MRIA Energy from Ireland's Waves and Tides

Collaboration and Innovation Challenges faced by the Ocean Energy Sector and Possible Solutions

Discussion Paper

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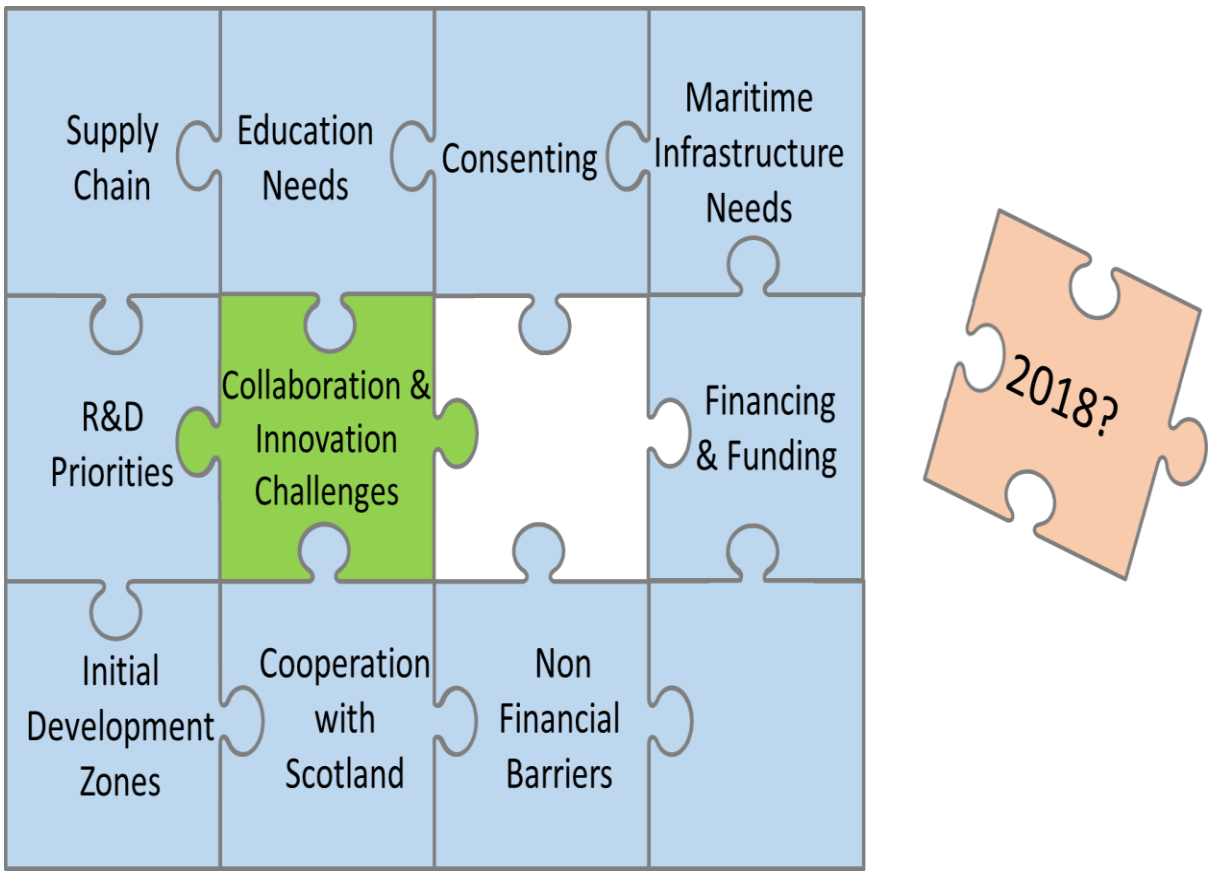


Preface

This Paper was prepared and published by the Marine Renewables Industry Association (MRIA) with the generous support of the Sustainable Energy Authority of Ireland. The MRIA represents the marine renewables emerging technologies on the island of Ireland, although this Paper focuses on wave and tidal energy ('ocean energy'). This is the tenth annual Paper published by the Association about policy topics relevant to marine renewables.

The jobs and income potential of ocean energy globally is well documented (see recent MRIA Papers at www.mria.ie for detail on this) and Ireland is uniquely qualified to exploit this given our abundant wave resource off the West coast (and a significant tidal resource in Northern Ireland) as well as our significant R&D facilities and supportive Government policies, although the ongoing saga of the new consenting regime to be set out in the Maritime Area and Foreshore (Amendment) Bill is an issue. Of wider concern is the small scale of almost all ocean energy companies - Ireland is home to about 9% of the global population at present - and their failure to collaborate on R&D. Ocean energy companies are unique – small, with limited financial resources and yet engaged in capital intensive innovation on the frontiers of man's knowledge. They have been quite effective in advancing our knowledge of how to convert the kinetic energy contained in waves and tides into electricity. They could do more with greater intercompany collaboration and with tailored company development support from the agency with experience and expertise in ocean energy, Sustainable Energy Authority of Ireland (SEAI).

This Paper deals with these issues and sets out the research and industry views which led to the actions recommended. The recommendations boil down to giving SEAI the remit, under a special protocol with Enterprise Ireland, to provide company development support to ocean energy firms in their early years. The recommendations, if implemented, could make the difference between Ireland playing a lead role in this potentially huge industry of tomorrow and being an 'also ran' in the one field where we have a natural resource of scale.

Summary of Recommendations

The Marine Renewables Industry Association recommends, in summary, that:

1. The Sustainable Energy Authority of Ireland (SEAI) de facto role as the development agency for early stage ocean energy companies should be formally recognised in agreement with Enterprise Ireland in particular. This would extend SEAI's remit beyond its traditional role of supporting prototype development, research infrastructure etc into also supporting ocean energy, floating wind and 'hybrid' (floating wind + wave) companies to develop as businesses until they qualify for mainstream Enterprise Ireland and IDA support

2. SEAI's role, in keeping with Recommendation 1, should be limited by a protocol with the other agencies to its own funding schemes and to specific company development tools

3. The original promoters (ESB, MRIA and, particularly, SEAI as well as Scottish Enterprise) should continue to sustain the Ocean Power Innovation Network (OPIN) until appropriate EU support can be sourced to scale up this vital European effort

4. A 'company Accelerator' should be organised from time to time by SEAI for the marine renewables emerging technologies enterprises

5. All firms approved for support under the Prototype Development Fund and the forthcoming Pre-Commercial Technology Fund should be required to attend an Accelerator as a condition of grant support. The State body, NDRC, should be contracted to supply at least the first ocean energy Accelerator

6. SEAI should contract with IRDG or a similar suitable supplier to provide a crowdsourced innovation platform for energy companies

Contents

1. *Marine Renewables Industry Association*

The Marine Renewables Industry Association (MRIA) represents the principal interests on the island of Ireland engaged in Marine Renewables Emerging Technologies (MRET)[1], including ocean energy which is the focal point of this Paper. The Association includes firms engaged in device development and manufacture, utilities and developer interests, professional firms, R & D businesses and academic researchers. The Association is an all-island body. For further details, please go to the Association's web page, www.mria.ie . You may follow MRIA on Twitter at *@Marineireland*.

There are 286 ocean energy companies in existence globally – 202 in wave energy and 84 in tidal energy. One estimate is that the annual turnover of the wave companies is €250k pa[2]. This figure is probably skewed by a small number of firms and, so, most enterprises may have a much lower level of annual revenue, much of which may comprise of externally sourced research funding of one sort or another. The experience of tidal companies is probably at the same level as the wave companies. There are at least 26 ocean energy companies on the island of Ireland, mostly in the Republic, and, thus, Ireland accounts for almost 10% of the world ocean energy enterprise population[3]. It is important to identify how the growth of Irish ocean energy companies can be ramped up given the Ireland's enormous wave resource, excellent R&D facilities, relatively large population of device companies, export opportunities etc……and the income creation potential of the sector outlined at 2 below.

The purpose of this study is to examine an important aspect to this complex challenge: the role which collaboration on innovation can play and how new, extra initiatives might be delivered.

The terms of reference are dealt with in more detail at 4 below.

[1] Wave + tidal energy = ocean energy (+ floating and fixed offshore wind plus 'hybrids' i.e. combined floating wind and wave) = marine renewables. The MRETs are wave, tidal, floating wind and 'hybrids'. The Association decided in mid-2017 to extend its coverage to floating wind and to 'hybrids'. This Paper focuses on ocean energy i.e. wave and tidal

[2] Sources: www.emec.org.uk; www.exceedence.com research

[3] An indication of how 'strong' our position is lies in the calculation that, on a population basis, the US should have 1300 ocean energy companies to match Ireland's position whereas, in fact, it has only a handful.

2. *Ocean Energy Potential of Ireland*

1.1 Opportunity of Ocean Energy

Ocean Energy Europe[4] has noted steady progress in ocean energy:

'As a fledgling industry, the European ocean energy sector is making positive progress. Several European utilities and engineering giants from Europe, the US, Japan and Korea have all invested in SMEs, testing programmes and early project development in Europe. This clearly points to growing confidence in the viability of these technologies[5]*.'*

Another authoritative source, the European Commission-prompted *Ocean Energy Roadmap*[6], takes an ambitious stance:

'Ocean energy is abundant, geographically diverse and renewable. Under favourable regulatory and economic conditions, ocean energy could meet 10% of the European Union's (EU) power demand by 2050……Ocean energy can be an EU industrial success story. With favourable support over the coming decade, Europe will obtain leadership in a global market, worth a potential €653bn between 2010 and 2050 and an annual market of up to €53bn, significantly benefiting the European economy. The successful development of a competitive European ocean energy industry would also place the European industry in a prime position to seize export opportunities in the global market…Today, 45% of wave energy companies and 50% of tidal energy companies are from the EU…. The global market for ocean energy could see 337GW of installed capacity by 2050, a third of this would be in Europe' p.7, 13.

Previous MRIA Papers have set out in detail the state of the art of ocean energy technology, detailed the international economic opportunity it presents and made the argument that in due course ocean energy (not to speak of floating wind and 'hybrids') can achieve an acceptable Levelised Cost of Electricity (LCOE) i.e. become cost competitive[7]

[4] The EU-wide trade association for ocean energy. MRIA is a Board Member. Previously known as European Ocean Energy Association (EU-OEA)

[5] *Industry Vision Paper 2013* Ocean Energy Europe

[6] *Ocean Energy Strategic Roadmap Building Ocean Energy for Europe.* Prepared for the European Commission, 2016. Available at https://webgate.ec.europa.eu/maritimeforum/en/frontpage/1036.

[7] See, for example, *Non-Financial and Non-Technical Barriers to the Development of the Ocean Energy Sector in Ireland Discussion Paper* February 2017 at www.mria.ie

The opportunity in ocean energy-resource rich Ireland has at least two possible dimensions – the ENTERPRISE and the ELECTRICITY EXPORT MARKETS. There may also be scope for LOCAL ELECTRICITY SUPPLY in Ireland.

1.2 ENTERPRISE

The ENTERPRISE element ranges from research and development and device manufacture to operations and maintenance, finance and legal support. This '*supply chain'* in Ireland has an opportunity in wind-based energy, particularly offshore wind, in the UK which is now a major industry. Wind energy on land is facilitating support companies in Ireland to grow their experience and their skills… as will other forms of renewable energy such as solar…. and will facilitate a number of them to capitalise on the future offshore renewable energy opportunity.

1.3 EXPORTING ELECTRICITY AND LOCAL MARKET OPPORTUNITIES

All of the stakeholders in ocean energy accept that the enormous scale of the Irish wave resource (together with a limited resource in tidal in the Republic, although not in Northern Ireland where substantial tidal projects are already in train) represents a potentially huge opportunity for ELECTRICITY 'EXPORT via grid interconnectors. This is based on the likely emergence of an EU energy market and a Euro grid; potential demand in England in particular; the development of ocean energy technology and other factors. The aborted *Inter-Governmental Agreement* negotiation on energy between Ireland and the UK could have enhanced this opportunity quickly.

The arrangements sought then may be revived in time due to UK generation-capacity constraints although the impact of Brexit on this and other aspects of energy is unknown at present. Recently, a Memorandum of Understanding between Eirgrid and RTE (Réseau de Transport d'Electricité, the French transmission operator) was signed[8]. The Memorandum of Understanding is an agreement between the two operators to move to the next phase of development of the Celtic Interconnector Project. This phase, which will take two years to complete, will comprise initial design and pre-consultation for an electricity interconnector between Ireland and France.

In time, large scale deployment of ocean energy devices should drive the cost of ocean energy down as 'economies of scale' and the 'learning curve' effect kick in.

[8] On 21 July 2016 on the occasion of the visit of President Hollande of France to Dublin

Opportunities for ocean energy to meet LOCAL MARKET OPPORTUNITIES in Ireland must not be ruled out. A lot of technical issues could be resolved in ocean energy over the next ten years; the intermittency of renewables will be addressed by new electricity storage solutions, particularly in the field of batteries; there may be technical breakthroughs which make ocean energy competitive with traditional energy feedstocks; etc. Two emerging elements that will have a positive impact are floating wind and 'hybrids': devices that combine (floating) wind and wave energy devices.

