BLUEPRINT FOR OFFSHORE WIND IN IRELAND 2020-2050:

A Research Synthesis

Work Package 6: Synthesis

Deliverable 6.2 FINAL SYNTHESIS REPORT

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Disclaimer

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Glossary of terms

AA Appropriate Assessment

AREG Aberdeen Renewable Energy Group

ALK Alkaline water electrolysis

AFLOWT Accelerating market uptake of Floating Wind Technology

AMETS Atlantic Marine Energy Test Site

ABP An Bord Pleanála

BFOW Bottom Fixed Offshore Wind

BOWL Beatrice Offshore Wind Farm

CAPEX Capital Expenditure

CCS Carbon Capture and Storage

CfD Contracts for Difference

CPPA Corporate Power Purchase Agreement

CRU Commission for Regulation of Utilities

DC Direct Current

DCACNT Dept. of Climate Action, Communication Networks & Transport

DECEX Decommissioning Expenditure

DEVEX Development Expenditure

DHLGH Department of Housing, Local Government and Heritage

EC	European Commission
EEZ	Exclusive Economic Zone
EI	Enterprise Ireland
EIA	Environmental Impact Assessment
EOWDC	European Offshore Wind Deployment Centre
ESBN	Electricity Supply Board Networks
ETS	Emissions Trading System
EU	European Union
EV's	Electric Vehicles
FADs	Fishing Aggregation Devices
FDI	Foreign Direct Investment
FLOW	Floating Offshore Wind
GHG	Greenhouse Gas Emissions
GIS	Geographical Information Systems
GNI	Gas Networks Ireland
GSI	Geological Survey Ireland
GVA	Gross Value Added
HMI	Hydrogen Mobility Ireland
HOOW	Harnessing Our Ocean Wealth
Hs	Significant Wave Height
HSE	Health Service Executive
HV	Horizontal Visibility
HVDC	High-Voltage Direct Current
IDA	Industrial Development Agency
IMO	International Maritime Organisation
IWEA	Irish Wind Energy Association
LCoE	Levelized Cost of Electricity
LNG	Liquefied Natural Gas
MAC	Maritime Area Consent
MI	Marine Institute
MIC	Maximum Import Capacity

MICAs	Marine Installation Conservation Areas
MPAs	Marine Protected Areas
MPDM	Marine Planning and Development Management Bill
MRIA	Marine Renewables Industry Association
MSP	Marine Spatial Planning
MVDC	Medium-Voltage Direct Current
NGOs	Non-Governmental Organisations
NIMBY	Not in My Back Yard
NMCI	National Maritime College of Ireland
NMPF	National Marine Planning Framework
OECM	Other Effective Conservation Measures
O&M	Operations and Maintenance
OPEX	Operational Expenditure
ORE	Offshore Renewable Energy
OREDP	Offshore Renewable Energy Development Plan
OSPAR	Oslo/Paris Convention (Protection of the Marine Environment of the NE Atlantic)
OSW	Offshore Wind
PEM	Proton Exchange Membrane
PI	Planning Interest
PCIs	Projects of Common Interest
PPA	Power Purchase Agreement
R&D	Research and Development
RE	Renewable Energy
REFIT	Renewable Energy Feed-In Tariff
RDF	Refuse Derived Fuel
R&I	Research and Innovation
RESS	Renewable Electricity Support Scheme
ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation
SEAI	Sustainable Energy Authority of Ireland
SEM	Single Electricity Market
SFI	Science Foundation Ireland

SID	Strategic Infrastructure Development
SMAZ	Strategic Marine Activity Zones
SME	Small and Mid-size Enterprise
SMR	Steam Methane Reforming
SOF	Solid Oxide Fuel cell
SOV	Service Operations Vessels
SPA	Special Protection Area
TEEG	Techno, Economic, Ecological and Governance
TER	Total Energy Requirement
TES	Tomorrow's Energy Scenarios
TLP	Tension Leg Platform
UK	United Kingdom
UMAS	University Maritime Advisory Services
WACC	Weighted Average Cost of Capital

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Executive summary

Offshore wind will be a key energy source of the future in a world striving to decarbonise and meet commitments under the Paris Agreement. While Europe has been a leader in offshore wind, and many other countries around the world are developing capacity to leverage the benefits of this sustainable source of renewable energy, Ireland has been slow to develop offshore, choosing to focus to date on the onshore resource. However, Ireland is now fully embracing the opportunities presented by offshore wind and recognises the value and scale of the resources due to meteorological conditions and the extensive maritime territory available to it. In fact, the first national targets for offshore wind, given in the Climate Action Plan in 2019, have been increased in the Programme for Government in 2020. The target is now for 5GW by 2030, with an intent to develop tens of gigawatts into the future. For example, the government has indicated that 30GW of Floating Offshore Wind (FLOW) could be developed off the west coast of Ireland going forward. The rapid development of FLOW technology, which can be deployed in deep Irish waters, is a game changer to enable such a scenario.

These ambitious targets present a turning point. However, in order to reach such long-term goals, capacity needs to be built in the short to medium term. Therefore, it is imperative that plans for Bottom Fixed Offshore Wind (BFOW) in the Irish Sea are realised in the first half of the 2020s, whilst giving effect to processes that inspire confidence among stakeholders and the coastal communities they may involve. Effective decision-making requires access to multiple forms of knowledge, including knowledge of the natural marine environment, of the metocean conditions, of the potential of technological solutions, and of the cultural and socio-economic context for development. The EirWind project was designed to address national gaps in knowledge in relation to offshore wind in Ireland. As a result, it involved a multidisciplinary approach, involving up to 18 researchers and seven academic staff, engaged through MaREI in University College Cork. Over twenty-five individual reports and studies were produced, covering issues with data and Geographical Information Systems (GIS); cost optimisation; ecosystems governance, and route to market.

This document is a synthesis of the research conducted by the EirWind project team, over a two-year period from August 2018 to July 2020. It presents a blueprint for consideration by policymakers. The approach to this research synthesis places the market as the central factor for analysis. As previously stated, Ireland has an abundant wind resource, requiring export markets to realise its considerable potential. The market opportunities described in this report, start with national targets for 70% of renewable electricity by 2030. In response, the Arklow project and the seven 'relevant projects' identified by the government this year, will be the game-changers; - the projects that will pave the way for future development. Effective delivery of the Renewable Energy Support Scheme (RESS) is central to this in the early 2020s. There is a considerable learning curve to be achieved in the decade ahead, to get things right for these projects which are at various stages of development.

EirWind analysed three scenarios for production zones in the Irish Sea, the Celtic Sea and the Atlantic. The bottom-fixed offshore wind scenario in the Irish Sea, for a 500MW farm coming on-stream in 2025, is the most cost-effective with an estimated range of €51-66/MWh. Floating offshore wind in the Celtic Sea shows considerable potential; an estimated Levelized Cost of Energy (LCoE) range of €63-90/MWh for circa 1GW coming on stream in 2035. For the Atlantic zone, the wind resource yields a high capacity factor (62%). The estimated LCoE range (€75-107/MWh for 1GW from *c.*2035) is higher than the Irish and Celtic Sea scenarios, primarily due to the harsher conditions reducing the number of weather windows available to complete offshore operations.

EirWind findings indicate that there is a route to market for up to 25GW of offshore wind in Ireland, with 6.5GW to 7.3GW possible by 2030, taking development scenarios for existing electricity transmission and future green hydrogen production into consideration. The potential is possibly much greater, but whether the opportunity exists for 30, 40, or even 50GW depends on an ability to act now. The studies synthesised here suggest that pathways for FLOW and hydrogen need to be enabled, in parallel with support for the relevant projects, in the next 18 to 24 months. The forthcoming auction rounds for offshore wind will provide a competitive landscape for BFOW. A timeline should also be specified for technology specific FLOW auctions taking into consideration the pre-commercial status of this technology.

Furthermore, there is a need to initiate a market development plan for a hydrogen economy which extends globally, as presented in this report. This will be a key enabler for offshore wind development at scale. Hydrogen has raced to the top of the green energy and green recovery agendas, in a manner that was not anticipated, when the EirWind research programme was being planned just three years ago. The European Union (EU) Hydrogen Strategy, published at the end of the EirWind project, states that from now to 2030 investments in electrolysers of the order of €24 to €42 billion would be required and this will support the hydrogen market development process by making hydrogen more competitive. In addition, investments of €65 billion are expected for the development of hydrogen distribution and storage.

EirWind results show that hydrogen production costs of less than €5/kg are possible in an integrated production system which couples a 500MW wind farm to a large scale hydrogen production facility. The additional delivery costs result in a final cost to customers of €8-€9/kg of hydrogen which begins to look competitive with respect to petrol and diesel if a decarbonising subsidy is introduced. For the first step on the offshore wind hydrogen pathway, it is recommended that a 100MW pilot hydrogen facility, linked to FLOW is supported. This pilot could also demonstrate how green hydrogen can be used for domestic industrial processes, such as oil refining and cement manufacturing, for fuel cell electric vehicles in targeted transport sectors, and as an alternative to natural gas for home heating to complement electrification. The big prize is envisaged as bulk green hydrogen production from FLOW, (e.g. off the west coast of Ireland), for export. This would position Ireland as a net energy exporter whilst achieving long-term energy security.

The challenges pertaining to such a growth trajectory for offshore wind, are described below in the Blueprint, and in more detail in the supporting technical reports and studies (e.g. studies on co-existence with fisheries, Marine Protected Areas (MPAs), data, and social licence to operate). The challenges are not insurmountable, but they require government resources in order to be addressed in such a way that principles of sustainable development and community engagement are at the core. Therefore, the critical path to offshore wind development is contingent on decisions the government will make now, on investing in more personnel for key government departments and agencies. Up to 30 new personnel are recommended to be recruited in the next 18 to 24 months.

This EirWind research synthesis strongly suggests that this is a sectoral investment worth making. The socio-economic study indicates that in 2030, 6.5-7.3GW of domestic offshore wind development would support between approximately 12,000 and 13,500 direct and indirect jobs in the domestic supply chain, with a total Gross Value Added (GVA) impact of circa €2bn for the period 2020-2029. Peripheral coastal communities could be transformed by new employment opportunities, however, the development of the supply chain needs to be undertaken in such a way that as much local content as possible can be secured. This study recommends at least three port clusters as catalysts for jobs and enterprise in the Irish Sea (e.g. Rosslare), the Celtic Sea (e.g. Cork Harbour) and the Atlantic coast (e.g. Shannon Foynes and Killybegs).

A national route to market study should be prioritised, including a cost benefit analysis of national investment scenarios for large-scale interconnectors and hydrogen. Regional plans are further envisaged for the three production zones (Irish Sea, Celtic Sea and Atlantic). These should contain the timelines for roll-out of commercial activities and pilot and demonstration-scale projects. At the local level, investment in key ports is a critical enabler; coupled with the opportunity to attract Foreign Direct Investment (FDI) e.g. into the Shannon region as a manufacturing hub.

Exchequer funding and private investment will play an important role in providing the financial support to fully exploit the opportunity that the emerging offshore wind sector in Ireland represents for the taxpayer, the labour force and consumers. Given the strategic national interest of offshore wind, a task force is recommended to mobilise and coordinate priority actions in the months ahead. Route to market needs to be prioritised, to decide on how Ireland, with an offshore wind energy resource, far greater than it can consume, will become an energy exporter. European funding can also be leveraged, as the Green Deal provides a stimulus to rebuild the economy post COVID. The pandemic, climate and biodiversity crises, which served as the backdrop to the EirWind project, have accelerated at unprecedented rates. Offshore wind is only one part of the sustainability solution, however, it can play a major role in the future security and wellbeing of Irish people, for generations to come.

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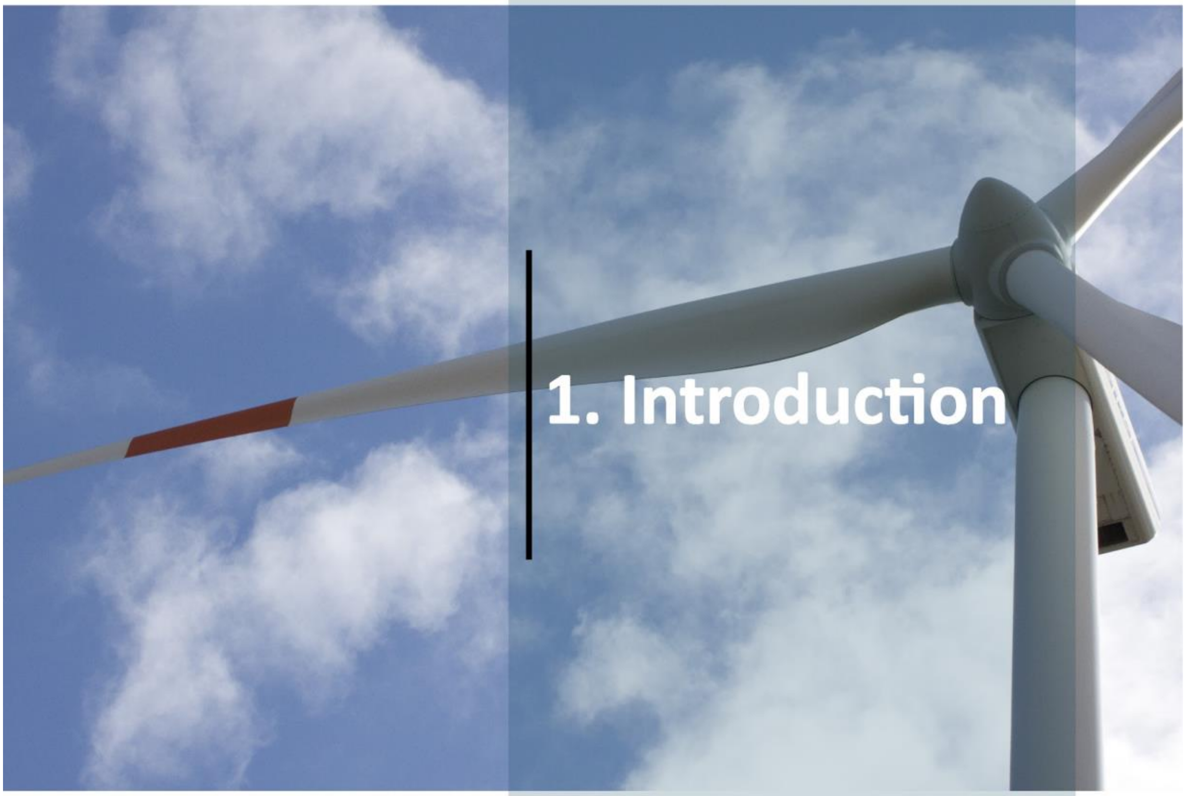


1. Introduction

1. Introduction

This report is relevant to policy makers, industry leaders, marine advocacy groups and other stakeholders concerned with realising the potential of offshore wind. It provides a synthesis of the work undertaken over twenty-four months as part of the Science Foundation Ireland (SFI) industry-led EirWind research project. The EirWind project was implemented by a multidisciplinary research team in MaREI, University College Cork, involving marine biologists, economists, ecologists, engineers, environmental scientists, geologists, geographers, GIS technicians, modellers, naval engineers and social scientists. The research was supported by ten industry partners - Brookfield, DP Energy, EDPR, Enerco, ENGIE, ESB, Equinor, Simply Blue Energy, SSE Renewables and Statkraft. Supplementary detailed technical material is available on the EirWind project website http://www.marei.ie/eirwind, and in the final report to SFI. The structure of the current report is as follows: Chapter 2 outlines the vision/opportunity for offshore wind in Ireland; Chapter 3 presents the challenges to be overcome; Chapter 4 describes options for development pathways; and Chapter 5 summaries conclusions and recommendations arising.

1.1 General Background

The instability and vulnerability of the energy sector has been highlighted in recent times on a global scale. The previously unimaginable plunge in oil prices below $0 a barrel in April 2020 sent shockwaves through the financial markets, and exposed the increasing vulnerability of the global energy system. The issue of energy security for a small, open economy, such as Ireland's, has been recognised since the foundation of the State. Visionary leadership in 1920s Ireland, led to the development of the ground-breaking Shannon hydroelectric scheme at Ardnacrusha. This was a key influencing factor in the socio-economic development of Ireland throughout the 20th century. However, this did not set the course for energy self-sufficiency. With limited opportunities for further large-scale hydro development, imports of coal, oil and gas became the norm, until by 2014, 97% of energy came from imported fossil fuels.

The roll-out of renewable energy technologies has advanced in recent years, as Irish policy makers set targets for decarbonisation and weaning-off of fossil fuel dependencies. Ireland's success in harnessing wind energy from onshore wind farms, resulted in wind energy providing 29% of Ireland's electricity needs by 2017, a significant achievement, as the second highest share of electricity from wind energy in Europe. Wind energy is a twenty-first century success story for Ireland. However, there are challenges to finding more suitable sites for wind turbines onshore, and the success of onshore wind is overshadowed by the fact that the citizens of Ireland have minimal control over their energy destiny.

At the time of writing, the outbreak of the COVID-19 global pandemic has created unprecedented disruption to civil society and challenges for economic stability. The radical shift in world-order has focused immediate attention on the need to protect the most vulnerable members of our communities. At the same time, questions arise as to what a safer, more equitable world will look like, post pandemic. The inextricable link between the health of the planet and people, has led to a renewed focus on human health and well-being, and the existential crisis created by biodiversity loss and climate change. We can see first-hand how leadership, solidarity and ingenuity can shape positive outcomes, even in the darkest of contexts.

This report provides an important energy element in a blueprint for a post pandemic world, that seizes the opportunity for transformative change in light of the sustainability challenges we face. Over the coming months and years, choices will be made that will shape society for decades ahead. We can no longer be complacent about the risks identified by science, whether they relate to the threat of global pandemics, the implications of climate change, or lack of energy security. The choice must not be to defer decisions on the avoidance of catastrophes. Instead, decisions must be made on how quickly we can accelerate towards pathways that can ensure a safe and sustainable future.

The pursuit of renewable energy to achieve a decarbonised world, to ensure energy security, and to realise new opportunities for economic growth and human wellbeing, is one such critical pathway. The Irish government has made incremental step-changes to steer a course that will realise this potential for our island nation. However, the track record has not been as good as it could be; the Irish situation has been characterised by failure to achieve key renewable energy targets to date. The choice now facing Irish politicians is less about what to do, but more about how to deliver the transformative changes we need to see. We know we need to move towards a renewable energy future. We can see that the political appetite now exists to address these challenges, as a result of the new Programme for Government agreed in recent weeks. This represents a major turning point for renewables, and specifically for offshore wind in Ireland. The target for offshore wind has been increased from 3.5GW by 2030 last year, to 5GW this year. Furthermore, the government has flagged the potential for 30GW of floating wind in the Atlantic.

The questions are i) What should the energy mix of the future look like? ii) How can the government incentivise industry progress towards renewables? iii) How can the energy citizen be engaged? iv) How should governance be adapted to deliver more effective and efficient decision-making processes? In short, what does a modern day Ardnacrusha look like? The answer lies offshore. Ireland’s geo-strategic position endows it with one of the best wind energy resources in the world; a vast maritime territory for the exploitation of offshore wind; and the potential to access new market opportunities; - at a point in time, when multiple factors align to put offshore wind at the top of sustainability, climate, energy and economic recovery agendas. This EirWind Blueprint presents a vision for offshore wind in Ireland, and guidance on the sea-change required to unlock Ireland’s maritime economic potential, not seen since the foundation of the State.

1.2 Offshore Wind Overview

Europe has been a global leader in the development of offshore wind. The first commercial BFOW farm was constructed in Denmark in 1991. Today, Germany and the United Kingdom (UK) together account for almost two thirds of all offshore wind installed worldwide. By 2019, the world's total offshore wind capacity was 29GW, with jurisdictions such as China, the US, South Korea, Taiwan and Vietnam, among others, all gearing up to place more wind turbines offshore, leading to record-breaking levels of installation of new capacity. This surge in offshore wind projects worldwide is linked to i). the benefits of offshore wind, ii). the global market, and iii). state-of-the-art technology.

Offshore Wind (OSW) is a clean, renewable energy that can help to decarbonise our total energy requirement in the long-term. It has an advantage over other forms of renewables, including biomass and solar photovoltaics, due to its low Greenhouse Gas (GHG) emissions and reduced environmental impact. The offshore environment provides an opportunity to tap in to a more powerful and consistent wind resource, with the potential to generate more electricity at a steadier rate than onshore wind. As suitable land becomes scarcer for onshore wind, the marine environment provides an alternative space for the construction of wind turbines. The global market for offshore wind has expanded by 30% per year between 2010 and 2018 (IEA, 2019a).

Bottom fixed offshore wind technology is typically in the form of a monopile or jacket/tripod. BFOW can be deployed in water depths of up to approximately 50m. A number of fixed substructure concepts have been developed to meet different site characteristics e.g. soil type; water depth; and means and location of manufacturing etc. According to Wind Europe, steel monopiles are the most common in Europe (Wind Europe, 2020). Advances in technology have helped the BFOW sector to develop, including larger turbine sizes, specialised lifting equipment, installation and crew transfer vessels, and remote control and monitoring facilities. Capacity factors at 40-50% in new offshore wind projects match efficient gas powered plants and exceed those of onshore wind.

European auctions are now contracting projects into the 2020s on a zero subsidy basis, or below €46/MWh as seen in the recent UK Contracts for Difference (CfD) round (based on UK 2012 strike prices adjusted for inflation). Zero subsidy is subject to certain market conditions whereby the state takes on certain development costs of the site and/or transmission. 2016 proved that the wind industry (onshore and offshore) can significantly contribute to the global climate change solution as it overtook coal as the second largest form of power generation capacity consisting of 17% of Europe's installed total. The increasingly competitive nature of constructing wind farms offshore will lead to continued market expansion over the next two decades, with modelled scenarios estimating growth rates of 13% per year (IEA, 2019a). The Renewable Electricity Support Scheme (RESS) will be critical to the success of offshore wind in the 2020s and beyond.

Rapid developments in FLOW foundations are opening new markets. The three basic types of FLOW technology are the Tension Leg Platform (TLP), semi-submersible platform, and the spar buoy, which can be deployed in circa 60-1000m water depths (Figure 1.1). Floating offshore technology is in a pre-commercial phase, requiring development at volume and scale, to bring the cost down. In order to achieve this, FLOW also requires treatment as an emerging technology with respect to government financial support mechanisms, which should differ from mature and established technologies. This will evolve rapidly over the coming decade. At the same time, there is still lots of capacity for bottom-fixed foundations in most markets around the world.

A number of pre commercial FLOW projects have been developed or announced at pilot and demonstration scale in Europe from the UK (e.g. Hywind Scotland 30MW; Kincardine 50MW), Norway (e.g. Hywind Tampen 88MW), France (Groix Belle Ile 30 MW), Portugal

(WindFloat Atlantic 25MW), and Ireland (AFLOWT 6MW pilot). The Erebus 96MW pre-commercial FLOW demonstrator is in development off the coast of Wales, via a joint venture between Total and Simply Blue Energy (an Irish Small and Mid-size Enterprise (SME)).

FLOW projects are also being progressed in other jurisdictions with long coastlines, good wind resources and steeply shelving seabed bathymetries, such as the east coast of the US, Vietnam, Japan and South Korea.

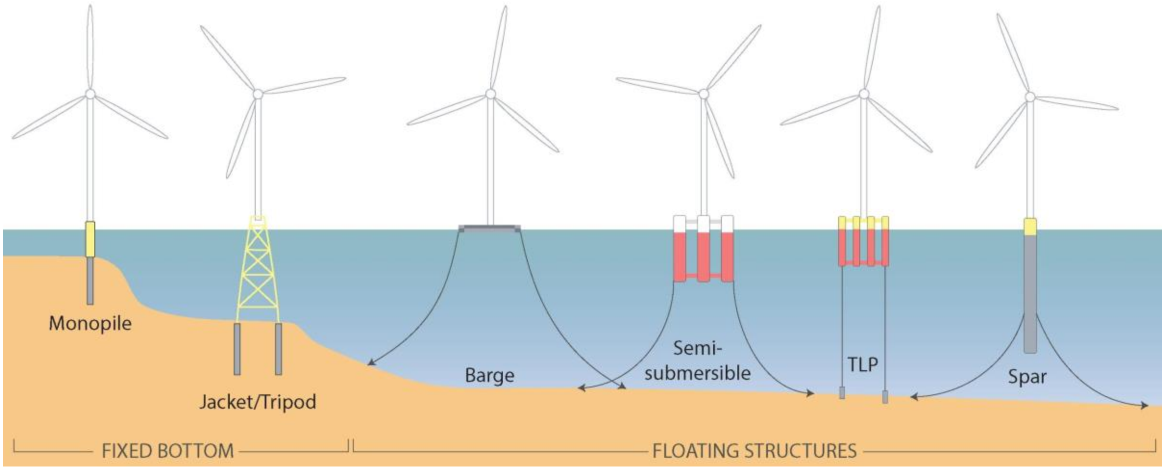


Figure 1.1: Common types of support structure technologies for bottom fixed and floating offshore wind turbines. [Source: Adapted from Principle Power]

1.3 The Blueprint approach

The aim of this Blueprint is to bring together the research generated by the EirWind project, to identify actionable pathways for the future development of offshore wind in Ireland. The potential for future uptake of the recommendations is the prerogative of policy-makers. The EirWind approach to a blueprint for the sustainable development of offshore wind report is based on comprehensive synthesis of the EirWind research. This Blueprint report brings together a body of information from relevant literature, as well as new knowledge generated by the project (Appendix 1).

A review of select blueprints and masters plans from other jurisdictions around the world, namely New York State and Virginia in the US, the Netherlands and Taiwan (Table 1.1), showed that there is no one example of a visioning or planning process that represents a mirror image for Ireland to follow **(EirWind: Dinh et al., 2019)**. Nevertheless, elements from the case studies can be relevant in an Irish context. Lessons learned indicate that consideration of spatial and temporal scales are essential in developing the blueprint for the sustainable development of offshore wind in Ireland.

Table 1.1: Comparison of three case studies. [EirWind: Dinh et al., 2019].

Blueprint	**Target (Scale, timeline)**	**Aspect different from Ireland**	**Unique aspect relevant to Ireland/EirWind project**
Blueprint and Master Plan for the **New York State** Offshore Wind	2GW by 2030, 9GW by 2035	Extremely high volume of demand in electricity; Backup/balancing generation available; Present low penetration of renewable electricity; Strong coordination and support policies	Sequential process of developing offshore wind capacity; Blueprint includes site, grid, and economic studies; and stakeholder engagement; Over twenty supporting studies in the master plan
Vision for the Offshore Wind Supply Chain in **Virginia**, U.S	2GW in 2025 – 2030; 5.4GW by 2034 Hub for the East Coast offshore wind supply chain	Pre-existing infrastructure (ports, etc.); Energy supply mix: natural gas, motor gasoline, nuclear and inter-state electricity; Present low penetration of renewable electricity	Issue of energy security (energy consumption in Virginia is more than 2.5 times greater than the production); Virginia Office for Offshore Wind to provide a clearinghouse and facilitator to advance offshore wind; Cluster: hub for the East Coast offshore wind supply chain; Roadmap for offshore wind supply chain
Offshore Wind Energy Road Map 2024-2030, **Netherlands**	11.5GW by 2030; from 3. in 2019	The North Sea is intensively used; one of the busiest seas in the world; Relatively shallow waters and proximity of good ports and industrial energy consumers	Government designated offshore wind farm zones, where offshore wind is given priority over other activities; A national Energy Dialogue
Offshore Wind Development in **Taiwan**	520MW in shallow-water in 2020; 800 turbines (4GW) prior to 2030	High demand in energy (population of 23.6 million in 2018); Readiness of technology and supply chain	High potential offshore wind; High potential in deep water (90GW) with 9GW feasible; Nuclear power free in 2025; Clear roadmap/master plan for offshore wind; Meaningful name "Thousand Wind Turbines" of the Project; Subsidy policies and demonstration Incentives

1.4 Ireland overview

Ireland owes its wind energy resource to its geographic location at the eastern edge of the Atlantic Ocean, which provides abundant fetch for mid-latitude winds to deliver energy to Ireland's offshore areas. These wind energy resources are simulated, and predicted by models that reveal Ireland's advantageous abundance of wind energy, relative to other European nations (Figure 1.2). Ireland's sea area (at circa 880,000km^2) is around ten times the size of its landmass, and the country has one of the best offshore renewable energy resources in the world. This offers significant potential for offshore wind, wave and tidal energy. Ireland's Offshore Renewable Energy Development Plan indicates that the total amount of offshore wind farm development possible is 34.8GW - 39GW without likely significant adverse effects on the environment (DCCAE, 2014). Ireland clearly has a unique position with offshore wind.

