategy2014-2020/EPA%20Research%20Strategy%202014-2020.pdf>)

¹⁸⁷ The Climate Action and Low Carbon Development Bill (2015) (available at <https://www.oireachtas.ie/documents/bills28/bills/2015/215/b215d.pdf>)

responses to changes caused by climate change); both of these require the development and submission of Sectoral Plans from the Departments.

Research Capabilities (Maturity Assessment)

This research theme is assessed overall at “Defined”- early stage “Established”. While the dimensions relating to Infrastructures showed the key characteristics of the “Collaborative” level, the Human Capacity and Networks & Relationships dimension showed key gaps in capacity, specifically relating to Ocean Chemistry and international collaborations.

Human Capacity: “Defined – Established”

Capacity in marine climate change research is assessed to be between “Defined” and “Established” as

dedicated research facilities exist, as identified below, and there is some evidence of collaboration nationally and internationally, albeit with limited industry participation. However, the ad-hoc nature of funding in critical areas and programmes means that it is difficult to retain valuable capacity and research know-how. As part of the continued evolution of competencies in climate change research, it is necessary to further promote and encourage strong collaborations between the centres of excellence nationally (thereby moving national human capacity from “Defined-Established” to “Collaborative”), ideally through a single coherent national research centre featuring a strong marine dimension.

Within NUIG, Climate Change research has been consolidated into an integrated **Centre for Climate and Air Pollution Studies (C-CAPS)**. Research is organized into four main sub-themes – Atmospheric Composition and Emissions, Air Quality and Pollution, Ocean-Atmosphere Exchange, and Climate-Ecosystem Interactions. C-CAPS aim to quantify key atmospheric processes and transport emission inventories. These data feed into predictive systems, such as a coupled ocean-atmosphere model and marine ecosystem models, which are crucial to accurate climate change scenarios. C-CAPS is hosted within the **Ryan Institute for Environmental, Marine and Energy Research**.

The **Irish Climate Analysis and Research UnitS (ICARUS)** as part of the Department of Geography at Maynooth University is a national leader in the area of climate change providing integrated climate system research, solutions, data and advice to the scientific community, policy makers and for the benefit of society both nationally and internationally. Research undertaken at ICARUS aims to

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 19: Irish Research Maturity in Climate Change showing the different levels of maturity for human capacity, infrastructure and networks

advance our fundamental understanding of past, present and future climate variability and change, and to provide cutting-edge analysis of future impacts, vulnerabilities and adaptation in line with strategic national and international priorities. In delivering these aims, core research strands in ICARUS are focused on the analysis of change in atmospheric, terrestrial and marine environments, palaeoclimatology, regional climate modelling, catchment hydrology and water management, and the assessment of environmental and socio-economic impacts and adaptation.

The **Marine Earth Observation (EO) & Applied GIS** group in **UCC** work closely with colleagues in the Centre for Marine and Renewable Energy **MaREI**. Specific capacity has been developed in EO-derived information discovery and extraction; EO data processing, applications and integration; communications and outreach; and user-needs gathering, stakeholder engagement and capacity building. **Future Earth Coasts** is hosted by MaREI and is coordinated by the Environmental Research Institute at UCC. Future Earth Coasts is the new name for the longstanding Land Ocean Interactions in the Coastal Zone (LOICZ) project. The goal of LOICZ was “to provide the knowledge, understanding and prediction needed to allow coastal communities to assess, anticipate and respond to the interaction of global change and local pressures which determine coastal change.”¹⁸⁸

The **Irish Centre for High-End Computing (ICHEC)**, founded in 2005, is Ireland's national high performance computer centre. Its mission is to provide High-Performance Computing (HPC) resources, support, education and training for researchers in third-level institutions and, through technology transfer and enablement, to support Irish industries large and small to contribute to the development of the Irish economy. ICHEC provide computational resources, technical and scientific support to a large number of Irish academic research projects.

The **UCD Meteorology & Climate Centre**, within the School of Mathematics, is Ireland's leading academic centre for research and education in meteorology and climate science running courses at both BSc and MSc level and offering PhD opportunities. They work closely with **Met Éireann** and ICHEC in contributing to the development of both the EC-EARTH Earth System global model and Regional Climate Modelling activities. Within the wider School of Mathematics there is further modelling expertise including wave and wind resource modelling.

Over many decades **Met Éireann** staff have compiled measurements of temperature, pressure and other weather parameters, and these now provide essential “ground truth” for monitoring the Irish climate. Met Éireann recently contributed to a climate change research report, in collaboration with

¹⁸⁸ http://www.igbp.net/download/18.950c2fa1495db7081e194f/1430900189660/IGBP_report_33-LOICZ.pdf

the EPA, ICHEC and UCD. The report, *Ensemble of regional climate model projections for Ireland*¹⁸⁹, provides an analysis of the impacts of global climate change on the mid-21st-century climate of Ireland. Met Éireann is a partner in the **EC-Earth** climate modelling consortium and also a member of the EC-Earth Steering Group. An annual subscription is paid to the consortium – these funds are used to employ a support scientist who works at ECMWF on behalf of EC-Earth. Current work involves tuning of the coupled global Earth System Model (ESM). Met Éireann is provisionally committed to delivering a number of CMIP6 simulation contributions in the coming years.

ESMs, such as EC-Earth, are currently the only way of providing society with information on the future climate. EC-Earth is developed as part of a Europe-wide consortium thus promoting international cooperation and access to a wide-knowledge data base. It further enables fruitful interactions between academic institutions and the European climate impact community.

Irish scientists from **NUIM** and **UCD** have contributed to the World Climate Research Programme's Coordinated Regional Downscaling Experiment (**CORDEX**) running downscaled simulations from a number of Global Models for the European region (**EURO-CORDEX**) together with partners from across Europe and beyond.

The **Marine Institute** undertakes observations of the marine environment and ecosystems, including oceanographic sections and inshore/shelf water surveys observing physical oceanography and chemical oceanography (nutrient, carbon). Coastal monitoring of phytoplankton and benthic organisms are also undertaken. The MI and NUI Galway have been collaborating on marine inorganic carbon system observations, documenting increasing ocean acidification in offshore surface and deep waters of the Rockall Trough due to atmospheric CO₂ uptake, as well as investigating complex drivers of spatial and temporal variability of the inorganic carbon system in coastal waters. The MI has also developed marine modelling capabilities.

The MI has co-chaired the **Joint ICES/OSPAR Study Group on Ocean Acidification (SGOA)** that was formed to develop an ocean acidification monitoring programme for the waters of the OSPAR area. SGOA brings together experts from the disciplines of chemistry, biology, and others to address the challenge of designing a long-term monitoring programme that examines both the biogeochemical changes associated with ocean acidification and the responses of potentially-sensitive marine life. The MI is also a member of the **Global Ocean Acidification Observing Network (GOA-ON)**, which is a collaborative international approach to document the status and progress of ocean acidification in

¹⁸⁹ Ensemble of regional climate model projections for Ireland, 2015 (available at http://www.epa.ie/pubs/reports/research/climate/EPA%20159_Ensemble%20of%20regional%20climate%20model%20projections%20for%20Ireland.pdf)

open-ocean, coastal, and estuarine environments, to understand the drivers and impacts of ocean acidification on marine ecosystems, and to provide spatially and temporally resolved biogeochemical data necessary to optimize modelling for ocean acidification.

Infrastructures: “Established – Collaborative”

Nationally, atmospheric and terrestrial monitoring is considerably more established and currently there is no long term funding of marine climate change observations and monitoring. There are some examples of nationally available test beds and research platforms that are used for climate change and ocean acidification research. Some of these are also a key part of European networks of research infrastructures. Infrastructures for climate change research are assessed as “Established to Collaborative”. However, increased collaboration, membership and investments in European and international climate change research infrastructures is seen as critical for Ireland in order to leverage limited national investments.

The **Mace Head Atmospheric Research Station** has the dual status of a WMO GAW research and monitoring ‘global’ station and a European Monitoring and Evaluation Programme (EMEP) supersite. It is operated by NUIG’s School of Physics and Ryan Institute’s Centre for Climate and Air Pollution studies (C-CAPS). Its mission is to monitor long-term trends of atmospheric composition change, essential climate variables and air pollution, and to facilitate key-processes research into the evolution of atmospheric composition and to its impacts on climate change. The research station has been part of the following European research infrastructure networks – **ACTRIS**, European Supersites for Atmospheric Aerosol Research (**EUSAAR**) and European Fleet for Airborne Researchers (**EUFAR**).

Within ICHEC, the **Fionn HPC** enables a wide range of R&D including an increased resolution in weather and climate forecasting in conjunction with Met Éireann. ICHEC are also partners in the **PRACE** infrastructure. The PRACE project is a European body that aims to co-ordinate access to the very largest computer systems at a European level.

The **national research vessels**, the RV *Celtic Explorer* and RV *Celtic Voyager* are core research infrastructure that Ireland’s researchers in the marine climate change field access through grant-aided ship time programmes and calls. The vessels are available for European transnational access through **Eurofleets 2**.

Burrishoole (Newport) is the only catchment in Ireland so far collecting data relevant to climate change, and this includes the tidal transitional waters of Lough Furnace. Studies have been undertaken on the effects of climate change in the Burrishoole catchment. This facility, which was established by the Salmon Research Trust in 1955, now has a number of unique long-term datasets

(up to 50 years in some cases) on air and water temperature, rainfall and the migration of wild salmon and maturing European eel, which provide an ideal opportunity to study the long-term effects of climate change. A network of modern monitoring stations, collecting a variety of information to a very high degree of accuracy, was installed in the catchment, which has augmented the existing monitoring network.

Tide predictions (and by extension sea-level rise) are derived from harmonic analysis of data measured at a series of tide gauges around the Irish coast (**Irish National Tide Gauge Network** is made up of gauges operated by various groups including the Marine Institute and the Office for Public Works). There are also predictions for a limited set of locations based on data obtained from the Marine Institute Regional Ocean Modelling System (ROMS) model (Ocean Forecasts). Data from the national network does not currently qualify as a contribution to the **Global Sea Level Observing System (GLOSS)**; Ireland is one of the few developed nations that do not contribute sufficiently qualified data to the global system.

Networks (Industry engagement): “Defined – Established”

Ireland has internationally recognised research centres established in the climate change field and is currently defined as “Defined-Established”. However, expertise is clustered in centres within the HEIs, with limited inter-institutional research centres. A dedicated research centre devoted to climate change research could provide a unique opportunity to build on existing strengths and to develop industry-academic relationships.

Existing research centres have demonstrated success in gaining FP7 and H2020 funding in the climate change field. Opportunities remain for enhanced international and European collaborations through increased involvement in the IPCC, GO-SHIP network, and the MCCIP in the UK.

Research Topics

Given existing competencies and investments across the range of HEIs and state agencies, research topics should focus on retention of hard-won expertise and capacity, whilst leveraging increased collaborations within Europe and internationally.

The establishment and resourcing of long term observation stations to measure current marine biological, chemical and physical parameters is a prerequisite baseline necessary to compare against climate change moderated biogeochemical scenarios.

From a national perspective carbon and nutrients work (including ship based time series) is at a critical juncture with a potential for significant gaps in expertise. Some key areas of research in relation to ocean acidification (OA)/carbon measurements are:

- Broad scale acidification trends, including understanding OA in deep water masses
- Local influences and variability in the carbonate system (e.g. coastal water bodies, cold water coral habitats)
- Impacts on sensitive species/habitats from multiple stressors including OA
- Evaluating threats to commercial harvested species (e.g. shellfish aquaculture)

There is a need to look at sustained infrastructure requirements necessitating dedicated funding lines but also strategic collaborations and focus in a number of key areas. Unlike the UK, France or Germany, Ireland is too small to be a leader across the climate field, but development of niche areas may be more beneficial in order to ensure participation in transnational research projects. Similarly, there is a base level of infrastructure, particularly in the area of ocean observation, which is a prerequisite for inclusion in international research coordination, which Ireland has yet to achieve. Given our low resources but shared sea area, it would be advantageous to collaborate meaningfully with UK, European and international researchers, networks and infrastructures.

Human Capacity

- An **integrated observing system** should be established for core physical, chemical, and biological (phytoplankton, zooplankton, fisheries) variables, which should include high frequency stations (e.g. moorings). Infrastructure and data could provide a platform and supporting data for national climate change research. An observing network should consider how to maximise synergies with other activities and policy drivers, (e.g. MSFD, WFD, Fisheries) to add value and maximise the use of resources.
- **Modelling** capacity (including downscaled coupled biogeochemical models) to support ecosystems studies and future projections.
- Research **on climate change and ecosystems, including projected impacts, socioeconomic consequences and adaptation** strategies – focusing on coastal as well as offshore. This could also consider *vulnerability assessments* for habitats/species and ecosystem services.