3. National Policy Position

3.1 Final Step on Journey to Decarbonisation

Meeting the European Union's and Ireland's (corresponding) decarbonisation objectives by 2050, will require virtually full decarbonisation of electricity generation and the matching electrification of the heating and transport sectors. These two sectors alone account for around a third of CO2 emissions.

MRIA expect significant growth in energy storage as well as demand side management solutions and other smart grid developments to facilitate the very high renewable penetrations that will be required (see the recently published *ESB Networks* innovation strategy[9]: 330,000 homes with e-heat, 1,300MW energy storage and 2,500 MW customer flexibility by 2030). Achieving these targets is vital: the authoritative *Climate Science Special Report* just published in the US by leading academics and federal agencies is just the latest compendium of stark, objective evidence of the potentially devastating climate change underway[10]. It is noteworthy too that the *Citizens Assembly* voted recently that climate change should be at the heart of Government policy in Ireland[11].

In order to fully decarbonise the energy system by 2050, it is clear that onshore renewables such as wind and solar PV alone will not suffice as these markets will saturate in time and present challenges to the operation of the grid due to their intermittency and lack of output diversity across the projects. The next step may be to harness the offshore wind resources in the Irish Sea utilizing fixed offshore wind technology and, where appropriate, floating offshore wind turbines: suitable locations are near the demand centres; the fixed offshore wind technology is already mature and is commercially available to do this.

[9] www.esbnetworks.ie/innovation
[10] https://science2017.globalchange.gov/
[11] https://www.citizensassembly.ie

This technology will also support more renewables overall on the system because it will provide some diversity compared to land-based wind.

The final step on the journey will be to secure additional renewable energy sources off the West and South West coasts, providing further renewable energy, higher load factors and more diversity in the renewables mix. Options at the moment include nascent technologies such as wave, some tidal, floating offshore wind and hybrids of these. It is likely that a mix of these innovative, emerging technologies will be required. The ultimate mix will depend on the relevant commercial and technology developments, grid availability, system technology and diversity requirements, local consenting factors and the extent to which they are supported through their early development stages. There is also the added attraction of both potential electricity export and capitalising on Ireland's 'early mover' advantage in the innovative technologies with all of the positive implications this may have for supply chain income and job creation, particularly along the West coast of Ireland.

3.2 National Ocean Energy Policy

Ireland–North and South–is a potential renewable energy powerhouse and the sum of its wind (both onshore and offshore), wave and tidal resources is deemed by Siemens to account for 1/3 of all such resources in Western Europe[12].

Ocean energy development is a clear policy concern of the Government of Ireland. It has been singled out as a national priority for research and development support[13]. Supporting the emergence of this industry was set as one of a handful of strategic goals fixed for national energy policy to 2020[14]. The policy statement on the Green Economy, published in November 2012, also highlighted the potential importance of the sector and pledged support.[15] Ireland plays a leading role in a variety of EU supported projects e.g. MARINERG-i, the Bryden Centre etc

The UCC Beaufort building, part of University College Cork and headquarters of the SFI-funded MaREI Centre, was opened in 2015 and houses the *LiR* national

[12] Siemen's presentation

[13] *Report of the Research Prioritisation Steering Group*, Forfas, March 2012

[14] *Strategy for Renewable Energy 2012-2020* Department of Communications, Energy and Natural Resources, 2012

[15] *Delivering our Green Potential - Government Policy Statement on Growth and Employment in the Green Economy* Department of Jobs, Innovation and Enterprise, November 2012

ocean energy tank testing facilities. The new complex and MaREI Centre itself are in receipt of substantial financial support from the Department of Communications, Climate Action and Environment (DCCAE, previously the Department of Communications, Energy and Natural Resources-DCENR), Sustainable Energy Authority of Ireland (SEAI) and Science Foundation Ireland (SFI) with cash or contributions in kind from around 50 industry partners.

The *SmartBay* Marine and Renewable Energy test site in Galway Bay continues to support the progression of ocean energy and novel marine technologies through the TRL[16] stage gates. The test site has secured significant capital investment support from industry, SEAI and SFI. To date, a total of 12 industry and 44 R&D projects have been undertaken at SmartBay. Since 2012, a total of 35 different projects have been supported to use the facility under a special access programme [17]. In 2016, Irish SME *SeaPower* was awarded funding from SEAI to test their device at SmartBay. Phase 1 of the performance and survivability test programme was successfully completed in March 2017. SmartBay Ireland has been successful in EU funding applications, with 8 projects already funded, 1 project completed in 2017 while several other projects are in contract negotiation stage or under evaluation by the European Commission.

The SmartBay team is providing test site access and marine science support for the following projects: RECODE (to assist in the development and testing of an umbilical cable monitoring system); FORESEA (to support testing and validation of low carbon technologies in marine test centres); MARINA (to promote responsible research and innovation in Europe's R&D); COLUMBUS (to improve the dissemination and exploitation of EU funded R&D outputs); JERICO-NEXT (involves harmonization and improvement of ocean observation and R&D through facilitated access to research infrastructures); and MARIABOX (development, testing and validation of a multi-parameter autonomous marine bio-chemical sensor). MARINET2 (free access to test sites for marine renewable energy technologies) and MaRITeC-X (to assist in the creation of a Marine and Maritime Research and Innovation Technology Centre of Excellence based in Cyprus).

SmartBay is a partner in the €11m FORESEA project which opened its fourth call for support package applications in October 2017. To date, SmartBay has received a number of applications for future access to the test site. Successful

[16] Technology readiness Level (TRL)
[17] National Infrastructure Access Programme

applicants receive free access to test ocean energy technologies in real-sea conditions at the project's network of open sea test centres. The project is funded through the Interreg new programme, part of the European Regional Development Fund. The project aims to encourage longer term testing and technology de-risking, thereby leveraging further investment and enabling progression towards the marketplace.

The recent application for a new lease for the test site in Galway Bay, which would allow an increase in the range of new novel marine technologies that can be tested at the site, was successful. The SmartBay test site will underpin the growth of the marine renewable energy and sensor technology sectors in Ireland.

To the north of SmartBay, work by SEAI is in hand to develop, on a phased basis, a full-scale test site (Atlantic Marine Energy Test Site, AMETS) at Belmullet in County Mayo. Although there is no device at present which could survive at AMETS in winter (at least!), it is a smart investment in the future and *'successfully tested at AMETS'* could well become a vital marketing tool in ocean energy globally.

The most important recent policy development in Irish ocean energy was the publication of the *Offshore Renewable Energy Development Plan*[18] (OREDP) in February, 2014. The OREDP contained a number of new initiatives including extra financial support, an initial market support tariff for wave and tidal energy etc. It is being implemented by a Steering Group of officials representing all relevant Departments and agencies.

Financial support for ocean energy overall by Government has increased in recent years e.g. SEAI recorded support for project no.100 early in early 2017 and has expended €14m + to date in support of those projects. Policy work continues apace e.g. the recent consultations on tariff supports for renewables[19] while a mid-term review of the OREDP is nearing to completion[20].

[18] OREDP: *Offshore Renewable Energy Development Plan - a Framework for the Sustainable Development of Ireland's Offshore Renewable Energy Resource* Department of Communications, Energy and Natural Resources, February 2014. The Plan deals with offshore wind energy as well as wave and tidal energy

[19] https://www.dccae.gov.ie/en-ie/energy/consultations/Pages/Renewable-Electricity-Support-Scheme-Design-Consultation.aspx

[20] https://www.dccae.gov.ie/en-ie/energy/consultations/Pages/Public-Consultation-on-the-Draft-Mid-Term-review-of-the-OREDP.aspx

The main State funding for ocean energy companies has been provided by the SEAI Prototype Development Fund (PDF) and this has met the needs of the industry to date. The OREDP envisaged up to a further €30m being injected into the industry from about 2018 through to 2020. Some of this would, of course, be required to meet the ongoing investment needs of the various test facilities and the balance would be directed to fund projects under the PDF (and a forthcoming Pre-Commercial Technology Fund (PCTF) – see below).

The MRIA, in a paper published in late 2015, called for the establishment of a Pre-Commercial Technology Fund (PCTF), which would complement the PDF. The PCTF would broadly mirror the approach of Wave Energy Scotland (WES) but with modifications based on Scotland's experience and Ireland's needs. Most importantly, the PCTF should complement, not duplicate, the work of WES. The document proposed that SEAI utilise an SBIR[21] mechanism to seek solutions to various issues (focused, but hopefully not exclusively, on wave energy) via a series of competitions and the provision of 100 % funding.

SEAI commissioned consultants to help them design an appropriate PCTF for the Irish market. The consultants (MRIA has been interviewed) reviewed a range of funding mechanisms (SBIR, Grants, Prizes etc) to ascertain which is most suitable for progressing Irish technologies to the next stages of TRLs and what levels of funding are required to get access to AMETS and beyond. It is envisaged that PCTF will be launched in 2018.

In addition, it is understood that the European Commission will launch a Call soon under Horizon 2020 to run an EU wide PCTF -like scheme. Irish officials have indicated that it is something that they are closely watching and are lining up appropriate partnerships in anticipation of the Call. There will be a challenge to coordinate all of the three approaches – WES, PCTF and 'EU PCTF' – but, nonetheless, the approach is to be warmly welcomed, as it will bring extra funds into the industry. In regard to the PDF, it will continue to fund prototypes and its (intentionally) wide terms of reference mean that the funding offered is flexible for a wide range of TRL developments.

Despite the progress recorded above, there is still much policy and practical work to be done. Most pressing of all, the 'consenting' legislation to support marine economic activity such as ocean energy must be updated via *the*

[21] Small Business Innovation Research, a mechanism whereby a State body can procure pre-commercial innovation solutions to issues

Maritime Area and Foreshore (Amendment) Bill which is reportedly imminent (as it has been in each legislative session since at least 2011!) and which, once more, is on the Government's legislative programme for this session.

In Northern Ireland, the home of considerable expertise in the marine, e.g. Harland & Wolff Heavy Industries, the first offshore leasing round has taken place and two significant tidal projects (100 MW each) were among those selected. However, the current focus of British energy policy to secure lowest possible cost renewables has militated against MRET and it will be interesting to observe how this ultimately plays out. Significant R & D work continues to be recorded in Northern Ireland e.g. under the *Centre for Advanced Sustainable Energy* (CASE) at Queens University Belfast.

3.3 MRIA Policy Studies

This paper is the eighth in a series of studies into long-term development issues in ocean energy undertaken by the MRIA.

The first of these dealt with the third-level education needs[22] of ocean energy and led directly to the establishment of a Master's degree in engineering focused on ocean energy executed jointly by a number of institutions (led by University College Cork - UCC) in both Ireland and Northern Ireland.

The second study reviewed research and development in ocean energy in Ireland[23] and was published in September 2012. It identified a series of five research priorities in ocean energy, both for the research community and, also, for those engaged in the allocation of research resources.

The third study examined the supply chain for ocean energy[24] in Ireland and was published in June 2013.

The fourth Paper was published in December 2013 and dealt with the potential for co-operation between Ireland and Scotland in ocean energy[25].

[22] *Third-Level Education Needs of the Ocean Energy Industry – to maximise the job and income potential of Ireland's ocean energy resource* MRIA August 2011

[23] *Research and Development and Ocean Energy- A Review of Research and Development in Ocean Energy in Ireland* MRIA September 2012

[24] *The Supply Chain for the Ocean Energy Industry in Ireland – Discussion Paper* MRIA June 2013

[25] *The Opportunity for Co-Operation and Collaboration between Ireland and Scotland in Ocean Energy* MRIA December 2013

The fifth Paper dealt with the maritime infrastructure needs of ocean energy[26] and was published in December 2014 and focused on ports in particular. A key recommendation was that preliminary planning should commence for a port facility in Mayo which might be needed in the 2030s.

The sixth paper was published in February 2016 and dealt with funding the development of the ocean energy industry in Ireland and its core recommendation, the creation of a Pre-Commercial Technology Fund, has prompted interest in official circles[27].

The seventh paper was published in February 2017 and dealt with the non-technical barriers to the growth of Irish ocean energy[28].

All of these Papers (and others on subjects such as initial development zones, consenting etc.) are available on the Association's website, www.mria.ie .

4. Terms of Reference

There is a broad consensus among the frontline agencies and industry groups in Ireland (but also in Northern Ireland, Scotland and elsewhere) about a major roadblock to the development of ocean energy: generally, the companies engaged in ocean energy device and sub-system development are too small to attract the resources, key staff and other requirements to build successful enterprises.

This is important for several reasons. The three jurisdictions together are the global centre of the nascent ocean energy industry and even companies located in other areas with wave and tidal resources (such as Scandinavia and France) are drawn to working with these capstone countries. Moreover, there is emerging frustration among policy-makers and potential customers alike at the perceived slow progress on developing wave and tidal energy convertors to high Technology Readiness Levels e.g. TRL 7/8. In addition, (partial) alternatives to ocean energy are increasingly vying for policy-makers attention and money as well as potential customers' orders. Most notable here are solar energy and fixed offshore wind.