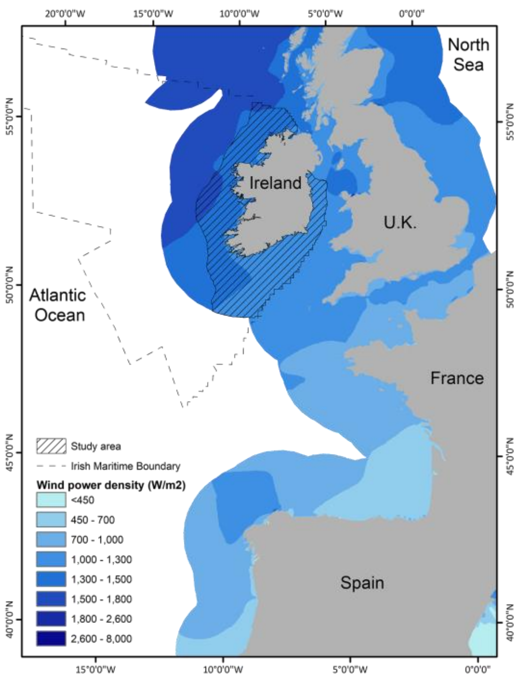


Figure 1.2: Modelled wind resource relative energy density. [Data source: *Global Wind Atlas 3.0, 2019]*

At present, there is only one operational offshore wind farm in the State, the 25.2MW Arklow Bank Wind Park off the east coast (Figure 1.3). The lack of development, since the Arklow Bank project was completed in 2004, stemmed from a predominance of terrestrial wind to meet renewable targets; coupled with a lack of subsidies for offshore wind, and inadequate planning and foreshore consenting process.

Despite an abundant natural resource, Ireland's offshore wind sector is underdeveloped relative to its Northern European neighbours. However, the national position is rapidly changing. With improvements in technology and reductions in cost, as well as changes in marine planning and consenting, offshore wind in Ireland is at a significant new point of departure. This is reinforced by the fact that the first national target for offshore wind development was set in the Climate Action Plan in 2019 with a 3.5GW target by 2030 (Government of Ireland, 2019). This was subsequently increased to 5GW in the Programme for Government (Government of Ireland, 2020). The Programme for Government also aims for a 7% reduction in carbon emissions per annum between now and 2030; moves to develop 30GW of floating wind in the Atlantic; the enactment of the Marine Planning and Development Management Bill by Q1 of 2021; a new Climate Action Bill in Q3 of 2020; and the speeding up of the provision and permission of grid connections.

Plans are underway for the extension of the Arklow Bank project, which has been consented for a minimum total installed capacity of 520MW. Furthermore, in May 2020, seven BFOW projects were given 'relevant project' status in the context of the forthcoming Marine Planning and Development Management Bill to be enacted. The draft transition protocol defines relevant projects as (a) offshore wind projects which applied for and substantially advanced, or were granted a lease, under the Foreshore Act 1933; and/or (b) offshore wind projects which have a valid connection agreement from EirGrid or are confirmed by EirGrid as eligible to be processed to receive a valid connection offer.

Developers of 'relevant projects' will be facilitated over earlier stage projects when the new offshore consenting regime comes into play. Depending on the outcome of their progression through the planning process, the seven relevant projects have the potential to deliver 3.8GW as part of Ireland's strategy to deploy 5GW of offshore wind between now and 2030. This, together with the natural resource, proximity to market, availability of grid, and water depth, will see a concentration of BFOW development in the Irish Sea in the near future (See Table 1.2 and Figure 1.3).

Table 1.2: 'Relevant' projects, identified by the government in May 2020, being facilitated for a planning interest when the new marine consenting legislation is enacted.

Project	Location	Capacity	Developer
Oriel windfarm	East coast (Irish Sea)	330MW	Parkwind NV/ESB
Dublin Array (Bray and Kish Banks)	East coast (Irish Sea)	600MW	Innogy
Codling Bank (Phase 1 and phase 2)	East coast (Irish Sea)	2,100MW	Fred Olsen/EDF
North Irish Sea Array	East coast (Irish Sea)	500MW	Statkraft
Skerd Rocks	West coast (Atlantic)	100MW	Fuinneamh Sceirde Teo

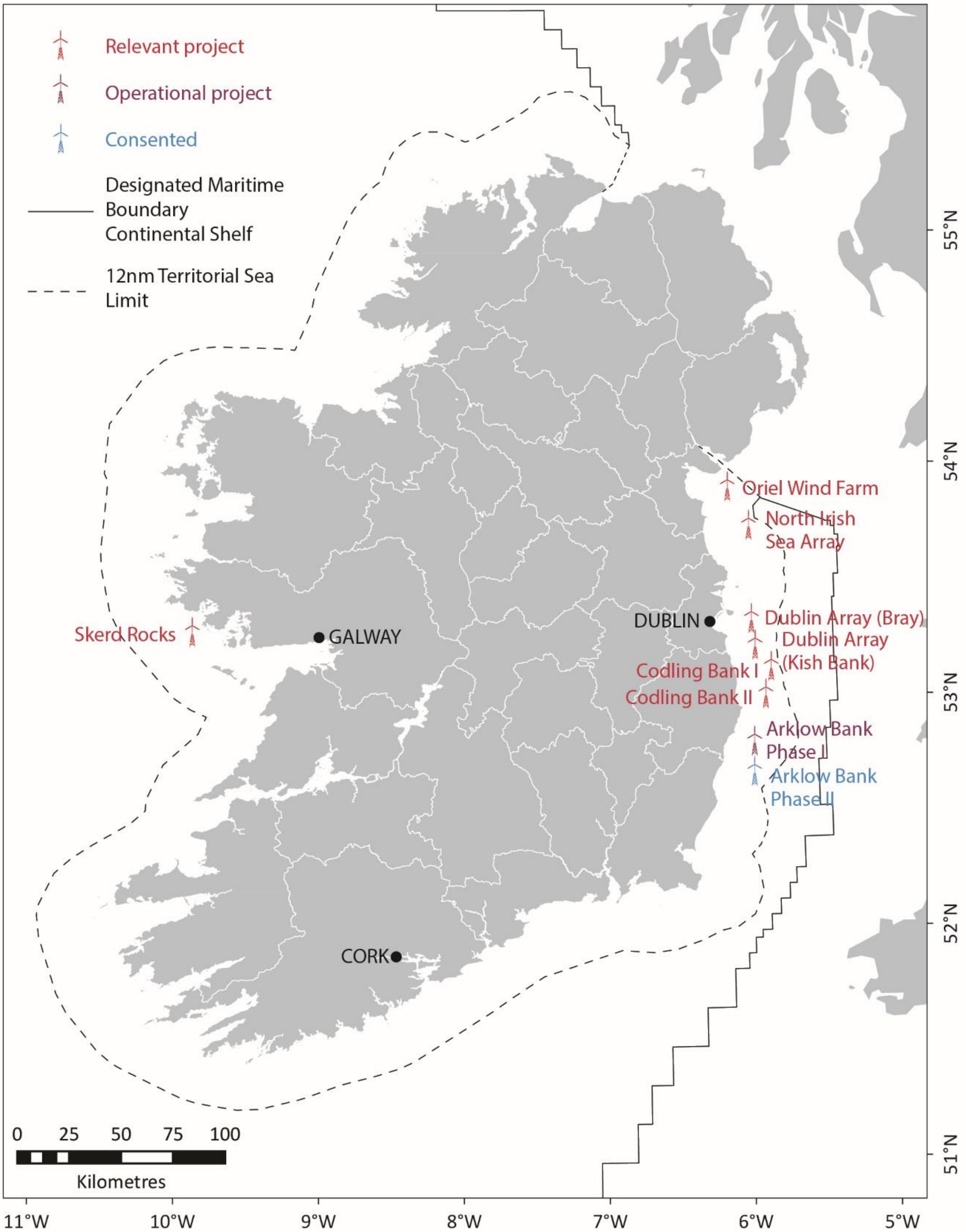


Figure 1.3: Operational, consented and relevant BFOW projects in the Irish Sea.

Figure 1.4 below shows additional interest in the offshore wind market in Ireland. The promoters of these projects seek clarity on the consenting regime in order to progress. These wind farms in the Irish and Celtic Sea are at early exploratory and consultative stages. They include FLOW proposals in the Celtic Sea. The wind resources, depth of water and availability of space in the Celtic Sea and the Atlantic Ocean make these locations attractive for

FLOW projects. The metocean conditions in the Atlantic make the techno economic viability of projects there a challenge, but this is quickly changing.

The pioneering Accelerating market uptake of Floating Wind Technology (AFLOWT) project, Ireland's first FLOW pilot, will demonstrate the survivability and cost competitiveness of FLOW at the Sustainable Energy Authority of Ireland (SEAI) test site, near Belmullet in County Mayo. The project draws from expertise across Europe through the EU Interreg programme. It will be instrumental in activating the supply chain in Ireland, as well as opening up the Atlantic to a new era of offshore wind development. The FLOW concept, designed by Saipem, is to be tested at sea over one year in the early 2020s.

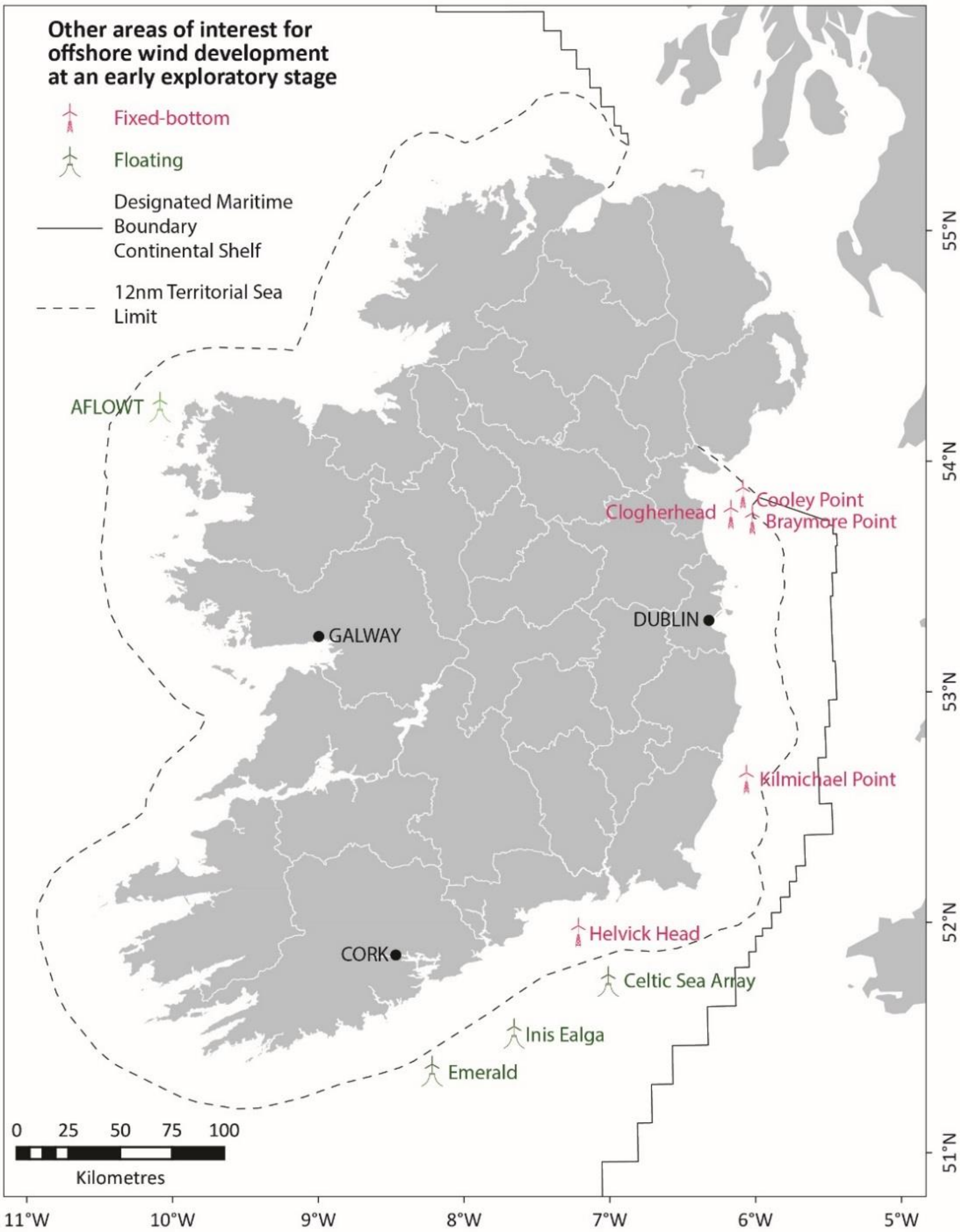


Figure 1.4: Other areas of interest for BFOW and FLOW in the Irish Sea and Celtic Sea at an early exploratory stage, and the location of the AFLOWT project off the coast of County Mayo.

Taking floating wind into consideration increases the potential to grow Ireland's offshore wind sector by an order of magnitude. Approaching offshore wind for Ireland at scale, provides an opportunity to transform Ireland's ocean economy. The realisation of this potential depends on initial progress in developing the supply chain through the BFOW projects planned for the Irish Sea.

1.5 Policy and Legal Progress

Significant progress has been made on a range of relevant policy areas at the national level over the past couple of years. These include the publication of the Climate Action Plan and the RESS in 2019. The National Marine Planning Framework, which will address forward planning at sea, has been progressed, and there is clarity on the timeline for its delivery (to the European Commission by March 2021). Over the past six years the Department of Housing, Local Government and Heritage (DHLGH) has led a process to reform the marine consenting legislation, to streamline the process of planning at sea and to align it with the requirements to build capacity to comply with the EU Maritime Spatial Planning (MSP) Directive. The Offshore Renewable Energy Development Plan (OREDP) is another policy that has significant implications for offshore wind. The OREDP 1 underwent a mid-term review in 2018 and OREDP 1 expires this year. Work will commence on OREDP 2 in 2020. The OREDP is an important policy instrument for the future development of the offshore sector, as well as other emerging marine renewable technology.

1.5.1 Marine planning and development reform

The government is currently engaged in reforming the laws governing Ireland's maritime area. Ireland is required by the EU's Maritime Spatial Planning Directive to put in place a Marine Spatial Plan (MSP) for our maritime area by March 2021. Ireland's MSP will be called the National Marine Planning Framework (NMPF) and its development is being led by the DHLGH. The NMPF is a forward plan for the next 20 years setting out how the maritime area will be used and protected. The NMPF will provide the policy context in which consent decisions will be made in the future. Simultaneously a draft Maritime Jurisdiction Bill 2019 has been published and is being progressed by the Department of Foreign Affairs and Defence. If enacted this will revise and consolidate the law of the State in relation to maritime jurisdiction and specifically make further provision for the rights of the State in its maritime jurisdictional zones in accordance with the United Nations (UN) Law of the Sea Convention. The Bill clarifies that in addition to the State's sovereignty over the territorial sea, property in the territorial seabed and in the natural resources of the territorial sea are also vested in the State. The Bill also makes clear that in addition to the State's sovereign rights over all forms of potential energy, property rights in all those forms are also vested in the State.

No formal process currently exists for authorising development beyond the foreshore (12nm or 22km from high water mark on the shore). The Marine Planning and Development Management (MPDM) Bill will introduce a new 'maritime area' comprising internal waters, territorial sea, Exclusive Economic Zone (EEZ) and continental shelf (Figure 1.5) which equates to an area of approximately 490,000 km^2. This legislation will introduce a new marine planning regime including a new regime for development management and consent. The Bill will bring efficiency and clarity to the process for approving offshore wind developments and other maritime infrastructure projects. It will also restate and update the legislative underpinning for marine spatial planning. Under the MPDM Bill, a number of specific types of marine related development, including offshore wind farms, will be considered under a new procedure which will be the responsibility of An Bord Pleanála (ABP). This regime will be similar in nature to Strategic Infrastructure Development (SIDs) operated under terrestrial planning. The Bill is still under development and some provisions may change as work on it progresses.

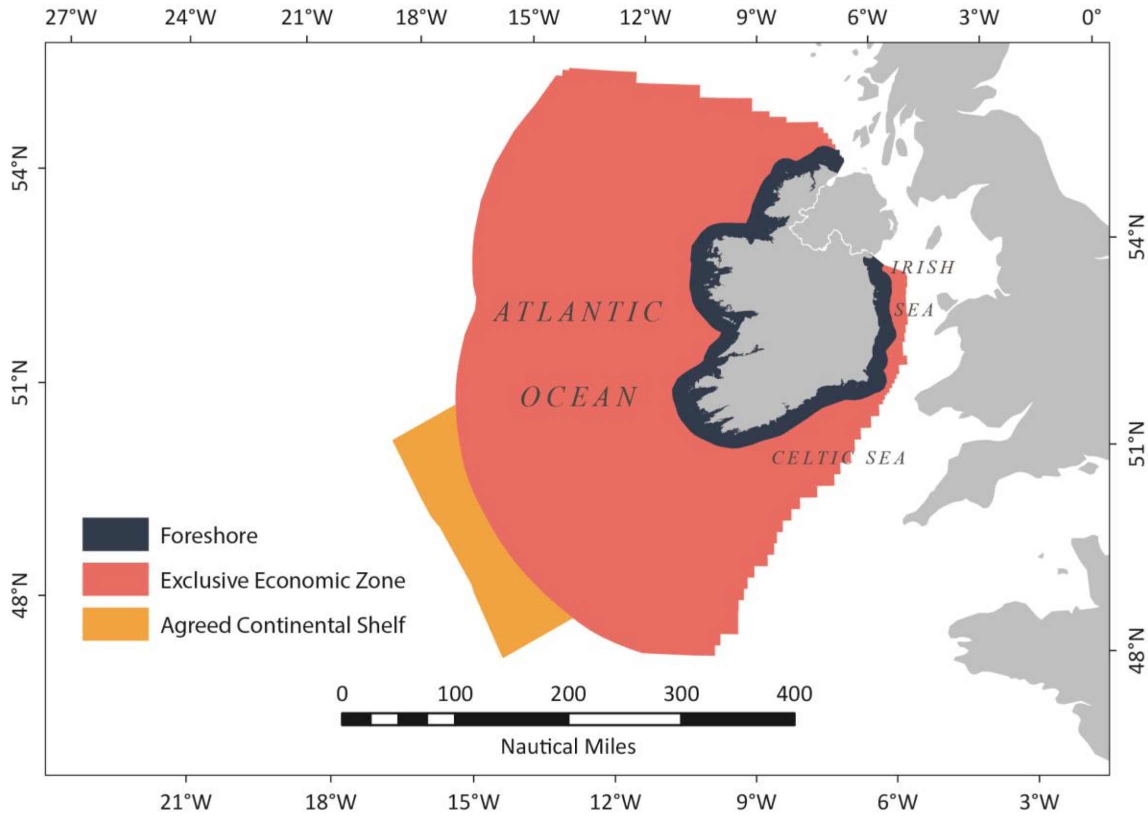


Figure 1.5: The Maritime Area proposed under Marine Planning and Development Management Bill [Source: DHPLG, 2019].

1.5.2 New system for development management and offshore consenting

Table 1.3 presents an overview of the government departments and agencies that will be responsible for various regulatory and policy aspects of offshore wind, once the MPDM Bill is enacted. A process flow diagram is presented in Figure 1.6 illustrating how the development management and consenting process may work in a decentralised approach. First, offshore wind developers must secure a Planning Interest from the Minister of Climate Action, Communications Networks and Transport. A Planning Interest is granted if the developer is deemed capable of undertaking and completing the project from the financial, technical, organisational and legal perspectives.

Only when a developer secures a Planning Interest, (approval by the Department of Climate Action Communications Networks and Transport (DCACNT) of an applicant's financial and operational capacity and track record) can they then move to apply for planning permission from ABP. Pre-application consultation will consider, among other issues, whether the development is in line with the NMPF and other government policies. Once an application is received, ABP will liaise with the statutory consultees, review the environmental assessments, manage submissions and conduct oral hearings if required. If planning permission is granted, the developer can take part in a competitive process for subsidy support under the RESS to construct and operate an offshore wind farm. Successful bidders can then apply to the DCACNT for a Maritime Area Consent (MAC) which is the property consent and allows the developer the right to occupy the part of the maritime area where the development is located. Once a MAC is received, the grid connection application can be processed, followed by an application to construct a generating station and a licence to generate electricity. Construction of the wind farm can then commence. Electricity Supply Board Networks (ESBN) will perform the necessary upgrades to the transmission system as instructed by EirGrid.

The body that will oversee enforcement of the planning consent conditions is in the final stages of being determined. An Oversight Body that will facilitate and coordinate the Offshore Renewable Energy (ORE) consenting process is referenced in the draft MPDM Bill; however, there is not yet clarity on who will perform this role.

It remains to be seen whether a centralised approach, which is also provided for, might be adopted by the government, as the Minister is yet to decide. There are also questions on where and how Strategic Marine Activity Zones (SMAZs), provided for in the MPDM Bill, will be designated. The outcome of the grid consultation on options for offshore wind, open at the time of writing, is likely to inform the approach (DCCAE, 2020).

Table 1.3: A simplified overview of the roles of each of the government departments and agencies from an operational perspective once the MPDM Bill is enacted.

	MARINE PLANNING, POLICY DEVELOPMENT, LEGISLATION AND STRATEGY	**CONSENTING AND OPERATIONS**
DHLGH	NMPF delivery; Responsibility for the MPDM Bill; Lead development of SMAZ; Secondary legislation and transition planning associated with MPDM Bill	Development of planning guidelines; Applications for site investigation under the current Foreshore Act for offshore wind projects

DCACNT	Delivery of Climate Action Plan and OREDP; Ireland's ORE strategy; ORE elements of the MPDM Bill; Secondary legislation relevant to the ORE sector; Establishment of an ORE development body; Design of RESS auctions	Process Planning Interest applications; Process Marine Area Consent applications; Development of future charging regime; Management of granted Planning Interest and Maritime Area Consents; Planning interest and Maritime Area Consent compliance and enforcement
ABP	Determines applications for strategic infrastructure development (existing); Determines appeals and certain other matters under the Planning and Development Act 2000, as amended	Pre-application consultation; Process applications for marine environmental surveys (site investigations) following grant of planning interest; Process applications for planning permission; Consider submissions; Oral hearings (if applicable)
CRU	Implement government policy; Oversee the wholesale all-island Single Electricity Market (SEM); Set network development and connection policy	Process applications for a licence to generate and authorisation to construct
EirGrid	Network, access and scenario planning; Determine necessary grid upgrades; Delivery of RESS auctions	Transmission System Operator; Preparation of grid connection offers as directed by the Commission for Regulation of Utilities (CRU); Determine grid connection point and infrastructure upgrades required for individual wind farms
ESB		Build and maintain transmission system including upgrades required for offshore wind developments as directed by EirGrid
STATUTORY CONSULTEES	Feed into policy development and working groups, e.g. for definition of SMAZ	Review planning permission, consenting applications and Environmental Impact Assessments (EIAs)/ Appropriate Assessments (AAs) where appropriate

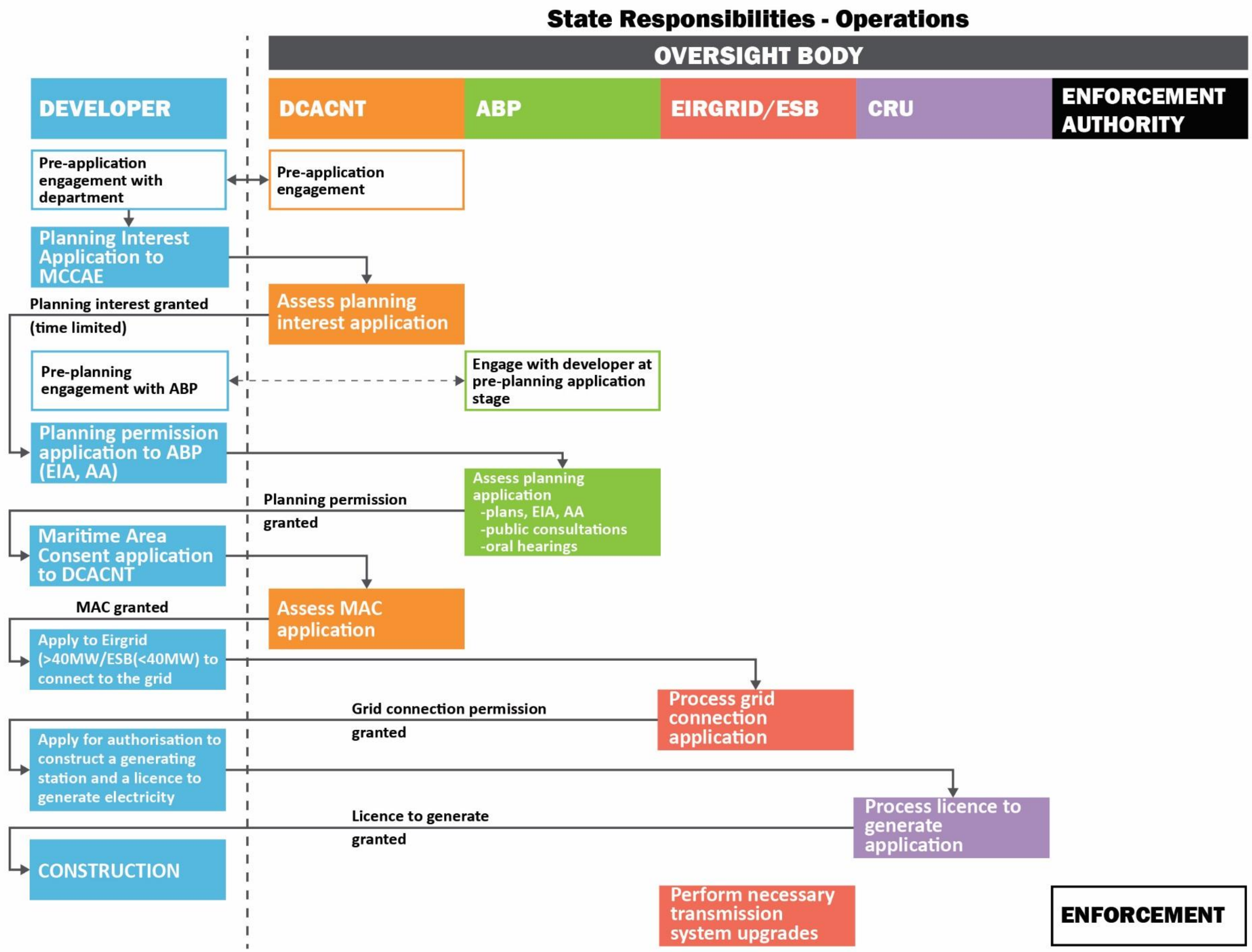


Figure 1.6: Process flow chart for the proposed consenting process under MPDM **(EirWind, Judge *et al.*, 2020)**

1.6 Conclusion Chapter 1

In conclusion, security of energy supply and the need to decarbonise the economy, are major policy drivers for the development of offshore wind in Ireland. Given (i) the high potential and unique resource offshore, (ii) advances and cost reduction in BFOW technology, (iii) the potential for FLOW technology in Irish waters, (iv) that the lowest CO_2 emissions come from of offshore wind over any other energy source, (v) the new targets for offshore wind in the Programme for Government (vi) and the opportunity to replace large shares of fossil fuels in electricity, transport and heat sectors, - the opportunity for offshore wind in Ireland is significant. The question is how to ensure that the full potential of Ireland's offshore wind opportunity is realised in a sustainable way.