Infrastructure

- Investment to establish operational **GLOSS tide-gauge stations** and continued sustained national contributions to European infrastructures, e.g., **Euro-Argo** and **ICOS**.

Networks

- Enhanced engagement with European and international networks, e.g., GO-SHIP, IPCC, and MCCIP.

Focus of Funding

To summarise, in order to transition from “Defined” or early stage “Established” through to a “Collaborative” maturity level for research in climate change, the key focus areas for funding could include:

- Supporting inter-institutional collaborative research through dedicated funding calls. Research on climate change is highly inter-disciplinary with impacts on a range of other research themes and topics in the marine (e.g. ocean observation, marine biodiversity, modelling).
- Establishing a research programme of scale in Ireland, to be integrally linked to sustained investments in an integrated ocean observing system (infrastructure). This is underpinned by key international, European and national policy drivers (COP21, IPCC, G7 Science & Technology Ministers, European Marine Board, JPI Oceans, EPA).
- Increasing strategic engagements with key European and international infrastructures and networks in order to add specific value to national investments. This will increase collaborations with the wider global community and contribute to global goals on monitoring climate change impacts and mitigation strategies.

Ocean Observation

Overview

The ocean and coastal seas are critical to the earth's global systems and the future of humankind, regulating weather and climate, the concentration of gases in the atmosphere, the cycling of nutrients, and providing important food resources. The impact of human activity on ocean and coastal processes is of growing concern. The transformation of ocean and coastal observational data into information (syntheses, analyses, assessments, forecasts, projections and scenarios) enables good management of the human relationship with the ocean. This data is acquired by in situ instruments on ships, buoys, floats, ocean profilers, cabled observatories, balloons, samplers, and aircraft, as well as from all forms of remote sensing, including satellites.

Ireland's research infrastructure and international networking in seabed mapping is established and its achievements are internationally recognised. However, human and financial resources are required to maintain seabed mapping capacity. Ireland has a modest ocean buoy network, a coastal navigation buoy network, a national ocean test tank facility and early demonstration stage cabled coastal observatory infrastructure. There is a service level agreement between Marine Institute and the Department of Defence that provides access for marine researchers to Irish Navy and Air Corps infrastructure. Ireland's membership of the European Space Agency (ESA) permits Irish companies and research teams to bid for ESA contract development work in a range of space programmes. Although Ireland's National Space Centre, an independent teleport operator, currently does not have direct access to Sentinel data, the Irish Centre for High End Computing (ICHEC) has a contract with ESA for the delivery of EO data from the Sentinels providing direct access to Irish researchers and industry.

Irish earth and ocean observation research human capacity is concentrated in MarEI EO Applications team in University College Cork and the National Centre for Geocomputation at NUI Maynooth with pockets of niche relevant sensor and other research in DCU, DIT, UL, and NUI Galway.

Context

In Europe most in situ ocean observing activities continue to be carried out under research agency support and on research programme time limits. Data sharing remains incomplete, although the EMODnet and SEADATANET initiatives are addressing this. There is a need to establish effective partnerships between ocean research and operational communities and to engage in timely, free and unrestricted data exchange. There has been progress in Ireland in identifying national contact points for earth observation and agencies responsible for data acquisition, but it is fragmented. The Department of Jobs, Enterprise and Innovation and Enterprise Ireland represent Ireland at ESA.

National marine (Marine Institute and Geological Survey of Ireland) and climate institutions (EPA, Teagasc) have taken responsibility for seabed mapping and ocean and earth observing systems and providing unrestricted data exchange. Ocean and coastal observation is limited by lack of suitable instruments and techniques, including difficulties with the fundamental observing technique, instrumentation, measurement methodology, suitable calibration/validation techniques, spatial and temporal resolution, ease of operation, and cost. Research is needed to improve the ability to blend different datasets and/or data sources into integrated products. Identifying surrogate measurements for good environmental status parameters (e.g. SST for salinity) and developing associated cost effective sensors is a short term goal for environmental monitoring.

Relevant Documents / Sectoral Plans

Ireland's strategy for research in ocean and coastal observation is guided by a number of International, European, and National policy documents.

A Framework for Ocean Observing by the Task Team for an Integrated Framework for Sustained Ocean Observing, UNESCO 2012¹⁹⁰, recommended that co-ordination of ocean observations should be organised around “essential ocean variables (EOVs)” that will be implemented according to their readiness levels and maturity. At the same time innovation must improve technology readiness levels and build capacity.

The Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)¹⁹¹ recognises that ocean observations underpin all efforts by Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to mitigate, and adapt to, climate change. The plan seeks to implement a comprehensive observing system for “essential climate variables (ECVs)”; generate global analysis products; improve key satellite and in situ networks; and strengthen national and international infrastructure. The ECVs will be provided by a composite system of in situ instruments on ships, buoys, floats, ocean profilers, cabled ocean observatories, balloons, samplers, and aircraft, as well as from all forms of remote sensing, including satellites. The Plan seeks to strengthen existing international and national data centres so that there is appropriate infrastructure in place for the flow of all ECV data, as well as integrated products, to the user community.

¹⁹⁰ (available at <http://unesdoc.unesco.org/images/0021/002112/211260e.pdf>)

¹⁹¹ (available at <http://www.wmo.int/pages/prog/gcos/Publications/gcos-138.pdf>)

The European Marine Board (2013): **Navigating the Future IV, Position Paper 20**¹⁹² recognises that a relatively mature European ocean observing infrastructure capability already exists but that it is fragmented. It recommends funding for the development of sensors, platforms, and cross sector research to ensure that marine science benefits from developments in other sectors. The adoption of legal instruments (such as the ERIC) may facilitate the collaborative funding of research infrastructure from national budgets. Legislation such as the Marine Strategy Framework Directive will drive the integration of European ocean observing infrastructure.

JPI Oceans (2015) Strategic Research and Innovation Agenda 2015-2020¹⁹³ identifies 10 strategic areas including observing, modelling and predicting ocean state and processes. A coherent assessment of good environmental status (GES) in European waters, that would include support for e-infrastructures for computing, modelling, forecasting and early warning systems, is a short term target.

In 2010, the EPA commissioned a report on '**An Earth Observation Strategy for Ireland**' (Kelly, 2011)¹⁹⁴ as part of the **Climate Change Research Programme (CCRP) 2007-2013 report series**. This report outlines that a national EO strategy is required for Ireland to effectively engage with European and international initiatives. Kelly (2010) identifies the benefits of Ireland's engagement with initiatives such as **Copernicus**, along with processes administered by the **European Space Agency**, and the **Intergovernmental Group on Earth Observations (GEO)**. These include supporting national governance and operational activities, the enhancement of technology related research and development, the development of a vibrant downstream EO service industry that can generate employment and enhance national self-sufficiency, and our ability to compete for non-exchequer funding available through funding programmes such as Horizon 2020. A national strategy is required to enhance work in the area '*to serve the environmental, scientific and technological needs of Irish society and economy, by fostering strong industry and science research partnerships and developing a skilled workforce that is responsive to global commercial demands*' (Kelly, 2010).

Harnessing Our Ocean Wealth (2012)¹⁹⁵ sets out a roadmap for the Government's vision, high-level goals and integrated actions across policy, governance and business to enable Ireland's marine

¹⁹² European Marine Board (2013). Navigating the Future IV. Position Paper 20 of the European Marine Board, Ostend, Belgium. ISBN: 9789082093100

¹⁹³ JPI Oceans Strategic Research and Innovation Agenda 2015-2020 (available at https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/JPI%20Oceans%20SRIA_0.pdf)

¹⁹⁴ An Earth Observation Strategy for Ireland, 2011 (available at https://www.epa.ie/pubs/reports/research/climate/CCRP_8_web.pdf)

¹⁹⁵ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

potential to be realised. Action 3 of Harnessing Our Ocean Wealth is to develop and implement systems to provide real-time operating, surveillance and monitoring information on activity within Ireland’s maritime domain. The development of national capacity in the acquisition, management and manipulation of remote sensing data provides a key enabler for this vision through more efficient and better informed decision making and opportunities for economic growth through the development of innovative downstream products and services.

The **Integrated Mapping for the Sustainable Development of Ireland’s Marine Resources** Programme (INFOMAR) is developing its strategy for phase 2 data exchange and integration in line with Key Action 23 of Harnessing Our Ocean Wealth. Phase 2 will include research and education initiatives that will strengthen value added exploitation of INFOMAR data.

Guided by these policy documents, research capacity in seabed mapping and ocean observation has evolved in Ireland and pockets of semi-coordinated expertise exist. There is a need now to consolidate government department and national agency responsibility for ocean and coastal observation so that the current fragmented research capacity can be integrated into a policy driven research network with industry participation.

Research Capabilities (Maturity Assessment)

The overall Irish research capability in seabed mapping and ocean observation is “Established”. This reflects the somewhat fragmented nature of research in the field within the HEI sector, particularly in relation to direct in-situ observation capacity. However, there are collaborative levels of infrastructure with nationally available equipment pools, and those HEIs engaged in this research area are active internationally. There is also industry collaboration, but it is fragmented.

Human Capacity: “Established”

There are agencies and several research centres with human capacity and research infrastructure relevant to seabed mapping and ocean observation including Marine Institute, Geological Survey of Ireland, INFOMAR, iCrag, MaREI, ICHEC, Tyndall National Institute. In addition there are pockets of relevant research within third level institutes including DCU, DIT, NUIG, NUI Maynooth, UCC, and UL. There are relevant established Principal Investigator positions and PI-led research teams particularly those within MaREI Spoke 6

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 20: Irish Research Maturity in Seabed Mapping & Ocean Observation showing the different levels of maturity for human capacity, infrastructure and networks

Observation and Monitoring for Marine Renewable Energy. The level of participation in international research awards and participation by industry is increasing.

Infrastructures: “Established – Collaborative”

Ireland’s research infrastructure in seabed mapping operated by the Marine Institute and the Geological Survey of Ireland includes ocean and coastal research vessels, deep-water ROV, ocean buoy network, tidal gauges, a cabled coastal observatory (SMART Bay), and laboratory facilities. A coastal navigation buoy network is operated by the Commissioners of Irish Lights and a national ocean test tank facility is operated by University College Cork. There is a service level agreement between Marine Institute and the Department of Defence that provides access for marine researchers to Irish Navy and Air Corps infrastructure that includes eight ships and two aircraft. Although Ireland’s National Space Centre, an independent teleport operator, currently does not have direct access to Sentinel data, the Irish Centre for High End Computing (ICHEC) has a contract with ESA for the delivery of EO data from the Sentinels providing direct access to Irish researchers and industry. There are nationally funded test and demonstration facilities that represent best in class research infrastructure. These centres have associated post-doctoral training and some participate in EU infrastructure networks that encourage European research institutes to access the Irish infrastructure for test and demonstration purposes.

Networks (Industry engagement): “Established – Collaborative”

There are multiple teams within the coastal and ocean observation community concurrently participating in H2020 projects. The research themes are government policy led and there is growing industry participation in defining research themes, particularly within the SFI funded research centres.

Research Topics

Two main business drivers for ocean and coastal observation were identified by an “Innovation Meets Industry” workshop at Oceanology 2016 in London – de-risking commercial operations in the marine sector by improving metocean and climate change modelling, and developing new cost effective sensors, power systems, high bandwidth communications, data processing and data interpretation. Regulatory driven environmental monitoring is also a key driver of coastal and ocean observation. Irish researchers are currently engaged in each of these topics, particularly DCU’s Centre for Sensor Web Technologies, University of Limerick Mobile and Marine Robotics Research Centre, MarEI’s EO Applications team in UCC, INFOMAR’s operational team and iCrag’s Marine Geoscience Spoke.

Focus of Funding

The focus of funding to Irish coastal and ocean observation researchers should be to bridge the gap between them and the private sector end users of products and services generated from coastal and ocean observation data. The link between Irish researchers and intermediate public sector government departments and national agencies responsible for maritime surveillance and environmental monitoring is developing progressively. However, there are tier 2 intermediary companies that supply environmental monitoring and metocean forecasting services based on coastal and ocean observation data to companies in the shipping, ports, fisheries, aquaculture, oil and gas, marine renewable energy, defence, deep sea mining, insurance, and subsea cable sectors. There are also SMEs that supply products and services (such as mobile phone apps) based on coastal and ocean observation data to the public for niche interests. These are the companies that will commercialise the products and services that will be sold to the tier 1 companies engaged in shipping, ports, fisheries, aquaculture, oil and gas etc. Assistance is needed for researchers to identify the appropriate intermediary company commercialisation partner who will invest in and guide aspects of the on-going research that have commercial potential.