[26] *Maritime Infrastructure Development Priorities to Support Ireland's Future Ocean Energy Industry* MRIA Discussion Paper December 2014

[27] *Funding the Development of the Ocean Energy Industry in Ireland-Discussion Paper* MRIA February 2016

[28] *Non-Financial and Non-Technical Barriers to the Development of the Ocean Energy Sector in Ireland-Discussion Paper* MRIA February 2017

In late 2015, representatives of development agencies[29] from several EU regions, a utility[30] and a trade association[31] met to discuss the progress of ocean energy. The participants agreed that the sector was being held back by the focus on solving problems by individual companies and by a generally weak value chain. The group concluded that collaboration on innovation (e.g. to sort out the technology development element of ocean energy's value chain) between companies and the involvement of firms from other industries (i.e. bring related industry value chains to bear) was a key to moving European ocean energy forward. It was decided to establish the *Ocean Power Innovation Network* (OPIN) on a pilot basis. The original partners have been joined in this project by others, including new partners from France and Sweden. As the project develops, other European innovation actors, clusters and intermediary organisations with an interest in ocean energy, or in related sectors which could contribute to building a new ocean energy value chain, will be sought for collaboration projects and for the expansion of the OPIN network.

The original founding bodies have acted as a temporary steering group for OPIN and have organised three OPIN Symposia and one Cross Sector Workshop to date. *OPIN Symposium Dublin* (September 1st 2016) was about introducing OPIN and its approach to ocean energy and a number of case studies in collaboration were showcased e.g. the Industry Research Development (IRDG) group told the story of their innovation group while Siemens spoke of their experiences in collaboration and innovation. *OPIN Symposium Edinburgh* (December 1st 2016) dealt with the 'learnings', in different areas such as operations and maintenance, for ocean energy from other industries – drinks, aerospace and oil and gas. *OPIN Symposium Belfast* (March 9th /10th 2017) initiated a Share Fair (brokerage between companies) and, also, the OPIN Linked In group. It involved a site visit to a real collaborative project (which had been prompted by a meeting at OPIN Symposium Dublin) between two companies, QED Naval and Cimpina. Speakers experienced in high-end innovation (Bombardier) and a range of marine renewables projects (e.g. B9) spoke at the main event. *OPIN Cross Sector Workshop Aberdeen* (June 14TH 2017) was the first OPIN event focused on briefing and networking with another sector – oil and gas. The event was designed to attract the oil and gas value chain where there is perceived potential for collaboration with ocean energy. It involved a series of

[29] Principally, Sustainable Energy Authority of Ireland (SEAI), Scottish Enterprise and Invest Northern Ireland (InvestNI)
[30] Ireland's ESB which promotes the NER 300-supported WestWave project to develop a 5MW wave array off the Irish west coast
[31] Marine Renewables Industry Association (MRIA)

briefings, discussion groups and networking sessions about ocean energy – the current R&D effort, the way in which the ocean energy supply chain works and updates on the latest ocean energy projects such as MeyGen, Open Hydro and WestWave.

The current pilot OPIN model does not have the resources or delivery structure and capacity to achieve the objective set out above of prompting Europe wide collaboration on innovation. EU funding support – which is being sought - would allow scaling up of activity, an effective delivery structure and strong partnership working across the countries / regions, increasing the opportunities for learning from cluster and cross-sectoral models which have worked in other countries, and enable both wider and deeper engagement with and between SMEs and other innovation actors. The attendance at OPIN has steadily increased from about 50 in Dublin to about 80 in Aberdeen with the attendance largely drawn from industry.

In short, the ocean energy sector in Ireland – and in Europe generally – must find practical solutions to the related company and technology development problems or face a huge challenge: either industry in other parts of the world will take the lead (and win the well-documented jobs and wealth creation prizes) or other forms of renewable energy may come to dominate and leave little space for ocean energy even when its technology eventually matures i.e. becomes a reliable source of electricity at competitive cost levels. The thinking behind OPIN has a distinguished heritage. For example, the (oil and gas) collaboration called CRINE in the 1990s is credited with leading to a 30% reduction in the cost of new offshore projects[32] in Scotland. The EU is supporting collaboration projects along the lines of OPIN in other fields such as PERMIDES[33] which funds innovation partnerships to digitalise biopharmaceutical R&D.

The purpose of this study was to identify the ways and means of tackling the twin aims of building capacity to innovate and collaborate and seeking solutions to common technical challenges…beyond initiatives such as OPIN (in which MRIA is deeply involved) already in operation.

The support of the Sustainable Energy Authority of Ireland for this project is gratefully acknowledged. In the light of SEAI support, this paper was written with a Republic of Ireland emphasis to it. However, it should be noted that the

[32] *What can we learn from CRINE?* Digital Energy Journal, August 2015
[33] www.permides.eu

Association is an all island one and this is reflected in the make-up of MRIA's membership.

5. Strategic Issues Explored

The Association undertook a review of the issues outlined at 4 during 2017 in interviews, on a face to face basis in most instances, with a wide spread of interests, particularly in Ireland and the United Kingdom. A list of those companies and institutions interviewed for this paper is contained in Appendix 1.

The interviewees were probed about the background to their companies, their criteria for success and their role models. Each interview then went into the collaboration and innovation experiences (if any) of each interviewee (company), attitudes to the key issue of Intellectual Property Rights (IPR) as well as their views on collaboration with some emphasis being placed on their experience and opinion of the OPIN initiative. The overall purpose was to exam the collaborative and innovation 'life experience' of each interviewee to serve as an input and backdrop to new ideas about how to tackle the issues which are the subject of this Paper and to do so in additional and novel ways. It is important to note that those interviewed ranged from start-up ocean energy enterprises to major multinationals such as 3M.

In line with the normal practice in MRIA Papers, direct quotes are given anonymously. However, a record of most views – over 280 substantial views were recorded by the Association in the course of preparing this Paper – is set out at Appendix 3[34]. Typically, just a handful of 'voices' is quoted under each heading in the main body of the Paper below.

6. Issues and Views

6.1 View of Ocean Energy

Companies and other interests engaged with ocean energy tend to be a mix of pioneers, entrepreneurs and scientific explorers. They continue to be quite optimistic about ocean energy despite the financial struggle almost all enterprises face at this early stage of a new industry, a major new technology, and they tend to hold the same views from year to year, focusing on the 'old reliables' as the following selection of views illustrates.

[34] About 20% of views are omitted altogether because they are too company specific or because they are commercially sensitive. All views, however, are on file with MRIA.

'The challenges for ocean energy are market, technology and, in Ireland, the current lack of a modern consenting system'

'Ocean energy is like the first generation of the Ford Fiesta and our products cost at least ten times what the mature models will turn out to cost'

'All it will take is for one ocean energy device to work and everyone will pile in again to the sector'

'The good news is that EMEC is full and has a good pipeline'

'Ocean energy projects need persistent, consistent industrial capital to get done'

'The biggest obstacle to ocean energy is that we don't have basic technology solutions which are reliable and robust for Wave Energy devices'

6.2 Collaboration on Innovation

There is understanding about the importance of collaboration although some interviewees struggled to figure out a practical set of steps to deal with it:

'*The biggest problem in ocean energy is the lack of collaboration between technology developers e.g. Aquamarine and AWE should have collaborated in some way as they were both going after the same solutions'*

'In ocean energy, it helps nobody that pockets of people are doing their own thing'

'Companies in ocean energy are too small. Most of the device developers don't have the skills to do the job properly; they want to get devices in the water too early. Many developers think that they can develop great intellectual property but are not in a position to defend it'

'Formula 1 car racing has improved a lot in terms of sharing recently e.g. rebadging of engines. The majority of F1 innovation comes from a secretive place but sharing of, notably, engines was necessary to keep the industry alive'

'There was a second epoch to ocean energy involving such companies as Pelamis, Wavebob etc and we now need to create a third epoch – at present, we see a lot of people reinventing the wheel but we need collaboration. The whole IP issue is driven by VCs'

6.3 Lessons of Collaborative Experiences

Views were sought on the experience to date of companies of collaboration and what made this element of the exercise particularly interesting was the views of the non-ocean energy companies who typically had significant experiences to draw on:

'The Global Wind Alliance was the first big collaboration and it worked because it brought together component suppliers to the after-market (not OEMs) and it undertakes a combination of refurbishment and the provision of bits and pieces such as capacitors. It is well respected by the utilities. The Global Maritime Alliance didn't work because there was no industry to target, it wasn't a commercial venture'

'Our lessons from collaboration: 'you need to kiss a lot of frogs to find a Prince'! Success rate is 2 or 3 out of every 10 projects at best'

'Collaboration does work. There can be a lot of inertia in projects – they can be hard to get moving, arrange meetings etc; passive partners are an issue – a lot of people just get involved in collaborative projects to get the grant and are not interested in the project per se'

'Lessons of our experience in collaboration and innovation: it's all about the idea; does the partner with the idea know the market? Big issue is later on when market access arises – big partner has the access and wants most of the profit; we are open-minded on IP issues'

'Choice of partner: must have strong balance sheet, extensive international reach and technically competent with solid support expertise'

'Measures of success: orders for participants; access to larger companies; and credibility bestowed on SME members; and 'onshoring' i.e. stuff being done locally that was previously bought into Northern Ireland'

'The lessons of our past collaborations? Your ideas must benefit others without benefit to you. if you don't collaborate, your door will be closed; companies generally are too small to have a separate voice that will be heard e.g. by large companies; and you will value other peoples' mistakes; big companies will only regard you in a customer/vendor manner and not as fellow collaborator and partners'

'Lessons of our experience? Vertical collaboration is easy. The real issue relates to competitors collaborating and concerns about 'stealing' of IPR'

Interestingly, a number of the ocean energy companies interviewed identified role models, particularly with a view to collaboration on innovation:

'Role models? RPS and 'WET Labs (Seabird Scientific Inc)'

'OpenHydro are our role model – they have survived and have a very well-developed strategy'

Our ideal collaboration partner would be Wavestar in Norway'

'The ideal partner? Someone with a strong balance sheet behind them e.g. Schottel; Atlantis; OpenHydro.'

'Model company for us is Denroy which is an SME; identified an area of interest to themselves; and they have a clear idea of how their technology could evolve'

6.4 Intellectual Property Rights

Surprisingly, even among ocean energy company promoters, the seeming focus of many small ocean energy companies on Intellectual Property Rights (IPR) are a source of frustration (as they are, perhaps in a low-key way, among policy-makers too):

'IPR is generally overrated, money down the drain, a lot of nonsense. Companies should focus on differentiating themselves in the marketplace by being there first and having a clear view as to who the clients potentially are and what service do they want…and then you have to deliver'

'The IPR issue is about ownership and exploitation and, in fact, by following the IPR route all you are doing is telling the world what is in it; it may be better to keep the 'secret sauce' secret and to keep a project moving'

'IP is a hypersensitive issue. Lessons from various projects are not being shared'

'Lot of devices are similar and differ only in detail – they are not necessarily patentable ideas'

'There are a number of lessons of our experience. First, IPR. This is perceived as more of an issue than it is in practice. If IP is jointly generated, then it defaults to the university who, however, must offer their industry partner a license within 6 months of the project (concluding). Again, to illustrate the point, only one patent has been registered to date. However, IPR could be a big issue going forward and the policy is being reviewed now. Second, projects must be truly industry driven or they will be academic in direction and execution. Third, it is vital to manage expectations between the academic and the industrial sides'

'IPR is a badge of honour, it is expensive and badly understood! It is very difficult to get to the point of total protection…. we have never sought patents as a consequence'

6.5 Attitudes to Ocean Power Innovation Network (OPIN)

Interviewees' views on OPIN were sought and even non-ocean energy companies were enthusiastic about the venture:

'OPIN brings people out of their comfort zones'

'OPIN needs to move the sector along the development path'

'OPIN needs to challenge developers' assumptions – the technology developers in ocean energy are all living in bubbles and concealing their views and knowledge'

'Ocean energy companies can't do everything and there is a lot to be learnt from oil and gas in that regard'

'A lot of OPIN's benefits are intangible'

6.6 TASKS FOR OPIN

An ambitious range of tasks was prescribed for OPIN:

'Future OPIN sessions could include coverage of health and safety; insurance; the whole issue of deployment'

'OPIN needs to take the lead in making brand-building happen'

'The bit that is missing for OPIN is projects. Pick three headings under thematic areas e.g. biofouling; acoustics. Form teams, run workshops etc – use OPIN to develop projects to develop projects to trial new coatings for instance. Bring different sectors together to solve problems'

'OPIN should run targeted workshops to identify problems and then work up projects for funding support'

'Should focus on technology developers in OPIN and there is a need to look at the innovation process e.g. an OPIN day on product design'

'Priority technical issues for collaborative projects: survivability; PTO; materials – steel and concrete v new materials'; controls; resource characterisation – need to have strong data for bank financing etc'