Despite having one of the best offshore wind resources in the world, Ireland has been a slow entrant to the sector. From this slow starting position, things are at a turning point. Ireland has an opportunity to learn from other jurisdictions, to be totally self-sufficient in energy, and even an energy exporter. The feasibility of this, as a small island nation needing access to international markets, is explored through the next sections on opportunities and challenges.

2. Opportunities for Ireland

2. Opportunities for Ireland

The opportunities from the development of offshore wind in Ireland are fundamentally linked to the strength of the resource. However, the resource in itself has little value, unless it makes economic sense to harness it. The market opportunity is the critical factor for analysis, in order to understand what advantages can stem from tapping into that market potential **(EirWind: Dinh *et al.,* 2018)**.

The future market opportunities for offshore wind energy can be identified within the existing domestic electricity market as Ireland strives to meet EU Renewable Energy (RE) and national emissions/decarbonising targets. A further opportunity exists to export electricity using existing, proposed and additional interconnectors provided that the economic trading parameters are favourable. However, for large-scale growth in offshore wind development it will be necessary to explore new markets in other energy areas such as transport and heat and bulk energy export for example using the vector of hydrogen. In all of the above growth scenarios, driven initially by RE and emissions targets, there is an implicit increase in the national energy security of supply status which we believe should play a more significant role in future Irish energy policy development.

This chapter focuses on the market opportunities according to various market segments: i). the domestic electricity market; ii). interconnectors market; iii) the heat market iv) transport markets.; v). and the bulk hydrogen market. The second half of this chapter describes production scenarios, and the opportunities to be realised if these markets are unlocked.

2.1 The OSW energy electricity market opportunities

2.1.1 The Domestic Electricity Market

In 2019 EirGrid forecast a strong growth in electricity demand in Ireland for the coming decade, driven by industrial and economic productivity, development of new data centres, and increased uptake in electric vehicles (EVs) (EirGrid, 2019a). However, projections made in 2019 will have to be adjusted as the precise impact of the shutdown of the Irish economy as a result of COVID 19 remains to be seen. According to EirGrid, large energy users, primarily data centres have become a significant growth area in Ireland. As of today there is approximately 1,000 MVA (*c.*1GW) of demand capacity contracted to large energy users and the typical load currently drawn by these customers is approximately 35% of their contracted Maximum Import Capacity (MIC). This leaves considerable room for growth as this load is expected to rise as these customers build out to their full potential. Furthermore, there are many additional projects in the connection process and many that have made material enquiries (EirGrid, 2019a).

2.1.2 Current drivers for wind energy in the domestic electricity market

The main drivers for the development of onshore and offshore wind over the past twenty years have been renewable energy targets set by the EU which are then translated to domestic Irish targets. Since 2009 the Irish Government has supported the development of renewable electricity in Ireland through the Renewable Energy Feed-In Tariff (REFIT) helping industry achieve the targets up until 2015. The DCACNT have since developed the RESS which establishes an auction system for renewable generators. Action 28 from the

Climate Action Plan requires an increase in the volumes and frequencies of RESS auctions to deliver on the 70% renewable electricity target by 2030. The frequency of future RESS auctions is dependent on the renewable electricity project supply pipeline. It is envisaged that a minimum of four auctions will occur between 2020 and 2027 to deliver on the 2030 targets, with the first offshore RESS auction targeted for 2021. This will provide pathways for renewable developers including offshore wind projects as it sets out the indicative timelines and volumes for auctions over the coming decade and provides clarity for developers in relation to when they need to have their projects auction ready. The target in the Programme for Government is the connection of at least 5GW of offshore wind by 2030. Although the size of future RESS auctions are not yet known, if the short and long term targets in the Programme for Government are to be met, offshore wind will become a major contributor.

2.1.3 Corporate Power Purchase Agreement (CPPA)

A CPPA allows corporate energy consumers to purchase power on a long-term basis directly from renewable energy generators without being co-located. On the consumer side of the agreement customers get green energy, greater certainty over prices and an enhanced reputation from their reduced carbon footprint. This is an alternative to the traditional model where a utility purchases power from lots of energy generators, transports it on the electricity grid and then on-supplies power to the corporates. Data centres are the main large energy users and CRU has estimated that by 2027, 31% of all demand will be from data centres (CRU, 2018) which represents a 2GW of power demand.

Offshore wind farm developers in mature markets have started to look at CPPAs as a way to guarantee their revenue in the long-term (WindEurope, 2020). This is particularly important where zero-subsidy bids are being placed and developers are fully exposed to the wholesale market price. Even with considerable cost reductions, zero free subsidies will not be a universal phenomenon. As offshore wind comes on-stream in different jurisdictions, different regions will move towards low and zero subsidy at different rates. In a zero-subsidy world, the PPA must evolve to provide the bankability necessary for investor confidence in project finance. This is a future prospect for OSW in Ireland, as part of the longer-term development trajectory. In the shorter term, innovative models may be needed to set the level and duration of a PPA in the first place.

While support schemes remain the dominant route to market, some onshore wind farms in Ireland are already signed up to CPPAs including an entire 91MW wind farm to be operational in 2021 in Co. Donegal and contracted with Amazon (Goodbody, 2019). Furthermore, Action 29 from the Climate Action Plan is to ensure that 15% of electricity demand is met by renewable sources contracted under CPPAs by 2030. EirGrid's Tomorrow's Energy Scenarios (TES) projects a growth in annual Total Energy Requirement (TER) to between 37.2 and 45.5TWh by 2030, this means that for the 15% CAP target to be met, between 5.6 and 6.8TWh will need to be renewable sources contracted under CPPAs (EirGrid, 2019a). It is anticipated that a significant portion of this renewable electricity will come from PV (2.6TWh based on 1.5GW projections for PV in Climate Action Plan 2019). Conservatively therefore, a figure of 0.7GW of OSW is calculated to supply data centres. (calculated using a 50% C.F. for offshore wind).

2.1.4 Interconnectors

Figure 2.1 illustrates the existing and proposed electrical interconnectors for the whole island of Ireland **(EirWind: Todesco Pereira et al., 2020a)**. A summary of their capacities and project timeframes are also presented in Table 2.1 and Figure 2.1. Currently, Ireland has a total electricity interconnection capacity of 1GW and there is the potential to have up to 1.2GW additional capacity installed by 2026.

Table 2.1: Present and future interconnectors capacity of the island of Ireland.

Interconnectors	Power capacity	Commissioned/Expected
Moyle	500MW	2001
East West	500MW	2012
Greenlink	500MW	2023
Celtic	700MW	2026

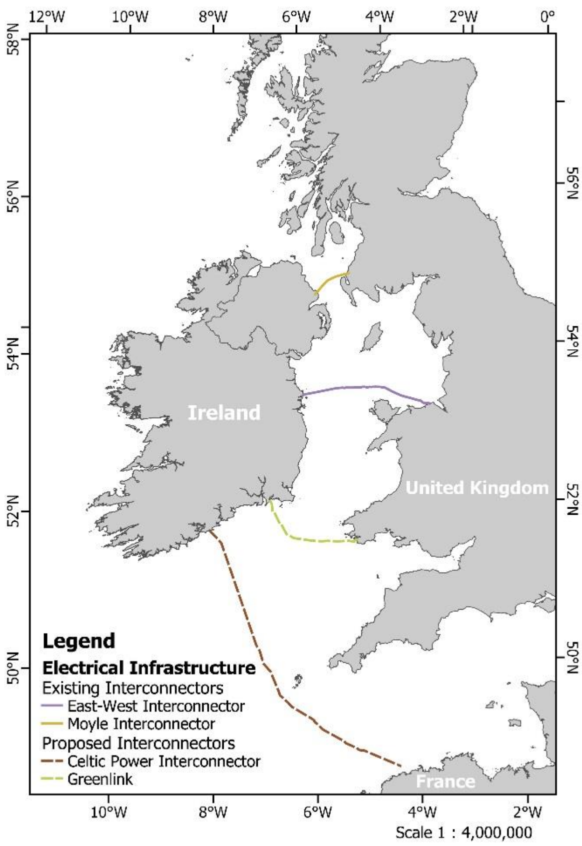


Figure 2.1: Existing and proposed electrical interconnectors in the island of Ireland (Scale 1: 4,000,000).

The operation of electricity interconnectors is subjected to electricity market dynamics. Thus, the electricity interconnection capacities cannot be considered as energy exporting potential. In fact, the electricity price of each node of the interconnector is what decides in which direction the electricity is most likely to flow. As the electricity price changes according to different supply and demand scenarios, the electricity direction changes accordingly. Between Ireland, the UK and France (potential future connection), the highest average electricity price is in Ireland. Therefore, electricity will be more likely to be imported rather than exported in the existing and proposed interconnector arrangements in the short-term. Furthermore, the interconnectors will also export surpluses from onshore wind. For this reason, a potential export factor of less than 30% is applied to the 2.2GW when calculating the OSW power potential of approximately 0.6GW.

2.1.5 Total Projections for the Electricity Market

The total market for OSW power is the sum of the demand in the markets segments listed in Table 2.2 below. In summary, if the domestic electricity market and interconnectors are realised to full potential then it is estimated that in the region of 6.3GW of OSW energy can be developed by 2030, 7.8GW by 2040 and 8.9GW by 2050.

Table 2.2: Projections of renewable electricity power (GW) to meet market demand

Market Segment	GW 2030	GW 2040	GW 2050
Traditional Domestic Electricity	5.0[1]	5.5	6.0
CPPA	0.7[2]	1.4	1.7
Interconnector	0.6[3]	0.9	1.2
TOTAL	**6.3**	**7.8**	**8.9**

2.2 Expansion of Markets for OSW Energy

It is not the resource, but the market that is the limiting factor to the development of offshore wind in Ireland. It is obvious from the estimate of 6.3GW by 2030 expanding to 8.9GW deployment in 2050, that the electricity

[1] Figure based on Programme for Government target of 5GW from offshore wind.
[2] Based on CAP target of 15% from Renewable Energy Sources (RES), assuming 50% of this will come from OSW.
[3] Based on <30% capacity availability for export on existing and proposed interconnectors.

market alone cannot exploit the resource at a scale which maximises the socio-economic benefits to Ireland. Thus the grand challenge is to identify new markets for the energy and to develop the appropriate innovative technologies and infrastructures to deliver the energy to these markets.

If electricity is the vector for the energy the obvious option would be to develop a direct current (DC) super-grid to connect Irish OSW to the European mainland along the lines of a 'SuperGrid' concept promoted by SuperNode. The SuperGrid is a realisation of the optimal amount of interconnection between European countries to facilitate renewable energy generation connection and smoothing by taking advantage of the temporal and spatial variations in renewable resources, mainly wind and solar. This would result in a meshed DC network across Europe. This, in theory, is an option and considerable time and resources are being expended on studies of this concept which may prove to be successful. In 2016, a joint political declaration established the North Seas Energy Cooperation, aimed at facilitating the cost effective deployment of offshore renewable energy, in particular wind, and promoting interconnection between countries in the region. Members include Ireland, Belgium, France, Germany, Luxemburg, Netherlands, Norway and Sweden.

There is no doubt that the wide-spread adoption of conventional HVDC and/or innovative Medium Voltage Direct Current (MVDC) superconductor transmissions system technologies could allow large development of electricity generation in remote locations while being transmitted long-distance to demand centres. The technology development is still at an early stage, and while it was outside the scope of the EirWind project, it could be factored into future projections for offshore wind capacity deployment.

An alternative approach involving more mature innovative technologies is to identify new markets for OSW energy by considering the total market for energy and identifying the sectors in which existing fuels can be substituted by an alternative fuel derived from OSW energy. In this scenario it is necessary to convert the electricity produced by OSW to a gaseous vector which enables access to gas grids and other gas infrastructures such as pressure vessels and tankers.

2.2.1 Ireland's Total Energy Requirement

The total energy supply for Ireland is normally divided into three sectors: electricity, transport and heat and the split is approximately 19:42:39 percent respectively in terms of Final Energy (Figure 2.2) and 32.2: 35.4: 33.5 percent in terms of Primary Energy (SEAI, 2019). A focus on Final Energy for electricity alone ignores the two other larger sectors, 96% of which are supplied by fossil fuels, oil and gas. However, in recent years there has been significant technological innovation worldwide which has enabled alternative fuel deployment. Fuels such as hydrogen, ammonia and bio-methane are becoming viable alternatives to oil and gas.

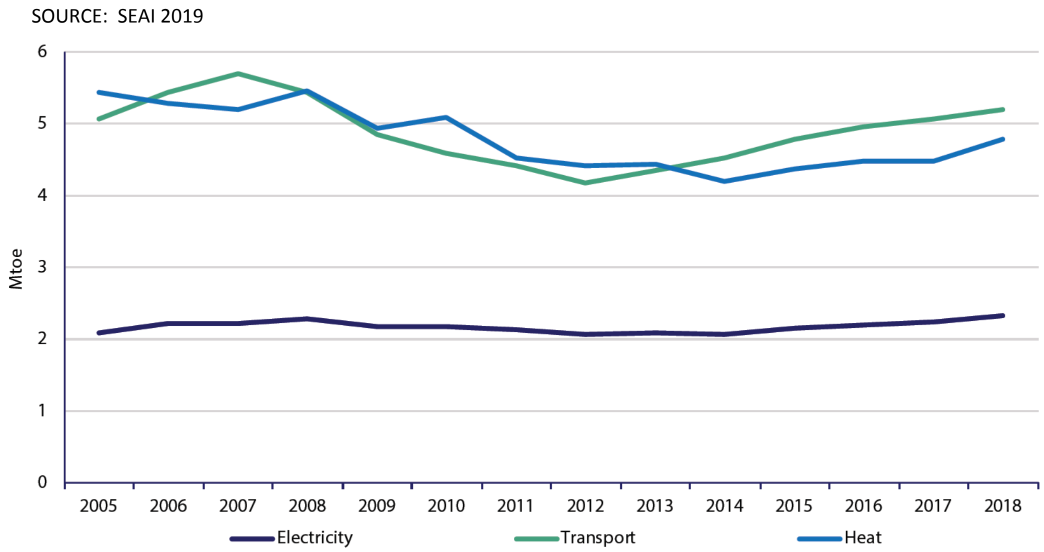


Figure 2.2: Final Energy in Ireland split between Electricity, Transport and Heat.

2.2.2. Green Hydrogen

Offshore wind can play the vital role of enabling green hydrogen production knowing that hydrogen is only as clean as the resources and the methods of production involved to generate it. Where hydrogen comes from is important. Grey hydrogen accounts for circa 95% of the hydrogen used in the world today. It is formed using fossil fuels such as natural gas. The most likely short-term options for creating carbon-free hydrogen at scale are blue hydrogen and green hydrogen: Blue hydrogen is where carbon emissions from the steam methane reforming (SMR) process are captured and stored (CCS); Green hydrogen is produced using water electrolysis to generate hydrogen and oxygen, using sustainable electricity in the process (Figure 2.3). The ideal scenario is to produce hydrogen from water by electrolysis that is powered by renewable sources such as wind or solar energy and to use it in fuel cells with air, thereby producing only water as a by-product, thus ensuring that each value chain, from production to end-use, is emissions free.

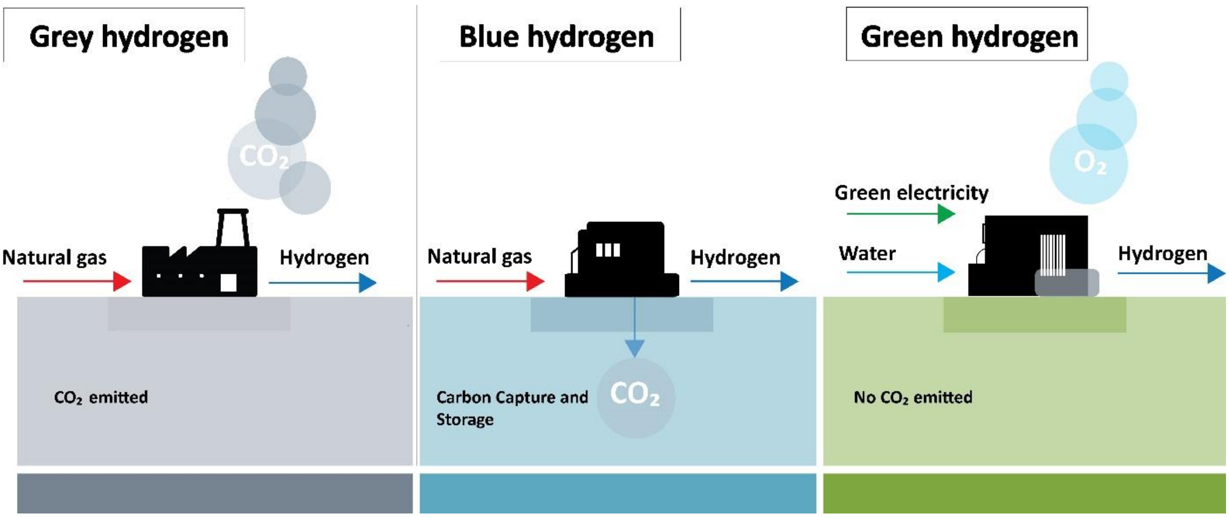


Figure 2.3: The differences between grey, blue and green hydrogen. (Adapted from: Gasunie).

There has been a huge surge in support for Hydrogen. Figure 2.4 gives more detail on the multiple use sectors in terms of global growth projections for Hydrogen. These developments have occurred at a level and speed that was unexpected when the EirWind research agenda was being scoped with industry partners in 2018. Recent months have seen the launch of the EU Hydrogen Strategy (European Commission, 2020a), the publication of Germany's National Hydrogen Strategy (The Federal Government, 2020), the launch of a new venture to develop a sustainable transport fuel hub in Copenhagen and the HydroFlex train. Studies on the future for hydrogen (IEA, 2019b; HMI, 2019; Hydrogen Council, 2017) paint a positive picture for the replacement of fossil fuels with hydrogen in the transport, heat and industry sectors.

There were a number of reasons why green hydrogen became a focus for study in the EirWind project: -

- ➔ Mature innovative technologies
- ➔ The cost of producing hydrogen from renewable electricity could fall by 30% by 2030 (IEA, 2019)
- ➔ Blue hydrogen opens a door for green hydrogen
- ➔ Necessary for at-scale decarbonisation of key segments (e.g. fuel cells for transport, gas grid, industrial processes)
- ➔ Existing infrastructure, skills and regulations
- ➔ Carbon tax will have a critical role in the detailed economic case for Hydrogen replacing oil and gas.

The European Commission plans for renewable hydrogen to be the most compatible option with the EU's climate neutrality goal in the long term. The Commission is proposing a gradual trajectory of a clean hydrogen economy within three development stages (European Commission, 2020a):

1. 2020-2024: goal of 1 million tonnes of renewable hydrogen with at least 4GW renewable hydrogen electrolysers installed to decarbonise existing hydrogen production
2. 2025-2030: 10 million tonnes of renewable hydrogen in the EU by 2030 and at least 40GW of renewable hydrogen electrolysers installed and 50% existing fossil-based hydrogen production could be retrofitted to produce low-carbon fossil-based hydrogen
3. From 2030 to 2050 renewable hydrogen technologies should reach maturity and be deployed at large scale to reach all hard-to-decarbonise sectors. Renewable electricity production to increase as 1/3 of electricity to be used for renewable hydrogen production by 2050

The Commission's hydrogen roadmap includes a suite of actions including investment strategies; boosting demand; regulatory aspects; support schemes, market rules and infrastructure and a Research and Development (R&D) programme.

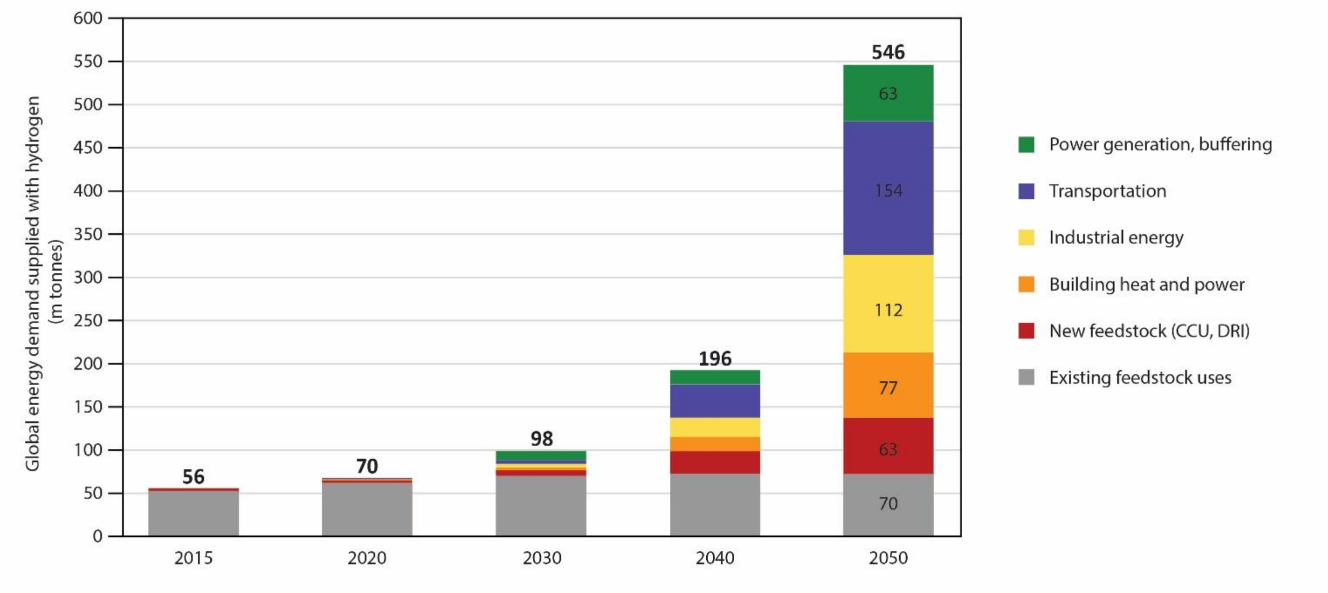


Figure 2.4 Global energy demand supplied with hydrogen

Advances in electrolyser technology efficiency and major cost reductions combined with the environmental and financial incentives associated with decarbonising society in general have made the concept of a hydrogen economy a reality (EirWind: Todesco Pereira et al., 2019); (European Commission, 2020a). These fuel substitution developments provide an opportunity for Ireland to expand our rich offshore wind energy resources to these carbon heavy sectors and in doing so resolves problems of emissions and security of supply as a bonus.

The EirWind project identifies that an expansion of the energy market for OSW can be achieved by converting electricity to hydrogen to gain access to the heat and transport markets in Ireland which are four times the size of the electricity market (EirWind: Laguipo et al., 2020a). In these energy markets, green hydrogen would displace carbon emitting fossil fuels of oil, gas and coal. The decarbonising benefits combined with import substitution and security supply are fundamental enablers to achieve this fuel transition (Dinh et al., 2020a). The following sections identify the potential markets in transport heat and industry including export for the Irish OSW energy resource.

2.2.3 Hydrogen Opens up New Markets in the Irish Transport Sector

In Ireland, the transport sector remains almost entirely dependent on fossil fuels, therefore, CO_2 emissions from transport are increasing with increasing energy use. CO_2 emissions from transport accounted for the largest energy-related emissions (40%), in 2018 and continue to increase year on year; 24% between 2012 and 2018. This makes transport the third-largest contributor to greenhouse gas emissions after electricity generation and agriculture in Ireland. The majority of transport CO_2 emissions arise from road transport and in 2016 private car use accounted for 52% of these (Department of Transport, Tourism and Sport, 2018). Decarbonisation of the transport sector is high on the Government decarbonising agenda in the Climate Action Plan and can be achieved by electrification (with 500,000 EV's targeted by the CAP by 2030) and introducing hydrogen as a transport fuel. A mix of technologies and approaches will be needed to get us to net zero by 2050.

Hydrogen as a replacement fuel for diesel and petrol has a much higher value then hydrogen for heat and industrial processes. However, hydrogen for transport requires a different approach in terms of delivery-to-market infrastructure involving significant capital investment and operational costs. But even with the higher delivery and operational costs, EirWind studies show that economies of scale in relation to electricity from OSW and centralised hydrogen production plants can reduce the unit costs of hydrogen to a point where the prospect of hydrogen for transport becomes viable **(EirWind: Laguipo et al., 2020a; EirWind: Laguipo et al., 2020b; Dinh et al., 2020a)**. EirWind results show that hydrogen production costs of less than €5/kg are possible in an integrated production system which couples large scale OSW to a large scale hydrogen production facility. The additional delivery costs result in a final cost to customers of €8-€9/kg of hydrogen which begins to look competitive with respect to petrol and diesel if some level of decarbonising subsidy is introduced **(EirWind: Laguipo et al., 2020a)**.

The Hydrogen Mobility Ireland (HMI) study (Hydrogen Mobility Ireland, 2019) developed a Hydrogen Roadmap for transport and gives a detailed account of the various steps that need to be taken in terms of infrastructure preparation and creation, market development and government incentives. The study gives a comprehensive and accurate indication of the complexity of the effort required to introduce hydrogen. The study also provides financial data to show that a consumer price for delivered hydrogen of between €7.8 and €9.25/kg can make the proposal economically viable, aligned with the EirWind findings **(EirWind: Laguipo et al., 2020a)**. The High Uptake scenario presented in the HMI study calculates a hydrogen for transport demand of 60,000t/day by 2030. The source of the hydrogen is from a number of geographically dispersed electrolyser plants driven by wind farms and a waste to energy plant combined with grey hydrogen produced at the Whitegate SMR plant. A modified version of the HMI proposed pilot project which includes more green hydrogen as a source and adopts the high uptake scenario approach would complement the market development objectives for OSW. The above hydrogen production rate using electrolysis would require approximately 1.1TWh of electricity which could be supplied by 0.25GW of OSW (using an average C.P. of 50% and accounting for system efficiencies). It is proposed therefore that a target of green hydrogen production from OSW of between 0.1 and 0.5GW producing green hydrogen for transport by 2030 could be set and reconciled with, and in support of, the High Uptake HMI scenario.

Each of the sub-market segments of private cars, LGV, HGV and public transport buses and trains has its own set of economic viability parameters and environmental benefits requiring specific analysis to determine the actions required for the fuel change. Within the motor industry there has been a strong bias towards EVs for private cars. The optimum solution will most likely be a combination of EV for private cars and FCEVs for LGV and HGV and public transport so initially the focus in Ireland could be in this sub-segment of the transport market.

As with the heat market, a phased approach is required for the period during which the market demand for hydrogen for transport is growing. During this period the use of blue hydrogen and the use of pilot demonstration projects is key to market development.

In relation to a target for 2050 the IEA projections of 25% of transport using FCEV's (IEA,2019b) is appropriate. Theoretically, we have calculated that up to 75% of the transport energy demand in Ireland could be supplied by hydrogen but taking the IEA figure of 25% this gives a Final Energy requirement of 15TWh using 2018 demand (SEAI 2019). Again using a 50% C.F. for OSW and applying system transformation efficiencies the required OSW capacity for this is 2.95GW.

In summary the expanded hydrogen for transport market for OSW could provide between 0.1 and 0.5GW by 2030 and conservatively 3GW by 2050.