Ireland's expertise in seabed mapping should be sustained and expanded by funding appropriate undergraduate and post graduate courses in an Irish third level institute. These courses could be expanded to provide capacity building in developing countries where seabed mapping is supported by international aid.

Engagement with the Sea

Engagement with the Sea is the third goal of Harnessing Our Ocean Wealth. Research themes associated with this goal cover diverse areas of:

Ocean Literacy & Education

Integrated Policy & Governance

- Socio Economics
- Law
- Planning & Governance
- Business Development

Information & Spatial Technologies, Analytics and Modelling

Engineering

Ocean Literacy & Education

Overview

The term ocean literacy relates to our understanding of the ocean's influence on society and society's influence on the ocean. Ocean literacy is about improving education and citizen and community awareness, knowledge and engagement, promoting the value of the ocean; as well as equipping citizens to make informed decisions in relation to the marine, forming a better governance of the sea and ensuring that the skills required for the ocean economy are in place.

Research in this field is required in a broad area of disciplines, bringing about a positive change through ocean literacy and education. Academic, economic and societal impacts of ocean literacy and education research include:

- Advancement of academic disciplines
- Improve cross disciplinary approaches, techniques and methodologies
- Enhance the knowledge economy
- Train and develop researchers' skills
- Improve teaching and learning

Research in this field should also include impacts relating to improving health and wellbeing, economic prosperity and regeneration; enhancing research capacity, knowledge and skills of the public, private and third level education sector; enhancing cultural enrichment and quality of life; as well as improving environmental sustainability and protection. Finally ocean literacy and education research can provide evidence based policy-making, influence public policies and increase public engagement with research and related societal issues (*Pathways to Impact, Research Councils UK*).

Ocean Literacy and Education is demonstrated in three areas concerning:

- Formal Education – Learning within a structured education system in which children or adults are required to demonstrate proficiency;
- Informal Education – Learning outside the established formal system that meets clearly defined objectives through organized education activities; and
- Outreach and Events – Activities that are designed to build awareness, develop relationships, promote education products, and inspire educators, students and the public to pursue further learning opportunities.

Context

European and Transatlantic environment

On a European and transatlantic scale there is a strong focus on Blue Growth (with links to the Atlantic Action Plan) in the EU Horizon2020 Programme, and the “**Galway Statement on Atlantic Ocean Cooperation, 2013**”, signed by the European Union, Canada and the United States of America, promoting ocean literacy to facilitate citizens’ understanding of the value of the Atlantic. The Atlantic Ocean Resource Alliance (AORA) Coordination and Support Action, funded under Horizon 2020, aims to provide Europe, the United States and Canada with relevant and responsive information on the status of a number of research areas to meet scientific and industry needs in the North Atlantic.

The **Integrated Maritime Policy for the European Union** aims to raise the visibility of Europe’s maritime identity and economic potential among Europeans. A number of EU publications report a need for collaboration and innovation between the public and private sectors to reduce the growing skills gap relating to the marine and education at all levels, which is central to the sustainable development of the blue economy. Further EU publications of interest include but are not limited to:

- Careers in the Blue Economy: How to close the skills gap and make the marine and maritime sectors more attractive to young people, 2015, Maritime Affairs and Fisheries
- European Commission's Annual Growth Survey for 2016, 2015, European Commission
- Training the 21st Century Marine Professional: A new vision for marine graduate programmes in Europe, European Marine Board Marine Graduate Education Working Group
- Rome Declaration – setting a vision for seas and ocean science, 2014, EuroOCEAN 2014 Conference, <http://www.marineboard.eu/science-strategy-publications>
- Navigating the Future, 2014, European Marine Board, <http://www.marineboard.eu/navigating-future-0>
- IOC Capacity Development Strategy 2015-2021, 2016, United Nations Educational, Scientific and Cultural Organization for the Intergovernmental Oceanographic Commission, http://www.ioc-cd.org/images/3897_15_IOC_E_F_2_langues_WEB.pdf
- Advice Paper No. 20 – October 2016 Citizen Science at Universities: Trends, Guidelines and Recommendations, League of European Research Universities

National Environment

The “engagement with the sea” goal of ***Harnessing Our Ocean Wealth - An Integrated Marine Plan for Ireland 2012*** aims to strengthen Ireland’s maritime identity and increase awareness of the value, opportunities and social benefits of engaging with the sea. The reports of the **Enablers Task Force on Maritime Spatial Planning** and the **Development Task Force** produced recommendations that are directly relevant to Ocean Literacy.

The **Expert Group on Future Skills Needs (EGFSN)** report *A Study of the Current and Future Skills Requirements of the Marine/Maritime Economy to 2020* (2015) provides an assessment of the future skills needs, labour market supply and demand trends across Ireland’s existing and emerging marine sectors. Recommendations relating to training, education and blue growth included establishing a Marine Discover Programme, modelled on the SFI Discover Programme, to raise awareness among students at all levels of career opportunities in the marine economy. As the recommended agency to coordinate this, the Marine Institute are currently reviewing the process to implement such a programme. Further Irish publications of interest include but are not limited to:

- **‘Education for Sustainability – The National Strategy on Education for Sustainable Development in Ireland 2014-2020’**, 2014, Department of Education and Skills, aims to ensure that ‘education contributes to sustainable development by equipping learners with the relevant knowledge, skills and the values that will motivate and empower them throughout their lives to become informed active citizens who take action for a more sustainable future’.
- **‘Our Sustainable Future: A Framework for sustainable development for Ireland’**, 2012, DECLG highlights that ‘education for development needs to be embedded at every level of the formal and informal education system’ and that ‘public communication is vital for sustainable development to be better understood and implemented’.

Research Capabilities - Maturity Assessment

To address the challenges and capabilities required to support ocean literacy and education as highlighted above, the ‘Maturity Assessment’ has been categorised into three broad research themes including Human Capacity; Infrastructures; and Network and Relationships.

Human Capacity: “Defined – Established”

Researchers are primarily from social and economic sciences involving EU projects in Ocean Literacy providing evidence of active research projects and activities at national and international collaborations including:

- The EU Sea for Society Project funded under the Seventh Framework Programme (FP7) involved NUI Galway, AquaTT and the Marine Institute; and the H2020 SeaChange project involves the Whitaker Institute NUI Galway and AquaTT, both promoting ocean literacy and sustainable action towards a blue society.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 21 Irish Research Maturity in Ocean Literacy & Education showing the different levels of maturity for human capacity, infrastructure and networks

- The Socio-Economic Marine Research Unit (SEMRU) at NUI Galway has produced two reports on *Ireland's Economy* that have improved awareness of Ireland's ocean economy.
- National Maritime College of Ireland (NMCI) has a track record in the provision of innovative seafarer/offshore training.
- The Strategic Marine Alliance for Research and Training (SMART) programme provides multidisciplinary bespoke courses as part of the third-level curriculum; European and International open ocean courses; Seagoing internships on-board the RV *Celtic Explorer*; Shore-based 'blue skills' workshops; and international summer schools.
- Specialised and applied Master's Programmes including Ocean Literacy and Education have been developed by Ireland's HEIs and courses are being developed in association with major R&D flagship Programmes.
- Linked to the SFI funded MaREI Centre is the All-Island Master's Degree in Marine Renewable Energy hosted by UCC and is delivered in conjunction with UCD, NUIM, NUIG, UL, CIT, DIT and Queens University, Belfast.
- The Marine Institute's Explorers Education Programme provides support to a network of ten outreach centres reaching eleven coastal counties in Ireland and provides formal education modules, resources and lesson plans for primary school teachers and students; teachers training through education centres; student teacher training at third level institutes; as well as long term evaluation and impact studies.

Infrastructure: "Defined"

Communities of interest exist with varying degrees of access to facilities and active research projects including:

- National Maritime College of Ireland, Cork is a purpose built facility and is an important element of the IMERC cluster.
- The Marine Institute's RV *Celtic Voyager* is used for on-board postgraduate courses with a number of HEI's including NUI Galway, GMIT, UCC.
- The Explorers Education Programme is funded by the Marine Institute and supports a network of ten outreach centres providing "fit for purpose" lessons and modules for the primary school curriculum.

There are opportunities to develop this area in research collaborating with industry, state agencies and HEIs.

Networks (Industry engagement): "Defined"

Ocean Literacy is reflected in various national projects and initiatives, ranging across computer science, social innovation, oceanography, science education and socio-economics, including:

- Networks and annual workshops include participation in the European Marine Science Educators Association (EMSEA) since 2012 and the Irish Ocean Literacy Network since 2015 which are both platforms for promoting ocean literacy in Ireland and Europe.
- International SmartOcean Enterprise initiative was designed to strengthen and build on Ireland’s emerging specialist capacity in the area of Marine Information and Communications Technology.
- DCU host the Marine and Environmental Sensing Technology Hub.
- The annual Our Ocean Wealth Summit which is organised as part of Seafest maritime festival brings together global and national leaders speaking about the ocean in relation to Ireland’s Integrated Marine Plan – Harnessing Our Ocean Wealth.

Research Topics

At a national level, research is required to support and assess all the relevant actions from *Harnessing Our Ocean Wealth* that are linked to its third goal of “Engagement with the Sea”. Inter-disciplinary research, in particular research in topic areas that span the humanities & social sciences and science, as well as technology & engineering disciplines is central to this. This includes those that investigate understanding and dissemination of knowledge in the broad area of the ocean and the impact this has on citizens. Research Topics in this theme also cross over into the multidisciplinary Research Theme of Integrated Policy and Governance (as outlined in the section below).

Actions that support the findings of the *Expert Group on Future Skills Needs* are also required as well as engagement and collaborations with key stakeholders including Departments, State agencies, HEI’s and industry in order to develop research through formal and informal education as well as citizen science and outreach.

The scope of Horizon 2020 funded projects also provide opportunities to cover a broad area of ocean literacy and education including environmental status, pollution affecting marine biodiversity and ecosystems, education and citizen science with an aim to disseminate information and engage key stakeholders and the public at large.

Focus of Funding

Engaging with government departments, State agencies, Higher Education Institutes and industry (with a marine and/or a formal education remit) to support the cross-cutting nature of ocean literacy is required to maximise funding for the ocean literacy and education programmes. A national Ocean Literacy Programme should build on expertise generated in EU Horizon 2020 projects, as well as building on national educational programme initiatives to further efforts to integrate the marine into the Irish education system from primary school level through to secondary and beyond.

Support for a community of interest among Irish researchers and businesses is emerging and a national coordinator would enable these researchers to better compete for funding from Horizon 2020 and other international funding programmes. This would also help increase the capacity and number of researchers active in this area. As Ocean Literacy is cross-cutting many existing sectors will benefit from extending into marine related areas – playing a key role in achieving the goal of increasing “engagement with the sea” and establishing mechanisms for follow-on funding in order to

retain capacity, which is to be considered past the end of grants in terms of growing and retaining expertise and reputation.

Specific training and education programmes that encourage a familiarity with issues relating to the ocean, both from an environmental protection and sustainable development viewpoint are required. In particular, programmes to “marinise” graduate and vocational training have the potential to rapidly raise the skill base available to the ocean economy in Ireland.

Integrated Policy & Governance

Overview

As our marine resources become increasingly viewed as the basis for a ‘blue economy’, so the sustainable development and management of our seas, oceans and marine and coastal resources increasingly requires a holistic and integrated system of governance. The need for integration and cooperation is increasingly recognised at the varying national and international levels of governance of our oceans.

Research & Innovation has a major role in supporting the development of both sectoral and the integrated marine policy agendas, at national, EU and international level. Research is essential in supporting societal challenges and cross-cutting priorities such as food security, climate change and sustainable development, but can also provide solutions, evidence and knowledge for governance of our vast marine resource, as well as the services and enterprises associated with it.

Research is required to support both analysis and decision-making at sub-sectoral and the wider integrated levels of governance and policy making. A specific challenge is translating the outputs of research and innovation to support development of policy, including the continuing evolution of an appropriate legislative and regulatory framework. The skills required, in what might be broadly described as ‘Marine Management’, range across scientific, technical, legal, social and economic disciplines.