'OPIN is a good networking Forum and focused on industry. Focus it on business issues and not just technical ones'

'The technical priorities for OPIN are: design for installation (installation is where the big costs are); the installation process e.g. station keeping; engineering of installation; efficiency issues e.g. oil and gas 12 hours on/ 12 hours off does not work for tidal installations where the working day would have to be broken up to match the tides'

'OPIN would be great at providing a 'dating agency' type service and could manage confidential issues too; other challenges for OPIN include how to tap into cross boundary innovation e.g. get oil and gas experts and consultants engaged, how to get supplier to the oil and gas industry involved with ocean energy issues such as mechanical connectors'

'OPIN: key features should include a protocol between the various agencies involved; one agency does courses on behalf of all participant; build in a business model characterisation element e.g. involving a session on Lean Business Models which allows groups to validate what they are about. Companies need to see companies get business out of OPIN and companies should dictate where OPIN goes'

'A big idea for OPIN is to look into which type(s) of machine is best, which machine class is best…little done by way of comparative studies'

'In favour of OPIN in principle but not clear as to how to optimise, how to get the right organisations and people involved; how to pick winners'

6.7 Open Innovation

MRIA was surprised by the interest in, and indeed consciousness of Open or Ecosystem Innovation (see 7) among those interviewed:

'An open ecosystem innovation set-up for ocean energy would be a great idea. Canadian zinc company did this at the very start of the internet- sought views on where exploration holes should be drilled …worked out very well'

'Ecosystem innovation is a good idea…Siemens do Challenges; Ryanair is doing the same'

'We learnt that technology development requires a pooling of the 'smarts' and you should find ways e.g. create an innovation ecosystem to open up OPIN'

'Ecosystem innovation is an interesting concept. Tidal is (or will be) consolidating into a handful of companies'

Collaboration…. involves crowd sourcing. A Problem Statement is inevitably brought to a Special Interest Group by a company seeking a real tangible solution by tapping into the experience, expertise of the Group. The collaboration area requires a soft, non-sensitive topic or two to start with'

6.8 Wave Energy Scotland Approach Lauded

In the course of discussions about collaboration in innovation, the extent of support for the *Wave Energy Scotland* (WES)[35] approach was noteworthy. To some extent the conversations mixed up support for the collaboration fostered by WES's policy approach and the level of funding support involved!

'Lessons learnt; we were naïve at the start; learned via our Wave Energy Scotland experience about engineering process…lots of useful workshops and seminars'

'In wave energy, we work with individual companies but really a Wave Energy Scotland approach is required – competitive funding for collaborative projects aimed at technical barriers'

'WES now doing their job better than was first the case which is understandable as they were thrown together because of the failure of Pelamis. They were very prescriptive at the

[35] See [35] *Funding the Development of the Ocean Energy Industry in Ireland-Discussion Paper* MRIA February 2016

outset but there is a different way of pulling together Calls today are 'landscaped'- WES understand the state of the art, they figure out what innovation can deliver and then formulate their Calls.'

'WES's stage gate approach is entirely sensible and includes a technical assessment process e.g. by the ORE Catapult. You have to take a system engineering approach in ocean energy – how to design, deploy, monitor, how to work in an array and how to monitor. If we just focus on PTO, materials etc, we can't answer these questions'

'Post Aquamarine, the Scottish Government stood back and asked 'what is needed to get the technology working?' The result was Wave Energy Scotland (WES) who have since become bullish on collaboration and their process e.g. competitions encourages collaboration'

'WES only brings technology up to TRL 8 or so. That is still far too early for private capital as technology still early stage, market unclear'

'We are now seeing a lot more established industrial firms involved in WES consortia which typically involve 3-5 companies. There is no doubt that the formation of a consortium gives a much greater chance of success to a project in marine renewables'

6.9 WAY FORWARD

In looking at the way forward in general for ocean energy, interviewees either went for 'big bang' solutions which may not be practicable (because, for instance, there is not yet a widespread appreciation of the medium-long term ocean energy opportunity which could translate into political support for a major transnational initiative) or for small-scale solutions particularly revolving around island communities:

'Break the mould, put up a €50m prize for the first working 2MW device'

'This industry requires a role model like DARPA or ITER - a big, well-funded multinational programme with a long-term perspective'

'The way forward really is to have public funding of a working array'

'Ocean energy needs a proper committee sitting for six months on the state of the industry. This would establish the position for each class of WEC and TEC and identify the best platforms for innovation….it would not be a Pandora's box. Such an approach would distil progress to date, frame issues and give a prognosis of where ocean energy is going and should go'

'The immediate way forward for small companies in marine renewables lies in focusing on opportunities in niche operation (e.g. the Barents Sea) and be part of an integrated system (i.e. hybrids – wind and wave)'

'Island communities etc niche opportunities for ocean energy are just that- niche opportunities. We need a competitive product to sell to normal scale utility markets'

7. Overview and Conclusions

The issues which are the subject of this Paper were put to interviewees – who were drawn from a diversity of backgrounds and experiences – in an open-ended fashion and the responses, therefore, were not pre-determined by the questions! Set out below is an overview of what was fed back by stakeholders.

First, the general perception of the 'industry' is positive with growing optimism about tidal and concern about wave particularly about the lack of technology convergence, an issue which also arises elsewhere, and about what has been diplomatically called the '…. lack of clarity about cooperation in the sector'[36]. What wasn't stated by interviewees is almost as important: the need as perceived by MRIA, for tangible signs of progress such as a range of wave devices 'in the water' at test sites (even if these sites are outside of Ireland) to ensure ongoing broad 'political' support (at policymaker level i.e. officials as well as politicians) which, in turn, leads to resources such as State grant schemes for the industry.

There is support for the concept of collaboration without necessarily understanding how this can be achieved beyond the OPIN initiative and without necessarily understanding that a development policy focused on collaborative innovation has profound implications for company behaviour, particularly in the sensitive field of Intellectual Property Rights.

Intellectual Property Rights policy is a very important roadblock to developing collaborative ocean energy development. Large organisations and those with experience in them are clear about how it can be a distraction, expensive to get and difficult to defend……while, in many instances, failing to eschew their own firms' rights to protect IPR! Small, entrepreneurial firms on the other hand are often quite fixated on IPR to the frustration of at least some stakeholders in ocean energy. The way forward clearly lies in firm IPR guidelines from funding bodies at least to set out a clear (and mandatory) pathway for grant-aided collaborative innovation groupings.

The Ocean Power Innovation Network received a heartening and decisive vote of support from all interviewed. It is seen as a major networking platform and there is a clear appetite for OPIN to move on to substantive *technical* issues by way of workshops, working parties etc. Generally, interviewees did not

[36] E.g. *Study on lessons for Ocean Energy Development* ECORYS and available at https://publications.europa.eu

highlight the scope for OPIN to catalyse real inter-company collaboration…….so far OPIN has not won EU funding support (which is fundamental both financially and as a signal to the wider policy making community about ocean energy and OPIN) which would support the structures and programmes necessary.

Wave Energy Scotland is a recurring theme, a leitmotif, of many conversations about ocean energy and clearly the key features of WES (including focus on problem-solving rather than energy convertor devices per se, collaboration requirements and, of course, 100% funding) are appealing. The Irish Government has a similar scheme under consideration (see 3.2 above) as does the EU. The early introduction of a Pre-Commercial Technology Fund (the mooted 'Irish WES') would give a boost to the sector and improve Ireland's international ocean energy image (impacted by the slow progress on consenting legislation).

The suggestions about the 'way forward' for Irish ocean energy are interesting but, in many instances, lie in the medium term. There are other, perhaps more banal issues to deal with first such as PCTF, consenting etc

In conclusion, MRIA believes that there is a broad understanding of the development issues affecting ocean energy and support for initiatives such as OPIN and PCTF required to move them on. There is perhaps less understanding that the development of new energy forms or applications can be a lengthy process and the historical record demonstrates this well in regard to the energy sphere…. but it also enables us to plot where we are and points strongly to what happens next.

The literature[37] suggests that ocean energy is in the 'formative phase' which is characterised as an 'era of ferment' with 'intense technical variation and selection, initiated by technological breakthrough and culminating with the emergence of a dominant design……the number of firms increases while sales remain relatively low'[38]. This is the stage ocean energy is going through today.

The next phase typically sees a transition from experimentation and pilot products to an upscaling stage which can see big increases in unit size of a technology and a reduction in the number of 'actors'. This is the phase which fixed offshore wind went through from the late 1990's. The first commercial

[37] Captured particularly well in *Measuring the duration of formative phases for energy technologies* Bento and Wilson published in *Environmental Innovation and Societal Transitions Journal 2016*
[38] Op cit at 1.

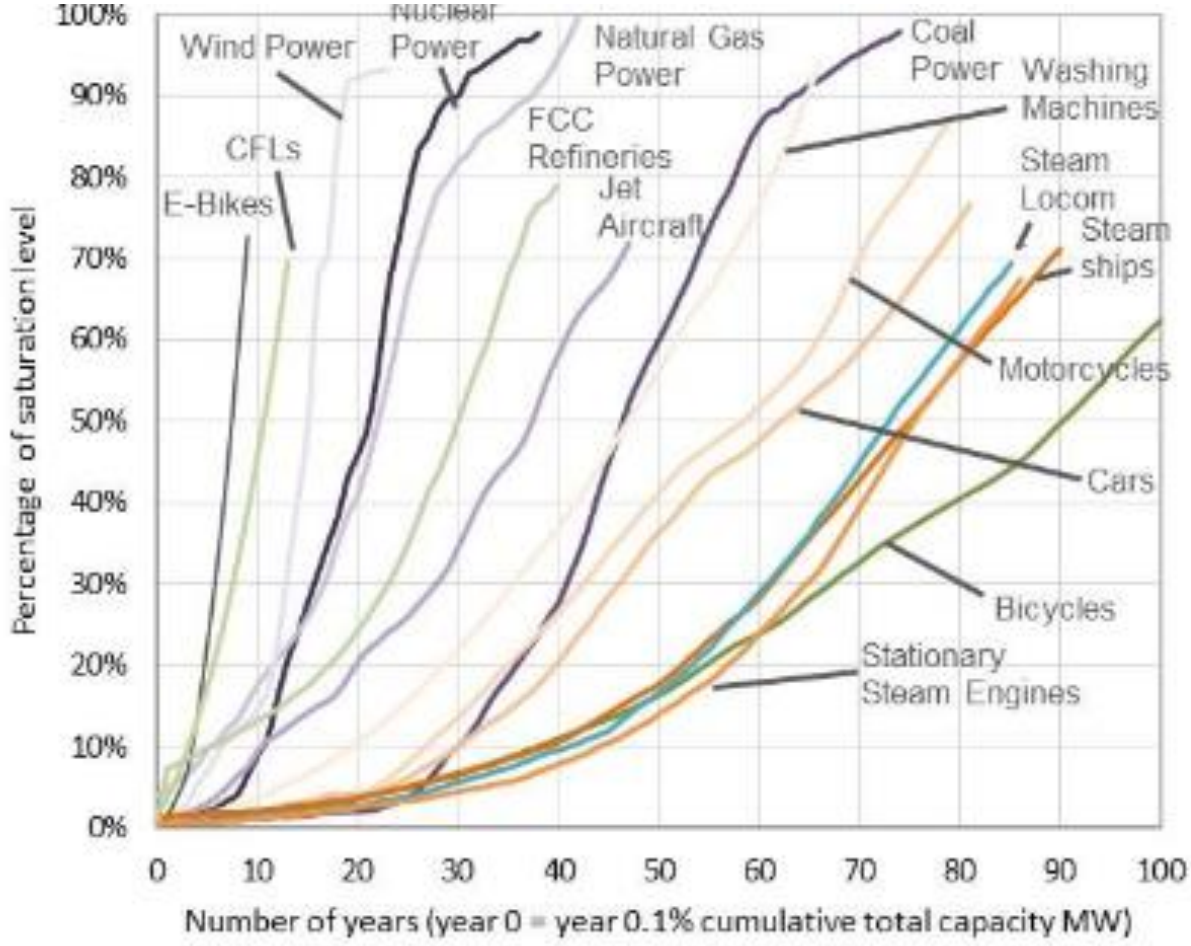
offshore wind farm of just 40MW located at Middelgrunden in Denmark opened for business in 2000……. and, just 17 years later there were 3,589 offshore wind turbines (at the end of 2016) in European waters with a total installed capacity of 12.6 GW (representing over 150% of the total installed electricity generating capacity from all sources on the island of Ireland). Even more impressive is the fact that at the end of 2016 a further 4.95GW was approved for installation at a total cost of €18.2bn[39]! The ECORYS report referenced earlier suggests that a concentration on sub-systems (the Wave Energy Scotland approach) will move wave energy in particular in this direction[40].

The offshore wind experience indicates that once the transition from 'formative' to a mature setting takes place, the growth in ocean energy and the creation of jobs and income in first mover nations (Ireland could be one) and those with the feedstock e.g. energy intensive waves (e.g. Ireland) could be of historical importance and impact.