2.2.4 Hydrogen / Ammonia for Maritime Transport

There is a growing interest in a number of maritime transport applications for fuel based on hydrogen in the context of decarbonising the shipping sector. The international nature of shipping, means that attributing CO_2 emissions to any one national economy is extremely complex. As a result, the International Maritime Organisation (IMO) has been playing a lead role in plans for limiting GHG emissions from shipping. According to a recent study by Lloyds Register and University Maritime Advisory Services (UMAS), zero carbon fuels for shipping are likely to be ready within the next two years, while the economic case will be driven by the evolution of energy/fuel prices over the coming decades (Lloyds Register and UMAS, 2020). One alternative, biofuels, are constrained by sustainability and availability factors. However, the production and transmission of zero carbon fuels from ammonia produced from hydrogen may provide a more resilient alternative. The supply of ammonia can transition from blue hydrogen (using Natural Gas and Carbon Capture and Storage) to green hydrogen (using renewable electricity), providing short and long-term advantages. The development of storage and bunkering infrastructure is a potential barrier to be overcome with regulatory actors. Ammonia requires less space than hydrogen, making it a better option for ships such as tankers or cargo ships that need to carry large volumes of fuel. To date, no ammonia-fuelled ships have been built, however, with the progression of technology, the maritime industry is likely to be an early adopter of ammonia for shipping as a zero carbon fuel, replacing the use of fuel oil in marine engines. This is being considered in the follow-up to EirWind, the H-Wind project (Dinh and Leahy, 2020). Geostrategic thinking could envision a refuelling hub for ships of the future for locations such as Shannon Foynes port.

Compressed or liquefied green hydrogen could be a choice for vessels that need to refuel regularly. An EirWind study on hydrogen fuel cells for crew transfer vessels for offshore wind concluded that hydrogen is as safe as Liquefied Natural Gas (LNG) for use in hydrogen-fuelled fuel cell vessels, if handled properly **(EirWind: Todesco Pereira, 2020b)** Hydrogen-fuelled transport vessels are an example of a niche market that could be developed. The UK is taking a proactive approach to research and innovation to underpin these new opportunities (Department of Transport, 2019). Based on the regulations standards and rules currently in place, the main safety concerns for the use of hydrogen and fuel cells on board of CTV lies on controlling fuel leaks, minimizing confined spaces, avoiding ignition sources, securing ample ventilation for confined spaces, and monitoring enclosed spaces to avoid any fuel accumulation above the fuel/air mix threshold that allows any combustion to happen.

Large scale bulk hydrogen production from FLOW linked to off-shore hydrogen production platforms could produce bulk hydrogen for export to be transported by tankers to global markets. In a global green hydrogen export market scenario, the associated growth in OSW resource development would be of the order of tens of GWs.

2.2.5 Hydrogen Markets for Heat

After the transport sector, the heat sector has the second largest demand for energy accounting for at least 39% of the total energy for heat use in Ireland as of 2018 (SEAI, 2019). Energy sources for heat are predominantly supplied by fossil fuels such as oil and gas. As of 2018, 42% of heat was derived from oil and 40% from natural gas. It resulted in 6,451 ktCO_2 and 4,546 ktCO_2 emissions from oil and gas respectively. Heat is the second largest source of energy-related CO_2 emissions in Ireland (SEAI, 2020). The Climate Action Plan identifies electrification and heat pump technology as central to the decarbonisation of the built environment to 2030. Other solutions will be required to achieve a net zero built environment such as hydrogen. Ireland has an extensive natural gas network comprising 2,200 km of transmission and 11,200 km of distribution pipeline (Gas Networks Ireland, 2014). Gas Networks Ireland (GNI) envisions the Irish gas network to be net zero carbon by 2050. GNI aims to inject 50% net zero carbon gases into the network to displace half of the natural gas required to meet consumer demand. It is planned that a large percentage of this gas will be 'blue hydrogen' coming from SMR with CCS. A target of 11TWh per annum of renewable gases will be injected into the network by 2030 (20% of current demand) and the volume of renewable gas and hydrogen will be increased to 50% by 2050 (Ervia, 2019).

The renewable gas and hydrogen targets of 11TWh by 2030 and 27TWh by 2050 provide an opportunity for 'green hydrogen' production from OSW but this does not provide a guaranteed market. The target will most likely be a mixture of 'blue hydrogen', renewable methane and 'green hydrogen' and the supply split will depend on a number of economic, political, geographical, geological and resource supply factors some of which will be out of the control of Irish industry and Government. Assuming that 10% of the 11TWh target could be met by OSW by 2030, increasing to c25% by 2050 a first estimate of the scale of OSW power development is given as: 0.25GW by 2030 and 1.5GW by 2050.

2.2.6 Green Hydrogen for Irish Industry

A number of industries in Ireland require heat or grey hydrogen for their industrial processes but the energy sources of natural gas, coal and oil are carbon intensive. The Programme for Government aims to cut carbon emissions by 7% per year between now and 2030 (Government of Ireland, 2020). The largest share of these emissions comes from the manufacturing of chemicals, food, beverages and cement. Even though manufacturing is a relatively small sector in Ireland, there are a number of carbon intensive facilities around the country, (e.g. oil refining and aluminium production). The cement industry uses petcoke, coal, waste tyres, biomass and a range of Refuse Derived Fuel (RDF) for the heat load, and electricity for mechanical load. A future scenario with green hydrogen and RDF replacing fossil fuels could provide a low carbon and sustainable future for the industry. The idea of producing a high quality green product almost entirely from local resources is very attractive. Likewise, for aluminium production, methane could be replaced with hydrogen to produce a low emission rated premium product.

Furthermore, a number of industries have adopted carbon neutral policies. Leading IT companies with a presence in Ireland, such as Apple, Google and Microsoft, have plans for zero emissions production by 2030. Green electricity will continue to play a role but there is also potential for industrial green hydrogen. The pipeline infrastructure is already in place to deliver a mixture of natural gas and hydrogen. Each industry will have its own set of economic parameters and corporate policies which will eventually determine whether hydrogen is the optimum vector to allow them to go green. The analysis will also be influenced by EU green trading arrangements involving coupling of different sectors. For example, the requirement for products used in a particular sector (e.g. building) to be manufactured in a green process could feed back to the manufacturing companies.

The key to the introduction of hydrogen to these industries is the reduction of green hydrogen production costs and the global indications confirmed by the results of the EirWind studies are the production costs are rapidly reducing with economies of scale and advances in electrolyser technology. The investment announced in the EU Hydrogen Strategy will give a further boost to cost reductions with support to the technology development component of the hydrogen economy. The strategy states that from now to 2030 investments in electrolysers of the order of €24 to €42 billion would be required and this will support the hydrogen market development process by making hydrogen more competitive. In addition, investments of €65 billion are expected for the development of hydrogen distribution and storage.

Thus the market opportunity for industrial green hydrogen has potential related to the 2018 energy industrial heat demand of circa 20TWh (given as 1.665mtoe in 2018, SEAI, 2019). If, by 2030, 5% of this demand was supplied by green hydrogen i.e. c1TWh, this would create a market for 0.25GW of OSW. An increase to 30% market share by 2050 would create a demand for 1.5GW of OSW. These projections are considered conservative and are very much dependent on the way in which green hydrogen is supported and adopted as the preferred energy source for a new green deal for a decarbonised world.

2.2.7 Green Hydrogen for Export

There is an existing global demand of 70 million tonnes of hydrogen per year and growing (IEA, 2019b). This growth is attributed to the pressing need for a decarbonisation tool due to environmental concerns. The EU Hydrogen Strategy considers that hydrogen '*offers a solution to decarbonise industrial processes and economic sectors where reducing carbon emissions is both urgent and hard to achieve'.*

The production of large scale 'bulk green hydrogen' will play a critical role in the decarbonisation of these various sectors referred to in the EU Hydrogen Strategy. The demand thus created for bulk green hydrogen for global industry provides a huge opportunity for Ireland to become an exporter of energy. It is difficult to estimate the demand this market will create at this point in time but recent studies are very optimistic and a number of ambitious projects have been announced including the Tractabel system for production at sea; the Arrowsmith Hydrogen project, Perth, Australia; Pale Blue Dot Energy - Acorn Hydrogen project in Scotland; PosHydon and Deep Purple. Europe is becoming a global centre of excellence for power to gas (Figure 2.5). The Dolphyn project is backed by the UK government, concerning a pilot to produce hydrogen at scale from floating offshore wind turbines. A proof of concept has been undertaken, to be followed by a 2MW pilot floating hydrogen production facility by 2024; a 10MW project is planned for 2027, with full-scale commercialisation thereafter.

The economics of this system depend on large scale deployment so the only projections that can be made are for capacities in excess of 5GW's by 2050 with the caveat that this will not happen without long term planning and support from Government. If Ireland is to become a major player in the international hydrogen market, it is necessary to make a clear statement of intent on the development of offshore wind for hydrogen production in Ireland. Since the resource is not a limiting factor, we identified a plausible range between 5GW and 10GW as an initial target indicator for hydrogen production. This is in line with initiatives for large scale hydrogen production from offshore wind coming from other European countries taking leadership in this market (Figure 2.5). Countries such as the Netherlands are including hydrogen, even though they have access to the electricity grid capacity as route to market. This is not an option for Ireland, making the need to develop production facilities for Ireland, key to unlocking offshore wind in this jurisdiction.

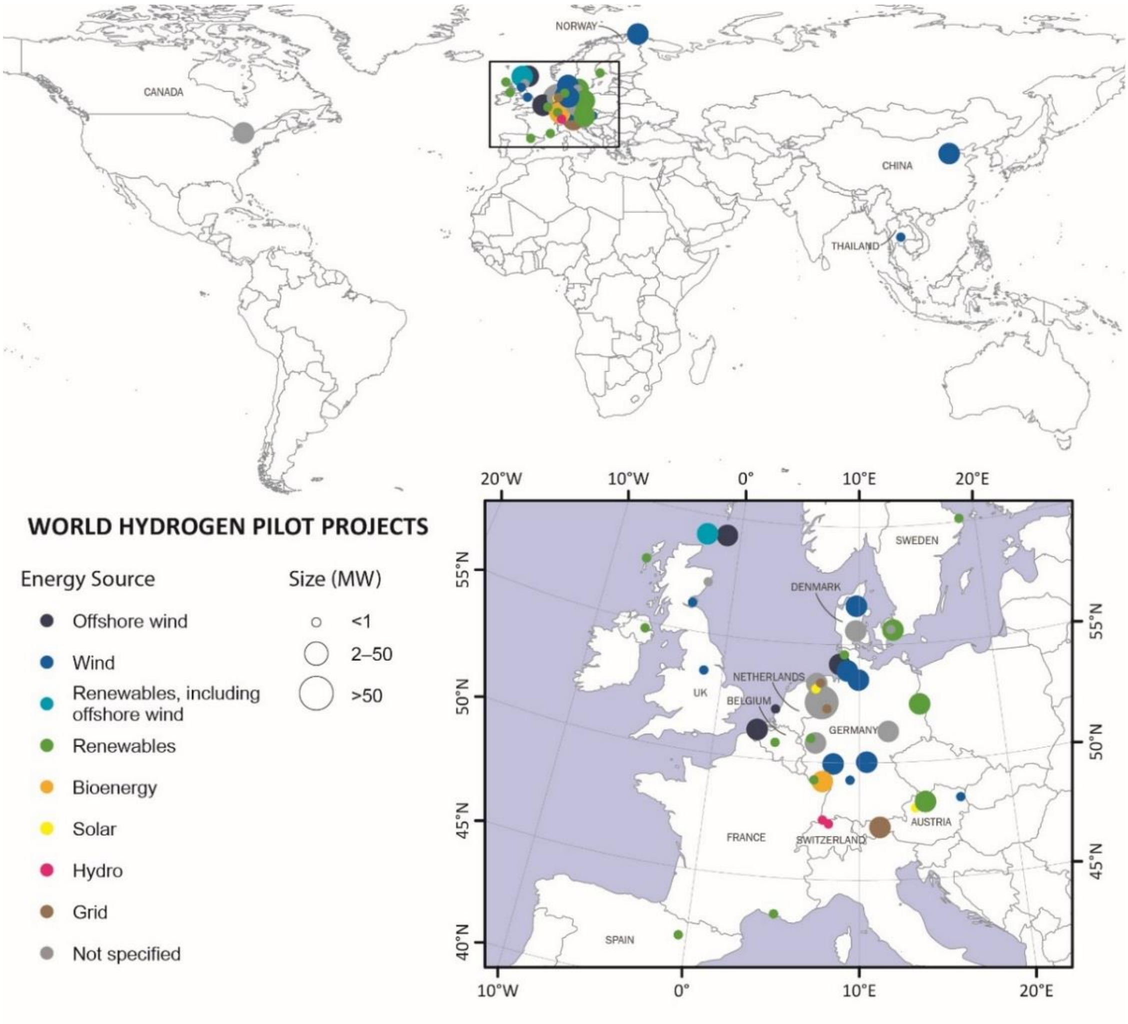


Figure 2.5: The distribution of world hydrogen projects, showing a concentration of activity in Europe (EirWind: Todesco Pereira, 2020).

2.2.8 Total Projections for Expanded Energy Market

The total market for OSW power is the sum of the demand in the markets segments listed in Table 2.3 below. The EirWind projection of up to 24.9GW by 2050 can be contrasted with the Wind Europe estimates of 22GW of OSW from Ireland for the same timeline (Wind Europe, 2020). The opportunity that hydrogen production brings is clear from the estimates of GW by 2050 (8.9GW for electricity only; up to 24.9GW if hydrogen is included).

Table 2.3: Projections of OSW to meet total energy market demand

Market segment	GW 2030	GW 2040	GW 2050
Electricity	6.3	7.8	8.9
Transport	0.1-0.5	1-2	2-3
Heat	0.1-0.5	1-2	2-3
Bulk hydrogen exported	0	1-2	5 to 10
TOTAL	**6.5-7.3**	**10.8-13.8**	**17.9- 24.9**

2.3 Meeting Market Opportunities through Offshore Wind Activity Zones

The realisation of the market opportunities for Ireland will depend on multiple factors, including whether some or all of the market segments in Figure 2.6 below are pursued. In order to achieve up to circa 23GW of energy from offshore wind by 2050, annual installation rates need to increase substantially from what is currently planned. EirWind consultations with experts in the offshore wind sector **(EirWind: Desmond & Butschek 2020)**, indicate that, in their opinion, the actual installed capacity could be anything between 1GW and 5GW by 2030.

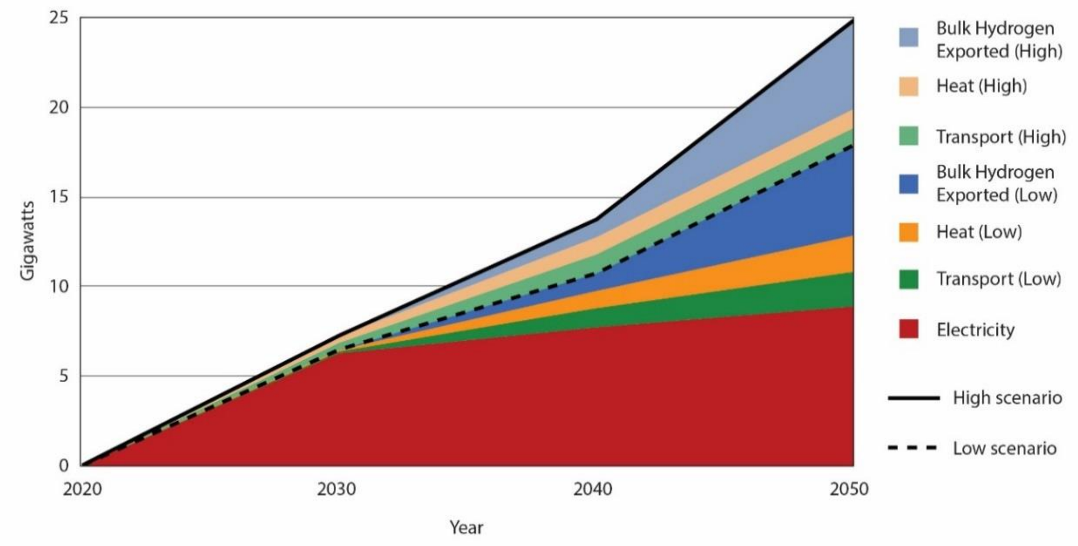


Figure 2.6: EirWind offshore wind production scenarios.

2.3.1 The Irish Sea OSW Production Zone

Demand from the domestic electricity market provides an immediate opportunity. The Irish Sea, which will be the first activity zone for offshore wind, has the added benefit of a route to market via plans for enhanced grid connectivity. The relatively shallow water depths in the Irish Sea (Table 2.4) define this production zone for BFOW (Figure 2.7). Relevant projects will be facilitated to proceed to apply for a Planning Interest. The Irish Sea OSW Activity Zone features the potential for bi-lateral collaboration across the Irish Sea with established UK suppliers and ports. For example, Mostyn in North Wales, specialises in the assembly and installation of wind turbines for wind farms, such as Walney and Gwynt y Mor, in the UK part of the Irish Sea. Announcements in the first half of 2020 concerning investment in Rosslare Europort as an offshore wind supply and logistics base for the Irish Sea, and plans for Arklow as an Operations and Maintenance hub for SSE's Arklow Bank Phase II project, are strong indicators of capacity building to facilitate the development of the local supply chain.

Table 2.4: Water depth for offshore wind can be divided into three categories. Each category of water depth has a different foundation technology that is the most viable associated with it.

Category	**Depth**	**Technology Type**
Shallow Water	<45m	Monopiles, XL monopiles, XXL monopiles gravity base foundations, jacket foundations
Transitional Water	45m – 70m	Gravity base foundations, jacket foundations
Deep water	80m +	Floating platforms

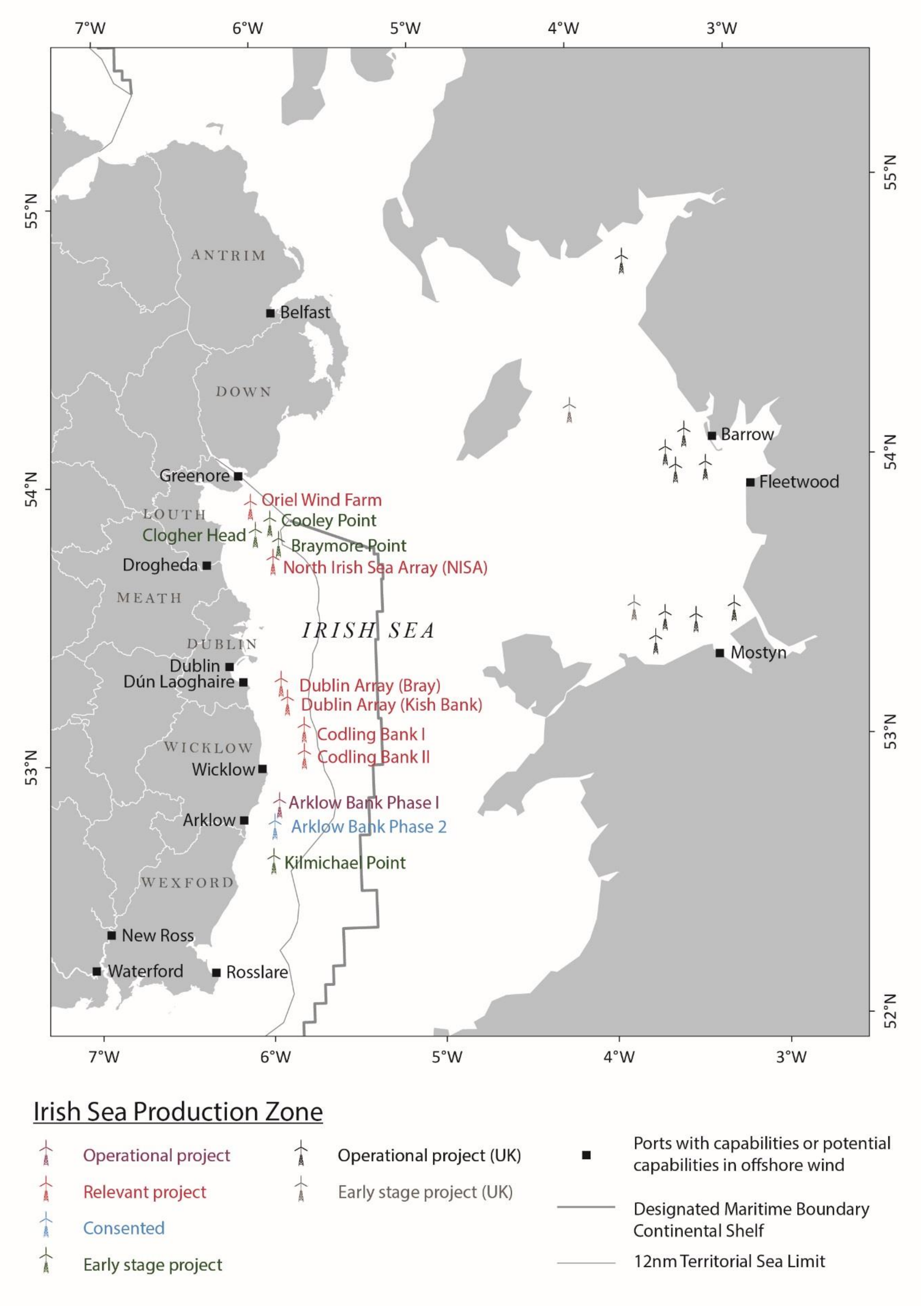


Figure 2.7: The Irish Sea Production Zone for BFOW.

2.3.2 The Celtic Sea OSW Production Zone

The realisation of the longer term production scenarios, e.g. ~18GW to ~25GW by 2050, will depend on market opportunities for the Celtic Sea and Atlantic production zones. A combination of grid upgrades, the Celtic interconnector, CPPAs, and new routes to market are required to facilitate the emergence and optimisation of a second production zone in the Irish part of **the Celtic Sea**, for a combination of BFOW and FLOW projects in transitional and deep waters (Figure 2.8), likely to start coming on-stream from the latter half of the decade (Table 2.5).

The situation is currently at a crossroads. A decision on whether to invest in more interconnector capacity to shift electricity to mainland Europe and UK; or whether to invest in building capacity for hydrogen production and infrastructure for distribution to market; is needed. It may not be a case of either or, but some combination of both solutions for route to market.

A strategic approach to the development of the Celtic Sea Production Zone requires consideration of the short, medium and long-term export opportunities. For example, UK offshore wind development has been concentrated in the North Sea to date. Low correlation of wind systems with the North Sea means that offshore wind production from the Celtic Sea provides a grid balancing solution for Europe when taking a systems view of UK energy requirements (WaveVenture, 2020). The development of the Celtic Sea Production Zone may be facilitated by taking a holistic view of its shared geography between Ireland and the UK. To date, a collective view of the Celtic Sea as an activity zone has been lacking, as attention has been focused on the Irish Sea. However, the realisation of the considerable potential of this zone (estimated as circa 10.5GW in the Irish part of the Celtic Sea), will benefit from ongoing capacity building around the Irish Sea projects. This zone may also be required as a fail-safe option in relation to meeting national climate targets in light of any planning issues that may arise with proposals for offshore wind in the Irish Sea.

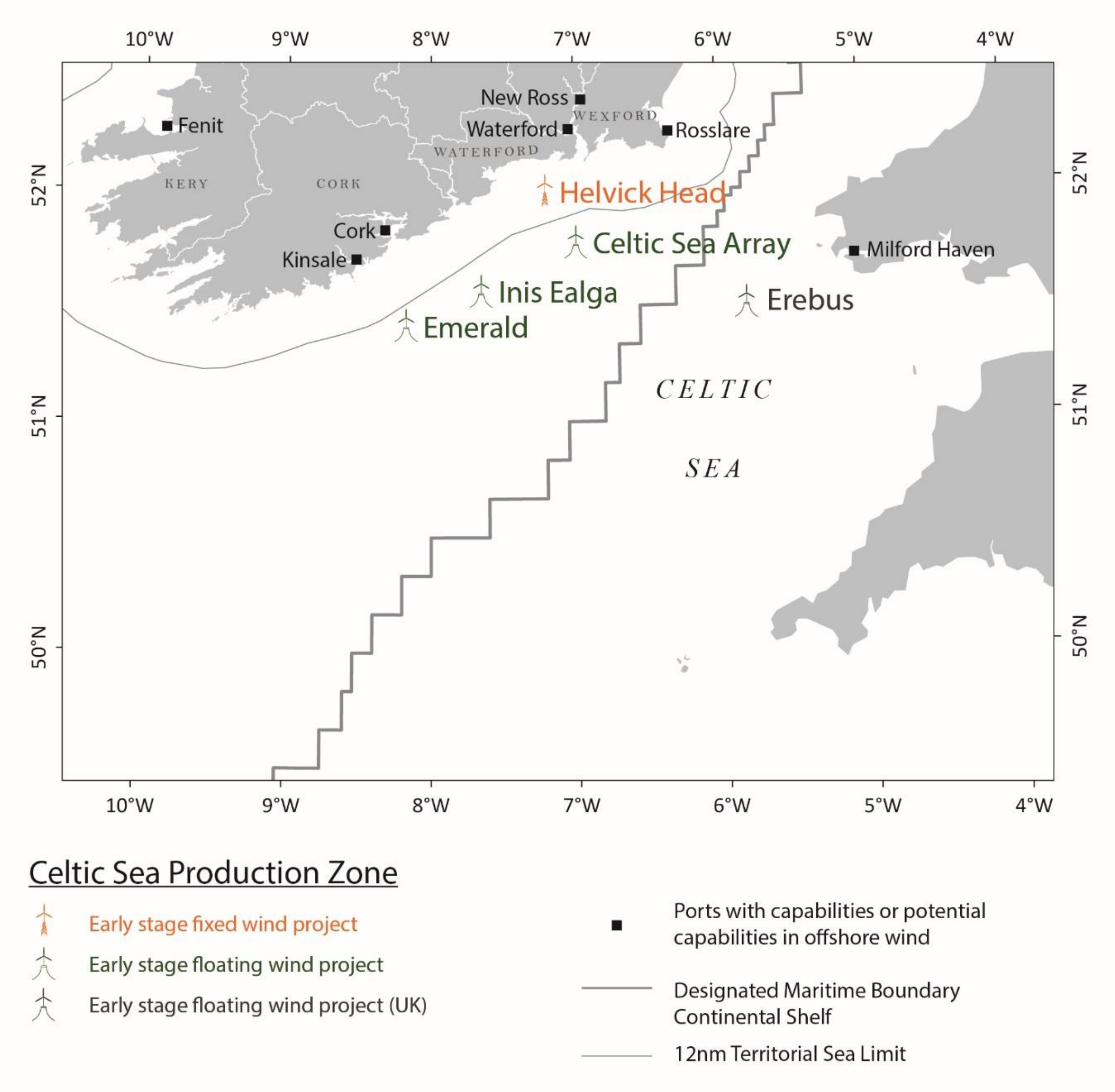


Figure 2.8: The Celtic Sea OSW Activity Zone for BFOW and FLOW.

2.3.3 The Atlantic OSW Production Zone

It is envisaged that techno-economic advancements in FLOW technology will facilitate the expansion of offshore floating wind at scale in deep waters in the Atlantic OSW Production Zone (Figure 2.9). The west coast opportunity may be kick-started by the domestic electricity market, as a result of the presence of a strong grid node at Moneypoint and Tarbert and through a logistics hub at Shannon Foynes (see Chapter 2 below). Activity on the west coast is likely to develop from circa 2030. Government ambition outlined in the Programme for Government (Government of Ireland, 2020) is for 30GW of FLOW in the Atlantic. There is potential for at least 10GW of offshore wind in the Atlantic Production Zone, based on the scenarios in Section 2.2 above, starting with electricity, and progressing to hydrogen at a scale. Tens of gigawatts may ultimately be realised via bulk hydrogen production and international distribution at a competitive market price.