As noted in *Harnessing Our Ocean Wealth* and the report of its Development Task Force, a particular challenge for Ireland is the relatively low level of ‘awareness’ of the strategic significance and economic development potential of the sector. The growing role of the inter-departmental Marine Co-ordination Group and the publication and ongoing review of *Harnessing Our Ocean Wealth* addresses this issue. Ireland faces an ongoing challenge in cultivating a deeper appreciation of marine policy and development issues throughout the wider public policy, administration, finance and industry sectors. Maximising the benefits of Ireland’s ocean wealth requires the engagement of government, state organisations, industry, researchers and the broader society through collaborative, integrated and innovative governance arrangements.

Major progress has been made in this regard since the launch of *Harnessing Our Ocean Wealth* and this is further strengthened by the commitment made in the recent Programme for Government to the continued implementation of *Harnessing our Ocean Wealth*.

Ireland’s Integrated Marine Plan recognises the importance of Research and Development (R&D) and other knowledge-generating activities (e.g. seabed mapping) in informing policy, governance

and regulation of the marine sector. The assessment of R&I requirements and capabilities pertinent to this topic is addressed, in this Strategy, under the headings of Socio-Economics, Legal, Business Development, and Planning and Governance.

Context

With the increased focus on our oceans, there is a growing realisation of the necessity for increased collaboration, cooperation and innovative governance of the oceans and the activities that it supports.

This is evident in a wide range of treaties, conventions, agreements and policies at international, EU, regional, national and local level, where ocean governance is recognised as essential for the sustainable management of our global seas, for example:

- At international level – the 1982 UN Convention on the Law of the Sea (UNCLOS), the FAO’s Blue Growth Initiative etc.
- At EU level – the Integrated Maritime Policy, the Common Fisheries Policy, etc.
- At international ‘sectoral’ level – the work of the International Council for the Exploration of the Seas, the International Maritime Organisation, etc.
- At a national level – Ireland’s Integrated Marine Plan - Harnessing Our Ocean Wealth, and related initiatives such as Marine Spatial Planning and the work of the Development Task Force.

Nationally, Harnessing Our Ocean Wealth¹⁹⁶, Ireland’s first Integrated Marine Plan (IMP), sets out a roadmap for the Government’s vision, as well as high-level goals and integrated actions across policy, governance and business, to enable Ireland’s marine potential to be realised. In implementing the Plan, Ireland has been gradually developing an integrated system of policy and programme planning for marine affairs. The vision and goals presented in Ireland’s IMP have been framed within the context of what is happening at the broader global and EU levels, particularly the Integrated Maritime Policy for the European Union, recognising the contribution the ‘blue economy’ can make to global economic growth and the need for appropriate policies, strategies and funding mechanisms to enable this.

Similar to the Integrated Maritime Policy for the EU, Ireland is putting in place a range of integrated actions across all relevant policy areas related to the seas including, transport, environment,

¹⁹⁶ HARNESSING OUR OCEAN WEALTH An Integrated Marine Plan for Ireland, 2012 (available at <http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf>)

offshore renewable energy, enterprise, employment, research, seafood and external relations.

Ireland's IMP also mirrors the IMP-EU by addressing cross-cutting issues such as:

- Blue growth (economic growth based on different maritime sectors)
- Marine data and knowledge
- Marine spatial planning
- Integrated maritime surveillance
- EU Strategy for the Atlantic and associated Action Plan

Ireland's IMP is supported by the development of coherent policy, planning and regulation – managed in an integrated manner through the inter-departmental Marine Coordination Group (MCG), chaired by the Minister for Agriculture, Food & the Marine and convened by the Department of the Taoiseach.

A SWOT Analysis of Ireland's status in respect to integrated Marine Planning & Development outlined in Ireland's European and Maritime Fisheries Fund Operational Programme 2014-2020¹⁹⁷ identified the following features (Table 2).

¹⁹⁷ The Operational Programme (OP) supported by the European Maritime and Fisheries Fund (EMFF) in Ireland aims at achieving key national development priorities along with the EU's "Europe 2020" objectives. The OP will support the general reform of the EU's Common Fisheries Policy (CFP) and the development of its Integrated Maritime Policy (IMP) in Ireland. A copy of Ireland's OP is available on http://ec.europa.eu/fisheries/cfp/emff/country-files/index_en.htm

Table 2: SWOT Analysis of Ireland’s status in respect to integrated Marine Planning & Development outlined in Ireland’s European and Maritime Fisheries Fund Operational Programme 2014-2020

IMP SWOT	
STRENGTHS	WEAKNESSES
<ol style="list-style-type: none"> 1. Vast maritime domain and associated resources with significant potential for growth 2. Integrated Marine Plan with Government approved roadmap with a clear vision, goals and 39 specific actions to deliver the vision 3. Rich and diverse range of species and habitats 4. Global reputation as a clean-green-marine environment providing both social and economic benefits 5. National capabilities and capacity in the area of surveillance and eco protection of Ireland’s maritime domain 6. Government commitment to implementing Marine Spatial Planning 7. Strong track record in marine science, research & innovation 8. Extensive seabed mapping programme 9. Online marine data discovery and access services 	<ol style="list-style-type: none"> 1. Difficult economic situation and associated resource constraints 2. Underutilisation of the vast maritime domain 3. Sectoral and demand driven development, licensing and regulation of marine-based activities 4. Lack of synergy with land-based planning 5. Lack of access to real-time activity and environmental information across Ireland’s maritime domain 6. Lack of overarching marine data architecture and collaborative framework 7. Data gaps particularly in relation to mobile and migratory marine species 8. Low public awareness of the potential of Ireland’s ocean wealth
OPPORTUNITIES	THREATS
<ol style="list-style-type: none"> 1. Significant under-utilised marine space, goods and services 2. Deliver a robust, evidence based forward planning approach to development 3. Coordinate and plan the implementation of all marine related policies, legislation and consenting processes 4. Improve engagement and participation in marine-related policy and decision-making 5. Strengthen collaboration and sharing of information and knowledge gathering across programmes (e.g. INFOMAR), sectors, regulators, stakeholders, researchers and neighbouring MS 6. Progress the development of a shared common maritime picture 7. Strengthen the innovation value chain from research through to commercial activity 	<ol style="list-style-type: none"> 1. Ad hoc sectoral developer-led planning, consenting and development 2. Uncertainty for investors 3. Future lack of investment (State and industry) 4. Duplication of data gathering, gaps in information and knowledge leading to ineffective decision-making and increase in costs 5. Failure to maximise data use across programmes, sectors, regulators, stakeholders, researchers and other Member States 6. Inability to engage with neighbouring planning systems 7. Failure to adapt to effects of climate change 8. Failure to respond in a timely fashion to environmental, safety and security events

Addressing the challenges and opportunities identified in the SWOT above, is a key objective of Ireland’s Integrated Marine Plan. In recognition of its vital enabling role in supporting sustainable growth, the Government established a Task Force charged with recommending a **Marine Spatial Planning Framework** for Ireland. In June 2014, the Irish Government announced its intention to progress the introduction of MSP in Ireland, acknowledging the importance of Marine Spatial Planning as a key enabler to help guide future policy, governance, investment, and development

decisions. The Marine Spatial Plan will underpin coherent and integrated marine planning and management and public participation, aimed at delivering a thriving sustainable maritime economy based on healthy, clean and productive marine ecosystems.

MSP will assist in coordinating the implementation of all marine related policies, developing effective legal and regulatory measures and support the realisation of the full benefit of our ocean wealth. The availability of suitable resources and expertise in the relevant Government agencies supported by research and knowledge-generating activities is vital to achieving an effective MSP system in Ireland. The preparation of a marine plan involves the collection and analysis of spatial data relating to the existing and projected future status of the area that is the subject of the plan.

A focused research and studies programme is needed to fill the knowledge and data gaps in the MSP 'toolbox'. This programme would support efficient and evidence-based planned use of marine space, and the goods and services central to achieving sustainable economic growth and development. Such a programme would also promote climate change adaption, risk prevention and management.

A second task force, set up under the auspices of the Marine Coordination Group and Harnessing Our Ocean Wealth, was the **Development Task Force**. Its report, published in 2015, identifies a number of aspects of the challenge in delivering the Harnessing Our Ocean Wealth objectives that fall within the area of developing the capacity and effectiveness of public policy formulation and implementation. Findings and recommendations that touch on this area include:

- Transformative actions required across government departments, public agencies, as well as business, regional and local organisations.
- An improved collective national consciousness of our marine asset, bolstered by incremental success, leading to Ireland achieving a place as a leading marine society. Such change requires collective effort, starting with our education systems, to build positive and meaningful engagement by government, industry and community based organisations with all aspects of the sea.
- There are diverse stakeholder and governance interests associated with the marine at present, and a whole-of-enterprise approach will require, for a period, a concerted response from Government and the wider public service. In order to ensure that marine is established at the heart of the government enterprise development process, the DTF proposed that an integrated Marine Enterprise Development Team be established.

The **Marine Co-ordination Group**, established to co-ordinate departmental actions, to a greater degree, across the marine sector, continues to be a significant vehicle for enhancing public policy

formulation and delivery across the sector. Plans to advance both Marine Spatial Planning and the enterprise development proposals of the Development Task Force are at an advanced decision-making stage. Funding (€10.6m), through the European and Maritime Fisheries Fund 2015-2020, established to implement the EU priority of Integrated Maritime Policy, has been secured to support the establishment of an integrated Marine Development Team (MDT) and the establishment of Maritime Spatial Planning in Ireland (the establishment of MSP in Ireland is also being part-funded through the lead Department's budget).

Relevant Plans and Policies

The publication of **Harnessing Our Ocean Wealth**, and the Integrated Marine Plan, is the most significant statement of national public policy for the marine sector. Other important publications, in this context, include the Marine Spatial Plan, the report of the Development Task Force and sub-sectoral policies and plans e.g. Fisheries, Aquaculture, Shipping and Offshore fossil and renewable energy resources.

Goal 3 (Engaging with the Sea), of the **Integrated Marine Plan**, notes that Ireland is a maritime nation with considerable natural resource assets and a rich maritime heritage (cultural, physical and ecological dimensions). Yet, **Harnessing Our Ocean Wealth** notes that, as an island nation, Ireland has overlooked the seas and oceans as a source of commerce and job creation, focussing on the land as the primary provider of food, energy and economic growth. The ambition under Goal 3 is to strengthen engagement with the sea – nurturing a maritime identity and increasing awareness of the value (market and non-market), opportunities and social benefits of the ocean resource as a national asset that needs to be protected, managed and developed for and by Irish society.

The report of the **Enablers Task Force on Marine Spatial Planning**¹⁹⁸, prepared under the aegis of the Marine Co-ordination Group in 2015, addressed the following:

- Emerging EU policy in relation to maritime spatial planning
- The need for any further legislative changes that may be required to support a national maritime spatial planning framework
- International best practice on developing integrated marine planning and licensing, benchmarking Ireland's marine regulatory framework
- National maritime spatial planning capacity and responsibility for data coordination and exchange

¹⁹⁸

<http://www.ouroceanwealth.ie/sites/default/files/sites/default/files/news/Final%20Our%20Ocean%20Wealth%20Enablers%20Task%20Force%20Report.pdf>

The report points to the need for robust plans as a sound evidence base, pointing to the fact that a substantial amount of marine-related data and information already exists (such as Ireland’s Marine Atlas¹⁹⁹), and this provides a good platform for the preparation of the first marine spatial plan. An expert advisory group is also recommended to assist in filling any gaps. The Task Force report outlines at least three categories of spatial information that are relevant (in line with the UNESCO guidance) – biological and ecological distributions, human activities, and oceanographic and other physical environmental features. Research into cumulative pressures of existing and proposed activities will need to be assessed, both in the area of the marine spatial plan and the adjacent coast. Research into potential conflicts and synergies between activities will also be required.

At the centre of a framework for MSP in Ireland, meaningful and early consultation with all stakeholders, including the general public, is essential. Engagement with regulatory and consenting authorities, sectoral and environmental organisations, coastal local authorities and development bodies is seen as critical to contributing to the management of land-sea interactions, and enabling the inclusion of marine-related opportunities in local and regional development plans.

The **OECD** has, recently, completed a study on the *Future of the Ocean Economy - Exploring the Prospects for Emerging Ocean Industries to 2030*²⁰⁰. The Report indicates strong growth in volume terms over the coming 15 years in shipping, shipbuilding and repair, port activity, marine supplies, marine aquaculture, offshore wind, and marine tourism. They expect weaker growth in capture fisheries and offshore oil and gas. Ocean renewable energy, marine biotechnology and CCS are also considered to possess considerable potential, the scaling-up of which, however, is unlikely to happen before 2030.