There are established indicators of the start of the formative phase of a technology e.g. such as first 'embodiment of technology' and first 'commercial application'. The end point indicators include number of units produced and upscaling[41]. Applying this approach to a sample of 15 technologies, as illustrated in figure 1, shows the significant length of time it takes to bring new technologies to fruition:

[39] https://windeurope.org
[40] ECORYS op cit
[41] Bento and Wilson op cit at 3.1-2

Figure 1[42]



A similar point is made in Table 1[43] below which illustrates the length of the formative phase for a variety of energy technologies e.g. natural gas power's formative phase could have taken up to 71 years! But, encouragingly, the mean and median figures for the formative phase for all technologies is in the region of 20 years -more detail is offered at Appendix 2 and is in line with research which indicates that the speed of diffusion of new technologies has speeded up over the past century[44]

[42] Op cit at 4.1
[43] Op cit at 4.2
[44] Op cit at 4.3

Energy technology	*Central estimate*	*Longest estimate*
Stationary Steam Engines	85	168
Steamships	19	114
Steam Locomotives	21	96
Bicycles	25	83
Coal Power	9	79
Natural Gas Power	25	71
Cars	23	82
Washing Machines	15	58
Motorcycles	21	71
Wind Power	15	115
E-Bikes	35	114
Jet Aircraft	7	40
FCC, Fluid Catalytic Cracking (refineries)	4	5
Nuclear Power	13	22
Mobile Phones	14	55
CFLs, Compact Fluorescent Lamps	20	27
Mean (all technologies)	**22**	**75**
Median (all technologies)	**20**	**75**

However, the encouraging 'news' for ocean energy is that the research to date does not take into account the impact of 'systemic conditions (e.g. investment in the production chain, supportive institutions) that accompany the emergence of new technologies'[45]. There is investment in the Irish ocean energy production chain e.g. the various R&D and test facilities and, as was touched on at 3.2 above, the institutional framework is both supportive and proactive.

Moreover, most important, research into innovation shows that '……institutional context was found to be *decisive* in the formation of new technologies' e.g. jet aircraft whose formative phase was squeezed into the World War 2 as a result of demand (from Air Forces seeking an advantage over

[45] Op cit at 1.

opponents) and technology push (resources concentrated on solving the engineering issues involved).
Thus, well documented history strongly suggests that ocean energy is in its formative phase and that current time horizons envisaged for ocean energy e.g. tidal energy being deployed from c2025 and wave energy from c2030 are in line with historic data and trends for *energy technologies.* It suggests too that the direction of policy ('institutional context') – support for R&D/test facilities, increased funding, innovation initiatives etc – is correct and should be stepped up. However, past experience offers a cautionary tale about efforts to accelerate the commercialisation of ocean energy – 'Policies pushing to commercialise pre-mature (energy) technologies by picking a technical design or shortcoming key formative processes can result in failure'[46]. Examples included the traumatic 'Growian' experience in wind in the 1980's which almost put paid to the German wind industry for good[47] and, in ocean energy, the experiences of Pelamis, Aquamarine Power and Pelamis. Hopefully, ocean energy won't need to emulate the experience of the Dyson vacuum cleaner whose bag-less technology took 15 years and 5,127 prototypes to perfect![48]

8. Recommendations for Further Initiatives

Notwithstanding the views expressed at 8. about the generally correct course of Irish ocean energy, there is, nonetheless, a potential 'Bermuda Triangle' into which all of the effort to date and the future promise could disappear or at least be marooned!

8.1 Ocean Energy's Potential 'Bermuda Triangle'

First, in the view of MRIA, Policy has some shortcomings noticeably, the lack still of a modern consenting regime and the need for 'early wins' e.g. getting the SmartBay site in Galway fully activated again; sorting out an appropriate support tariff regime for all Marine Renewables Emerging Technologies; and the introduction of a Pre-Commercial Technology Fund. However, policy-makers are well aware (not least because of MRIA representations!) of these issues and progress is happening. 'Policy' is a relatively strong point on the 'Triangle'.

[46] Op cit at 5.
[47] Growian –derived from the German word for 'wind-powered device' – was a pioneering 3MW wind turbine built by MAN in the early 1980's. It had a 100m tower, a 100m rotor diameter, a nacelle that weighed as much as a jumbo jet and the overall project cost €75m! Growian worked for 1% of its life and was closed in 1987. The influential *Der Spiegel* commented that 'We built Growian to prove that it cannot be done!'
[48]

Second, there is a now well-established need for collaborative innovation which arises from the complex technical challenges posed by ocean energy and the sheer capital intensity of the industry – it is unlikely (but perhaps conceivable) that a start-up which follows the usual stand-alone journey of a start-up can 'crack' ocean energy. Again, there is scope for comfort as Ireland is a leading light in the OPIN initiative…. but there is a need for more ingenuity in attracting new entrants – individuals and companies from outside the sector – into ocean energy collaborative innovation.

Thus, there is a need for continuous communication and pressure on the policy front and an urgent necessity to develop not only OPIN but also other avenues leading to collaborative development. But it is the third corner of the 'Triangle' which could be fatal: the small scale of the Irish ocean energy firms (notable exception: OpenHydro which is now part of the large French *Naval* group), particularly as the Republic of Ireland has modest tradition of mechanical and electrical engineering and, therefore, a limited number of potential industrial partners in these fields.

8.2 Irish Ocean Energy's Unique Challenge

There is a need for further initiatives for both weak points in our 'Triangle' and possible solutions often link the two. The remainder of this section of the Paper concentrates on conceivable additional initiatives for scaling small companies and for collaborative innovation.

Ireland, similar to other European countries, has a complex tapestry to support new companies in manufacturing and internationally traded services. These may arise from university spin-outs (e.g. from students and staff associated with the MaREI[49] consortium led by UCC – Exceedence Ltd[50] is a leading example) or one of the other centres of scientific excellence supported by Science Foundation Ireland and others. New companies of small scale may get (very modest) support from the Local Enterprise Offices programme; those with high potential may be supported by Enterprise Ireland's High Potential Start Ups (HPSU) programme but the bar[51] set is high and probably beyond the reach of companies in a technology which is at the formative phase such as ocean energy. Foreign direct investment has a well-trodden and effective

[49] www.marei.ie
[50] www.exceedence.com
[51] Applicants must be capable of achieving €1m in sales and 10 jobs within 3-4 years of start-up and have an experienced management team

pathway to follow via IDA Ireland[52] but, again, it is focused on established enterprises or even young companies who have achieved early scale. Ocean energy companies can certainly tap into the various conventional development schemes and occasionally qualify for modest funding. But, apart from their own capital (typically originating from friends and family), the main source of finance for ocean energy firms are the various EU Horizon 2020 programmes and SEAI's Prototype Development Fund. To add to the issue, almost all of the companies have limited management teams or even management skills and their principal interaction with the Government agency 'system' is almost always with SEAI.

The situation in Irish ocean energy is unique for Ireland– a large number of companies relative to the world population but almost all of them are in the micro category with no clear route out; an Irish natural resource of global standing; and a potential market which if exploited correctly and at an early enough stage could be transformative in its income and job creation impact on the traditionally less well-off West coast of Ireland. It calls for a different approach.

This study is focused on ocean energy – wave and tidal. However, there are two other categories of marine renewables emerging technologies – floating wind and 'hybrids i.e. combined floating wind and wave – which should also be beneficiaries of the recommendations made below. They too are characterised by small struggling enterprises, probably involve R&D waste and can make a significant contribution to Ireland's ambitions to exploit its offshore renewables and to build a global supply chain base in the marine renewables emerging technologies.

8.3 Formal Recognition of SEAI's Development Role

Recommendation 1: The architecture of Irish development agencies is well settled and the relative turmoil (including 'turf wars'!) that can follow from any redesign[53] must be borne in mind. SEAI has no formal role in business or company development but circumstances dictate that it is de facto the development agency for early stage ocean energy companies. This informal but vital role is undertaken with the goodwill of the established agencies,

[52] www.idaireland.com

[53] The Chairman of MRIA recalls with mixed feelings the break-up of IDA Ireland into two entities in the 1990s. The domestic agency thus created was merged with the technology agency, Eolas, to form Forbairt and then subsequently merged again with the Irish Trade Board to form Enterprise Ireland which became a most effective body following significant expenditure of time and effort by the staff team on organisational issues. SEAI was originally a unit of Eolas and was eventually spun off from Enterprise Ireland.

Enterprise Ireland and IDA Ireland, who have nothing to offer ocean energy firms and the companies have nothing to offer them e.g. new jobs and exports in the relatively short- term. Ocean energy lies outside their terms of reference in most instances because of the companies' scale (the exception which proves the rule is OpenHydro which has c160 employees in Ireland and works with IDA on development issues). The two agencies cannot be expected to divert expertise to a nascent sector when their resources are limited and the opportunities and tasks (e.g. Brexit) faced by more mature sectors are so demanding.
It makes sense now to address the institutional situations so that special tools (e.g. the PCTF) to support ocean energy and indeed all emerging marine renewables technologies can be progressed without danger of duplication or confusion or, indeed, controversy. In essence what is required is that SEAI's development role, as discussed, be recognised formally and this is recommended by MRIA. The importance of the symbolism and 'messaging' for ocean energy (in Ireland and abroad) involved in this suggestion should not be underestimated. It is noteworthy that SEAI has strong development genes - it was originally set up within a predecessor of Enterprise Ireland and was spun off because of the need for an agency devoted to renewable energy as the global climate change agenda grew.

8.4 Agreed Funding Schemes and Development Tools

Recommendation 2: It is recommended that SEAI's development role should be limited – there is no desire on the part of MRIA to divert the agency away from its core and demanding tasks – to specific funding schemes (the current Prototype Development Fund and the proposed PCTF) and to specific development tools, each of which would be separately agreed.

In addition, a protocol between the agencies should be negotiated so that there is a clear 'runway' from SEAI company development support to the agencies, particularly Enterprise Ireland, once companies reach their criteria e.g. qualify for the HPSU programme. It is not being suggested that SEAI should have a mandate which duplicates the work of Enterprise Ireland or IDA Ireland but rather that it should have a special, complementary role arising from the unique circumstances of ocean energy. Moreover, the organisational and staff demands on already-stretched SEAI should be minimised with the work involved in the new initiatives suggested at the Recommendations below being sub-contracted to other bodies where necessary.

The closest analogy to what is being proposed here is *Bord Bia – The Irish Food Board*[54] which lies under the Department of Agriculture, Food and Marine rather than the usual home for development agencies, the Department of Business, Enterprise and Innovation. Bord Bia was established (not without resistance by some parties behind closed doors!) because it was deemed that the scale of the natural resource (food in various forms) and of the industry coupled with the complexity and competitiveness of mature international food markets required a dedicated organisation that largely supplements the work of Enterprise Ireland[55]. Bord Bia supports companies in a variety of ways (e.g. distributor search, branding etc), most notably in export development (normally an Enterprise Ireland role). However, investment support is dealt with by Enterprise Ireland only.

8.5 Continued Support for OPIN

Recommendation 3: The core purpose of the Ocean Power Innovation Network is to raise the value chain level – explained in figure 2 – of ocean energy companies in Europe and, as a consequence, underpin Europe's industrial lead in the sector.

Figure 2

Value Chain Level	Features
0 No real VC	Mostly small companies working alone. Slow progress of 'sector' in dealing with identified challenges. No real or evident value chain. **Ocean energy is at about Level 0.5 today.**
1 First steps to a VC	A large number of companies meet in networking spaces, some collaborations emerge but most firms not equipped to do so. External value chains start to engage with ocean energy.
2 Outline of VC emerges	Sense of identity of ocean energy value chain grows, companies gain skills/exposure and are more capable of collaborative innovation.
3 Early VC as substantial number of companies develop ideas	A range of companies start to work together and seek support on e.g. funding their development; assessing their TRL level prior to an OPIN Challenge Call.
4 Emergence of Collaborative Innovation Groups	A number of companies emerge as potential leaders, key actors in various parts of the ocean energy value chain form groups and seek out long-term solutions to value chain development

[54] www.bordbia.ie

[55] Enterprise Ireland deals with foreign direct investment in food i.e. IDA Ireland has no role because it was deemed most effective to locate the resource and expertise in one agency.

5 Basic VC with capacity to grow	The value chain is now clearly identifiable, has potential success stories in at least some parts of the chain and has some capacity for self-starting growth e.g. by attracting commercial financial support**. Level 5 is the basic level which a sector must attain before real commercialisation begins.**

The means to be employed by OPIN to attain this ambitious aim would be to create a new cross-border, cross sector value chain for ocean energy using innovation collaboration tools.