This will happen at a stage when Ireland takes full advantage from a staged approach to capacity building for hydrogen. Further study of the potential of the Atlantic OSW area is required. The fact that FLOW technology is suited to deep waters further from the shore makes this an attractive proposition in terms of coexistence with tourism in the region (i.e. the Wild Atlantic Way).

The west coast has also been flagged as an ideal location for the development of wave energy. The ESB previously identified the WestWave site off the Clare coast, near Doonbeg, as a strategic location for the deployment of initial wave energy arrays. The co-location of FLOW and wave energy may be a future transition pathway, yielding benefits for the delineation of offshore space, and mutual benefits such as grid balancing and Operations and Maintenance (O&M). A summary of the characteristics of each of the three production zones is provided in Table 2.5.

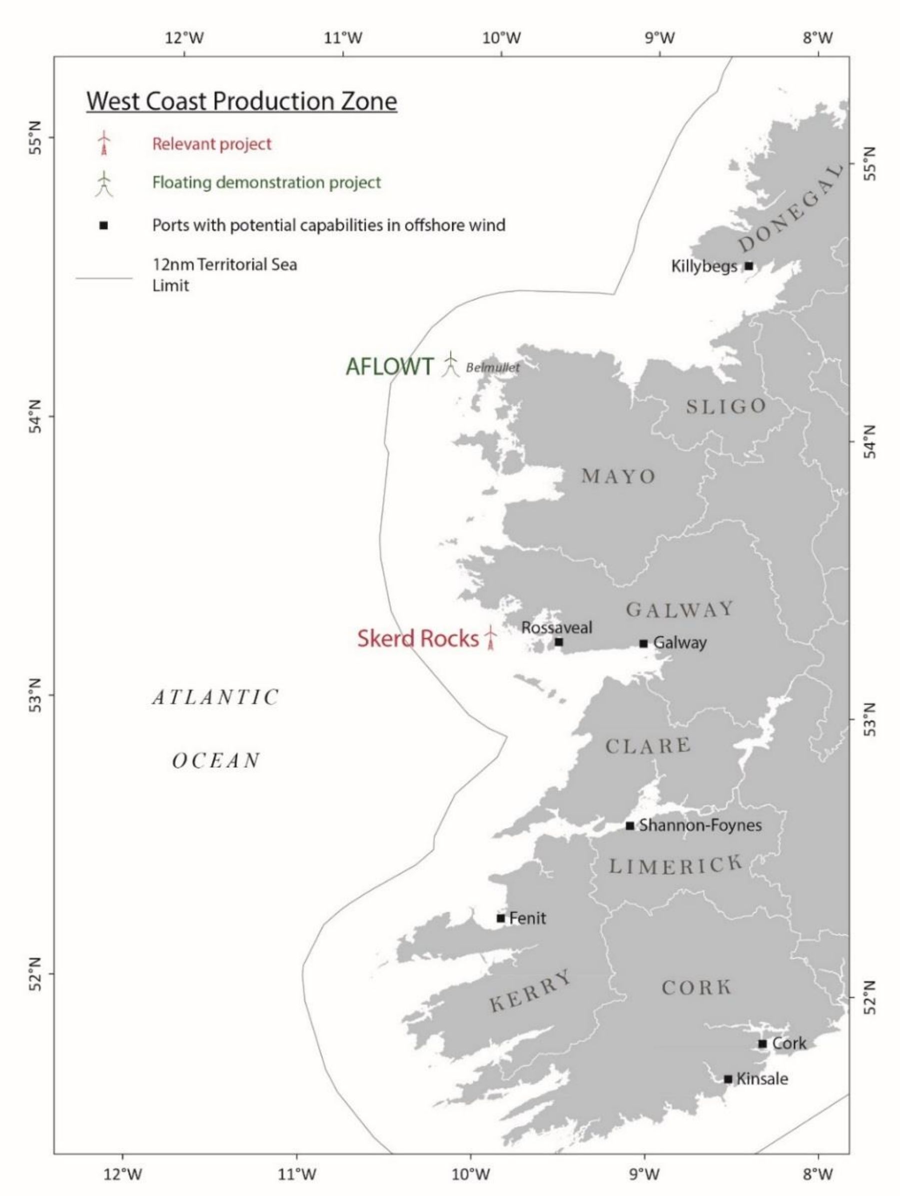


Figure 2.9: The Atlantic OSW Production Zone for FLOW.

Table 2.5: Key characteristics of Offshore Wind Activity Zones for BFOW and FLOW in Ireland to 2050

OSW Activity Zones	Irish Sea	Celtic Sea	Atlantic Coast
Water depth	Shallow/Transitional	Transitional/Deep	Deep
Plausible production potential	5GW	10GW	10GW
On-stream	2020-2030s	Late 2020s-2050	2030-2050
Route to Market	Domestic electric + interconnectors	Domestic electric + interconnectors + domestic hydrogen for transport and heat	Domestic electric + interconnectors + domestic hydrogen for transport and heat + exported bulk hydrogen

2.4 Strategic Advantages to be Realised from Market Development

2.4.1 Energy Security

Energy security comprises many diverse factors, including import dependency, fuel diversity, the capacity and integrity of the supply and distribution infrastructure, energy prices, physical risks, supply disruptions and emergencies (SEAI 2016). In 2014, 97% of energy imports were fossil fuels namely oil (56%), natural gas (31%), and coal (10%) (SEAI 2016). All of Ireland's oil was imported with an estimated cost of €4.4 billion in 2014, equating to 77% of the total cost of energy imports. The opportunity may be to offset this cost by developing indigenous energy resources. Also, from a geostrategic perspective, this provides a hedge against the vagaries of international fossil fuel prices into the future. In the shares of total energy supply in Figure 2.10, oil accounts for 48%, natural gas 29.8%, coal 7.6%, and wind 4.4%. This shows the massive opportunity gap to be filled as Ireland is weaned off fossil fuels.

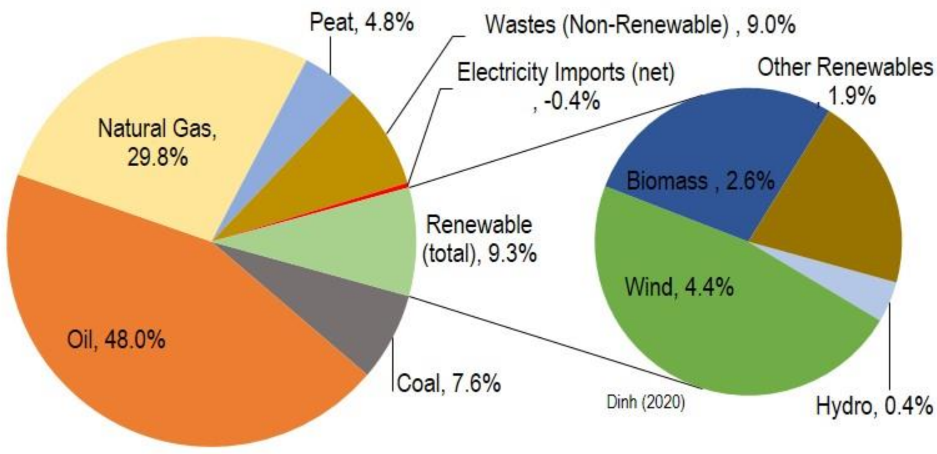


Figure 2.10: Shares of energy supply in Ireland in 2017 (total: 14,473 ktoe) **(Dinh, 2020c)**, data from (SEAI, 2018).

2.4.2 Energy Storage

Hydrogen production technology primarily introduced to allow access to new market sectors involves hydrogen storage **(Dinh et al., 2020c; EirWind: Dinh et al., 2020b)**. The scale of storage could be increased to provide large scale storage of variable wind energy. This would address a growing challenge of balancing during periods of low wind generation and curtailment during periods of high wind power generation **(EirWind: Bambury et al., 2020; Laguipo, et al., 2019)**.

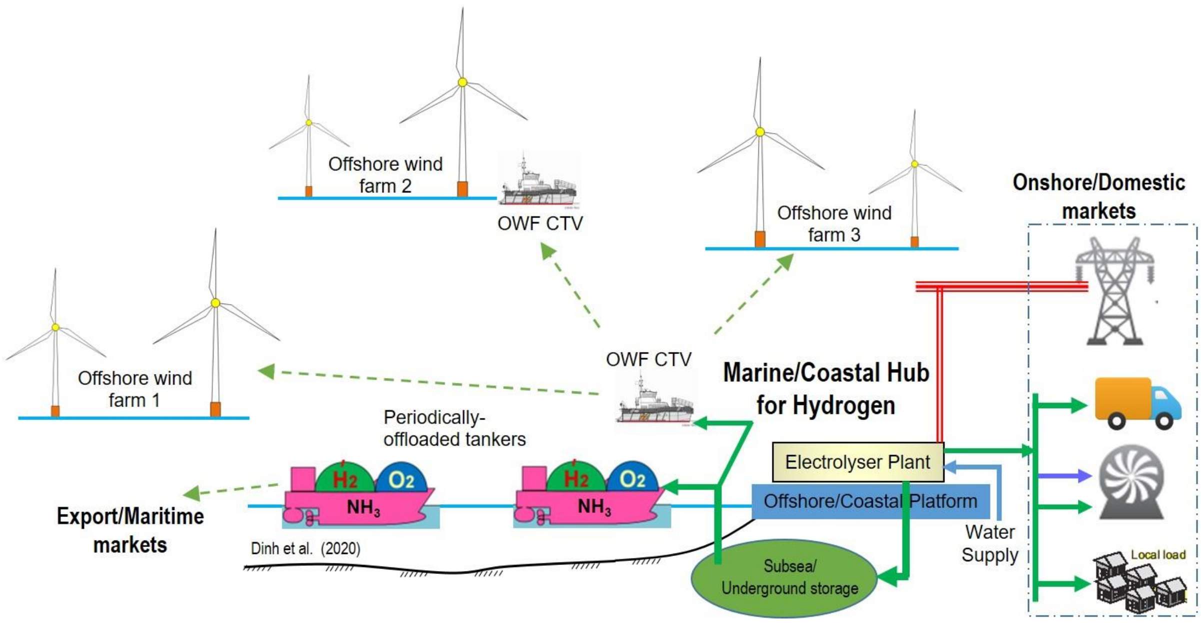


Figure 2.11: Hydrogen storage linked to offshore wind farms (Dinh and Leahy, 2020).

This scenario for Ireland is confirmed by international studies. For example, on a global scale, when considering the renewable electricity share as forecast by the IEA two-degree scenario, more than 500TWh of electricity globally could be converted into approximately 1.5EJ of hydrogen each year by 2050. As more and more renewable electricity comes into the supply mix the need for large scale storage increases exponentially according to studies carried out by Fraunhofer Institute and McKinney (Fraunhofer ISE, 2018)

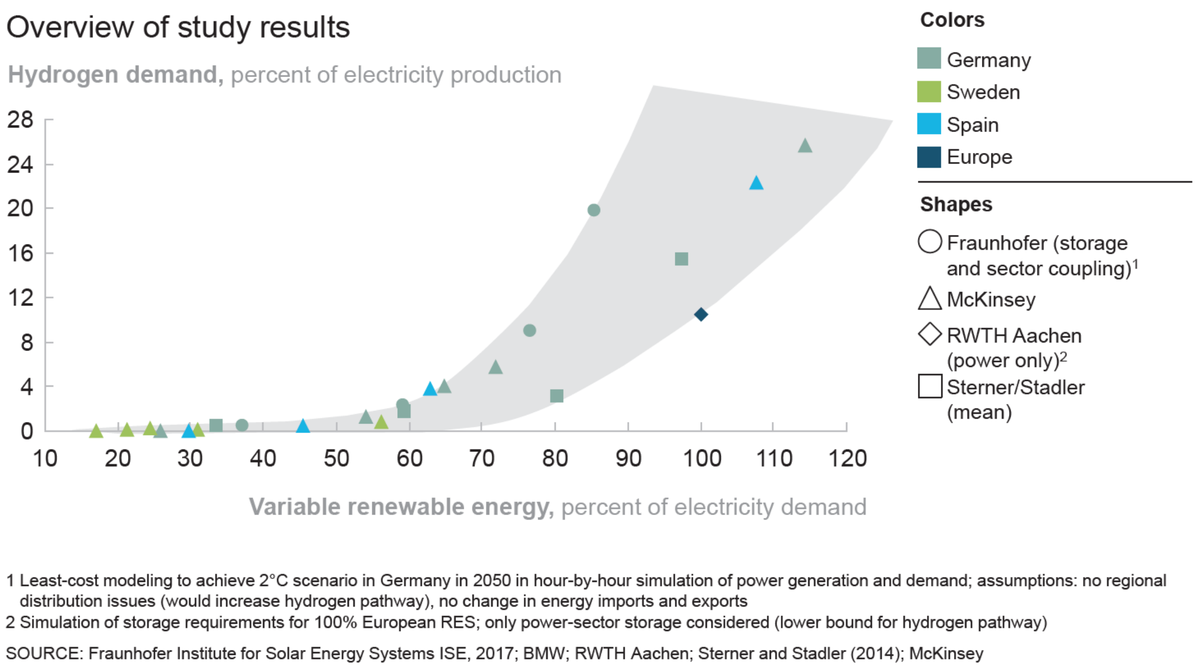
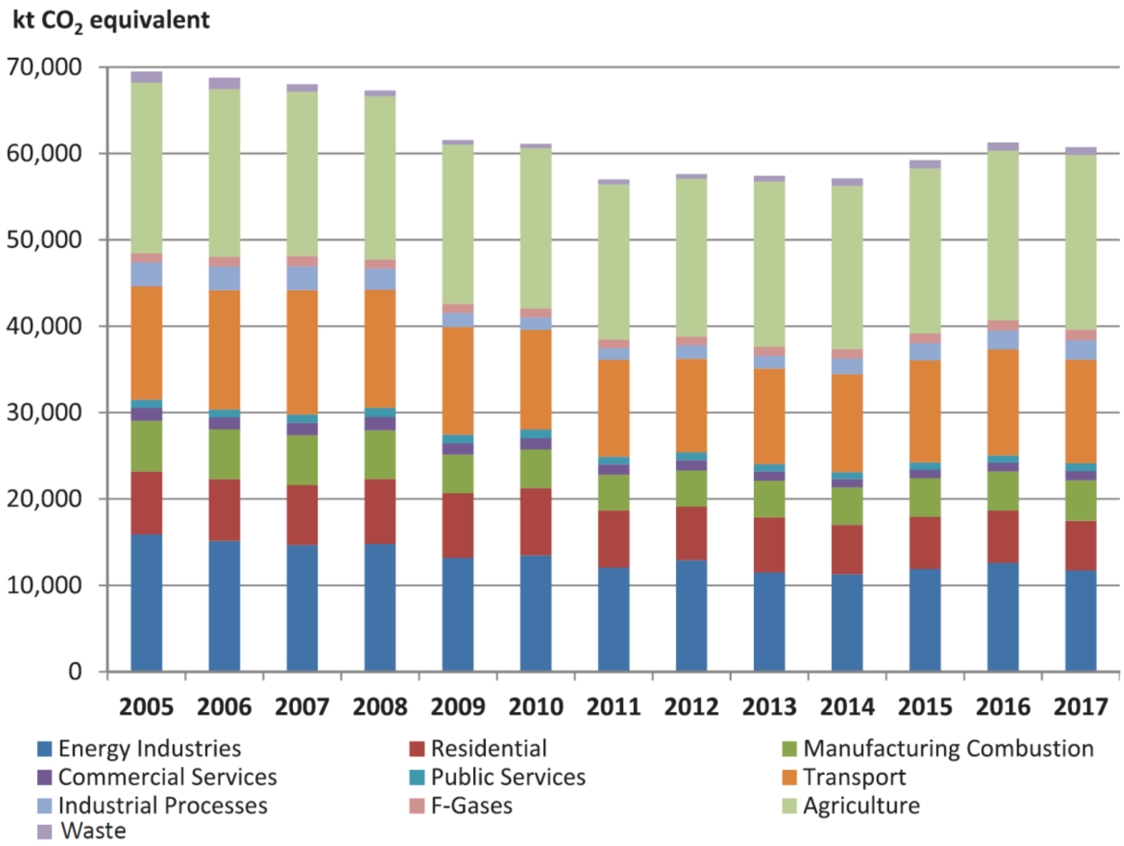


Figure 2.12 The need for hydrogen storage increases exponentially with the variable renewable energy share.

The long term goal of decarbonising the total energy supply in Ireland can be supported by large scale hydrogen storage in line with the studies described in Figure 2.12 above.

2.4.3 Decarbonisation of the Economy

In 2017, Ireland's Greenhouse Gas Emissions were estimated to be 60.75 million tonnes of carbon dioxide equivalent. Five different sectors – agriculture, transport, energy industries, residential, and manufacturing accounted for almost 90% of the national emissions total (Environmental Protection Agency, 2018). In addition to the contribution from electrification of the transport and heat sector, the increase in OSW renewables, coupled to the expanded market hydrogen scenario, will facilitate GHG emissions reductions. Figure 2.13 summarises Ireland's greenhouse gas emissions in the period 2005-2017 in which more than 65% come from electricity generation, built environment and transport sectors.



SOURCE: Climate Action Plan 2019

Figure 2.13: Ireland's greenhouse gas emissions from 2005-2017. [Source: Government of Ireland, 2019]

2.4.4 Job Creation and Economic Impact

The opportunity to create new jobs is a major benefit arising from the development of the offshore wind sector for Ireland. The EirWind project developed a complex model, which is reported in detail in **(EirWind, Kandrot et al., 2020a; Kandrot et al., 2020b).** The EirWind modelling suggests that in 2030, 6.5-7.3GW of domestic offshore wind development would support between 12,012 and 13,491 direct and indirect jobs in the domestic supply chain. This equates to between 29,702 and 33,558 person years of employment for the period 2020-2029. There is potential to create additional jobs, provided the supply chain grows more quickly than anticipated (Figure 2.14).

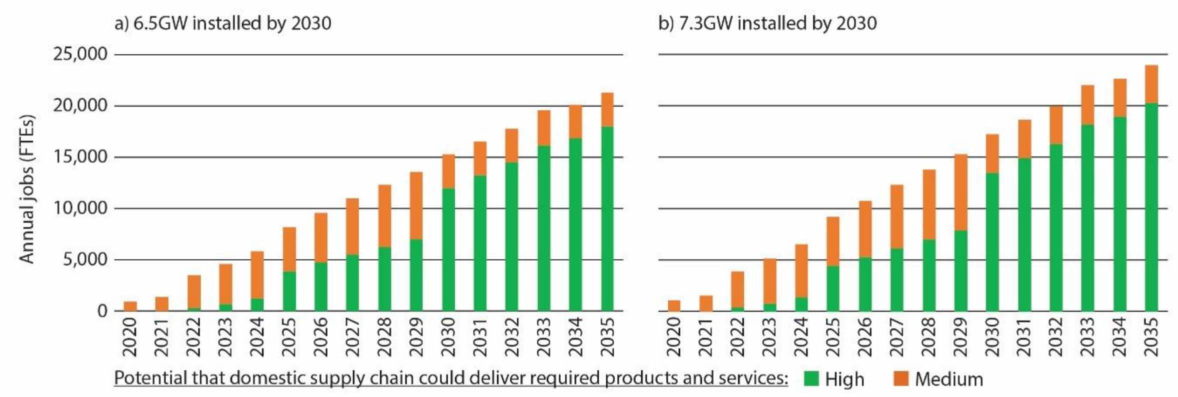


Figure 2.14: Potential employment impact associated with the domestic supply of products and services for Irish offshore wind projects for (a) low (6.5GW) and (b) high (7.3GW) cumulative installed capacity scenarios, modelled as part of EirWind **[EirWind: Kandrot et al., 2020a].**

EirWind model outputs further suggest that offshore wind could generate between €845m and €948m in GVA in 2030 (Figure 2.15), with a total GVA impact of between €1.98bn and €2.2bn for the period 2020-2029. This would contribute significantly to the ambition of Ireland's Harnessing Our Ocean Wealth strategy, which seeks to double the value of Ireland's ocean economy by 2030. This is the first study to quantify the GVA impact of offshore wind development for Ireland **(EirWind, Kandrot et al., 2020a; Kandrot et al., 2020b)**.

Unlike previous studies, our economic model assesses the near to medium term domestic economic impact of offshore wind development for Ireland. It builds on work by the Carbon Trust/IWEA, which suggests that Irish firms could currently capture 22% of the investment and could grow to capture 31-36%, and, in the longer term, as much as half (Carbon Trust, 2020).

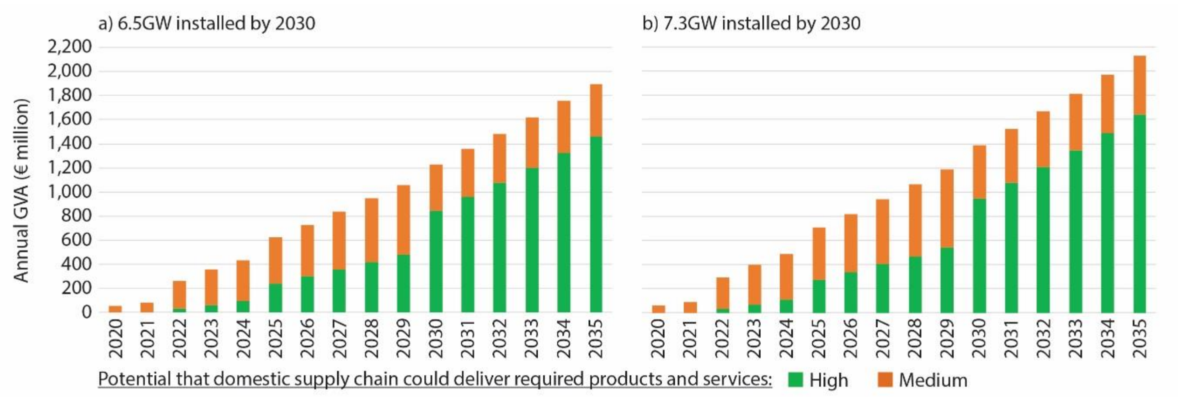


Figure 2.15: Potential GVA impact associated with the domestic supply of products and services for Irish offshore wind projects for (a) low (6.5GW) and (b) high (7.3GW) cumulative installed capacity scenarios, modelled in EirWind WP4, D4.10. **(EirWind Kandrot et al., 2020a).**

2.4.5 Regional Development

The potential for the development of offshore wind provides an opportunity to address Ireland's regional economic imbalance and associated issues, such as rural depopulation and the decline of many coastal communities, especially on the west coast. The concept of ports as stimulants and a locus for development within the regions emerges from the research conducted in the EirWind socio-economic study **(EirWind: Kandrot et al., 2020a; Kandrot et al., 2020b)**. Figure 2.16 shows the trend towards higher rates of social deprivation around ports on the west coast of Ireland. Investment in disadvantaged areas such as Killybegs or the Shannon region could help to address what has been a long-standing issue, of sources of job creation for rural Ireland.

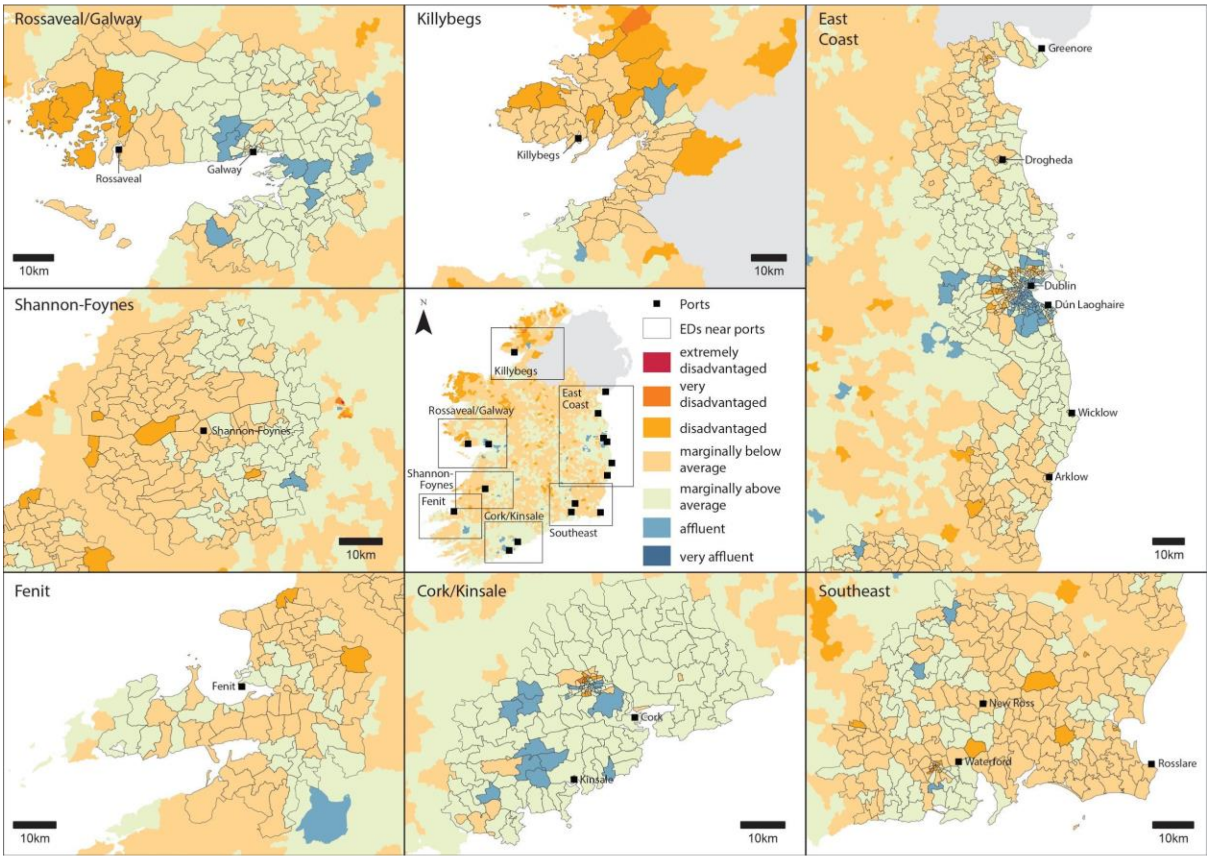


Figure 2.16: Social deprivation around ports with capabilities, or potential capabilities, in offshore wind. The hinterlands around peripheral, west coast ports tend to be characterised by greater levels of social deprivation than their urban and east coast counterparts, representing localities where the maximum socioeconomic benefits associated with offshore wind development can be realised. **(EirWind: Kandrot, et al., 2020a)**

2.4.6 Port Development

Port requirements for OSW can be grouped according to the scale of investment and space required for different activities associated with offshore wind, ranging from: - i). Large, strategic ports designated as manufacturing hubs (such as Green Port, Hull, UK); ii). ports for assembly and installation (such as Belfast); iii) small ports and harbours for operations and maintenance (such as Arklow).

Few European ports are capable of accommodating all the quayside manufacturing and assembly required for building and operating large-scale offshore wind farms. According to Leahy *et al*., (2020) Shannon-Foynes has high potential for staging *and* manufacturing. Manufacturing is a golden ticket for regional development; this is a strategic opportunity for the Atlantic Production Zone. Planned offshore wind activity in the Irish Sea has led to an investment in Rosslare, which is set to become a major hub for the assembly of turbines and logistical support. In early 2020, XELLZ, a Dutch logistics management company acquired 300,000m^2 of land in Rosslare for the development of an offshore wind supply base.