The Report notes that science, technology and data analytics are not being fully and effectively harnessed to the ocean management process. The data challenges facing effective marine spatial planning and ocean management are considerable. There is a great deal of uncertainty as to what is in the ocean, very little is known of the interactive effects of different uses and users in the ocean, and the ocean is a dynamic environment undergoing significant changes because of climate change. Large information gaps remain. Data on the marine resource is fragmented, difficult to locate, and biased towards the physical and ecological characteristics of the resource. This is due in part to the historical single sector approach to planning in the marine environment and the earlier emphasis on

¹⁹⁹ atlas.marine.ie
²⁰⁰

<http://www.oecd.org/futures/The%20Future%20of%20the%20Ocean%20Economy%20Project%20Proposal%20Dec%202013.pdf>

the biophysical rather than economic and social processes associated with the marine environment. When data are available, there is a diversity of data sources and data formats for policy makers, researchers and the public to disentangle.

These comments and the Report's summary findings and recommendations bear directly on the topics of Governance and Policy for the marine sector in Ireland. Its recommendations include:

- Consider the Ocean Economy as an economic system, as a cluster of interconnected industries (rather than a set of separate economic activities) that interact closely with marine ecosystems and their assets and services
- Improve the statistical and methodological base at national and international level for measuring the scale and performance of ocean-based industries and their contribution to the overall economy
- Support efforts towards better measurement and valuation of the ocean's natural resources and ecosystem services, notably at global level
- Better exploit potential technology and innovation synergies among ocean industries – innovation holds the key to their survival and success
- Business-as-usual expansion of economic activity in the ocean is not an option for the future
- Foster greater international co-operation in maritime science and technology as a means to stimulate innovation and strengthen the sustainable development of the ocean economy
- Strengthen progress towards integrated ocean management

Measures to enable more effective and more widespread use of integrated ocean management include:

1. Make better use of economic analysis and economic instruments
2. Improve data collection, management and integration
3. Promote more innovation in governance structures, processes and stakeholder engagement

The **World Ocean Council**, which has developed as a forum for the participation of ocean industries in issues concerning sustainable ocean management has had a focus, in its events, on these topics. The Sustainable Ocean Summit, being held in late-2016 has a specific session titled Improving Ocean Governance and Marine Planning, addressing:

- Law of the Sea: What the Development of a New Binding Legal Agreement Means for Ocean Industries and How to Engage with Other Ocean Stakeholders in Balancing Biodiversity and Sustainable Development

- Marine Planning and International Waters: Shaping High Seas Sustainable Development through Spatial Planning
- Marine Planning and the North Sea: Multiple Ocean Use and Sustainable Development in a Heavily Used, Transboundary Sea Basin
- Multi-use Offshore Infrastructure: Creating Synergies in Ocean Industry Facilities
- The Future of Ocean Habitation: Projects and Plans for Living On and Under the Seas

The **2007-2013 Research & Innovation Strategy for Ireland – Sea Change**²⁰¹, set out a number of research programmes under its Marine Policy Measure. Programmes and funding were targeted at research priorities and building research capacity across a range of key gap areas. Addressing one of these areas, in 2007, the Marine Institute funded a seven-year research programme in Marine Socio-Economics under the Beaufort Award Scheme aimed at addressing a gap in research capacity and capability in the area of marine socio-economics. The award led to the establishment of SEMRU – Socio-Economic Research Unit – in NUI Galway. Working in partnership with Teagasc’s Rural Economy Centre, and the Marine Institute, a key element of the award was to develop a sustainable approach to the ongoing collection of data, monitoring and reporting on Ireland’s Ocean Economy (direct value & employment and related downstream impacts). The Unit also carried out a number of specific research programmes supported by a number of PhDs and postdoctoral students.

²⁰¹ Available at <http://oar.marine.ie/bitstream/10793/69/1/Sea%20change%20part%201.pdf>

Research Capabilities (Maturity Assessment)

To address the challenges and required capabilities to support integrated marine policy and governance as highlighted above, the ‘Maturity Assessment’ has been categorised below into four broad research themes:

- Socio-Economics
- Legal
- Planning & Governance
- Business Development

The assessment addresses each of these themes in the context of current, planned and potential, under human capacity, infrastructure and networks. Maturity assessment of STEM related areas is addressed in other sections of this document.

Socio Economics	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Legal	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Planning & Governance	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Business Development	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figures 22, 23, 24 & 25 Irish Research Maturities in Socio Economics, Legal, Planning & Governance and Business Development showing the different levels of maturity for human capacity, infrastructure and networks

Human Capacity: “Defined – Collaborative”

Current research capabilities and initiatives in the disciplines related to policy development and governance are found in a number of institutions and State organisations. In the Higher Education sector key institutions include NUI Galway, through the Ryan and Whitaker Institutes, and University College Cork through the work of the Environmental Research Institute (ERI) and also through collaboration in the SFI centre for Marine and Renewable Energy (MaREI). In the State sector, scientific, technical, legal and economic capacity and expertise is available across a number of semi-state organisations such as the Marine Institute, IMDO and BIM and also government departments such as Department of Agriculture, Food & the Marine, Department of Housing, Planning, Community & Local Government and Department of Communications, Climate Action & Environment. A third component is IMERC – the Irish Maritime and Energy Resource Cluster incorporating expertise for UCC, CIT and the Irish Naval Service.

The capacity ranges from ‘collaborative’ in the area of economics, planning and governance, through to ‘ad-hoc’ to ‘defined’ in the area of legal and business development respectively. Although a number of high-profile PIs are involved in a range of research supporting integrated policy and governance, the primary concern is the critical mass required to fully develop and manage Ireland’s ocean wealth to its full potential. In some areas, for example marine spatial planning and business development, dedicated capacity and capability is planned to address the programmes and plans highlighted above (i.e. MSP and DTF task force report).

A summary of current and planned capacity is provided below.

The Higher Education Sector

NUIG

NUI, Galway has built up a tradition of excellence in marine research, which is a priority research area within the University. Centres of research within the university that are particularly relevant to the policy dimension include the Whitaker Institute for Innovation and Societal Change and also the Ryan Institute – NUIG’s hub for Environmental, Marine and Energy research²⁰².

As part of a multi-disciplinary approach to the marine, researchers from the **Ryan Institute** and the Whitaker Institute have a strong network of collaboration, linking the social, economic and scientific disciplines across a range of research topics. With a number of PI-led teams across earth and ocean science, botany, geography, engineering, chemistry and social sciences, it is reported that

²⁰² <http://www.nuigalway.ie/ryaninstitute/>

approximately 100 members of academic staff are affiliated with the Ryan Institute, with over 200 postgraduate and postdoctoral research members. This network of multidisciplinary researchers work under one or more of the Institute's three priority research areas of Environment, Marine and Energy. The Ryan Institute is overseen by an external advisory board of national and international experts working in key policy advisory roles.

Working closely with the Ryan Institute, researchers in the **Whitaker Institute** address the areas of business, innovation, economic development, and the public-sector. Through a large network of researchers (reported 200), across a range of disciplines and schools, a multi-perspective, impact-led approach is reported as central to the Institute's ethos. The Whitaker sees *"research not as an end in itself, but a means to an end. That is, a sustainable economy, an inclusive society, and a healthy democracy where academic debate and public conversation come together to advance the greater good and play an active part in shaping Ireland's future"*²⁰³.

The establishment of SEMRU (see below) as a defined cluster within the Whitaker is seen as an important commitment by the University to the area of research. Also of interest is the link between the Whitaker Institute and the Institute for Public Administration (IPA). This link offers a unique opportunity to further develop capacity and capability, infrastructure and networks across the public administration system.

In addition to, and in collaboration with, researchers in the Ryan and Whitaker Institute, the School of Law in NUIG continues to educate and train students in the areas of EU Law, International Law, Planning and Environmental Law. This includes topics related to Law of the Sea and European Fisheries Law. Strong international research links exist e.g. with the United Nations at UNESCO/IOC Advisory Body of Experts of the Law of the Sea, the European Commission, as well as with public and private bodies including the OSPAR Commission, the Office of Legal Affairs at the United Nations, the International Hydrographic Organisation, the International Council for the Exploration of the Seas, the North-Sea Regional Advisory Council, the Government of Scotland, and the Forum Fisheries Agency in the Pacific²⁰⁴.

The **Social and Economic Research Unit, SEMRU**, a cluster within the Whitaker Institute, was established in 2008 through funding awarded under the Sea Change Strategy and associated Beaufort Award (see above). The main research focus of the unit includes examining the economic utility of the marine resource (e.g. transportation, recreation) and ecological value (e.g. fisheries,

²⁰³ <http://whitakerinstitute.ie/about/>

²⁰⁴ <http://www.nuigalway.ie/business-public-policy-law/school-of-law/staff/ronanlong/>

aquaculture) derived from the productivity of associated ecosystems. Consideration of the social dimension in the management of marine ecosystems is also considered within the unit²⁰⁵. High profile and high impact projects include the collection and monitoring of socio-economic marine data for Ireland, the estimation of participation rates and value of marine-related recreation activities, an analysis of market orientation, competitiveness and innovation of firms in the Irish seafood sector, and many other research activities. Aspects of the Unit's work directly relate to Policy development, including raising awareness of the importance, economic value and societal benefits of the ocean resource. Collaborations are also strong across a range of organisations both nationally and internationally. Of significant impact to-date, three reports valuing Ireland's ocean economy have been published by SEMRU under the Beaufort Award in 2010, 2013 and 2015. Part-funded under the Beaufort award, working in collaboration with Teagasc, an input-output model has also been developed for the marine. This important research infrastructure looks at the linkages between sectors providing an estimate of indirect impact of Ireland's ocean economy. The model can also be used to undertake economic impact assessments of targets set out in national policy documents such as *Harnessing Our Ocean Wealth*.

UCC

The **Environmental Research Institute** (ERI) in UCC is an inter-disciplinary research group covering areas of environmental, marine and energy-based research. A reported 64 Principal Investigators, 70 non-tenured researchers and 65 postgraduate students with expertise in the biological, chemical and environmental sciences as well as environmental engineering, energy and environmental law work within the ERI. The aims of the Institute are *to foster collaborative, multidisciplinary environmental based research through a number of key research thematic areas, to train post-graduate research students for careers in the environmental sciences and engineering and, to facilitate the transfer of technology to industry*²⁰⁶.

Research at the Institute is focused on providing knowledge-based options to address major societal challenges and in developing and strengthening Ireland's leadership in eco-innovation and innovation in policy and governance. Since its inception the ERI has been acutely aware of the need to bridge the gap between research, innovation and commercialisation. To help achieve this the Institute continues to foster a broad approach to environmental research that ranges from "blue skies" research aimed at new knowledge creation, to applied research designed to generate

²⁰⁵ www.nuigalway.ie/semru

²⁰⁶ <http://www.ucc.ie/en/eri/mariecurie/abouteri/>

solutions to specific environmental challenges, through to contract-based work for industry and Government bodies.

A particular focus of the activities and expertise resides in the area of governance and law, with researchers involved in, and leading projects at, national, European and international levels across a range of issues including Environmental Law, Regulation and Policy, Maritime Spatial Planning, Integrated Coastal Zone Management, Climate Change Adaptation and Public participation. The objectives of the research within this thematic area are to (a) promote an integrated approach to coastal and ocean management and planning in order to fully realise the economic potential of key European sectors including aquaculture, fisheries, tourism and renewable energy and (b) improve understanding of Environmental Law, Regulation and Policy, and thus access to environmental justice, among all stakeholders in Ireland and beyond²⁰⁷. Researchers are also involved in MaREI (see below) as well as collaborating with the NMCI/CIT and the Irish Naval Service (INS) through IMERC (see below).

MaREI

MaREI is an SFI- funded centre for Marine Research and Energy, co-ordinated by **UCC**, one spoke of which is the Supporting Framework for the development of Marine Renewable Energy. The objectives of this spoke are:

- To develop governance, socio-economic, and planning tools to enable exploitation of MRE offshore of Ireland
- To provide targeted research addressing specific scientific challenges of direct concern to the MRE industry
- To educate and train a new generation of ocean energy engineers

IMERC

The Irish Maritime and Energy Research Cluster (**IMERC**), an alliance of UCC, CIT and the Naval Service, brings together researchers and expertise in the area of energy engineering, maritime operations, maritime technology and ecosystem governance. Recent focus includes stimulating the enterprise dimension of the cluster, which includes facilities for start-ups as well as Foreign Direct Investment.

²⁰⁷ <https://www.ucc.ie/en/eri/research/researchpillars/marine/governanceandlaw/>

Other HEIs

Other Higher Education Institutions on the island of Ireland such as DIT, UL, Maynooth, University of Ulster and Queens University Belfast are also involved in a range of education and research in the areas of business development, spatial analysis, integrated marine and coastal planning and development.