Specifically, OPIN aims to:

- Develop a joint vision among stakeholders on what needs to be tackled
- Foster networks for collaboration between SMEs and e.g. large cos, research bodies to tackle development of ocean energy's value chain
- Build the capacity of SMEs to collaborate on innovation
- Support Collaborative Innovation Groups formed to tackle OPIN Challenge Calls

Unfortunately, OPIN has not yet attracted sufficient resources to put the people, money and effort needed behind this unique inter-agency, trans-regional and trans-border EU initiative. The pursuit of funding is continuing and, in the meantime, it is recommended that SEAI and the other parties involved continue with OPIN on a scale commensurate with their existing resources. This means essentially that the current ad hoc OPIN leadership continue to organise Symposia with a focus on the themes identified at 6.5 and 6.6 above – networking opportunities and workshops on key topics i.e. seek to attain Value Chain Level 1[56].

It is recommended too that an early OPIN Symposium tackle the obstacle to development posed by many small firms' attitudes to Intellectual Property Rights. The aim should be to develop by consensus a template for adoption by collaborative groups, development bodies etc. A good starting point would be the template developed by Invest Northern Ireland for use in its Collaborative Growth Programme and also work undertaken by the EU IPR Helpdesk[57] could be utilised. There is a need to both educate entrepreneurs in particular about IPR and to adopt an IPR framework at development body level which facilitates Open Innovation.

[56] The Value Chain Levels identified at Figure 2 are the consequence of discussion between MRIA, SEAI and Scottish Enterprise

[57] www.iprhelpdesk.eu

8.6 A Special 'Accelerator' Mandatory for Ocean Energy Companies

Recommendation 4: The Recommendations above – proposals to recognise SEAI's company development role; to allow the agency to develop special funding mechanisms (the PCTF) and tools; and continue with OPIN to the extent possible with existing resources while funding for a full OPIN effort is pursued – are valuable. However, they do not directly address the weakest point on the 'Bermuda Triangle' identified at 9.1: the small scale of companies. Something special needs to be done to help the generally small or even micro sized companies *develop as businesses*.

'Accelerators' support early-stage, growth-driven companies through education, mentorship, and financing. Companies, typically at a start-up stage or level enter accelerators for a fixed-period of time and as part of a cohort of companies. The accelerator experience is a process of intense, rapid, and immersive education aimed at fast-tracking the life cycle of young innovative companies, compressing years' worth of learning-by-doing into just a few months.

Figure 3[58]

The Four Institutions That Support Startups

	INCUBATORS	ANGEL INVESTORS	ACCELERATORS	HYBRID
Duration	1 to 5 years	Ongoing	3 to 6 months	3 months to 2 years
Cohorts	No	No	Yes	No
Business model	Rent; nonprofit	Investment	Investment; can also be nonprofit	Investment; can also be nonprofit
Selection	Noncompetitive	Competitive, ongoing	Competitive, cyclical	Competitive, ongoing
Venture stage	Early or late	Early	Early	Early
Education	Ad hoc, human resources, legal	None	Seminars	Various incubator and accelerator practices
Mentorship	Minimal, tactical	As needed by investor	Intense, by self and others	Staff expert support, some mentoring
Venture location	On-site	Off-site	On-site	On-site

SOURCE "WHAT DO ACCELERATORS DO? INSIGHTS FROM INCUBATORS AND ANGELS" BY SUSAN COHEN, 2013; ADAPTATIONS BY IAN HATHAWAY

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The indications are that participation in an accelerator improves participants chances of reaching key milestones (e.g. raising capital); accelerator graduates

[58] *What Startup Accelerators Really Do* Ian Hathaway Harvard Business Review March 2016

are more likely to get their next round of funding faster than non-graduates; the value of accelerators lies in the learning environment itself; and accelerators seem to have a positive impact on entrepreneurial ecosystems, particularly in regard to finance[59]. There are qualifications to this list of positive experiences but, overall, accelerators seem to lead to generally good business outcomes for participants.

There are various accelerator experiences in Ireland and a further one is currently mooted for the marine industry generally. It is recommended that an accelerator specific to ocean energy be organised from time to time by SEAI. Ocean energy firms would benefit from learning together and the networking effect is also desirable. In particular, an ocean energy accelerator could be tailored to the needs of the industry. In due course, consideration can be given to Ireland taking the initiative, perhaps in conjunction with OPIN partners, to establish an ocean energy Global Accelerator along the lines of *Free Electrons* which involves eight utilities (including ESB) and eleven energy start-ups[60].

RECOMMENDATION 5: MRIA recommends that all applicants for support towards device or sub-system development under the Prototype Development Fund or the future Pre-Commercial Technology Fund should be required to attend an ocean energy accelerator as a condition of grant support. Such an experience will also help to prepare firms for collaborative ventures e.g. through OPIN. The process will, of course, need teasing out: what happens if an applicant is a mature firm? etc. But the principle must be firm: ocean energy is a unique opportunity for Ireland and all actors must play their part in ensuring that the maximum benefits are derived from it for Ireland. This means, among other things, fostering a robust population of Irish device and sub-system developers and they must be required, in return for State funding, to go through an accelerator to give their businesses the maximum chance of success.

RECOMMENDATION 6: SEAI does not have the staff or experience to set up and run an accelerator for ocean energy. Fortunately, there is a fellow body supported by the Department of Communications, Climate Action and Environment that does: NDRC.

NDRC was established by the Irish Government in 2007 to foster digital entrepreneurship within the economy. It does this by building and investing in

[59] Op cit Hathaway
[60] www.freelectrons.co

digital start-ups, over 220 of them since NDRC was founded. 'Our ultimate goal is to deliver a sustainable supply of globally scalable Irish digital companies, helping to create high value jobs and generate economic impact'[61].

It is a flexible and well-regarded body which works closely with Enterprise Ireland (recently examples were the successful tenders by NDRC to provide two regional accelerator programmes) and has run pre-accelerator programmes in Fintech, Healthtech and Insurtech with a variety of partners and has also worked with Accenture on its *Leaders of Tomorrow* programme i.e. it has experience of a number of sectors.

NDRC is an obvious source for an ocean energy accelerator or even a more flexible pre-accelerator programme because of its experience and credibility and its relationship with SEAI's parent Department. It is recommended that SEAI contract directly, at least for the first iteration, with NDRC for an accelerator programme specifically for ocean energy.

8.7 Crowdsourced Innovation

Recommendation 7: A recent survey of European (digital) start-ups, conducted by The Economist Intelligence Unit and sponsored by Android[62], shows that only 17% of the companies involved are self-reliant for innovation with the balance coming from Open Innovation of one type or other. Open innovation[63] involves both drawing on outside knowledge and on sharing knowledge too. Its benefits are held to include 'greater customer insight and improved commercialisation of new ideas'[64]. Open innovation embraces both collaboration of the face to face kind exemplified by OPIN – and innovation through open data, open source software and crowdsourcing platforms.

Crowdsourcing includes programmes that are close to accelerators such as the multinational firm Johnson Control's programmes *'…. Tyco's[65] innovation centres will be at the heart of this drive, combining local vibrant start up cultures with Tyco's expertise and global business to spur growth through*

[61] *NDRC Annual Report 2016 – 2017* http://www.ndrc.ie

[62] The survey and other information on Europe's open innovation opportunity are summarised in the *Economist* November 17th 2017

[63] Defined as "a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization's business model" in Chesbrough, H., & Bogers, M. 2014. Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. In H. Chesbrough, W. Vanhaverbeke, & J. West (Eds.), *New Frontiers in Open Innovation*: 3-28. Oxford: Oxford University Press. Page 17.

[64] *Economist* op cit

[65] Now part of Johnson Controls - press-release March 2016

innovation. We plan to partner with or invest in the most promising start ups with successful pilots, bringing new disruptive technologies to Tyco's products and services portfolio'. There are efforts to draw in individual new talents and ideas via crowdsourcing: GE, one of the world's largest industrial companies directly crowdsources engineering solutions online[66] and also works with crowdsourcing communities such as Quirky[67] which claims to have over 1.2m members and to have generated over 300,000 inventions. Finally, there are almost pure crowdsourced enterprises. The most interesting example is Perrinn Cars[68] which sources solutions to various car design elements, has a shared CAD system for those selected to work with the company and even has its own digital currency, COIN, to reward participants – a current task is Project 424 to build the world's fastest electric car.
The fact that Open Innovation online is becoming commonplace is significant because research shows that '….it is already challenging to create collaboration between strangers in face-to-face situations and the internet environment can make this even more difficult'[69]. Put bluntly, online innovation such as crowdsourcing is happening because companies need to do it for what are ultimately commercial reasons: low costs typically and ease of access to specialist expertise. Small companies such as those in Irish ocean energy need support to avail of it.

IRDG[70] is a long-standing Irish industry-led representation group with strong roots in healthcare and life sciences and with over 200 members. The organisation has a successful experience in arranging crowdsourced innovation based on a Member's Question Time approach. A company develops a Problem Statement and '……*A problem is placed in an anonymous format and circulated. Inevitably good answers emerge and we deal with 20-30 cases pa'*[71]

Irish ocean energy needs new participants in the sector both individuals and companies to accelerate innovation and to build companies to scale and all of the initiatives suggested in this chapter are geared to that end. It is worth trying out crowdsourcing, even at this early stage of the sector, for those reasons.

[66] See e.g. *How GE plans to act like a start-up and crowdsource breakthrough ideas* Wired 11 April 2014
[67] www.quirky.com
[68] www.perrinn.com
[69] *Motivating and supporting collaboration in open innovation* Maria Antikainen European Journal of Innovation Management, 2010
[70] www.irdg.ie
[71] Interview with IRDG

It is recommended that SEAI contract with IRDG, or another suitable body, to run a pilot crowdsourcing exercise for ocean energy companies which would require engagement (e.g. perhaps including through Engineers Ireland[72]?) with as wide a body of engineers and scientists as possible and which would require a structured effort to persuade ocean energy companies some at least of whom would be concerned with IPR issues.

[72] www.engineersireland.ie

Appendix 1: List of Bodies Interviewed

Timoney Technology
Techworks Marine
Blue Power
SmartBay
ESB (x 2 separate parties)
OpenHydro
Bluwind
Verdant Isles
MaREI
Wavepower
Johnson Controls
NDRC
Tidal Flyer
DP Energy
IRDG
Tyndall National Institute
Scottish Enterprise
Nautricity
CASE – Queens University
NIACE
B9
InvestNI
PWC
Google
Wave Energy Scotland
3M
Quoceant
Ocean Energy Catapult
Neil Davidson PR & Public Affairs
Wood Group

Appendix 2:

‘Start’ and ‘End’ (2nd table) of Formative Phase – Data

Formative Phase	INDICATOR	UNITS	STATIONARY STEAM ENGINES	STEAMSHIPS	STEAM LOCOMOTIVES	BICYCLES	WIND POWER	COAL POWER	MOTORCYCLES	CARS	E-BIKES	NATURAL GAS POWER	WASHING MACHINES	CFLs	FLUID CATALYTIC CRACKING (in refineries)	JET AIRCRAFT	NUCLEAR POWER	MOBILE PHONES
Reference Points	Invention (cf. invention lists)	Year	1707	1707	1769	1818	1888	1842	1885	1860	1897	1842	1884	1972	1929	1928	1943	1973
		Source	Haustein & Neuwirth	Haustein & Neuwirth	Mensch	Mensch	Gipe	Mensch	Van Duijn	Mensch	US Patent 596,272	Mensch	Van Duijn	IEA (2006)	Enos (1962)	Mensch	Haustein & Neuwirth	US Patent 3,906,166
Ex Ante START POINTS	First 'embodiment' of technology	Year	1712	1776	1804	n/d	1887	1878	1885	1873	1891	n/d	1904	1973	1940	n/d	1951	1946
		Model	Newcomen	Jouffroi's Palmipède	Trevithick's locomotive	n/d	First wind turbine	First power station in Bavaria	Daimler-Maybach's Reitwagen	Bollé's 1st steam vehicle	Electric tricycle by A.L. Ryker	n/d	First electric washing machine	GE invents spiral CFL	Pilot plant in Louisiana	n/d	EBR-I Idaho	First mobile phone in a car
	First application outside lab / commercial application (I)	Year	1712	1809	1824	1839	1891	1884	1894	1886	n/d	1884	1907	1980	1942	1941	1954	n/d
		Source (innov.list)	Von Tunzelmann (1978)	Silverberg & Verspagen; Haustein & Neuwirth	Mensch	Mensch	Gipe	Mensch	Silverberg & Verspagen; Van Duijn	Mensch	n/d	Mensch	Silverberg & Verspagen; Van Duijn	IEA (2006)	Silverberg & Verspagen	Mensch	Silverberg &Verspagen; Haustein &Neuwirth	n/d
	First application outside lab / commercial application (II)	Year	1712	1807	1814	1861	1891	1882	1894	1885	n/d	n/d	1908	1980	1942	1939	1954	1977
		Own Research	Newcomen	Robert Fulton's Clermont	Stephenson's Locomotion	Michaux's Velocipède	La Cour	Edison Electric Light Station	H&W motorcycles	Benz	n/d	n/d	Thor washer	Philips model SL	Enos (1962)	von Ohain's first flight	USSR's Obninsk plant	Prototype cellular system
	First sequential commercialization	Year	1717	1811	1825	1861	1977	1908	1900	1888	1970	1903	1908	1980	n/d	1952	1954	1979
		Number of Units	5	1	4	2	2	1	1330	n/d	n/d	1	n/d	100000	n/d	10	1	n/d
		Model	Newcomen	Paddle wheel and sail	Locomotion No 1	Michaux's Velocipède	Danish 3-blade (26kW)	Turbo generators	Werner (UK)	Benz car	n/d	n/d	Thor	Philips SL	n/d	Comet	APS-1 OBNINSK	First commercial system in Japan
Additional Indicators	First maximum in *public* R&D expenditure	Year	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	1971	1983	1987
		Public R&D in 2005$ million	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	11185	3963	15726