As outlined in the EirWind Issues Report **(EirWind: Chester et al., 2018)**, a number of other Irish ports may be suitable assembly and installation activities, to a point. Many Irish ports have the experience of being the port of entry for onshore wind turbines, including storage and marshalling requirements. The Port of Cork and Shannon Foynes (both Tier 1 ports) have immediate potential for installation activities arising from investments in deep water berths, for example, in Ringaskiddy and Foynes. Both are strategically located, have adequate water depths and proximity to production zones for BFOW and FLOW projects. However, despite some key assets, the port business models tend to be focused on the throughput of cargo, and there may be competition for space going forward.

As Irish ports are set to take on an expanded role in the offshore wind supply chain, investment is needed, for example in specialist heavy-lift cranes, as offshore wind components get larger and installation volumes increase (e.g. the new Siemens Gamesa 14-222DD with a capacity of up to 15MW, features 108m long blades. The nacelle weighs 500 tonnes). In order for ports to progress as centres of industrial activity for offshore wind, opportunities exist for agreements with developers and manufacturers, akin to the models used in the Port of Hull and Belfast Harbour (see **EirWind: Chester et al., 2018** for case study of Belfast Harbour, which has become a leading centre in offshore wind development). The semi-state dimension to Irish ports means that the government has a critical role to play in promoting strategic partnerships, and securing further investment. The Shannon-based Moneypoint coal-fired electricity power station, will close in 2025, freeing up jetties and other maritime facilities with perhaps some potential to be adapted for as a maritime operations hub for offshore wind. Killybegs, as referred to earlier, is also strategically placed and well-equipped to serve the northwest coast given time. Given perceived opportunities for the scale of marine renewables off the west coast (offshore wind and wave), the Marine Renewables Industry Association (MRIA), identified a 'western gap' and recommended that government keep an open mind about the need to develop a new port on the west coast between now and 2030 (MRIA, 2014). Opportunities also exist for multiple smaller ports right around the coast, which could facilitate O&M services.

The EirWind socioeconomic study recommends a strategic approach to the development of regional clusters around ports in preparation for new projects **(EirWind: Kandrot et al., 2020a; Kandrot et al., 2020b)**. This is aligned with the recommendations of the Carbon Trust offshore wind supply chain report (Leahy *et al.,* 2020), which promotes ports as centres for enterprise development and innovation.

2.4.7 Supply Chain Development Opportunities

Improving Ireland's share of the offshore wind supply chain is an important opportunity for job creation. These opportunities span various aspects of the supply chain, including preliminary Development Expenditure (DEVEX) stage, Capital Expenditure (CAPEX) (over 50% of overall cost relates to capital expenditure), Operational Expenditure (OPEX) (products and services associated operations and maintenance post construction) and Decommissioning Expenditure (DECEX) (the decommissioning phase) (Figure 2.17). Given the already established and experienced European supply chain, including the UK supply chain on Ireland's doorstep, the Irish industry can look to become leaders in the production of components and niche areas for BFOW developments in the Irish Sea. Offshore wind is still a maturing sector with many opportunities for innovation. For example, there is scope for improved reliability, automated controls, and technological improvements to facilitate health and safety for offshore personnel. Enterprise Ireland (EI), and the EI Offshore Wind Cluster, has been facilitating bilateral, business to business linkages with relevant UK suppliers, with a view to strategic partnerships. Opportunities also exist with other jurisdictions, including Norway, with its vast experience and capability from the development of North Sea gas and oil.

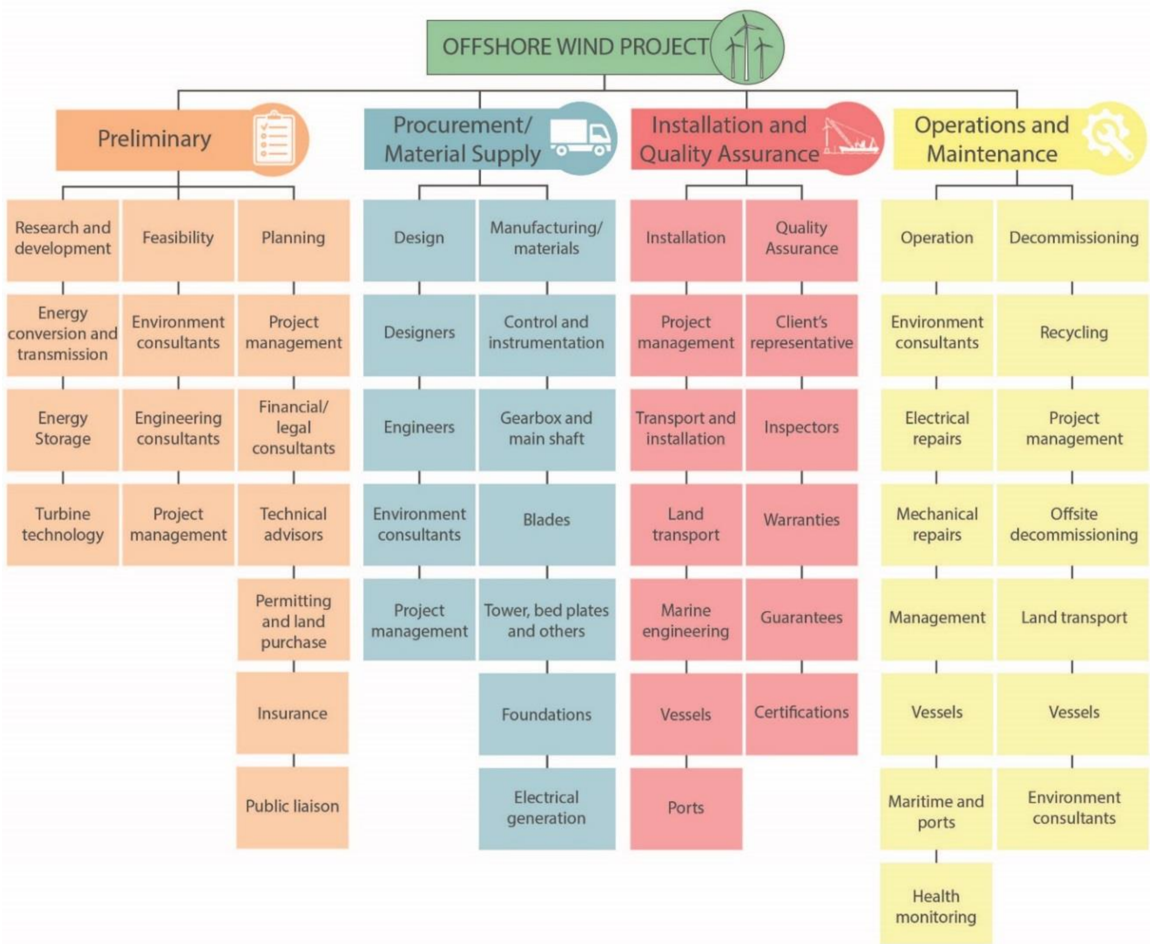


Figure 2.17: Overview of the supply chain components for offshore wind - **[EirWind: Kandrot at al., 2020a]**

The offshore wind supply chain is part of a global market, and very few countries have full supply chain capabilities at the sub-national level (More information on the offshore wind supply chain is available from **EirWind: Kandrot, et al (2020a); Kandrot et al., (2020b)**. As a result, developers often source much of their needs from overseas suppliers. This has led to the imposition of statutory or voluntary local content requirements. Local content policies require that a certain percentage of the value of a project is spent on domestically-manufactured goods or domestically-supplied services. On the one hand, this helps ensure money spent on a development is retained locally and supports local business and jobs. On the other hand, it can significantly increase the cost of developments, which may be passed onto consumers or taxpayers, and undermine industrial competitiveness and overall employment in the long-run (OECD, 2019).

The challenge for policymakers and developers is to achieve a balance between supporting the domestic supply chain, balancing investment from multinationals and keeping costs down. Assuming a total installed capacity of 24.9GW by 2050, based on CAPEX derived from a series of **EirWind case studies outlined in Section 3.3,** this would represent a total capital investment in the order of €87bn for 5GW in the Irish Sea, 10GW in the Celtic Sea and 10GW in the Atlantic. Substantial investment will come at risk from the private sector developers, typically in the form of Multinational Corporations. This inward investment is a key enabler for the development of the supply chain. The UK Sector Deal commits the offshore sector there, to increase UK content to 60% by 2030, as well as setting an ambition to increase exports from the sector by a factor of five to £2.6bn in the same period. Lessons learned from the UK experience suggest the merits of a supply chain plan, as part of a developer's application, rather than hard targets for local content.

Ultimately, an opportunity exists for a strategy to build a global supply chain, led by the enterprise development agencies, EI and the Industrial Development Agency (IDA).

2.4.8 Benefit Sharing with Local Communities

Community benefits allow some of the profits from local energy generation to stay within the community. Although benefit sharing is costly, the cost of ignoring local communities and thereby of failed projects, could be higher (Britto et al., 2019). Benefit sharing relates to both monetary (in-fund), non-monetary (in-kind) and ownership benefits (Figure 2.18). Full details of stakeholder perceptions of benefit sharing options for OSW in Ireland are in **EirWind: Kami Delivand and Cummins, (2020).**

Figure 2.18: Potential community benefit opportunities. The three main categories of benefits are monetary benefit, benefit-in-kind and co-ownership/ownership benefits. **EirWind: Kami Delivand and Cummins, (2020).**

In the context of wind energy (mainly onshore but also offshore), benefit sharing acts as a tool to establish and maintain positive long-term relationships with the local community. In Ireland, established practices for involving the local community in energy transition programs exist for *onshore* wind. Defining a community of interest for *offshore* wind projects is a challenge, especially for FLOW, where developments are out of sight. This makes offshore wind a poor fit for co-ownership models. Co-ownership, which is promoted in the RESS scheme for onshore wind, can be challenging from an administrative point of view, as well as requiring upfront investment from communities, which may not be forthcoming. In-kind and monetary benefits may be preferable at the early stage of the development of the offshore wind sector in Ireland. A focus on fisheries as a key community of interest may also be required. Examples of some of these practices associated with offshore wind developments elsewhere in Europe are shown in Table 2. 6.

Table 2.6: Examples of community benefits from offshore wind projects (2016-2019).

[EirWind: Kami Delivand and Cummins, 2020].

Project	Description	Link
Ørsted East Coast Community Fund	Launched in December 2016 as part of Ørsted's community engagement program for its Hornsea Project One and Race Bank offshore wind About £390,000 will be made available each year until 2037 from the main fund to support community and environmental projects Additional £75,000 is ring-fenced per year for a skills fund, designed to support a range of educational and training initiatives In total, up to £9.3 million will be made available for community and environmental projects in coastal areas of Yorkshire, Lincolnshire and North Norfolk over a period of 20 years. The fund has so far (April 2019) donated more than £900,000 to more than 80 projects.	Ørsted's East Coast Community Fund Gives Back And Walney Extension Community Fund
DONG Energy's Walney Extension offshore wind farm Community Fund in Cumbria (North West England)	In 2016, thirteen local organisations in Lancashire and Cumbria coastal communities have been awarded grants totalling £250,000 Each year about £600,000 is made available for community projects for the expected 25-year lifetime of the wind farm	DONG's UK East Coast Community Fund Up for Grabs
European Offshore Wind Deployment Centre (EOWDC) community fund by Vattenfall in and supported by Aberdeen Renewable Energy Group (AREG) Scotland	Annually investing £150,000 in the community benefit scheme for the 20-year lifetime of the 93.2MW offshore wind project (£1600/MW) The scheme will invest in projects that are long-term environmentally sustainable, contribute to a climate smarter world and are a benefit to the local community	EOWDC Community Fund Opens for Applications

Beatrice Offshore Wind Farm (BOWL)	588MW, 84 turbine Beatrice offshore wind farm Total £6m community investment fund for projects that will have the potential to deliver transformational social, economic and environmental changes in the local area while supporting long term community development e.g. the first round of the Partnership Fund for £600,000 to support transformative community projects (in Highland and Moray) in the first year	SSE Launches Beatrice OWF Community Fund
Innogy Wind	Community investment fund to benefit local communities up to 25 years to support voluntary and community groups working on social priorities (children; young people and families; education and learning; the environment)	RWE Innogy Hameldon Hill Wind Farm Community Investment Fund
Massachusetts large scale offshore wind project	Initial capacity of 804MW, 84 large turbines, 23 km off the state's coast Allocating USD 721,500 in grants to six academic institutions and labour organisations to establish workforce training and development programs to support the state's offshore wind sector *(The project has been delayed due to concerns around the project's impact on the local fishing industry)*	Massachusetts Allocates Funding for Offshore Wind Programs

2.4.9 Conservation Objectives

As the seas of Northern Europe are becoming a hotspot for offshore wind development, there have been calls for improved marine conservation in these same areas, as the effects of human activities increase (Hammar et al., 2016). As both these needs grow, a discourse on the potential synergy and compatibility of offshore wind power and marine conservation is essential. If Ireland is to steer a course towards a vision of energy self-sufficiency, then an opportunity exists for the possibilities of co-location with conservation objectives. Generally speaking, there are currently 78 MPAs, designated under European and national legislation, and 19 OSPAR sites in Irish waters (Irish Wildlife Trust, 2017). However, technically there are 78 Special Areas of Conservation (SACs) with marine qualifying features and 19 OSPAR MPAs (which are also SACs and derive their protection only from being SACs). The term MPA is not used in Irish law (as yet) and the EU interpretation of MPA refers to Special Protection Areas (SPAs), SACs or MPAs under other regional agreements (in Ireland's case, OSPAR).

With the ongoing effects of overfishing and climate change, an emphasis on MPAS in the National Biodiversity Plan, and targets to increase MPAS in the EU Biodiversity Strategy, MPA numbers can be expected to rise. Ireland is at 2.3% coverage of MPAs despite the international requirement for 10% so combining OSW with marine conservation could be one approach to increasing national MPA coverage. The programme for Government in 2020 specifies a requirement to realise the outstanding target of increasing MPA's in Ireland to 10% and to 30% by 2030. The EirWind Study on offshore wind and marine conservation (**EirWind: Sweeney & Cummins, 2020)**, found that trying to match an offshore wind farm with the function of an MPA can be challenging, but that nevertheless, an opportunity exists (e.g. Other Effective Conservation Measures [OECM]). Studies have shown that offshore wind farms increase biodiversity. (Hammar et al., 2016; Langhamer et al., 2009; Wilhelmsson & Malm, 2008) The question is how to systematically produce positive impacts through habitat creation? Marine Installation Conservation Areas (MICAs), proposed in **EirWind: Sweeney & Cummins, (2020),** offer a potential solution, with a focus on enhanced biodiversity through artificial reefs and Fishing Aggregation Devices (FADs). This has the potential to provide a win-win for offshore wind developers, conservationists and fishers.

2.4.10 Co-location with Aquaculture

With the development of Marine Spatial Planning in Ireland, it is timely to explore the opportunity for synergy and to understand the risks of sharing the same space between the offshore wind and aquaculture sectors. Overcoming technical, ecological, economic, policy and governance challenges requires research to develop new knowledge. Apart from the technical challenges of designing marine co-location which will combine several operations in the same sea space, there are non-technical issues that could stymie implementation. An opportunity exists to examine the environmental aspects, financial planning required by investors, trust to be built between the parties sharing the sea, multi-sectoral engagement with government bodies, and communication between partners who run these businesses. A TEEG approach which looks at the Techno, Economic, Ecological and Governance aspects of co-location should address the challenges. A multidisciplinary TEEG proposal, arising from the EirWind project, has been scoped to ensure that a wide perspective is taken so that existing research, opinions of stakeholders and new research, all come together to support co-location of offshore wind and aquaculture. Co-located aquaculture activities range from relatively low value, seaweed production; shellfish production (e.g. mussels on longlines); to high value (and higher risk) co-located fish farm production.

2.5 Conclusion Chapter 2

The approach to the development of OSW for Ireland described above is a phased, zoned and market based approach. The rate at which development will occur in the Irish Sea will depend on policy actions from the government. This will also be important in subsequent production zones (the Celtic Sea Production Zone and the Atlantic Production Zone), as well as recognition of the significance of FLOW, and the key role that it plays in the development of the resource in the Irish context; and a commitment to the hydrogen economy. To date, the focus has been on capacity building for BFOW in the Irish Sea. A more ambitious outlook, with a plan led-approach to market development in each production zone, is required to unlock the opportunities outlined above from the development of offshore wind. Floating wind energy is on the cusp of industrialisation. Utility scale projects are being planned for FLOW and for hydrogen production around the world. New technologies are emerging to drive this innovation-led sector. However, a number of technological and logistical challenges remain for OSW. These are examined in Chapter 3.

3. Challenges for Offshore Wind in Ireland

EirWind

3. Challenges for Offshore Wind in Ireland

This chapter aims to highlight the key issues that face Ireland as it develops a successful offshore wind industry. At present, Ireland faces challenges concerned with i). Government resourcing, ii). Accessing the physical environment, iii). Technical and logistical issues, iv). Markets and energy infrastructure and v). Lack of skills.

3.1 Challenges with Government Resourcing

3.1.1 Human Resources

An EirWind study to examine the human resources required in the civil service to ensure that Ireland's offshore wind targets can be achieved in a timely manner, revealed the need for circa 20-25 new personnel to be recruited in the next 12 to 24 months **(EirWind: Judge et al., 2020)**. The study identified a number of potential bottlenecks within the consenting process that must be addressed if Ireland's offshore wind targets are to be met. It is likely that ABP will receive offshore wind farm applications from Relevant Projects in 2021/2022. Each of these applications will be equivalent to a large SID with the added complication of being in a new space for ABP. Therefore, it is recommended that a minimum of 10 staff within An Bord Pleanála should be dedicated to offshore wind consenting.

Both the DHLGH, and the DCACNT will need additional resourcing to ensure efficient marine spatial planning and consenting processes. Expertise in marine spatial planning is required in the short to medium-term to ensure proper planning in relation to the relevant and enduring projects, and to develop SMAZ's that capitalise on Ireland's offshore wind potential (e.g. off the west coast).

The study highlighted the importance of having access to marine experts in the public service to ensure robust decision making, e.g. for the interpretation of EIAs and AAs, and also to engage in the marine spatial planning process so that potential issues are identified and understood at an early stage. The study also recommends that resources are augmented within statutory consultees to enable proper consultation and to minimise challenges on nature conservation grounds that could cause lengthy delays. Key statutory consultees include; the SEAI, the Marine Institute and the Geological Survey of Ireland. The establishment of a coordinated scientific research and data collection programme between these agencies is recommended to support the marine spatial planning and consenting processes and to ensure that the maritime area is managed to meet the long-term needs of the economy, the natural environment and the Irish people. The above recommendations on additional resourcing required assume a decentralised, developer-led scenario.

A government consultation open at the time of writing (DCCAE, 2020), has framed four approaches for feedback, ranging from decentralised (bottom-up) to centralised (top-down):

- Option 1: Developer led
- Option 2: Plan defined - developer consents and builds
- Option 3: Plan defined - developer builds
- Option 4: Plan led

While there is an up-front cost to the State to provide the proposed additional resourcing, (based on the developer-led Business-As-Usual approach), the economic benefits of offshore wind have the potential to far outweigh the initial investment, as outlined in the EirWind socioeconomic study **(Kandrot et al., 2020a).** Should the State take a greater role in developing offshore wind and move towards a centralised model, the resourcing requirements within Government departments and agencies will increase.

3.1.2 Organisational Structure

In a separate EirWind study, on a comparative analysis of the Irish and Scottish regulatory frameworks for offshore wind, interviewees were critical of the fragmentation within various government departments and agencies (**EirWind: O' Hanlon and Cummins, 2019**; O' Hanlon and Cummins, 2020). The research shows a strong perception from industry experts that the Irish government could do more to demonstrate support for offshore wind. The lack of a dedicated policy for offshore wind was raised as a key issue to be addressed. This was also flagged in the EirWind supported thesis by **Evans (2020)**. Figure 3.1 shows the policy gap concerning offshore wind in Ireland versus the UK as a whole.

The review of regulatory frameworks between Ireland and Scotland also identified the potential for better integration in decision making bodies through a single competent marine body for marine consenting. In Ireland, there are 11 government entities dealing with these legislative and policy requirements aspects. The lack of a single coordinating body is an ongoing issue for developers. Marine Scotland's One Stop Shop, enabled by the Marine (Scotland) Act 2010, was perceived from the research as a key factor in facilitating the Scottish offshore wind sector. While this is not a panacea, it helps end users navigate through the 'horrendogram' of policy and legislative requirements that need to be complied with in the development of offshore wind (Figure 3.2). O Hanlon and Cummins (2020) concluded that government reorganisation can be challenging, and in fact, change can be counterproductive in the short-term. Gravitating to more integrated online services could be facilitated to address lack of coordination across functions in the short term. The SEAI's ocean energy portal provides a potential building block for further expansion and development.

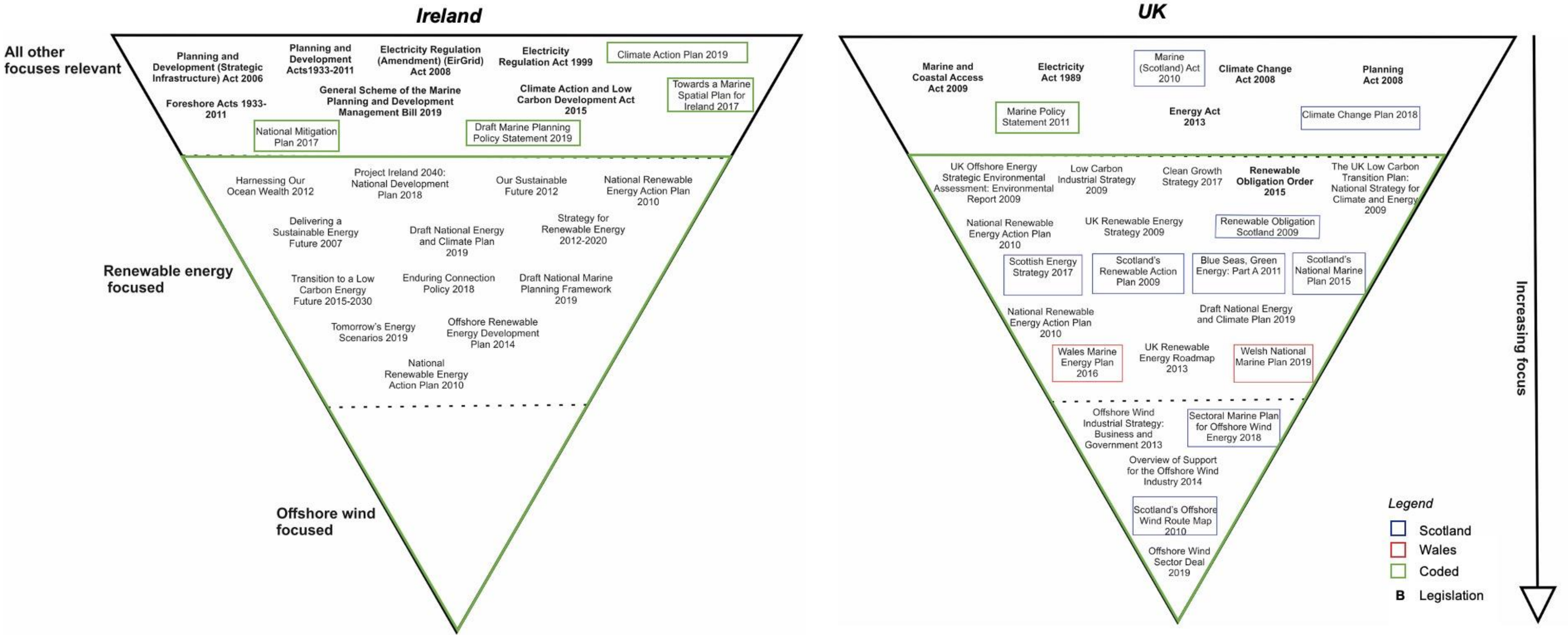


Figure 3.1: Novel Triangle Diagram showing the different levels of OWE focused policy and legislation in Ireland and the UK, alongside the more general renewable energy-focused policy **(Evans, 2020).**

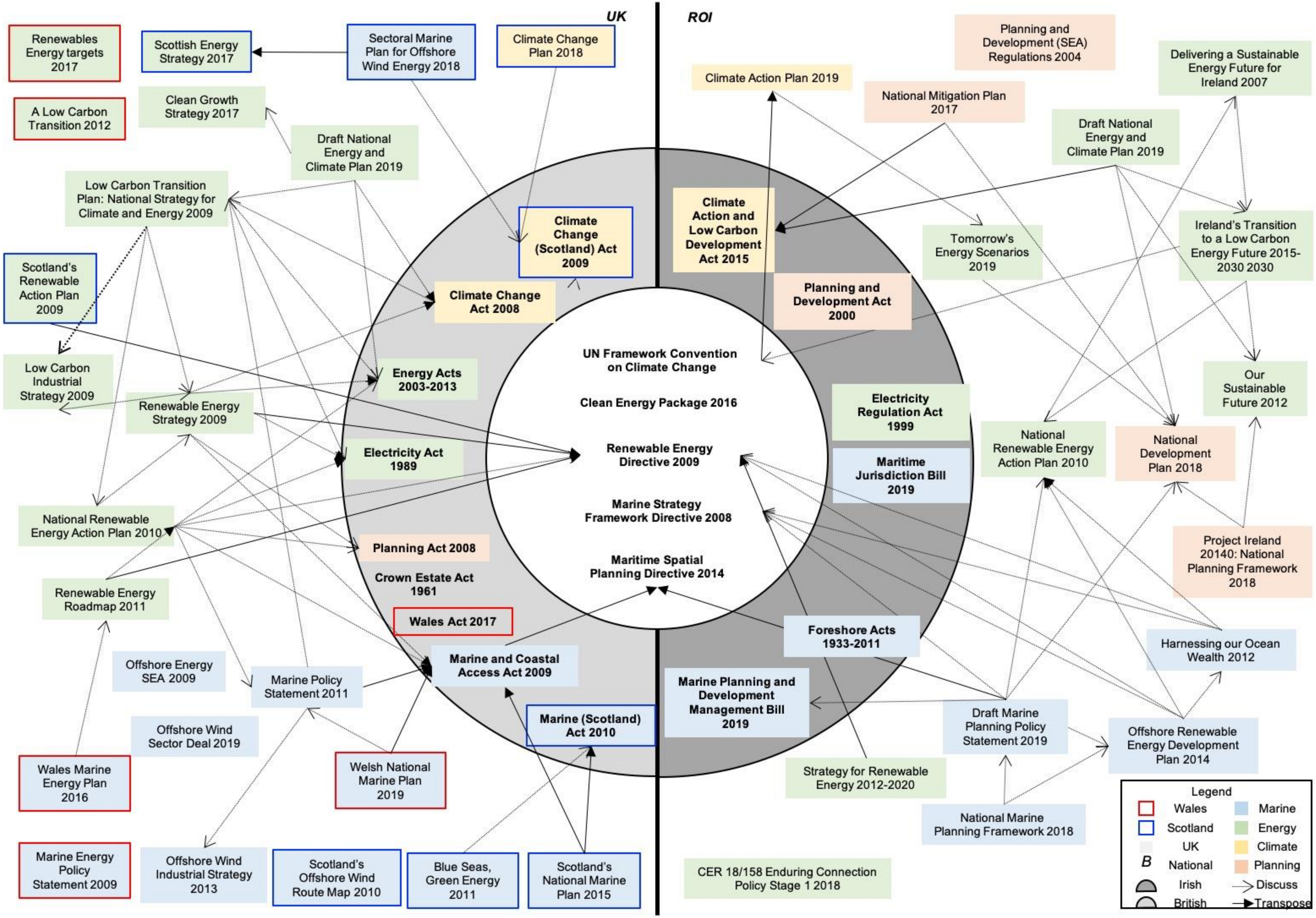


Figure 3.2: Comparative 'Horrendogram' of UK and Republic of Ireland policy and legislation, with UK legislation on the left and Irish on the right (**Evans, 2020)**.