State Agencies

Marine Institute

The Institute has a unique national mandate to lead the development of the marine sector – *‘to undertake, to co-ordinate, to promote and to assist in marine research and development and to provide such services related to marine research and development, that in the opinion of the Institute will promote economic development and create employment and protect the marine environment’* (Marine Institute Act 1991)²⁰⁸. The Marine Institute participates and supports the MCG, the key inter-departmental mechanism for formulating and implementing the strategies and programmes that will give substance to the achievement of the Harnessing Our Ocean Wealth policy. The core capabilities of the Marine Institute itself are critical to the ongoing performance of the tasks associated with this role. In recognition of this function, in 2015 the Institute formed a new service group, the Policy, Innovation and Research Support Services. This relatively small group works closely with a range of scientific, technical, policy and industry experts in the State, NGO and private sectors. The Marine Institute also provides a range of services in support of policy development and governance areas. This includes environmental, fisheries, and aquaculture surveys and monitoring programmes to meet Ireland’s national and international legal requirements, as well as provision of scientific and technical advice to Government to help inform policy and to support the sustainable development of Ireland’s marine resource.

In the area of marine/maritime economics, the Marine Institute continues to work closely with research groups in the area. The capacity within the organisation is limited although expertise exists in the Irish Maritime Development Office (IMDO) aimed specifically at Maritime Economics.

New and additional capacity will be formed in the Institute over the next couple of years aimed at addressing the scientific and technical support required to implement MSP in Ireland. A notable new initiative is that the integrated Marine Development Team is to be incorporated into the IMDO to address a number of the opportunities identified in the report of the DTF and also engage and collaborate across a range of agencies.

²⁰⁸ <http://www.irishstatutebook.ie/eli/1991/act/2/enacted/en/html>

BIM

The BIM Economics Unit provides high quality economic evaluations and advice on the Irish seafood sector to the Department of Agriculture, Food and the Marine (DAFM), the Irish seafood industry and the European Commission (under the Data Collection Framework). BIM designs, plans, and implements data collection programmes and analyses the resulting data to meet Ireland's current and future needs under the EU Data Collection Framework (DCF). Voluntarily submitted Economic data contributes to the economic understanding of the component sectors of the Irish Fishing, Aquaculture and Processing Industries in near real time, and contributes to the development of national strategies reliant on economic input.

In relation to the DCF, BIM conducts an annual economic survey in which all active vessels, over 10m LOA²⁰⁹ are requested to submit economic and operational details for the year. The data is grouped by fleet segment and the information submitted in aggregated format to the EU. This economic information on the operation of the Irish Fishing fleet helps to inform European fisheries managers and policy makers²¹⁰. The operation of the economic aspect of the data collection framework is reported as much improved relative to previous years with sampling targets increasing for some segments. Ireland has also increased its target sampling size in some instances in an attempt to tackle data-poor segments. There was an effort to collect more data from the under 10m fleet also.

Key objectives for Ireland under the Data Collection Framework (DCF) and EMFF are to strengthen and broaden economic data collection to fill identified gaps also maximising the value from any data collected under the DCF.

Key to further developing the area is the use of data collected under the DCF to add value nationally for Ireland. This includes using the data to develop and refine economic models as management tools. This move from data collection to interpretation and analysis will allow Ireland to further develop and predict future dynamics of the seafood sector e.g. by use for modelling impact of policies and scenario planning. Socio-economic studies of rural coastal communities including fisheries harbours, is also central to BIM's objectives in the area.

Economic data collection being carried out under the EMFF Operational Programme for Ireland as part of the DCF can assist with modelling the inputs, flows and multipliers in Ireland's coastal

²⁰⁹ maximum length of a vessel's hull measured parallel to the waterline

²¹⁰ Source: <http://www.bim.ie/dcf/> . Article 74 of the EMFF Regulation outlines that, sound and efficient fisheries management decisions under the CFP should be supported by research and cooperation activities, by the provision of scientific and socio-economic opinions and by the advice needed for the implementation and development of the CFP, including in biogeographically sensitive areas.

economies as well as at a national level. Studies, research and capacity building are required that builds on and adds value to this data for national return.

At present limited socio-economic capacity exists in BIM; however, plans are in place to increase capacity in the area.

Sustainable Energy Authority of Ireland (SEAI)

SEAI, under the direction of the Department of Communications, Climate Action & Environment, is the agency responsible for the development of marine renewable energy, within the framework of the Offshore Renewable Energy Development Plan (OREDP). The Plan is comprehensive in terms of scope and innovative in respect to the governance and co-ordination mechanisms that are in place to guide its implementation. In developing the Ocean Energy strategy, SEAI has undertaken detailed reviews of the economic benefits of OE development and of the supply chain capabilities. It has also engaged closely with communities that may be impacted by and benefit from OE development.

Others

A range of other institutions have research, analysis and training functions and skills that could be highly relevant to the marine sector. These include the **Institute of Public Administration**, the **Economic and Social Research Institute**, the **National Economic and Social Council** and the Social Science and Business Schools attached to some of the universities. The low level of marine-related activity in these is linked to the general point made above about the low level of general awareness of the strategic and economic issues and opportunities associated with the marine sector in Ireland.

Infrastructures: “Established – Collaborative”

A range of education and training offerings are provided across the Higher Education sector, on the island of Ireland, that are relevant to the management and governance of Ireland’s ocean wealth. In both NUIG and UCC relevant courses exist at undergraduate and postgraduate level. In NUIG, multidisciplinary courses are delivered at undergraduate (UG) and postgraduate (PG) level in the areas of Marine Science (UG), Earth and Ocean Science (UG), and Environmental Science (UG & PG). At postgraduate level a number of courses have distinct or partial marine modules. These include courses in Coastal and Marine Environments (PG), Ecosystem Conservation & Landscape Management (PG – partial marine), and Natural Resource Economics and Policy – Economic & Environmental Modelling (PG – partial marine). Previously, NUIG also offered education and training in Maritime Law through the School of Law (see above).

In UCC, of particular note is the Marine Management programme, which is part of an Applied Coastal and Marine Management MSc. This postgraduate course focuses on the science (including

the social sciences) of coastal and marine management and policy-making. Other courses, at both undergraduate and postgraduate level include Environmental & Earth Systems (UG – marine modules), Applied Science – Ecological Assessment (PG – marine modules), Marine Biology (PG), Marine Renewable Energy (PG), and Applied Science / Fisheries Management, Development and Conservation (PG).

In 2016, UCC announced a new Masters Programme in Maritime Law. The initiative, led by the Law school at UCC in conjunction with the Office of the Attorney General and the Naval Service, is planned for the autumn semester 2016. The Masters is designed to attract students from a wide array of marine related disciplines, including science and the environment, as well as law. This is seen by the university as a key component of Harnessing Our Ocean Wealth, by adding to the range of educational opportunities in the Marine sector for domestic and foreign students and providing professionals for industry and the growing marine economy in Ireland. This new postgraduate course is the first dedicated university master's programme in the areas of marine law, maritime law, maritime security and port law in Ireland. The programme aims to provide knowledge and expertise to practice marine and maritime law professionally, in the public and private sectors.

Spread across other HEIs, including GMIT, UCD, DIT, UL, TCD, IT Sligo, IT Tralee, IT Athlone, IT Limerick, University of Ulster and Queens University Belfast, a vast range of courses are also applicable to educating and training future researchers and practitioners in the area of integrated marine governance. This includes dedicated courses in Marine Spatial Planning (PG), as well as more generic courses in planning, environmental and resource management (UG and PG).

Data

As outlined above, Ireland's Integrated Marine Plan recognises the importance of knowledge-generating activities in informing policy, governance and regulation of the marine sector. Over the last decade, Ireland's capacity and capability to collect and report on data (economic, biological, environmental and social) has strengthened. The ability to translate this data into a format that can fully support the integrated governance of our seas and oceans, however, still requires further support and innovation. The further development of key data infrastructures and associated models (specifically in the area of socio-economics) is still at an early stage. Data gaps exist in a number of sectors. Issues related to CSO data (availability, sampling and granularity) remains an ongoing issue. Key pieces of infrastructure, such as the bioeconomic/marine Input-Output model produced by Teagasc in association with SEMRU, require further research, analysis, testing, interpretation and development, especially at sub-sectoral levels. Consideration of establishing a satellite account for the ocean economy needs to be further explored.

Other key data infrastructures include Ireland's Marine Atlas. The further development of previous/planned databases such as MIDI (Marine Industry Database of Ireland) and the Marine Researchers Portal are also relevant infrastructures, albeit historic and in need of updating.

Networks (Industry engagement): "Established – Collaborative"

Various policy and governance forums operate at a national, EU and international level. These open innovation forums allow for the engagement of a range of stakeholders spanning research, industry, NGO's, scientists, policy makers and the general public. Irish experts have a strong track record of informing and advising on sectoral and marine policy areas e.g. through forums such as ICES, OSPAR, UNESCO, EU expert Groups, Regional fisheries forums, and targeted task forces.

A number of sector-specific or multi-sector researcher-policy/stakeholder forums are already gaining significant momentum in Ireland. These include the structures set up under the Offshore Renewable Energy Development Plan (OREDPA), the annual Marine Renewable Industry Association Event, the annual Law and the Environment Conference (with dedicated maritime law sessions), the annual Beaufort Marine Socio-Economic Workshop, the annual Ocean Wealth Conference and related events. Under the previous research and innovation strategy – Sea Change – a number of implementation groups, with participants across State, research, industry and NGO's, were formed. The groups were active in the first year of the Strategy but either did not continue or were subsumed into other forums.

Outreach activities of research groups aimed at promoting the potential impact of the research and its key outputs are becoming an increasingly important focus for research funders. One challenge researchers have is trying to balance the indicators used in the Higher Education Institutes versus impact indicators used by the funder(s) of policy-related research.

Research Themes

The development of enhanced research capacity in respect to integrated policy development and governance embraces three core research themes, as illustrated in the figure below. Such research will provide data and evidence to support Ireland’s key national plans and strategic initiatives – Harnessing Our Ocean Wealth and its related initiatives – Marine Spatial Planning and the establishment of an integrated Marine Development Team.

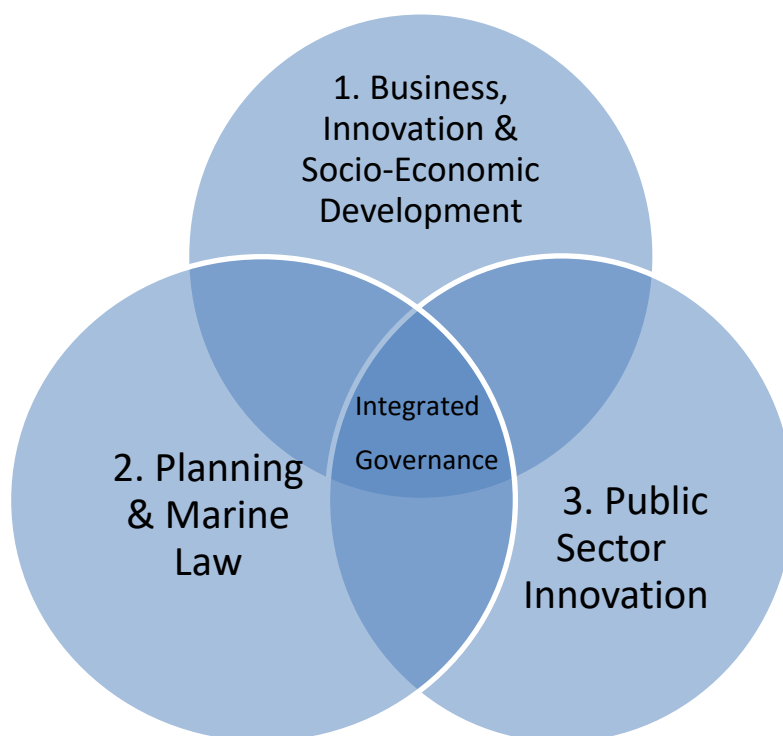


Figure 26: Core Research Themes identified to strengthen integrated governance of Ireland’s marine resource

Theme 1: Business, Innovation & Socio-Economic Development

The Integrated Marine Plan for Ireland comprises an ambitious series of targets and initiatives, the successful realisation of which entails a significant upscaling of information collection and processing capability as well as the initiation of a series of measures to support and drive business development in the marine sector.