Legend: n/d (no data), not applicable (n/a)

Formative Phase	INDICATOR	UNITS	STATIONARY STEAM ENGINES	STEAMSHIPS	STEAM LOCOMOTIVES	BICYCLES	WIND POWER	COAL POWER	MOTORCYCLES	CARS	E-BIKES	NATURAL GAS POWER	WASHING MACHINES	CFLs	FLUID CATALYTIC CRACKING (in refineries)	JET AIRCRAFT	NUCLEAR POWER	MOBILE PHONES
Ex Post END POINTS	Fraction of full technology lifecycle	Year of 10%K (cumul.#)	1870	1880	1880	1922	1985	1938	1949	1937	2005	1968	1951	1994	n/d	1969	1966	2001
		Year of 10%K (cumul.MW)	1880	1890	1900	1922	1991	1957	1956	1955	2005	1976	1962	1994	1945	1971	1973	2001
	Up-scaling of unit size	Year of 10% K (max. unit capacity)	1748	n/d	n/d	n/d	1999	1928	n/d	n/d	n/d	1943	n/d	n/d	n/d	1958	1960	n/d
Ex Ante END POINTS	Market structure	Year of peak in number of firms	1869	n/d	n/d	n/d	n/d	n/d	1921	1908	n/d	n/d	n/d	n/d	n/d	1973	n/d	n/d
		Year of "shakeout" (N falls -30% from the peak)	n/d	n/d	n/d	n/d	n/d	n/d	1924	1914	n/d	n/d	n/d	n/d	n/d	1979	n/d	n/d
		Year of min. market concentration ratio (CR4)	n/d	n/d	n/d	n/d	n/d	n/d	n/d	1911	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Cost reduction	Year of first 50% reduction in cost	n/a	n/d	1855	1897	n/a	n/a	n/d	n/a	n/a	n/a	n/d	n/a	n/d	n/d	n/a	n/d
		Year of max. % cost reduction	1727	n/d	1855	1897	2002	n/d	n/d	1924	2000	n/d	n/d	n/d	n/d	n/d	n/d	n/d
		% (max. cost reduction)	30%	n/d	85%	63%	15%	n/d	n/d	25%	22%	n/d	n/d	n/d	n/d	n/d	n/d	n/d
		Description (model, mass prod.)	Newcomen	n/d	4-4-0	Safety bike	Danish model	Conventional coal PP	n/d	Ford Model T	mass prod.	Conventional gas PP	n/d	n/d	n/d	n/d	PWR	n/d
	User adoption	Year of 2.5% potential market	1802	1830	1846	1886	1992	1917	1921	1911	2005	1928	1923	2000	n/d	1959	1967	1993
Additional Indicators	Patent application	Year of first peak	n/d	n/d	n/d	n/d	1980	n/d	n/d	1897	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
		Year of start of 2nd wave of increase	n/d	n/d	n/d	n/d	1996	n/d	n/d	1914	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Production scale up	Year of 10-fold increase in production	n/a	1820	n/a	1862	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	no/n.a.	n/a	n/a
		Year of highest growth	1720	1820	1850	1862	1978	1938	1901	1946	1998	1945	1921	1991	1956	1959	1993	1980
		%	838%	3417%	560%	7000%	450%	267%	194%	328%	263%	275%	132%	42%	7%	863%	700%	33%
	Dominant design	Year	1764	1807	1829	1884	1957	1920	1901	1909	1946	1939	1937	1985	1942	1958	1970	1973
		Model	Watt engine	Fulton's Clermont	Stephenson's Rocket	Safety bike	Gedser wind turbine	Pulverized coal system	"diamond frame"	Ford T	Tucker's Wheel motor unit	BBC Velow plant	Bendix automatic wash.mach.	Electronic ballast	Fluid Catalytic cracking	B707/DC-8	LWR (PWR)	Cooper's portable handset
	User adoption	Lead user? (Yes/No)	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No	Yes	No
	Up-scaling of unit size	Year of 10% K (avg. unit capacity)	1730	1830s	1840	n/d	1990	1926	1941	1918	1990s (late)	1906	1943	n/d	1942	<1958	1961	n/d

Notes: n/d = no data, n/a = not applicable

Appendix 3: Further Opinions of Stakeholders

Views of ocean energy

'A big issue is to identify Ireland's competitive advantages in ocean energy and then to work on 'anchoring' our talent at home'

'Wave is really tough and we are still devastated by the reputational damage done by the failure of Pelamis and of Aquamarine Power'

'The universal issue with ocean energy is that people do not understand what they are doing'

'It's like with an aircraft, you don't start by designing the undercarriage. You must design tested products for the market with high TRL levels'

'There are no decent innovative established companies involved in ocean energy and that is a problem'

'Ocean energy needs to happen. The big issue is the civils (civil engineering challenges), particularly how to get and sustain devices in the water'

'Floating wind is a hard one. Offshore wind to date has not delivered what it promised. I question the economic impact of floating wind. It is hard to make an argument for floating wind – even though the potential is great because there are no wind manufacturers in Scotland'

'The big blockage is lack of a visible revenue model for tariffs as this is the one thing that investors look for'

'What would move ocean energy on? There is not enough data available on wave and tidal resources and it would improve the outlook markedly if this was organised and made available through the public agencies'

'We are in competition with offshore wind and we need solutions to our cost issues to make ocean energy competitive. Cost is everything for investors at this stage of the industry'

'Interesting to look at Seapower and Ocean Energy who have achieved a great deal on a shoestring over a long period and at Wavepower who, with considerable resources, are tackling wave energy in a methodical way. These are all companies with a good business model'

'Our investor is from an oil and gas background and the oil and gas experience helped e.g. in installation'

'Pelamis was of a time…wave supported a then-Scottish Office policy trend towards renewables. We founded Ocean Power Delivery which led on to Pelamis and we grew randomly and entrepreneurially. Friends and relatives was the route which funded the first,

1/7 scale model. We then got in VC capital and that set-in train both our future progress and our future doom.'

'Portugal, for Pelamis, was about exit for the VC……Government and Eon paid for P2 and then issue again was about shareholder exit. If had time again, we could do it in half the time and with two thirds of the money'

'Ocean energy projects need persistent, consistent industrial capital to get done'

'No role models. Pelamis spent £95m, built 6 machines and generated (?) 3/400MW+'

'Developers need companies such as Quoceant involved, people who know and understand the issues. We need to establish an industrial interest again e.g. build around a £200MWh area'

'For the past 25 years, we have had a successful product strategy and that is the key feature of success for me… we are profitable'

'Lessons of our experience: first and foremost, listen to the market and engage with it. Over 60% of our effort is at the R&D/product end with the balance focused on customers. This imbalance is why we are so small; second, have the right people; finally, have a multifunctional series of teams reporting directly in to the senior management team'

'Timoney is 50 years old this year.... The big lesson of our experience is that you can't do everything. To be a success, a company must be best in the world at something, it's the only way to gain a sustainable competitive advantage…in Timoney's case, we are experts in independent suspension systems for heavy applications and now want to utilise our expertise and experience in the conventional trucking sector – 1-2 million units produced pa - where independent suspensions are unknown'

100 'We need strong technical assessors/committees in ocean energy to root out weak ideas at an early stage and to bring the benefits of engineering scaling experience to bear'

180 'Floating wind is a hard one. Offshore wind to date has not delivered what it promised. I question the economic impact of floating wind. It is hard to make an argument for floating wind – even though the potential is great because there are no wind manufacturers in Scotland'

'Timing is all e.g. we started to working with medical devices just as medical devices started to go digital'

'Very few companies think strategically about new projects and which ones will win out'

'Get big companies in at the early stage and build on Ireland's position as a research centre'

'Our big challenge is to get the LCOE of tidal devices down to offshore wind levels. We need to change the slope of our learning curve i.e. make it steeper'

'The big technology issues are demand side management (e.g. on community level storage), grid constraints and environmental issues'.

Collaboration

'(The lessons of Aquamarine Power) ……you can get via R and D grants to prototype stage. Thereafter, there is serious investment required to get the technology into the sea and that requires private investment'

'CASE and similar bodies are brokers between the academic and industrial worlds'

'CASE established on September 1st 2012. It received £5m from InvestNI to support research priorities identified by CASE across renewables. In addition, Matrix NI Science Advisory Board identifies priority areas for Government and they identified advanced materials, health, renewable energy and sustainable fisheries'

'CASE looked for areas of focus and called 70/80 companies together for a 'sandpit' session and in turn this led to an emphasis on turbines, demand-side management, energy efficiency and bioenergy. This was challenged as being too broad and was reduced down to new energy systems (energy storage), bioenergy (mostly biogas) and turbines (marine renewables)'

'CASE has held 6 open calls and spent £2m and allocated c£5m. It has a Steering Group and has supported 18 projects so far, including 5 in marine renewables which were awarded £1.06m'

'The mid-term review of CASE found that the body was perceived as a source of grants and needed to the centre of activity e.g. set up collaborative networks, participate in OPIN etc. CASE projects must have a collaborative element and companies have to provide an in-kind contribution. CASE has mandatory targets set by InvestNI'

'The soft impacts of CASE are hard to measure e.g. impact of networking; any such organisation should be able to influence policy'

'Lessons:

- *Need technical courses – started by MaREI recently*
- *Need support in writing grant applications*

Biggest worry? The industry needs a break-through in technology'

'The big challenge is to create the first product and that is always for a market of one which perhaps can lead on to a market of millions'

'The big challenge is to develop a recognisable product strategy – people then know who you are and what you do and helps to generate a world lead'

'Lessons of our experience? We have been consistent in our message of who we are and what we do; perseverance which is critical for marine renewables; and 'ride out the storm'

'We grew organically and we sold a small amount of equity but maintained control'

'Lessons of our experience: perhaps we moved too fast to achieve scale, to get product into the water in 2009-13'

'NIACE is the competence centre and NIACE is only the centre under CASE which is not industry specific. 11 projects have been completed and there are 7/8 ongoing. In addition, there are agreements being negotiated with similar centres in Canada'

'NIACE is seeking a hybrid model and relaxing its membership model. Unlike CASE, NIACE has feasibility study grants etc; we run open Calls in thematic areas'

'NIACE projects are defined by 3 x companies who contribute 25% of the cost in-kind; only 2 x partners are required for feasibility support; long-term projects take up to 2 years; non-members of NIACE can participate as long as any one project grouping comprises of at least 25% industrial members; membership fee is £5-6k pa for SMEs and £16k pa for large companies'

'NIACE act as brokers to generate projects e.g. at workshops'

'AMP sold a great story to ABB who became involved. Then two things happened. The technology didn't work and this was added to by the lack of confidence in the market e.g. tariffs, markets etc'

<u>IPR</u>

'IPR is not an issue for us. Our core expertise is our domain 'know how'; we bring expertise and knowledge to the party'

'Not too concerned about IP – it is overrated'

'Tesla has deliberately opened up all of its patents because it needs rivals in order to generate a market and e.g. facilities such as charging points. The same approach should be adopted in ocean energy'

'We are trying to move to a trust model – we always seem to start off with an IPR focus but it is a barrier to trust. Our view is that if you pay for it, you own it but if, for example, Enterprise Ireland supports a project then a field of view applies and royalties are capped'

'*Collaboration is not easy in projects…. SMEs are very protective of their IPR. It is important at the outset of collaborative projects to identify (potential) IPR we share and stuff we want to keep; important too to have complementary partners; CASE involvement is important but it's important to remember that the IPR belongs to the university'*

'IPR treatment depends on who brings what to the table. It is a very difficult issue and can stop a project in its tracks. Our preference is not to be overly constrained by our IP policy – we may, for example, be willing to license the outcome of a project to a partner and to give

them an assurance to that effect. We have a preference for our own Confidentiality Agreement'

'The licensing of technology is not something we do frequently but we do have definite 'dos' and 'don'ts' in that regard. Do: identify what is the scope of the work- who does it and where; seek a matched resource commitment e.g. in value terms and share the risk and the investment; where is the value in the project to your target client – why is it important to their business. Avoid at all costs: taking on insoluble problems, you must have confidence that you can come up with a solution'

'The big challenge for us is to get to OEMs, and thus go around established axle manufacturers. Our products need to be robust and low cost – latter is an important point'

'IPR concerns are not suitable to a cottage industry but if there were twenty well-resourced companies like Wavepower, there would be no sharing of IPR'

'Why not pool your IPR and share ownership?'