3.1.3 Data Issues and Data Gaps

While much commendable research has been undertaken on the Irish continental shelf (e.g. INFOMAR), more should be done to improve and streamline future offshore wind energy projects **(Peters et al., 2020)** (Figure 3.3). Currently, about 44% of the data required to analyse Ireland's offshore resources for wind energy development projects is publicly available. Some data (8%) exists but is unavailable to the public. The largest obstacles to future research consist of omitted data (e.g. data gaps in seabed sediment maps); these omissions constitute about 16% of the data required for thorough assessments. By comparing the required data against the available data, four types of data gaps and shortfalls were revealed: (1) omitted data; (2) unavailable data; (3) data with inadequate resolution; and (4) data with inappropriate file types.

Water depth and seabed morphology data are incomplete at high resolutions, especially for the west of central Ireland. These datasets are being improved by the multibeam bathymetric data being collected by the INFOMAR programme. Data on ocean currents are modelled at low resolutions, but higher resolution data should be acquired for site selection analyses. Although EMODnet has recently released annual datasets for vessel AIS data, critical information on fishing effort is missing for boats <12 m, which often lack such transponders. Gaps remain in the surface sediment dataset and, although EirWind research cruises (Peters et al., 2019a; 2019b) have filled gaps in limited areas, coverage remains variable. EirWind WP2 research has also improved these gaps with sophisticated seabed modelling using Empirical Bayesian Kriging. Sub-bottom information on stratigraphy and depth to bedrock are even more sparse and more difficult to standardise and compile. The full study is given in **EirWind: Peters et al., (2018a & 2018b).**

Figure 3.3: The need for an integrated approach to data collection to fill data gaps for effective planning and management **(EirWind: Peters et al., 2019c)**.

3.1.4 Competition for Marine Space

The expansion of offshore energy competes for space in an already busy seascape, and it will have many potential impacts on established patterns of sea use, rights of access, and social and cultural value systems (Kerr et al. 2014). Offshore energy developments also raise concerns about competition for access to resources and can lead to conflicts between existing (e.g., fisheries) and emerging uses (**EirWind: Kami Delivand & Cummins, 2020;** Jentoft and Knol 2014; Reilly, 2017; Ritchie and Ellis 2010). Effective marine management will not only need to balance the often competing demands of existing and emerging uses, but also maintain the underlying capacity of the marine environment that supports them.

This challenging task is made all the more difficult by the limitations imposed by most traditional modes of governance and management which are, in many cases, still sector based. The National Marine Planning Framework seeks to facilitate a more integrated approach to planning for the marine environment in Ireland. However, without clear development zones for different activities, co-existence may be challenging and contestation may increase. The allocation of space where two parties are both interested in the same location is an outstanding issue for the MPDM Bill. This will require consideration of measures such as conflict resolution.

3.1.5 Strategic Development Zones

In order to explore options for planning for offshore wind in Ireland, **EirWind: Desmond et al. (2020)**, consulted on the concept of Strategic Development Zones. A series of semi structured interviews, between March and May 2020, provided feedback on industry and policy stakeholder preferences for a broadly centralised versus decentralised approach to designating areas for OSW production. Over the course of these interviews, two development zone designation options were defined and their applicability in an Irish context were discussed.

Option 1 was described as a centralised approach whereby single wind farm sites are identified centrally and developers are invited to submit bids. This system was used in the UK Round 1 and Round 2 which covered all commercial offshore wind farm offerings from 2001-2010. Sites offered in the UK under this system had capacitates of between 100 to 500MW. This system has also been used in Belgium since 2000 to present with average wind farm capacities of 200 to 500MW. Option 2 was described as a more decentralised approach whereby large potential development zones are identified centrally and developers are then invited to identify their own sites within these areas and to submit their proposals. All proposals are then reviewed centrally. This approach is currently being used under the England and Wales Round 4 offering which will run from 2020 to 2030 with the aim to develop between 7 and 8.5GW of offshore wind.

A centralised approach has advantages such as providing developers with greater certainty, building central knowledge on marine resources and ecology, and facilitating a focused approach to community consultation and grid connection. However, this approach requires significant upfront investment of time and resources by government departments and agencies in order to identify the preferred development sites. Given that governments tend to move slower than the private sector and the existing strain on government resources **(EirWind: Judge et al., 2020)** pursuing this approach may introduce considerable inertia and stall the development of the industry.

While a decentralised approach de-risks these types of delays, under such an approach, large areas of the maritime area would need to be defined as development zones. This could result in greater stakeholder opposition from existing and future users of the marine environment. This decentralised approach also has inherent challenges for forward planning particularly with regards facilitating grid connection. A proactive approach to grid development by the TSO may be able to address this issue. While a national awareness campaign **(EirWind: Cronin et al., 2020a**) may be able to boost social acceptance.

As a result, a hybrid approach, blending options 1 and 2, may need to be considered. Regardless of the approach taken, clear indications on timelines and ambitions of the government will be essential going forward. The feedback from the interviews further suggests that there is a need for transparency in decision-making, irrespective of the approach taken. The EirWind study helps to inform a process for taking these considerations further. A methodology has been developed to specify the parameters pertinent to zone identification, including port, grid, fisheries, visual impact and water depth. Finally, the challenge of identifying development zones for OSW is fundamentally linked to available critical infrastructure, including grid, which is dealt with below.

3.1.6 Grid Development Model

The current onshore transmission grid could currently integrate 1.5GW of offshore grid capacity from the Irish Sea Production Zone, without any significant grid capacity expansion **(EirWind: Todesco Pereira et al., 2020a)**. Significant grid reinforcement would be needed to facilitate a 3.5GW target, as per the Climate Action Plan (EirGrid, 2019b East Coast Study). Presumably this is a greater issue given the new 5GW target. A consultation by the DCACNT was launched at the time of writing to inform the decision for a grid delivery model suitable for offshore grid in Ireland, with a focus on achieving the 2030 targets. The consultation is linked to an options document (Navigant, 2020), which outlines four approaches to building grid capacity: i). Developer-led; ii). Plan defined, developer consents and builds; iii). Plan defined, developer builds; iv). Plan led. This raises the question of centralised versus decentralised approaches to planning, a theme that has been flagged previously in the context of the MPDM Bill. It is unclear where the alignment will be in terms of planning for multiple uses of the sea via Strategic Marine Activity Zones, and planning for the connection of electricity from offshore wind, (generated in the maritime area), to the grid (on land).

There is also a significant challenge to plan now for grid requirements post 2030. This is of strategic importance, given the question about route to market for excessive offshore wind capacity coming that will be generated by the introduction of FLOW in the Celtic Sea and Atlantic Production Zones.

3.1.7 Impacts on Fisheries and Marine Mammals

Irish waters host highly productive ecosystems which support internationally economically important fisheries, and are home to at least 25 species of marine mammals. Both fish and marine mammals are vulnerable to disturbance from anthropogenic activities and pressures on their populations due to environmental changes. An EirWind study of the scientific literature assessed the potential impacts which may occur to the receptors of marine mammals, fish and shellfish resulting from the stressors occurring due to offshore wind farm developments **(EirWind: Critchley et al., 2019; Hunt & Jessop, 2019)**. The chief potential stressors impacts on marine life from offshore wind farms have been identified as 1) noise, 2) built structures, 3) vessel activity, and 4) cables, comprising both power cables and mooring lines (Figure 3.4).

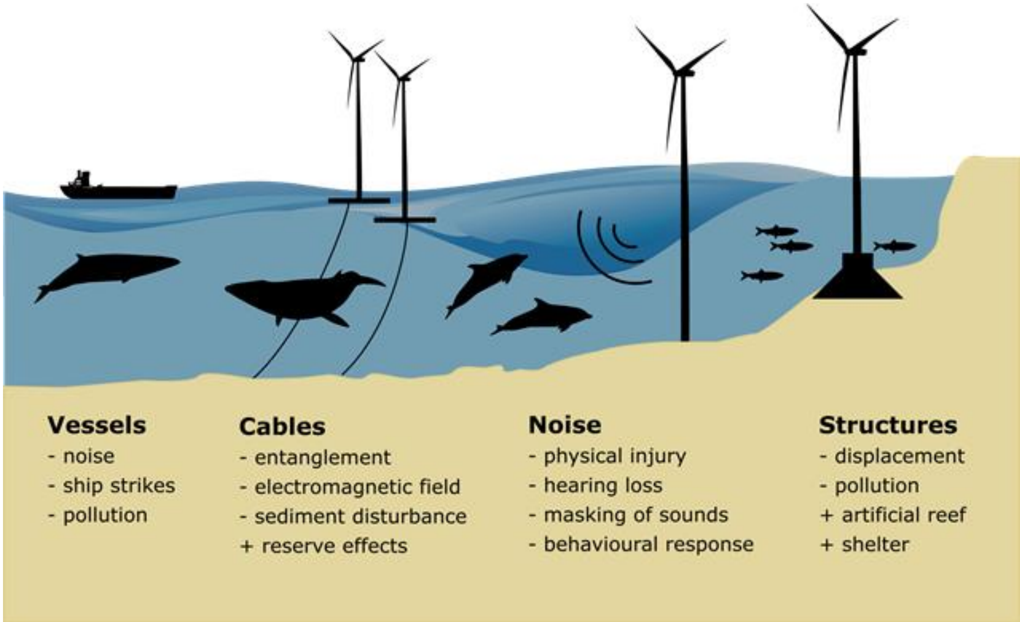


Figure 3.4: Impacts of OSW on fisheries and marine mammals.

The EirWind review found that noise, a known stressor of both marine mammals and fish, is currently the most significant stressor from OWFs. Impacts include acoustic trauma, hearing impairments, masking of biologically important acoustic signals, behavioural changes, and physiological stress. Some acoustic impacts are lessened by FLOW, which does not require piling or extensive seabed preparations. Man-made structures have the potential to negatively impact marine life through habitat displacement, pollution, and behavioural disturbances. However, they have also proven to benefit ecosystems through the addition of a complex hard substrate which can encourage reef growth and may provide greater foraging opportunities, as well as shelter from predators, fishing activities and shipping noise **(EirWind: Sweeney & Cummins, 2020)**. While localised increases in productivity and abundance of fish have been recorded around turbines, there is not yet evidence of increased productivity at a regional scale from the expansion of OWFs in European waters.

Vessels, whether commercial, shipping, or recreational, may impact both marine mammals and fish through noise, localised chemical pollution from leaks and spillages, possibility of ship-strikes, and as vectors for invasive species. Potential impacts from vessel activity include disruption to functional behaviours such as resting, foraging, or communication. In general, marine mammal numbers decrease in response to increased vessel numbers, and vessels travelling at speed have the greatest impact. Fish display lower anti-predator responses or spend more time guarding nests than feeding in the presence of increased vessel activity, and the review found a limited number of reports of fish being struck by vessels. The potential impacts from cables include possible entanglement, localised changes in the electro-magnetic field (likely negligible impact for marine mammals, local moderate impact for elasmobranchs and possibly some crustaceans), sediment suspension, noise/vibration, heat, and reef/reserve effects. However, this stressor is poorly studied, and more research would provide greater clarity on several of these issues.

3.1.8 Impacts on Seabird Vulnerability

Seabirds spend a significant portion of their time at sea, where they are vulnerable to impacts from marine energy infrastructure such as offshore windfarms. Therefore, it is essential that the potential risks to seabird populations, either through collision with turbines or displacement from important foraging areas, are assessed prior to development. Very little is known about the vulnerability of seabirds to offshore wind farms in Irish waters. In order to address this gap, seabird vulnerability indices were developed as part of the biological component of EirWind **(EirWind: Critchley & Jessop, 2019)**.

The study found that a move to using larger turbines with a sweep zone starting at 40 m above sea level will change the collision vulnerability of seabirds, generally lowering it overall. There is a distinction between the areas of highest vulnerability for collision susceptible species compared to displacement susceptible species. Therefore, it is most likely that the species and risk factors that need to be accounted for will vary by site and need to be considered through the Environmental Impact Assessment process. There is also a gap in understanding about cumulative impacts of multiple offshore wind farms. This is particularly relevant in jurisdictions such as Scotland, where offshore wind is a well-developed sector. Scientists are challenged to develop meaningful assessment frameworks, which will be required for decision-making going forward. This is an area for further research.

3.2 Dealing with Physical Challenges

3.2.1 Metocean Conditions

The Northeast Atlantic has one of the most energetic wave climates in the world, consisting of locally generated waves and swells that can propagate across the Atlantic. Many of the storms track from a SW direction and through the gap between Ireland and Iceland and this direction of approach can result in the growth of large waves (>30m) with high wave periods (>20s). Large waves begin to break from about 50m water depth and consistently reduce in height through further breaking and friction effects until they reach the coastline. The Irish Atlantic wave conditions in general become less severe from north to south but it should be noted that a 26m wave was recorded off the Cork coastline during Storm Ophelia. (The highest wind speed observed since records began was also during Storm Ophelia, at Roche's Point, County Cork @43.2m/s). The west coast experiences average significant wave heights (Hs) of circa 2.0m in the summer and 4.0m the winter.

In the Irish Sea, Atlantic swell can penetrate into southern areas but in general locally generated wind waves dominate the wave climate. The average Hs can vary between 1-2m depending on the location. There is also a complex tidal regime in the southern Irish Sea with a degraded amphidromic point located at Courtown. This results in variable tidal ranges and high tidal currents (1-2m/s). In addition, the tidal regime and the abundance of sediment south of Dublin Bay has led to the formation of a number of sand and gravel banks with potentially high sediment mobility which can provide design and operational challenges for offshore wind farms. In terms of wind speeds, the west coast has annual wind speeds of circa 13 m/s, while the east coast experiences lower annual wind speeds (7m/s).

3.3 Technical and Logistical Challenges

There are many technical and logistical challenges associated with developing offshore windfarms and each wind farm site presents its own particular set of challenges which can be related to ground conditions; environmental conditions; water depth; distance to port; grid connection etc. **(Judge et al., 2019).** There will be different logistical challenges for FLOW since the assembly and installation process will be much different to BFOW, (e.g. full assembly at port with subsequent tow out to site where the platform is connected to the moorings and dynamic cable). However, there is little standardization at present. Therefore, a feedback loop is required between technology design optimisations and overcoming logistical challenges to achieve the solution with the lowest Levelized Cost of Energy (LCoE).

To examine the challenges specific to the Irish offshore wind industry in greater detail, three theoretical but representative wind farms were modelled in the Irish Sea, Celtic Sea, and Atlantic Ocean. The primary aim was to determine their potential in terms of energy production and estimated costs (LCoE), but also to highlight the location-specific challenges posed for OWFs in these locations, in order to provide recommendations from potential cost-reductions and pathways for future development. The sites and the baseline LCoE estimates are summarised in Table 3.1.

Table 3.1 **EirWind Case-study Analysis**

Site	**Unit**	**Irish Sea**	**Celtic Sea**	**Atlantic Ocean**
Turbine		12	12	14
Substructure		XL Monopile	Semi-submersible	Semi-submersible
Number of turbines	*Number*	41	83	71
Farm capacity	*MW*	492	996	994
Farm lifecycle	*Years*	25	25	25

Start	*Year*	2025	2035	2035
LCoE Low*	*€/MWh*	**51**	**63**	**75**
LCoE medium*	*€/MWh*	**58**	**70**	**84**
LCoE high*	*€/MWh*	**66**	**90**	**107**
DEVEX	*€/MW*	**269,684**	**173,378**	**173,727**
CAPEX	*€/MW*	**2,283,813**	**3,438,864**	**4,289,440**
OPEX	*€/MW/yr*	**94,888**	**62,358**	**84,672**
DECEX	*€/MW*	**214,367**	**185,812**	**424,560**
Salvage revenue	*€/MW*	**58,615**	**80,281**	**81,542**
Availability (energy-based)	*%*	96.94%	96.88%	93.67%
Capacity factor	*%*	55%	58%	62%

** It should be noted that the LCoE is highly dependent on the discount rate applied. Therefore, an estimated range of LCoE is presented for each case-study based on a high/medium/low discount rate scenario of 3%; 5% and 7% for BFOW and 5%; 6.5% and 10% for FLOW.*

The fixed offshore wind scenario in the Irish Sea, for a circa 500MW farm, coming on-stream in 2025, is the most cost-effective of the 3 scenarios (the estimated range of €51-66/MWh), indicating why fixed sites in the Irish Sea have been prioritised for Offshore Wind Farm development. Analysis found that significant cost reductions could be achieved by further improving turbine reliability. This reduces the number of failures, increasing turbine availability to produce energy, and minimises the expensive offshore maintenance required. The choice of substructure is also a key cost-driver and is extremely site dependent. Results indicate that an XL monopile is likely to be the most cost-effective due to the simple fabrication process.

Floating offshore wind in the Celtic Sea shows considerable potential (an estimated LCoE range of €63-90/MWh for circa 1GW coming on-stream in 2035 is presented in Table 3.1 above and this site achieved a capacity factor of 58%). However, attaining the medium estimated LCoE requires a number of interim steps, which are needed to reach parity with fixed offshore wind and/or industry targets of €40-60/MWh for floating wind by 2030 (Figure 3.5).

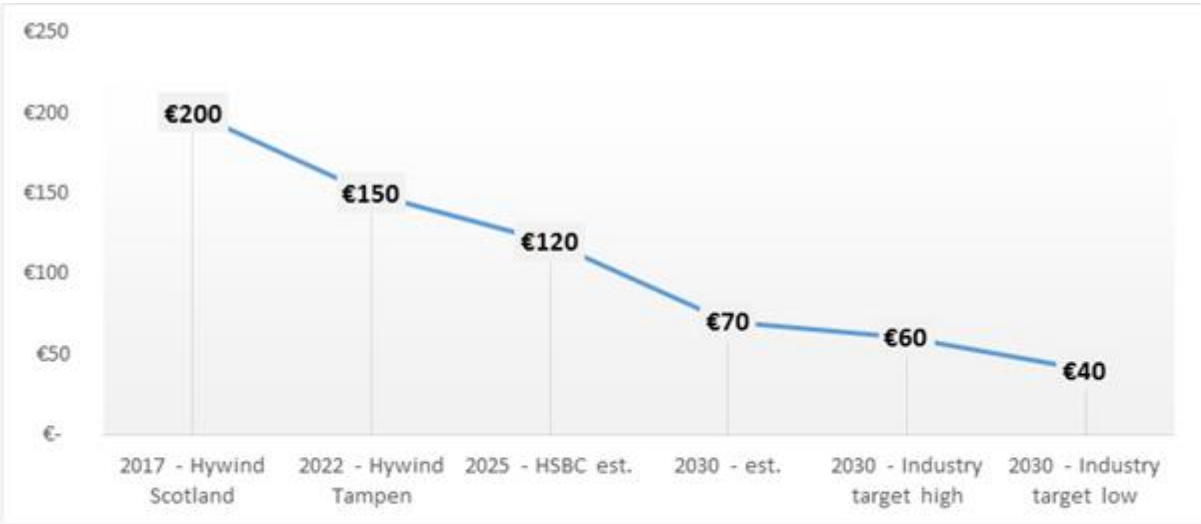


Figure 3.5: Floating Offshore Wind LCoE forecasts (€/MWh). [Source: Moestue, H., 2018]

Optimisation analysis indicates that platform cost savings can be found with improved design that reduces steel consumption and weight, while maintaining stability. Economies of scale could be achieved through large-scale manufacturing processes (e.g. for a 1GW farm). Also, there may be considerable savings in concepts that utilise cheaper or a combination of materials. Optimising moorings and anchor systems can also provide cost savings. The modelled FLOW scenarios were validated against current industry practices. However, optimisation studies indicate that increased experience and standardized best practices could reduce the time required for offshore operations, ultimately providing cost and time savings.

For the west coast, Atlantic Ocean conditions provide a very promising wind resource as is demonstrated by the high capacity factor achieved (62%). However, the same challenges apply as outlined for the Celtic Sea site with the need for a stepping-stone approach to deploying a 1GW farm c.2035. Increased turbine reliability; design optimisation for substructures, mooring and anchor systems; improved manufacturing processes and growing economies of scale would provide key cost-savings (Judge et al., 2019). However, conditions in the Atlantic Ocean also present significant additional technical and logistical challenges that need to be overcome in order to take advantage of the significant resource available and to find further cost reductions. The estimated LCoE range (€75-107/MWh) is considerably higher than the Irish and Celtic Sea scenarios, primarily due to the harsher conditions reducing the number of weather windows available to complete offshore operations (installation, maintenance and decommissioning).

Weather windows

Weather Windows are a period during which the sea-state, usually defined by its Significant Wave Height (Hs), does not exceed a certain desired value. Most offshore activities are restricted by technical, operational and Health and Safety limits related to weather conditions that operators must work within. These weather limits vary depending on the activities that are being conducted, and the equipment and/or vessels that are being used. They are critical to any offshore operation and often have a large bearing on the economic viability of projects. Analysis of various weather windows for Atlantic Ocean sites was undertaken by Barker (2019) using 25 years of hindcast wave data.

The probabilities of achieving a 24hr weather window, where the wave height is 2m or less, range from a low value of 11% in February to a high of 57% in June. Based on current technologies and the most sensitive logistical processes (e.g. technician transfer from vessel to turbine), it would be extremely difficult to achieve a wind farm installation and operation that would be competitive with those in less extreme environments. To operate in these challenging conditions, the Atlantic Ocean scenario utilises a Service Operations Vessels (SOV) to undertake maintenance activities, assuming that a walk-to-work system would facilitate technician transfers in wave heights of up to 3m Hs. In comparison, less expensive CTVs were implemented for the Irish and Celtic Sea sites with transfers up to maximum of 2m Hs. Analysis showed that further improvements in accessibility could be achieved if technician transfer limits increased to 4m Hs in the Atlantic. This is considered achievable with the latest SOV and gangway systems, but was not implemented in the scenario as the Health and Safety implications of working in these conditions needs further examination.

3.4 Social Challenges

3.4.1 Coexistence with Fisheries

While offshore wind developers are emerging as new users of Irish waters, the long-established commercial fishing industry in Ireland has been using the sea space for generations. The fishing industry represents huge social and economic value for coastal communities and is the mainstay of their maritime heritage. Irish vessels landed €247.8m worth of catch in 2018 (Central Statistics Office, 2020). The value of net exports (exports minus imports) of seafood in 2019 was €285m (BIM, 2019). The number of direct employees in sea fisheries, aquaculture and seafood processing were 3,033, 1,948 and 4,206, respectively. Therefore, there were 9,178 people directly employed by the sea food sector which accounts for 7% of the total coastal employment.

The operation of offshore wind alongside fishing may present actual or perceived opportunities or incompatibilities. For example, wind farm construction and cable laying may negatively impact fish habitats or cause safety and economic risks for commercial fishing vessels (e.g. through gear fouling on cables). Given the economic and environmental importance of the generation of electricity from offshore wind turbines and the economic and cultural importance of marine fisheries, one objective of the EirWind programme was to seek mutually beneficial solutions to support coexistence opportunities between these two important sectors (The full report on coexistence with fishers is in **EirWind: Kami Delivand and Cummins (2020).** Constraints to coexistence currently exist at a number of levels, for example, with regards to regulations that prohibit fishing vessels providing guard boat duties for offshore platforms. Offshore wind project proposals have mushroomed over a relatively short period of time, leading to concerns about space for fishing being squeezed by offshore wind and Marine Protected Areas. The lack of a national forum for dialogue means there are many unanswered questions about the future possibility of compensation or other measures.

3.4.2 Social Licence for Renewables (culture of objection)

Attainment of social licence to operate from the general public is a complex task, sometimes difficult to harness and often challenging to conclude. Ireland has strong environmental NGOs with an impressive track record of influencing the development of strategic infrastructure. Results of the EirWind national study of public perception of offshore wind farms **(EirWind: Cronin, et al., 2020a)** show that the general attitude of the public towards offshore wind farm development in Ireland is supportive, however a small proportion of those questioned would not support wind farm development, by objecting actively either at a national (2%) or local level (7%). Fourteen percent of those questioned in the national survey said that they would either actively or passively object to an offshore wind farm planned for their locality.

This follows the trend shown in previous studies whereby resistance to offshore wind farms is usually in the minority (Sokoloski et al., 2018). Nevertheless, however small, this is the cohort with which offshore developers must engage. Effective stakeholder participation and engagement must include timely access to clear and relevant information, highly skilled facilitation and trusted intermediaries **(EirWind: Cronin & Cummins, 2018; 2019)**. Specific participation techniques each have different outcomes and relevance to each group involved, but common to all techniques is the importance of trust, transparency and fairness in the process. Coastal partnerships, currently under consideration by the DHLGH, could facilitate capacity and trust building, if done right. Lessons can be learned from previous partnership experiments, including the Bantry Bay Charter Project (Cummins, 2011).

The findings of the EirWind survey study also show that education influences people's attitudes to OSW and that there is a need for a public awareness and information programme, which is currently lacking. A communications campaign needs to be prioritised, building on findings such as how people are influenced by the prospects of job creation, how people are concerned about climate change and understand the link with renewable energy; and how people are influenced by the media.

3.4.3 Influence of Media Framing

An EirWind review of media content **(EirWind: Cronin et al., 2020b.)**, shows that reporting levels in the sampled Irish media about offshore wind energy have increased over a five-year period. The narrative has been dominated by government and economic themes, with relatively less coverage of societal and environmental issues. The tendency has been towards negative reporting of government decisions or actions. However, holding government to account is an important role of the media. In general, the review of the print media in the Irish broadsheets reflects the issues of the day. When presented year by year, they reveal the story of steady progress in the development of offshore wind in Ireland.

There was a notable increase in coverage of a number of new and strategic developments throughout 2018-2019. The question of how this is reflected in public perception remains unanswered due to the narrow scope of this study. However, the importance of media in framing narratives has been shown to be important from the literature. Understanding what influences public perception is key to learning what triggers can be used in order to influence public perception. There is a need for much more attention to be given to this issue, as public understanding is critical to the development of offshore wind.

3.4.4 Visual Sensitivity

Despite positive attitudes nationally towards the shift to renewable sources of energy, there is a strong sense of 'Not in My Back Yard' (NIMBY) when it comes to the siting of the onshore wind farms (Brennan, 2017). This phenomenon, which derives from the impact of man-made structures affecting the landscape, is also felt globally when it comes to offshore wind farms. (Christoforaki & Tsoutsos, 2017; López-Uriarte, et al., 2019). In particular, the visual impact of offshore wind turbines may be pronounced due to the presence of tall structures in an 'empty' landscape (Sullivan, et al., 2013). Due to the increasing trend in both turbine height and wind farm footprint, it is becoming more challenging to mitigate the visual impact of offshore wind farms.

Therefore, it is important to take visual sensitivity into consideration in the site evaluation process, to avoid public opposition to development in visually sensitive areas. An EirWind visual sensitivity analysis presented the first national offshore assessment of 12MW turbines for Ireland, and the first study to factor in horizontal visibility (HV). The seascape character assessment underway for the Marine Institute at the time of writing, provides additional baseline information to inform a national approach to the question of visual sensitivity. The variable nature of the seascape, together with variability in OSW technology, may be incorporated into the development of new national guidelines.

3.5 Energy Infrastructure Challenges

3.5.1 Electricity Transmission and Distribution

Additional sources of domestic electricity demand such as transport and heat electrification will require investment in onshore electricity transmission and distribution systems requiring social licence, and capital investment. The growth in the demand for electricity for large industrial loads, primarily data centres, has been quantified in Chapter 2. This market expansion would require additional investment in onshore electricity transmission and distribution systems, requiring public support for issues that have previously been contested, such as the construction of pylons and development of large data centres.