Marine/Maritime Socio-Economics Research Programme

- Strengthen the collection, reporting and monitoring of Ireland’s Ocean Economy at macro and sectoral levels and enhance the value of data collection by strengthening its utilisation in economic analysis
- Build an understanding of the dynamics of the sector(s) across areas relating to competitiveness, changing supply and demand needs, supply chain and life cycle analysis, regional disaggregation of data and other inter-related activities (direct, indirect & induced)

- Develop a better understanding of impact (social and economic) of national and international strategies, regulation and development policies in order to maximise value added from Ireland's marine resources and expertise
- Benchmark the performance of the Irish marine economy on a sector-by-sector basis with other high performing marine economies
- Carry out and promote research into the non-market value of marine ecosystem services
- Develop a programme of marine social research, at both macro (ocean economy and resources) and sectoral level – topics include social acceptance and willingness to pay for market and non-market goods and services and the socio-impact assessment of planned initiatives

Business Development & Innovation Research

- Undertake the industry and market analysis needed to identify the drivers of growth in each sector of the marine economy
- Establish an understanding of Ireland's competitive advantages across the various marine sectors
- Provide technical, marine-specific knowledge and expertise in order to assess and develop a number of demonstrator projects (as outlined in the report of the Development Task Force)
- Strengthen current measures to establish incubation centres and industry clusters in Cork (IMERC) and Galway (SmartBay)
- Institute a series of Investor conferences to develop wider awareness of business opportunities associated with the Irish marine resource and develop appropriate business and public/private networks and understandings

Capability

In 2016 the Marine Institute issued a call for research proposals as part of a national research programme of marine socioeconomics. The project aims to strengthen the valuation of Ireland's ocean economy, ensuring the timely availability of marine economic statistics, providing an evidence-base for policy and decision-making, economic forecasting and scenario planning. Further details are available on: <http://www.marine.ie/Home/site-area/research-funding/research-funding/marine-institute-funding-marine-socio-economics>

The establishment and operation of the Marine Enterprise Development Team (proposed by the DTF) will provide substantial capability in supporting the Business Development and Innovation initiatives outlined above.

Theme 2: Planning, Legislation & Integrated Governance (incl. regulation)

Forward looking economic, social, and legal research and planning are required to identify emerging opportunities, assess the adequacy of existing legislation and planning mechanisms and enable the MCG and the development agencies to establish fit-for-purpose processes.

- Support efficient and evidence-based planned use of marine space, goods and services central to achieving sustainable economic growth and development and promoting climate change adaptation, risk prevention and management
- Facilitate the use and sharing of best available marine environmental, social and economic data and information e.g. further development of Ireland's Marine Atlas
- Improve data and knowledge generation, management and sharing including the development of new products and services (e.g. Ireland Marine Atlas and delivery to EMODNET), in support of a range of policies and directives such as CFP, Natura, MSFD and MSP
- Collect, collate and map accurate, up-to-date spatial and temporal information on marine ecosystems and human activities taking place within Ireland's maritime domain to support marine spatial planning
- Develop strong modelling and decision support capabilities
- Increase inter-agency cooperation and information sharing at national, EU and international level, together with industry and research collaboration
- Develop integrated/coordinated marine and coastal planning, licensing and regulation in order to sustainably maximise the potential for Ireland's ocean and coastal economies
- Better understand the implication of climate change on ecosystem goods and services and human activities through monitoring and modelling
- Ensure that effective capability is in place (in both the public and private sectors) to assess the implications of EU and other international legislation, both to protect the marine environment and resource and to facilitate business development planning, and associated project, financing and insurance contracting

Capability

Mechanisms being put in place to implement the MSP process will support aspects of this theme, others will be supported by the Marine Enterprise Development Team and the capabilities that exist in the ERI (Cork) and SEMRU.

Theme 3: Public Sector Innovation

Achieving the objectives of Harnessing Our Ocean Wealth entails an ongoing process of awareness-raising across the public and private sectors, of the opportunities for marine resource development, as well as a progressive upgrading of public sector capabilities to manage the research, business development and associated governance and regulatory procedures entailed.

- Ensure full participation and engagement by relevant agencies in the establishment and work of the Marine Enterprise Development Team, proposed as a key initiative by the DTF
- Continue support for awareness-raising events such as the annual Harnessing Our Ocean Wealth conference
- Support the renewal of an Association of Irish Marine Scientists
- Enhance capability to reuse and mine relevant research and resource Data for policy analysis purposes, by strengthening capabilities in public sector agencies

Capability

There is a limited capability in respect to actions associated with this theme in a number of public sector agencies, in the ERI (Cork) and the Whitaker Institute (NUIG).

Focus of Funding

Challenges in developing a programme of research aimed at supporting marine policy include a lack of critical mass and the ability to transfer knowledge into the policy and governance framework.

Capacity

Overall, complementary research capacity exists in the HEI sector across the socio-economic, legal and governance disciplines. In some areas the HEIs lack critical mass, e.g. in the area of socio-economics and law.

Capacity in the State organisations is limited (particularly in the area of economic, social and spatial analysis). To-date, the State has been dependent both on the HEIs and also contracted expertise. Further expertise is required in State organisations to ensure the agencies and Departments are equipped to fully implement the Vision and Goals outlined in Ireland's Integrated Marine Plan.

There is a significant value to be derived from strengthening NGOs' capacity to deepen their knowledge and understanding of the issues they address.

Infrastructure

Relevant elements of the infrastructure required to support actions under these themes include the Marine Atlas, MIDA, the industry databases assembled by SEAI/EI, MaREI, IMDO, as well as the MI, and other agencies.

Networks

Networks in the context of these themes are largely ad-hoc. The mechanisms that have been put in place to implement the Offshore Renewable Energy Development Plan provide a good template for other sectors.

Actions to support the themes above include:

- Continue to build/support strong 'centres of excellence' (CoE's) with complementary skills across the HEI and State sectors
- Promote collaborations between marine CoE's, (e.g. Whitaker, ERi, IMERC etc.), and agencies, such as IPA and ESRI, to enhance innovation in the areas of socio-economics and planning, governance and business development
- Commission and promote high-level studies on Policy issues in the marine sector (MI,MDT and MSP Team)
- Examine the current and planned policy framework in order to consider the best organisational structures for engaging with stakeholders on an on-going basis at the appropriate scale
- Develop a fully comprehensive suite of progress indicators and socio-economic targets
- Continue to build social and economic impact assessments of the Ocean Economy
- Strengthen agency capabilities to utilise and add value to data collected for routine purposes, e.g. national catch return data, collected by BIM notes
- Strengthen the capabilities of the State to support the work of the MCG, to implement commitments under the Harnessing Our Ocean Wealth policy, and to implement key sectoral policies, e.g. the CFP and the OREDP
- Commission research to better integrate enterprise opportunities arising from, currently, largely autonomous and unconnected sub-sectoral development plans e.g. aquaculture, fisheries, oil and gas etc.
- Undertake a valuation of public sector capacity required to address opportunities in Ireland's marine sector that are currently in place and required from now to 2020
- Establish a (distributed) degree in Marine Management (Economics, Law, Maritime operations and vessel/operations management, and Engineering project management
- Establish a focused research and studies programme to support Maritime Spatial Planning to fill the knowledge and data gaps

Information & Spatial Technologies, Analytics and Modelling

Overview

Ireland has a strong presence in global information technologies via the presence of major FDI in the sector and active indigenous companies and innovation. The Digital Ocean identity for Ireland is a developing one with active public sector organisations and established research and teaching institutions.

The area identified here is understood to incorporate ICT, GIS, analytics, data and numerical modelling.

Context

The adoption of information and also location technologies is the subject of national strategies²¹¹ and European and global initiatives.

These include, for example, eGovernment plans that encourage the adoption of technologies for integrated and accessible approaches to public service delivery. These national eGov approaches are informed by EU policies and strategies including the Digital Single Market²¹².

Systems and services are also being developed at European level that support or facilitate national activities. For example the ESA²¹³ Sentinel observation platforms, and the Copernicus programme and its Marine Environment Monitoring Service (CMEMS).

Statutory aspects such as the INSPIRE²¹⁴ and Re-Use of Public Sector Information²¹⁵ EU Directives promote and provide regulatory basis for open data and cross-European harmonised datasets.

Ireland's enterprise policy Enterprise 2025: Innovative, Agile, Connected²¹⁶ identifies "Marine" and "Green technologies" as sectors where untapped potential exists.

Enterprise development plans and support are extensive in the broad ICT area but the 2015 Marine Development Task Force and its focus on 'marinising/strengthening/developing' of existing products and services, leads now, for example, to Enterprise Ireland seeking to fund a Marine Campus Incubation Centre to nurture spin-in and spin-out companies in marine sectors including marine ICT.

²¹¹ Examples being eGovernment 2012 – 2015 (<http://egovstrategy.gov.ie/>), and Public Service ICT Strategy (<http://ictstrategy.per.gov.ie/>)

²¹² <https://ec.europa.eu/digital-single-market/en/digital-single-market>

²¹³ http://www.esa.int/Our_Activities/Observing_the_Earth

²¹⁴ <http://inspire.ec.europa.eu/>

²¹⁵ <https://ec.europa.eu/digital-single-market/en/european-legislation-reuse-public-sector-information>

²¹⁶ Enterprise 2025 Ireland's National Enterprise Policy 2015-2025. Department of Jobs, Enterprise and Innovation, Dublin 2015

Importantly, the area of Information & Spatial Technologies, Analytics and Modelling is very much in support of other sectors, and as such the context as outlined for other areas in this document is relevant e.g. Marine Strategy Framework Directive, EU Data Collection Framework.

Research Capabilities (Maturity Assessment)

This research theme is firmly at the established level with strong potential to grow to the collaborative level with the research capability to participate in large scale research centres. A key inhibitor in this regard has been sourcing adequate industry funding for such centres.

Human Capacity: “Established”

- There are PI led research teams working across a wide range of application areas utilising IT, GIS, analytics, modelling.
- The SFI-funded MaREI programme provides a platform for inter-institutional collaboration and a relatively stable structure for research and innovation effort, building on longstanding activity in marine ICT, GIS and modelling in the institutions.
- The SFI-funded Insight Centre for Data Analytics has an extensive body of researchers across institutions and has significant potential to develop a marine spoke.
- The NUI Maynooth capacity in broad geo-technologies is notable and has a marine aspect, with other capacity that could be marinised.
- Other institutions provide further research and learning capacity e.g. DIT with its geomatics focus; NUIG and the Irish Centre for High End Computing (ICHEC); WIT TSSG & ArcLabs and its marinising potential.
- In numerical modelling the Marine Institute has a core team, with NUIG and other individuals under MaREI having expertise.
- The substantial capacity within the FDI IT sector, and the local micro to medium IT company area, provides the potential for ‘marinisation’.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 27: Irish Research Maturity in Information & Spatial Technologies, Analytics and Modelling showing the different levels of maturity for human capacity, infrastructure and networks

Infrastructures: “Established – Collaborative”

- Infrastructure requirements encompass software (proprietary and open source), hardware, hosting-facilities including Cloud, high-end computing, and access to suitable data streams. These are typically in place.
- For many computing activities the costs are relatively modest, but for others there is a requirement for substantial data capacity, scalable computing, including processing power. Further & on-going access to high end computing is required.
- The infrastructure to generate and manage data streams such as earth observations platforms and sensors (remote and in-situ), can be substantial in a marine environment; but some are increasingly lower cost and accessible (e.g. drone, some sensors), or can leverage facilities (e.g. MaREI, the ICHEC ESA/Sentinel ground segment).
- State bodies such as the Marine Institute and the Geological Survey operate and provide significant infrastructures and data, including INFOMAR²¹⁷, the Galway Bay Ocean Observatory, and the Digital Ocean platform²¹⁸, that can be leveraged. The National Biodiversity Data Centre²¹⁹ provides a biodiversity data management platform.
- As identified by the Marine Institute²²⁰ and others, there is significant additional opportunity to leverage Ireland’s infrastructure and marine area, to promote Ireland's digital ocean opportunity highlighting how technology companies can drive new forms of innovation in the blue economy using Ireland as a test-bed with its significant marine resource, expertise and infrastructure.

Networks (Industry engagement): “Established”

- Many of the institutions are heavily involved and reliant on national collaboration-based funding (e.g. those funded by Science Foundation Ireland), and participate in H2020 projects and calls.
- State bodies (e.g. the Marine Institute and the Geological Survey of Ireland) are engaged in international collaborations (e.g. SeaDataNet, EModNet).
- The existing strengths of Insight and others provide significant marinating opportunities.
- Initial industry support for the MaREI research centre is promising; Insight has progressing industry ties; while the EI Marine Campus Incubation Centre call is notable.