'Not a fan of Intellectual Property. It stops progress. Inevitable that we will move to open source'

'There is no collaboration. IPR is so important to people. Need to open up IPR. OH spend €1m pa to maintain patents. Thinking of relaxing this (partly because of DCNS who are well armed with lawyers'

'Andor spin-off experience was one where the work including IPR was kept in-house and we didn't patent it because we couldn't afford to defend patents'

<u>Collaboration</u>

'A business model that works is needed for ocean energy product development. The sector hasn't been able to attract established companies with big balance sheets'

'The Global Wind Alliance and the Global Maritime Alliance are interesting sources of lessons for collaborations. Most importantly they demonstrate that companies both want to get together with others but also there needs to be fairly early commercial benefit from doing so, companies want early wins'

'The key issue in collaboration is building a social environment for the partners. The Global Wind Alliance worked inter alia because it had a good leader and was commercially driven; one early feature was a 2-day meeting including an overnight. Important to get meetings hosted in companies from an early stage'

'Consortia that work effectively have at least two common features: they clearly define the role and goal of the consortium and, second, they are balanced (e.g. there is at least one 'big' company involved).

'We are still heavily invested in tidal and getting good results – Scotrenewables, Atlantis/MeyGen, Nova Array' and Nautricity'

'Wave is struggling – we only have Albatern, Quoceant, QED Naval and a number of early start-ups – and Wave Energy Scotland is taking the lead in this area'

'The advantage of tidal is that it provides 'firm' power'

'Our business is built around collaboration…. hence our annual flow of royalties'

'We collaborate outside of Ireland e.g. Horizon 2020; ESA; German Space Agency; Danish Technology University; Woods Hole Oceanographic Institute….in Ireland, our main collaboration is with MaREI'

'The main lesson of our collaborative experience is that the relationship must be built on mutual respect and on open communications'

'Partners find each other, won't work if you have to bang heads together' (doing jv with Paul Brewster re his device, BP's PTO)'

'ESB team at Dogpatch incubator has learnt a lot from other people; has made contacts and find it a good sounding board'

'Benefits of DCNS involvement:

- *Access to technical expertise*
- *Access to funding*
- *Good job done by locating OH in Services Division which is agile*

On the negative side, they are pushing for a return on investment and that lead on to working on industrialisation and building a roadmap, all of which is perceived by OH as a challenge'

'Lessons from collaboration venture:

- *Collaboration is very difficult if only one partner controls the intellectual property as this brings a wariness into the relationship*
- *Both sides must commit full-time resource to the venture*
- *The senior partner (Verdant Power) doesn't have the commercial skills to build a successful business*

'Working with up to 10 top wind companies but you have to have the right building blocks in place for collaboration to work'

'In thinking about whether or not to collaborate, remember that you must add at least one nought to costs and this will have a big bearing on the first requirement for any small business: survival'

'Very important to make it easy for companies to form partnerships so make the bureaucratic load as light as possible'

'3M are a good example of a company that collaborates to solve company problems provided that they can roll out the solution to markets around the world'
'We want relationships with the potential for us to be bought out by our partner'

'The lessons of our collaborative experiences are: have a clear statement of own company IPR and protect it. Danger is that you teach rivals how to do your business. Best thing is to work with parties who have complementary IPR. Choose collaborators across different dimensions – for example, we need collaborators who complement us in our relatively weak area of sales and marketing'

'We had big problems dealing with utilities..... as we were an R&D company with no project management skills'

'We were trying to do three things at same time: develop the technology which was all about cost and performance; develop solutions to ancillary issues such as how do we deploy and service the device at an economic cost; and develop projects to generate a market with each project taking c5 years to mature and we were doing so in partnership with utilities'

'We did a couple of joint ventures e.g. in tidal. Utilities make the best partners due to experience, expertise and transparency'

'Lessons of our experience? Always do as you say you are going to do; never promise anything you can't deliver'

'The CRINE report for oil and gas in 1994 was a key to reducing costs. Joint industry projects (e.g. as used by MCS) were also important'

1'Lessons of our experiences: don't tell people about your vision as they will then trip it up; choosing the right people is key to any adventure as is the need to do your ground work in advance'

'Collaboration boils down to the core partners'

'Collaboration emerging in offshore wind – there are gaps in data, consenting etc and the industry is interested in funding projects with the support of MaREI'

'Wavepower will need partners at full scale because of the hundreds of €millions in cost involved'

'Lean Wind is an interesting precedent for the wave and tidal industry – joint industry programme to address joint issues e.g. access to turbines'

'CASE established on September 1st 2012. It received £5m from InvestNI to support research priorities identified by CASE across renewables. In addition, Matrix NI Science Advisory Board identifies priority areas for Government and they identified advanced materials, health, renewable energy and sustainable fisheries'

'CASE and similar bodies are brokers between the academic and industrial worlds'

'CASE looked for areas of focus and called 70/80 companies together for a 'sandpit' session and in turn this led to an emphasis on turbines, demand-side management, energy efficiency and bioenergy. This was challenged as being too broad and was reduced down to new energy systems (energy storage), bioenergy (mostly biogas) and turbines (marine renewables)'

'CASE has held 6 open calls and spent £2m and allocated c£5m. It has a Steering Group and has supported 18 projects so far, including 5 in marine renewables which were awarded £1.06m'

'The mid-term review of CASE found that the body was perceived as a source of grants and needed to the centre of activity e.g. set up collaborative networks, participate in OPIN etc. CASE projects must have a collaborative element and companies have to provide an in-kind contribution. CASE has mandatory targets set by InvestNI'

'The soft impacts of CASE are hard to measure e.g. impact of networking; any such organisation should be able to influence policy'

'InvestNI support companies who want to do joint R&D with a two-phase approach. First, scope out the opportunities with others. We look at the results of the scoping study against InvestNI criteria and studies must contain a road map and an evidence base. Other key point is IPR – some projects get into this at too early a stage; InvestNI has its own templates to suggest and, of course, there is the Lambert Agreement between UK universities'

'We have 62 networks (starting from 2008) and 15 are at the scoping stage. A good example is PolymersNI has 75 members and has been going for at least 5 years'

'Networks walks away if the university partner goes away'

'There is no trust when companies come together initially, an honest broker is needed and attendance sheets are a key KPI'

'We offer 100% scoping funding up to £25k and £170k over 3 years against a full, stage 2, project. Payments are made retrospectively. In phase 2, we expect quarterly meetings, we provide design support services e.g. for branding, support collaborative R&D, Innovation Vouchers and trade missions. We look for a lead company and provide a list of qualified facilitators (we provide training for facilitators). Our £170k grant is for facilitation, travel etc'

'The European Health Alliance has 600 members in its ecosystem'

'I work with account managers who focus on Horizon 1 –products exist but the client doesn't know it; Horizon 2 – is a matter of adjusting existing solutions; Horizon 3 is where there is no commercial option and long-term collaboration is required; these are peer sized companies such as GSK, Unilever who have decision-takers in the UK/Ireland'

'We do work with SMEs where we need the capability of a specific SME and/or where there is a big opportunity'

'Our projects are risky and take a long time (2-3 years) to come to fruition. They are high risk/high reward'

'We do act as commercialisation partner to entrepreneurs but we would always be concerned about the strength of the underlying IPR'

'Our Horizon 3 projects take up to as much as 5 years, depending on the project and whether technical breakthroughs are required. We put commercial targets on them at the point where the scope of work is decided'

'Aquamarine did try to get Bosch to deal with the PTO, approached Pelamis about joint development of the Isle of Lewis site. The company was not concerned about IP and tried to get collaboration going'

<u>OPIN</u>

'OPIN is worthwhile. We are making contacts at the sessions; it was really useful to meet Cimpina at OPIN Belfast recently'43 'Companies don't want any involvement in the nuts and bolts of running OPIN, perhaps involve companies at an advisory board type level?'

'Once you bring SMEs together, they will discuss tender opportunities, make connections and so on – look at the extremely successful EU FORSEA scheme'

'Recruiting networks? We issue thematic Calls, each of which is focused on potential networks with the potential to internationalise, with clear leadership and with clear objectives'

'OPIN is great and it could so easily have been interpreted as 'more of the same'. Nonetheless, it is going to be difficult to operate on an 'invite only' basis as the population of potential participants is too small. Nonetheless, OPIN is welcome as it will keep Northern Ireland engaged with ocean energy'

'Challenging to make big company bureaucracies work with start-ups'

'Went to OPIN Dublin but, given our project manager role, won't go again due to time pressures and priorities'

'OPIN is a good approach but we must avoid it becoming too dominated by bureaucrats and academics'

'OPIN can attract engineering experts and not just salesmen from oil and gas'

'Put a big challenge e.g. over resource use and people will find a way to meet it'

Wave Energy Scotland

'WES (in my external to WES view) see a proof of concept device going into the water in 2020. That will be a critical point as further progress will need private investment. The dilemma is how to get big 'balance sheets' involved – perhaps a tax incentive?'

'Wave Energy Scotland was great…and it paid the wages!'

'Success will come from concentrating on PTOs rather than seeking to build a full Wave Energy Device'

'Too early to say if WES is a success – only 2.5 years into a 5-year term. All Calls have been populated. A total of 56 projects involving 150 organisations have arisen from 4 Calls with 22 projects running. Total funding amounts to £25m, of which £15m has been spent.'

'Brokerage events prior to each Call are a key feature of WES. They enable companies to get together and we have had 100 companies at each event to date'

'IPR – WES has clear rules on this and, for instance, IPR must be licensed out at market rates. We have signed 56 contracts to date and only one or two have had difficulty regarding IP. All parties must declare their 'background' IP at the outset'

'We are satisfied that the aspirations of WES are correct and that it is the right model'

Open and Crowdsourced Innovation

'The problem with 'Problem Statements' is that it is very hard to anonymise them and/or to make them relevant'

'How do you know if an idea is commercial? TRL level is one measure – it is independent and quantifiable'

'An ecosystem is important – look at the positive example of software in Ireland. Indeed, we had an investor who looked into our local ecosystem as a factor in their investment decision'

'Interestingly, crowdsourced funding subscribers want recognition in some way for their involvement e.g. a t-shirt and they want regular updates on the progress of the business. There are renewable energy companies in the US who have crowdsourced successfully'

'Crowd sourcing is based on a Members Question Time approach. A problem is placed in a anonymous format and circulated. Inevitably good answers emerge and deal with 20-30 cases pa'

'I was sceptical about crowdsourcing of funds until I saw a company do it successfully (they were oversubscribed!). They used a specialist company to do it for them and they did have a tangible realistic model for their technology'

'An ecosystem is important – look at the positive example of software in Ireland. Indeed, we had an investor who looked into our local ecosystem as a factor in their investment decision'

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'Can you design into wave and tidal machines components that are used in other industries?'

'Corporate commitment of partners is critical'

'An Innovation Ecosystem would be a great idea as it would bring in new faces to the ocean energy'

'There are a lot of misconceptions about innovation e.g. Innovation Vouchers (Enterprise Ireland) are about buying services from academics, not necessarily about innovation – they are misnamed'

'Open innovation is something we do in Johnson Controls while Tyco had its Tyco Garages in Cork (n.b. works with Israeli companies), Israel (n.b. start-ups), Bangalore (software) and California (software and start-ups)'

'The digital life cycle is very short and you have to jump on opportunities…we can scale Irish digital start-ups globally'

'Companies compete (e.g. via a pitch) to get on the NDRC programme, about 1 in 14 get an investment. Porter Shed is joint venture with Enterprise Ireland in Galway, it is not a co-location but a stand-alone operation'

'We did the Scotrenewables project because it is interesting and, so far, is working well'

'Development business is not like making widgets…. can't plan in a conventional way'

'Not sure that mentoring works. Happy to go about picking peoples brains'

'IRDG started with a focus on representation/grant application adviser to today's organisation with 70 members and 2 staff in phase 1 to 220 members and 3(?) staff today. 'We now represent ourselves as IRDG The Innovation Network. Organisation is self-funding but bear in mind that it has been in existence for at least 25 years. May close office and all work from home as is case with most staff today'

'There is a lot of mistrust over open platforms. They are deemed too onerous; return is not worthwhile and the funding involved is probably too small'

'Collaboration pillar involves crowd sourcing. A Problem Statement is inevitably brought to a Special Interest Group by company seeking a real tangible solution by tapping into the experience, expertise of the Group. The collaboration area requires a soft, non-sensitive topic or two to start with'

'Crowd sourcing is based on a Members Question Time approach. A problem is placed in an anonymous format and circulated. Inevitably good answers emerge and deal with 20-30 cases pa'

'We don't put projects out to an 'ecosystem' normally except for some in the automotive after-market business unit which is a very niche area and one which can draw off enthusiasts'

'Don't know if EDF engage with small companies but they do have a Dogpatch (name of the incubator facility utilised by ESB)'

'A good example of our open innovation is we are working with a small Israeli company whose synthetic radar is complementary to a Tyco camera product. We have a stake in the company and resell the overall product'

'In F1, Perrin (car?) was crowd designed – ex Williams engineer'