²¹⁷ <http://www.infomar.ie>

²¹⁸ <http://www.digitalocean.ie>

²¹⁹ <http://www.biodiversityireland.ie>

²²⁰ For example as highlighted at Digital Ocean Seafest 2016 event
<http://www.smartocean.ie/sites/default/files/img/events/DigitalOceanProgramme.pdf>

- There is opportunity to build on various engagements with industry e.g. SmartBay, and make them highly collaborative, non-proprietary, and with a strong incentive or requirement to have engagement between sectors (private, public, educational) and within the private sector (large multinationals and local SMEs).

Research Topics

- As data streams grow, and access to them simplifies, a focus on the potential outcomes of analysis on that data is growing and presents opportunities.
- Building on the test labs, instrumentation and sensors in MaREI, the Galway Bay Ocean Observatory, and elsewhere, there is now an opportunity to analyse the data arising.
- With our extensive North Atlantic seabed, there is opportunity to innovate in the creation of substantial digital ocean platforms with operational and commercial benefits.
- Continue to identify research and innovation aspects and their suitability for collaborative works across sectors, for support and engagement from public bodies, and for ultimate commercialisation.

Proposed Focus of Funding / Instruments

- Support to key institutions and networks to get on an ESFRI Research Infrastructures Roadmap²²¹.
- Along with H2020 and other programmes, to utilise the ESA funding opportunities to get Irish-led marine EO and ICT projects.
- Provision of non-technical financial and management support²²² to spin-outs to ensure commercial fundamentals are stable while delivering on innovation, and to ensure existing funding supports are available at high-risk stages for companies, and at sufficient levels of availability.
- Use of Small Business Innovation Research (SBIR)²²³ as a mechanism to enable public sector bodies to connect with technology businesses (currently marine or non-marine) to provide innovative solutions to specific marine sector challenges.

²²¹ <http://ec.europa.eu/research/infrastructures/>

²²² E.g. company operations, project management, financial management, business development, senior hands-on support through drawdown monthly hours and structured 'drop-in' services.

²²³ <http://www.sbirireland.ie/About/>. Also see <https://www.sbir.gov/about/about-sbir>.

Engineering

Overview

A myriad of core engineering disciplines support marine projects. Ireland is well served by universities that produce upwards of 500 engineering graduates annually. Engineers provide essential contributions to the marine and maritime economy through product and process innovations, and the development and delivery of critical infrastructure. Mechanical, civil, electrical, electronic, chemical, and software engineers contribute an array of engineering systems knowledge relevant to the maritime economy.

Engineering departments in Ireland's universities provide professional education based on engineering sciences to equip graduates to contribute to the design, analysis, production, maintenance and management of a variety of engineering systems. The marine sector is supported by engineers working in areas of energy conversion devices, power generation and distribution, marine structures – such as harbours, ports, piers and tidal defence systems, and floating and sub-sea structures. Extensive modelling capabilities provide insights to tidal flows and the maintenance of navigation aids.

Marine Engineering activity in Ireland is at a low level, which is linked to the low level of industry activity in many areas of the ocean economy.

This problem needs to be addressed in order to achieve the growth targets for Ireland's economy defined in *Harnessing Our Ocean Wealth*. This is a significant industrial development challenge, which was addressed by the recommendations from the Development Task Force, where a new integrated Marine Development Team will adapt a whole-of-enterprise approach at company level. The Development Task Force also concluded that, to drive the economic agenda, a set of projects that can demonstrate Ireland's intent for the sector was needed. The action required to create more marine successes was defined in the recommendations from the Development Task Force on "Demonstrating Intent – an Initial Investment Programme".

The delivery of the demonstrator projects would generate the demand and facilitate the improvement in maturity levels of Ireland's research and industrial capabilities in Engineering.

There are some examples where demand exists, for example, training for Seafarers, where dedicated courses are offered by NMCI in the areas of Nautical Science, Marine & Plant Engineering and Marine Electrotechnology. However, these alone are insufficient as a foundation for future developments and are unlikely to enable research excellence to be built.

Industrial activity in Ireland, and consequently demand for marine engineering, is very low in the fields of materials, structures, hydrodynamics and energy aspects for the marine and naval sector. Increased activity in these areas will also help create opportunities in large global markets for research of the maritime, oil and gas and offshore renewables industries across the world.

Strong "marine" engineering sectors exist in other countries, where universities offer degree, masters and PhD courses, and have internationally recognised staff, in the fields of ship design and other engineering systems operating in the maritime environment. Test facilities required include towing tanks and wind tunnels and collaboration with industry is evident through the formation of research hubs.

Existing capabilities in other marine engineering fields, for example in ocean energy, could provide opportunities to extend into these areas to help create a base from which a dedicated marine engineering capacity could grow in the medium to long term.

The success of the "Integrated Marine Development Team" and the delivery of the demonstrator projects identified by the Development Task Force are key steps to realising the goals of *Harnessing Our Ocean Wealth*.

Context

The study and investigation of engineering systems operating in the maritime environment underpins Goal 3 in **Harnessing Our Ocean Wealth**, i.e. to strengthen our "Engagement with the Sea".

Engineering capabilities are a critical component in realising the step-change increase in turnover for the general marine sector that has a target to achieve €1,200 million turnover by 2020 and includes Ports and Maritime Transport Services, Maritime Manufacturing, Engineering, Offshore Oil and Gas, and other marine industries.

Under *Capacity, Education, Training & Awareness*, action #27 is to continue to build marine overall research capacity and capability through targeted national and international programmes. This is a separate action from the skills study which is related to supply/demand issues on the labour market.

The actions under *International and North/South Cooperation* in *Harnessing Our Ocean Wealth* are relevant to developing opportunities from the existing shipbuilding and heavy marine engineering strengths in N. Ireland, which have evolved around Harland & Wolff in Belfast.

Among the cohesive set of recommendations from the **Development Task Force** "Demonstrating Intent" is centred on supporting demonstrator projects that fit within the report's

‘Marinising/Strengthening/Developing’ Strategic Framework. Engineering capability in the fields of structures, energy conversion, naval architecture and design for the sea will be needed for demonstrator projects in:

- Frontier Aquaculture (Food from the Sea)
- MRE Devices & Arrays (Energy from the Ocean)
- Marine Engineering (Energy from the Ocean)
- Ocean Racing Yacht Platform (Enterprise & Industry)
- Offshore Platforms End-of-life Services (Enterprise & Industry)

The “Integrated Marine Development Team”, as recommended by the Development Task Force, will also play a crucial role in creating the demand for marine engineering capability in Ireland. This would be achieved through the adoption of a *whole of enterprise approach* with a focus that includes building an Irish Marine industry network, strengthening maritime clusters, supporting existing industry through the introduction of marine specific SBIR schemes, supporting new businesses through creating new start-ups, and the use of dedicated incubation/acceleration facilities and actions in support of FDI.

In conjunction with generating the demand for Marine Engineering capability in Ireland, developing and improving the maturity level and capabilities of Ireland’s Engineering sector in respect to engineered systems operating in the maritime environment will be crucial to embedding the longer term benefits to Ireland from these developments and, ultimately, contributing to Goal 3 in Harnessing Our Ocean Wealth on “Engagement with the Sea”.

Relevant Documents / Sectoral Plans

See Overview section above.

Research Capabilities (Maturity Assessment)

Of all the research themes examined in preparation for this strategy, the Engineering theme was the least defined, failing to be assessed even at ad-hoc level. This is not reflective of the level of engineering expertise available in Ireland, nor indeed of the level of engineering research. It does, however, show the very low level to which this expertise and research capacity is applied to the marine sphere.

Human Capacity: “Ad-hoc”

Engineering departments in Ireland’s universities provide professional education based on engineering sciences to equip graduates to contribute to the design, analysis, production, maintenance and management of a variety of engineering systems. However, due to the low level of marine engineering industry in Ireland, there is no evidence of specific degree, masters and PhD courses offered for disciplines like naval architecture/ship design that are required for the design and construction of engineered systems operating in the maritime environment. As a consequence, Ireland has no recognised research or university-based staff in maritime aspects of these disciplines and relies on other countries to do this.

Where demand exists in Ireland, for example in training for Seafarers, there are dedicated courses offered by NMCI focused on the operation and maintenance of ships.

Strengths in other marine engineering fields, for example in ocean energy, could provide opportunities to extend into these areas to help create a base from which a dedicated marine engineering capacity could grow in the medium to long term.

Funding and delivery of the demonstrator projects identified by the Development Task Force would create conditions to enable Ireland’s engineering base to improve its maritime engineering capacity over time.

The use of SBIR to promote innovation, as highlighted in **Innovation 2020**, focused around the demonstrator projects, could help create a generation of new businesses while at the same time building capacity for maritime capabilities in Ireland’s engineering research base.

	Human Capacity	Infrastructure	Networks & relationships
Translational			
Collaborative			
Established			
Defined			
Ad-hoc			

Figure 28: Irish Research Maturities in Engineering, showing the lack of levels of maturity for human capacity, infrastructure and networks

Infrastructures: “Ad-hoc”

There are purpose-built facilities at NMCI to support the courses offered, which include ship engine room equipment, simulators and associated workshops.

There are no facilities related to naval architecture or ship design; however, the test tanks designed for marine renewable energy systems could be used for other marine and structural design applications.

An international collaboration programme, to build links with purpose-built facilities in other countries, could provide access to facilities that Ireland does not currently possess, for example in wind tunnels or tow-tanks, while at the same time creating opportunities for the transfer of expertise from cross-cutting areas like ocean energy.

Networks (Industry engagement): “Ad-hoc”

The courses offered by NMCI/CIT include work placement and the industry links, through the Irish Naval service and NMCI/CIT engagement in IMERC, provide access to useful networks in this regard.

The lack of capacity, due to lack of demand from existing industry in Ireland, in the broader areas of Maritime Engineering means that there is little scope to engage with the major industrial players in design and construction for shipping, offshore oil & gas, offshore aquaculture and renewable energy.

Support for the development of expertise in the ocean energy sector, to identify and target opportunities to transfer and apply relevant capacity and test infrastructure to maritime engineering, for example in the development of the next generation of floating wind turbines, could help extend and build capacity, while at the same time fostering links with industry.

The funding for delivery of the demonstrator projects identified by the Development Task Force could also be structured to incentivise collaboration between industries, from within or outside Ireland, and Ireland’s engineering research base.

Ultimately, the success of the whole-of-enterprise approach to be adopted by the “Integrated Marine Development Team”, as recommended by the Development Task Force, will be crucial to generating the enterprise activity that will create the demand for marine engineering capability in Ireland.

Support for the work of the “Integrated Marine Development Team”, could focus on:

- Building an Irish Marine industry network and strengthening maritime clusters
- Supporting existing industry through the introduction of marine specific SBIR schemes

- Creating new start-ups and use of dedicated incubation/acceleration facilities

Research Topics

Engineering capability in the fields of structures, naval architecture and design for the sea will be needed for demonstrator projects identified in the **Development Task Force** report, namely:

- Frontier Aquaculture (Food from the Sea)
- MRE Devices & Arrays (Energy from the Ocean)
- Marine Engineering (Energy from the Ocean)
- Ocean Racing Yacht Platform (Enterprise & Industry)
- Offshore Platforms End-of-life Services (Enterprise & Industry)

Focus of Funding

The focus of funding and support for Engineering in marine areas is primarily needed to establish a basic level of capacity and recognised expertise that can draw on strengths in related areas, such as ocean energy and marine geosciences.

Funding is needed to support the transfer and extension of engineering capabilities, which are currently focused on land-based activities in Ireland, in fields such as civil engineering, mechanical engineering and electrical engineering, to research and develop solutions for the demonstrator projects identified by the Development Task Force.

Attracting experienced staff in materials, structures, hydrodynamics and energy aspects of the marine and naval sector could link to activities in existing engineering centres, for example in marine renewable energy. This could be developed into a wider maritime engineering/naval architecture capacity over time and help to begin to build Ireland's reputation in marine engineering through niche areas, for example structures for ocean energy and offshore aquaculture.

Actions should ensure that existing test infrastructure is accessible and usable for application to research projects in the wide range of areas linked to the demonstrator projects identified by the Development Task Force, for example, the use of the Galway Bay test site for testing floating wind turbine systems.

The success of the "Integrated Marine Development Team" and the delivery of the demonstrator projects identified by the Development Task Force are critical challenges. A key first step will be the effective networking of the currently fragmented marine engineering sector. Support for existing industry through the introduction of marine-specific SBIR schemes, creating new start-ups and strengthening emerging hubs/clusters, will create a base from which a dedicated marine Engineering capacity could grow in the medium to long term.