3.5.2 Grid Integration of Wind

Integrating large amounts of wind generation onto a synchronous system presents significant challenges, as the characteristics of wind generation are different to traditional generation sources. Wind generation is inherently variable; this variability must be managed to ensure demand for electricity is always met. Additionally, wind generation is a non-synchronous technology, which poses challenges when integrating into a lightly interconnected synchronous system **(EirWind: Laguipo et al., 2019)**. EirGrid has developed the DS3 system services programme in order to increase the permitted contribution of non-synchronous generation sources, however it is clear that a significant expansion of this programme will be needed in order to facilitate integration of several gigawatts of additional offshore wind capacity without incurring large volumes of curtailed wind energy.

3.5.3 Electricity Interconnection Infrastructure

As the offshore wind energy resource exceeds the capacity of the domestic electricity market, and as new offshore wind projects are developed, additional electricity export markets will become important particularly after 2030. Even if sufficient interconnection capacity is present, developers will need assurance that potential export markets will indeed exist, for example in Great Britain or France, bearing in mind the considerable offshore wind capacity under development in these countries. The LCoE of Irish offshore wind would have to be sufficiently low to ensure competitive pricing. The existing two interconnectors between the island of Ireland and Great Britain currently deliver a net import of electricity to Ireland. For the calendar year February 2019 – January 2020 there was a net import of 634.6GWh to the All-Island system **(EirWind: Todesco Pereira et al., 2020a)**.

3.5.4 Challenges for Expansion to Transport Market

The manufacture of green hydrogen from variable RES is not a fully mature technology. The long-term performance of the PEM and ALK and SOF electrolysers is still at the assessment stage in a number of pilot studies **(EirWind: Todesco Pereira et al., 2019).** Production costs are still relatively high and the expectation is that these will reduce significantly due to a major increase in demand and mass production efficiencies similar to what has happened in PV production for example. The capacity factors of offshore wind-to-hydrogen electrolysers will be of the order of 50% at best, which means that these high CAPEX assets **may** not be **effectively** utilised where technical solutions will be required **(EirWind: Laguipo et al., 2020a)**. By 2030 significant cost reductions are expected, but there is still considerable uncertainty surrounding the future evolution of power-to-gas costs (European Commission, 2020a).

3.5.5 Gas Infrastructure Challenges

An expansion of the gas network will be required in a post-2030 scenario where a large proportion of offshore wind generation is dedicated to hydrogen production. Expansion of the gas network is currently happening. However, the gas grid will need to be modified to accommodate large percentages of hydrogen. While local distribution systems are mainly composed of polypropylene pipes, transmission pipelines and interconnectors are constructed of steel which will be vulnerable to hydrogen embrittlement. This may limit the maximum allowed blend percentage of hydrogen, and may particularly limit hydrogen export by pipeline. For the domestic transport market, a large roll-out hydrogen filling station will be required and the current unit cost is extremely high.

The Republic of Ireland (ROI) will depend on sales of hydrogen which at the early stages of hydrogen introduction for transport will be relatively low while demand is yet to achieve large scale. Other options for hydrogen delivery to filling stations are possible involving tankers and gas cylinders and to date this option has not been fully analysed from a financial viability perspective. Some end-user equipment will require modification in order to function safely and efficiently with hydrogen blend, however most modern equipment will require minimal adjustments which can be carried out during routine servicing. Larger units such as gas turbines for power generation will require modification but the costs will not be prohibitive.

At present, the main purpose of the gas interconnectors is to import natural gas to supply the Irish domestic market. Recently a project aiming to reverse the capacity of the Moffat entry point was proposed which will allow Ireland to export natural gas. In practice, the amount of gas exported will be significantly lower than that imported. This is because Moffat will be the main source of natural gas for Ireland due to the decommissioning of the Inch entry point (Kinsale gas field) in 2020 and the reduced production in the Corrib gas field. Although the Moffat interconnector is able to supply current and future demands of gas to Ireland, this brings serious concerns regarding security of supply as natural gas imports from Moffat will account for approximately 86% of annual gas system demands by 2026 (Gas Networks Ireland, 2018).

3.5.6 Operational & Maintenance challenges

Offshore wind O&M challenges are well reported in the literature **(Judge et al., 2019)** and in EirWind research **(EirWind: Chester et al., 2018).** The west coast scenario will be particularly challenging for O&M. Electrolyser O&M is another challenge. It is likely that initial power-to-gas conversion will be carried out on land to minimise O&M costs. There are uncertainties surrounding cell lifetime and cell performance over time which will only be resolved as the technology matures.

3.5.7 Health and Safety Considerations of Hydrogen use

A review of the safety aspects of hydrogen in the context of Crew Transport Vessels **(EirWind: Dinh et al., 2019; Todesco Pereira, 2020b)**, found that overall, hydrogen is safe if safety standards are complied with. In addition, based on the regulations standards and rules currently in place, the main safety concerns for the use of hydrogen and fuel cells lies in controlling fuel leaks, minimizing confined spaces, avoiding ignition sources, securing ample ventilation for confined spaces, and monitoring enclosed spaces to avoid any fuel accumulation above the fuel/air mix threshold that allows any combustion to happen.

3.5.8 Hydrogen Economic Challenges

The current low cost of fossil fuels is a threat and it is expected that if RE derived fuels become a threat to market share there could be further oil price reductions. There is currently a gap between the levelized cost of hydrogen derived from fossil fuels, even with the additional cost of carbon capture and storage, and 100% renewables-derived "green" hydrogen. The role of Carbon Tax in this scenario is extremely important **(EirWind: Laguipo et al., 2020a).** However, recent initiatives from Germany and the European Commission (Krukowska, 2020; European Commission, 2020a) have placed the emphasis on "green" hydrogen from renewable electricity, rather than cheaper, less sustainable "grey" hydrogen.

3.5.9 Challenges for the Heat Market

Unlike the transport sector, hydrogen for the heat market can be delivered to the end-user using a modified version of the existing infrastructure. It can be introduced in a phased way up to a maximum of 20 to 25% hydrogen with little or no cost for the partial conversion. For greater percentage of hydrogen in the gas mix other modifications to appliances will be necessary but this can be technically achieved as detailed in the H21 proposal for Leeds (Northern Gas Networks, 2017).

Currently, the main challenge facing the introduction of hydrogen as a replacement fuel for natural gas in both the domestic and industrial market sectors is the low cost of the fossil fuel. The EirWind study estimates that the delivered KWh cost for hydrogen produced from OSW is in the range €0.015 to €0.017 compared to average domestic prices of €0.007 (ex VAT) (SEAI, 2019). The gap at present needs to be made up by measures which reflect the political will to solve the decarbonisation challenge.

3.6 Lack of Offshore Wind Energy Skills

A survey of supply chain stakeholders undertaken by SEAI (2014) determined that one of the greatest holdbacks to developing a sustainable energy supply chain in Ireland is the need for adequate skills. The skills required in offshore wind are varied and unique to each stage of a project's life cycle. Specialised fabrication and manufacturing skills are necessary for the numerous components involved; ranging from the large scale rolled steel required for XL monopiles to specialised carbon fibre knowledge for turbine blades. The installation process is a short term requirement (1-3 years) that needs expertise in offshore processes including pile hammering, and heavy crane lifts offshore. Whereas, operations and maintenance require long term expertise (20 years +) in wind turbine repairs, ranging from annual predetermined maintenance to the corrective maintenance and replacement of large turbine blades. These activities require some skills that are not currently present in Ireland. Some of them, such as rolling steel, will not be required, as this specialism will come from elsewhere.

In comparison to its European counterparts, Ireland has a limited established ocean economy and limited transferable skill sets from the oil and gas industry. Therefore, it needs to take advantage of the knowledge of surrounding countries with experience in large complex offshore projects in the short-term, to learn and train for future self-sustainability. Ireland can benefit from its shipping and maritime transport, and fishing experience. As an island, Ireland has high interactions with the ocean with 90% of all import and export being generated via maritime routes. Fishers have also adapted to working in harsh conditions.

While there is a rapidly growing uptake of apprenticeships in Ireland, there is a lack of training opportunities specific to offshore wind, and also to hydrogen. Ireland has excellent facilities for such training (*e.g.* the National Maritime College of Ireland (NMCI) in Cork), but there is a need to introduce and develop new schemes, particularly in the areas of welding, crane operation, drill operation, and Remotely Operated Vehicle (ROV) operation (Leahy *et al.*, 2020). There is also a need to raise awareness of the upcoming employment opportunities in offshore wind in Ireland and to attract prospective students and jobseekers to these opportunities.

4. Blueprint for Offshore Wind in Ireland

4. Blueprint for Offshore Wind in Ireland

Offshore wind energy has the potential to deliver transformative change in Ireland. The question is how to turn the opportunities into reality, and to ensure the ambition demonstrated in the Programme for Government 2020, can be realised. The blueprint concepts presented here, outline a pathway for the sustainable development of offshore wind, based on the findings from the EirWind research project, and consultation with key stakeholders. The development of subsequent policies, masterplans, spatial plans, and guidelines are the prerogative of policymakers.

4.1 Setting a vision for offshore wind

Getting the sequencing right is an important part of what happens next. The first step is to develop a shared vision. A compelling vision can help to define what success looks like. The advantage of developing a *shared* vision in consultation with relevant stakeholders relates to greater buy-in, engagement and diversity, (as shown in EirWind research on the topic of Social Licence to Operate).

> ***"Develop a shared vision to harness the full potential of Ireland's unmatched offshore wind resource to transform our energy future"***

4.2 Gearing-up for offshore wind

Offshore wind is at a critical turning point in Ireland. The opportunities are immense, as outlined in Chapter 2. After a slow start relative to other European jurisdictions, the tide has turned. There are now clear signals of a national intent to develop the sector. However, as shown in Chapter 3, there are a number of social, economic, environmental and engineering challenges that need to be overcome. Delivery of BFOW in the first half of the 2020s in line with the Climate Action Plan and Programme for Government commitments is critical to kick-start an offshore wind industry in Ireland. Ireland needs to make rapid progress to sustain confidence in the industry and lay the foundation for a future where Ireland has the opportunity to be a world leader. While offshore wind generation in the 2020s will be needed to meet climate targets and satisfy domestic electricity demand, a central challenge is how to develop vectors for energy transmission and export opportunities, as Ireland has more offshore wind energy resources than energy demand that offshore wind can supply.

Future progress is dependent on government commitments to develop the industry. Realising the 30GW of offshore wind signalled in the Programme for Government requires incentives for FLOW, expansion of the total energy market to mainland Europe, targets for hydrogen production, and technology specific revenue support schemes (RESS) to encourage investment. The section below outlines how Ireland can gear-up on efforts to overcome these challenges, - to realise the ultimate opportunity of becoming a net exporter of energy to the world. This gearing-up process is designed to address the market segments via the three production zones in the Irish Sea, the Celtic Sea and the Atlantic Ocean, described in this synthesis report, and according to the scenarios in Figure 4.1.

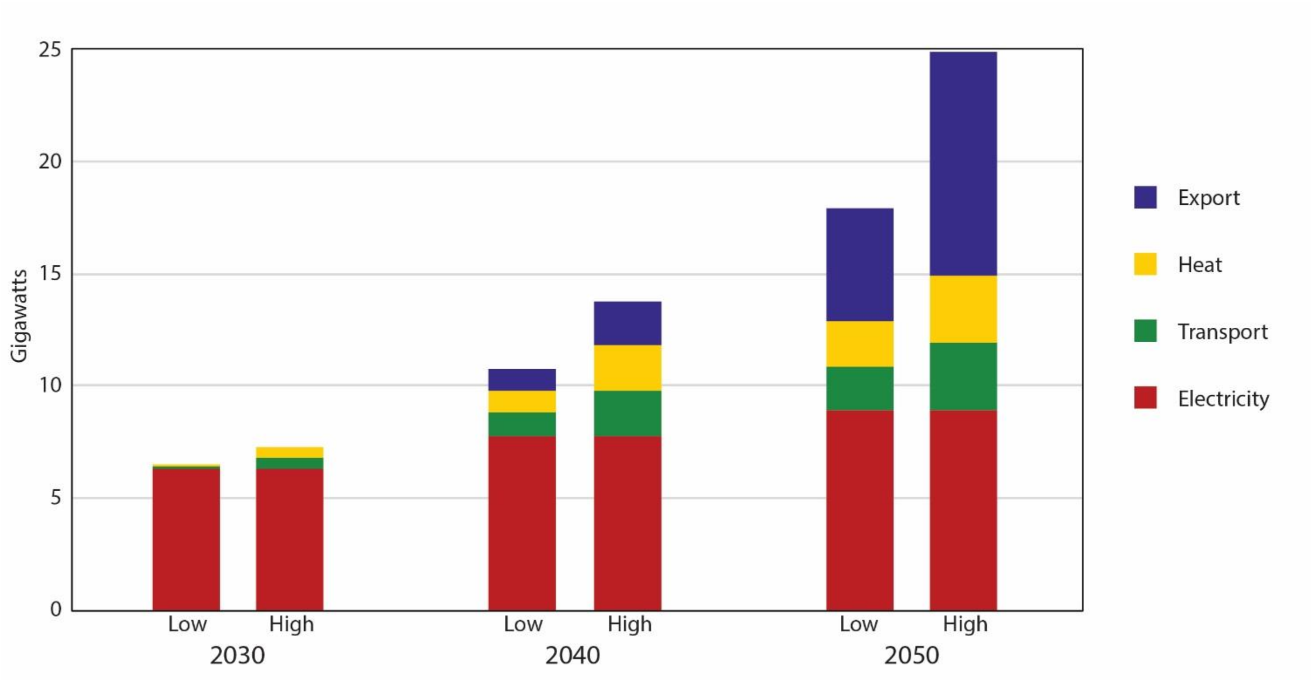


Figure 4.1: Summary of EirWind market targets - high and low scenarios.

4.2.1 Actions for Gearing Up on Offshore Wind

Figure 4.2 outlines the steps to be taken in the short medium and long term, as part of a roadmap for offshore wind in Ireland. It is apparent that numerous actions are 'bunched' in the graphic in the period between 2020 and 2021. The main message emerging here is that numerous actions need to start now to achieve the timelines and scenarios addressed in this Blueprint. The specific actions are described in more detail below.

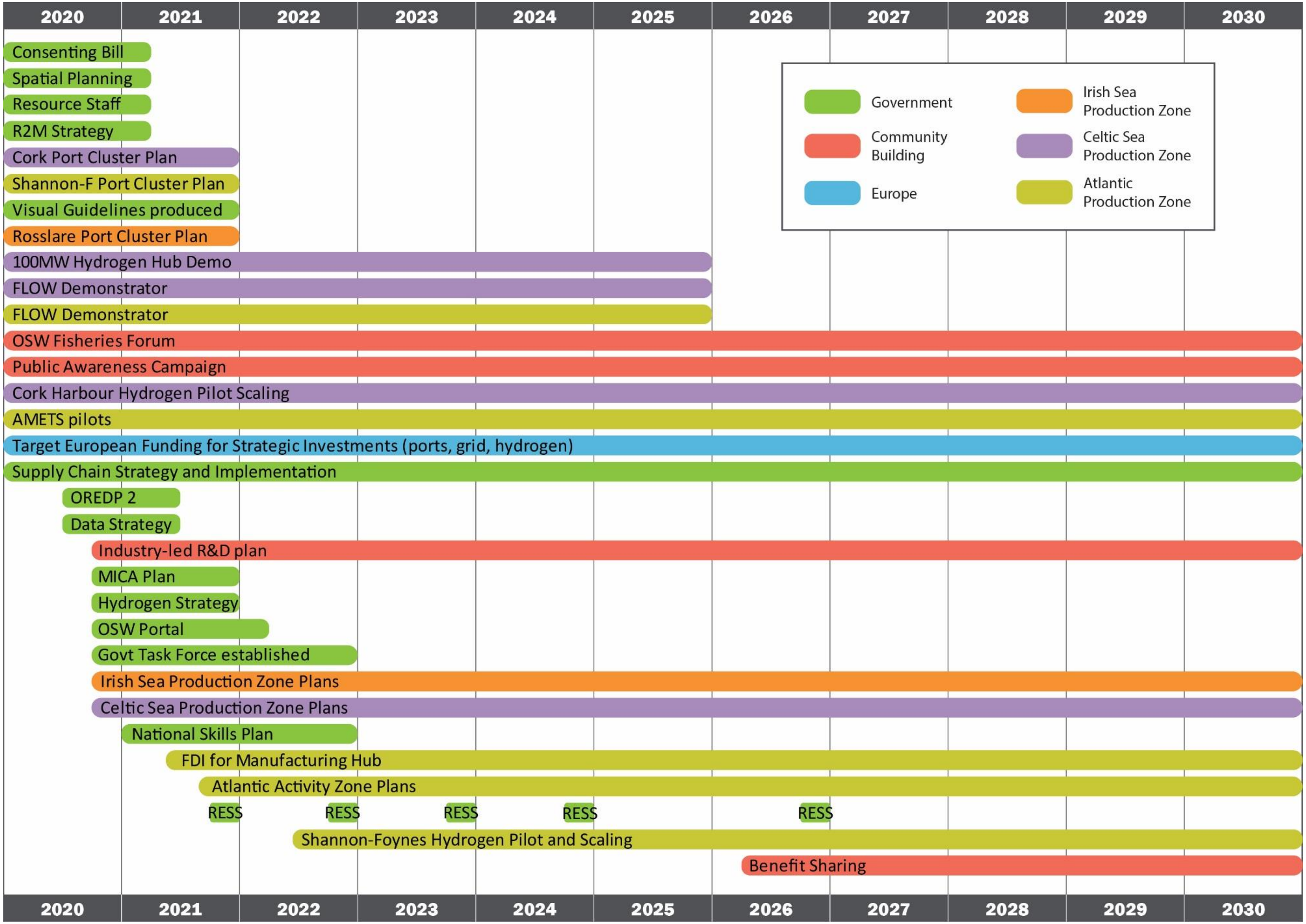


Figure 4.2: Blueprint Conceptual Framework / Roadmap for development.

1. **Prioritise the enactment of critical legislation**

The Programme for Government makes a commitment to legislating for the MPDM Bill. This, and related legislation such as the Maritime Jurisdiction Bill, is a top priority action. The MPDM Bill is a critical enabler, required as a matter of urgency. Achieving site control is a critical milestone for offshore wind developers. The sector will remain in limbo until there is a pathway for the transparent processing of lease applications for the full maritime area.

2. **Extra staffing in relevant government departments and agencies**

Our analysis suggests that approximately thirty new staff are required in the next 12 to 18 months in key government departments and agencies (e.g. An Bord Pleanála and SEAI where EU funding has been approved for extra staff to deal with the emerging offshore technologies but without national approval to date). This is a critical enabler to be prioritised in the short-term. Scores more staff may be needed as the industry ramps up. Government has a pivotal role to play in facilitating trust-building with multiple stakeholders via the development of fair and transparent decision-making processes. This can be facilitated with adequate levels of expertise and capacity in the right positions.

3. **Policy developments**

The second OREDP 2 provides an opportunity in the coming year to reset the policy framework for marine renewables for the decade ahead. This is a chance to frame national commitments in the development of new markets for Ireland's continental-scale offshore wind resource. The EirWind research has shown the importance of the market as the critical factor for analysis and action and indicates a plausible scenario of >25GW by 2050, based on route to market, excluding new interconnectors and/or the emergence over time of Pan-European grid arrangements.

Other instruments, such as the planned development of Harnessing Our Ocean Wealth II and Ireland's National Energy and Climate Plan in the short term, provide further opportunities for stakeholder engagement, visioning, target-setting (e.g. for FLOW and hydrogen), and action.

4. **Government taskforce for OSW**

Government task forces are often established by Ministers to identify solutions to problems or to oversee the implementation of initiatives in the national interest (e.g. the Mobile Phone and Broadband Taskforce). With political chairs or co-chairs, a task force is typically a relatively small group of participants, brought together for a clear purpose, over a specified period of time. A task force dedicated to addressing the challenges outlined in Chapter 3 of this report, particularly energy infrastructure issues, would be a strategic benefit to the sector. Such interventions are needed, in an 'all-hands-on-deck' approach, to set the course for the future.

5. **Coordination of regulatory process**

A one-stop-shop portal for offshore wind, complementary to plans for more generic marine or ocean energy portals, would provide clarity to developers, who are challenged with navigating around complex regulations and multiple departments and agencies. There may be a case for organisational change in the future. However, organisational change often comes at a cost in terms of time lost in the establishment of new systems. A portal provides an opportunity to move towards better coordination and integration of the regulatory process in the short term. This could be followed up by an 'Oversight Body' to coordinate and signpost offshore developments along the lines of Marine Scotland's arrangement in this regard.

6. **Prioritise a national OSW Route to Market Strategy**

Unlocking the benefits outlined in Chapter 2 requires leadership to lay the foundations for the enterprise and export potential of electricity and gas produced from offshore wind. The decade ahead, from 2020-2030 will be a defining decade, to seed investment in production pathways for green hydrogen, as well as investment in grid reinforcement; and decisions on interconnectors and perhaps ultimately, in a SuperGrid. The focus in EirWind has been on green hydrogen, as a result of the research programme that was originally scoped in consultation with industry partners. As a result, there is a focus on pathways for hydrogen production and delivery to new markets. There is no panacea on the question of molecules versus electrons. In reality, a combination of both vectors for energy transmission will be required and in relation to macro scale OSW, a hybrid approach involving offshore grids and floating hydrogen production platforms may prove to be optimal.

Countries like Germany have placed a large bet on green hydrogen, to secure a position as a global leader in the energy transition. A national Route to Market Strategy for offshore wind is a priority if the 30GW of FLOW in the Programme for Government is to be progressed. A comparative analysis of the costs and benefits associated with interconnectors and gas infrastructure needs to be undertaken as part of this process, - building on the work undertaken by EirWind. A national route to market strategy for offshore wind in Ireland is key to opening a new chapter for FLOW and green hydrogen, in addition to realising the benefits of BFOW in the Irish Sea.

7. **Kick starting FLOW**

Initial market support

FLOW technology is a potential game-changer for offshore wind and energy production in Ireland. As seen previously, the technology is being deployed at pre-commercial levels around the world. More deployments will bring the costs down and make the technology more attractive to finance into the future. Ireland is well-positioned to benefit from this, but decisions need to be made quickly on the level and type of policy support that will be offered.

Technology specific auctions for FLOW, should be prescribed within the RESS process, with a specific premium for FLOW, which is not competing with BFOW. Auctions for FLOW should facilitate i). progress towards long-term competitiveness; ii). an international market signal; iii). development of supply chain and local content; iv). energy security; and v). decarbonisation. Auctions should be designed which in the early years are ring-fenced to FLOW, where the lowest cost is not the deciding factor, considering FLOW is an early stage technology, which is not yet truly cost competitive, but which holds long term economic benefits and low carbon energy security.

Provision should be made for revenue support for two pre-commercial demonstration projects, to trigger FLOW in the Celtic Sea and the Atlantic Production Zones over a relevant period of time, as each zone has unique characteristics and potential benefits. Following the UK Crown Estate model, demonstration areas could benefit from reduced seabed leasing charges in return for innovative proposals that would be a step towards fully commercial pathways as well as a special revenue support as part of the overall support package in OREDP 2 for new technologies. An opportunity exists in the pending stakeholder consultation on the MPDM Bill, to explore the opportunity to extend provisions for test and pilot activities, to provisions for allocating space for demonstration activity along the lines just outlined in the Celtic Sea (off Cork) and the Atlantic (off Clare).

Furthermore, the review of the OREDP (2018) proposed that the initial market scheme for wave and tidal technology, (from 2016 equivalent to €260/MWh for up to 30MW), should be raised and expanded and that it should take floating wind into consideration. A new opportunity exists for OREDP 2 to specify provisions for an incentive 'pot' to support experimental devices deployed at small capacity levels and an adjunct scheme to support larger scale pilot facilities such as a FLOW deployment to supply a pilot hydrogen facility ashore (see #8 below).

8. Kick-starting green hydrogen from offshore wind

Progress towards a green hydrogen transition requires strategic planning for hydrogen production facilities. Green hydrogen hubs can be envisioned for each of the three marine renewable energy production zones, building on existing industrial activity and infrastructure (e.g. in Dublin, Cork and Shannon). Regional hydrogen concepts can be envisaged, as part of an integrated, national approach to development. Market activation measures need to start now to boost demand and facilitate scaling into the future (e.g. market activation initiatives for hydrogen in domestic heat, transport and industry as described in Chapter 2).

Initial analysis of the potential for an electrolysis demonstration plant in Cork Harbour **(EirWind; B9)** suggests there is merit in such an approach as a kick-starter project to build towards a vision of Ireland as an EU global centre for hydrogen technology. This study provides a conceptual overview of a 100MW hydrogen production facility, coupled with a FLOW project (100MW) off the Cork coast: -

Green Hydrogen FLOW Demonstration Plant (also see below – Cork Harbour Hub)

The construction of a 100MW hydrogen demonstration plant, with the potential to scale-up to full industrial levels, would require supports such as funding for investment in an electrolyser-based production facility. A fully coupled project, with FLOW as the source of electricity for the electrolysers, would kick-start the production of green hydrogen from floating offshore wind (see below on a FLOW demonstrator). Mechanisms for revenue supports (e.g. technology specific auction rounds, or a feed in tariff for emerging technology) would need to be designed within the next circa 12 to 18 months.

Cork Harbour is an ideal location for a demonstration project for a number of reasons: i). In this research synthesis, the sequencing for the development of the offshore wind sector in Ireland envisages the initial projects for FLOW in the Celtic Sea; ii). areas of the harbour are zoned for industrial and energy activities; iii). space exists; iv). the hydrogen produced can be supplied to large industrial users in the harbour (e.g. oil refining); v). viability of distribution via capacity in the gas grid; vi). viability of distribution of hydrogen for transport applications, including existing supply chain services from the oil refining sector.

This initiative would be instrumental in moving the dial for hydrogen production, in line with the incremental market development scenarios outlined in Chapter 2 (i.e. 200MW to 1GW of hydrogen produced for heat and transport from offshore wind by 2030). A suite of measures need to be coordinated to facilitate progress towards economies of scale (e.g. CO_2 pricing for fossil fuels used in the heating and transport sector and exempting the production of green hydrogen from taxes, levies and surcharges).

9. Supply Chain strategy:

Work by EI and the IDA has helped to understand the supply chain opportunity for Ireland. Fundamentally, investment and project development are a prerogative for indigenous supply chain firms to emerge. Therefore, the most important recommendation here is for government to take action to facilitate relevant projects, and initiate FLOW and coupled green hydrogen production.

Other pertinent steps for gearing up include: i). Facilitation of Business to Business networking to develop the supply chain; ii). Expansion of indigenous industries into the offshore wind sector; iii). Opening of international markets for hydrogen; iv). Evolving RESS to incentivise the need for local content; v). Technology specific RESS for BFOW, demonstrators and FLOW; vi) addressing the skills gap by developing vocational training courses for working offshore (e.g. with NMCI and Letterkenny IT); and vii). Promoting training for hydrogen production, storage and distribution (e.g. Skillsnet).

10. Marine Installation Conservation Areas

MPAs can be implemented with different levels of access to, and protection of, the marine environment. These include complete 'no go' and 'no take' zones; to restricted access, and restricted activity zones. EirWind research demonstrated the potential for MICAs by enhancing biological productivity through artificial reefs and/or FADs. The opportunity presented by MICAs to enhance fisheries and habitats could form an innovative approach to planning for Ireland's MPAs. Offshore wind projects that include actions with consequential outcomes for marine conservation could be positively weighted in applications for leases and/or RESS.

11. Planning guidelines for environmental impact of offshore wind

Planning guidelines for onshore wind, given credence under Section 28 of the Planning and Development Act 2000, provide advice to local authorities on planning for onshore wind energy. They also provide relevant planning advice to developers and the general public. Work on landscape character assessment aids the implementation of the guidelines, which have proven to be important in the planning and management of onshore wind in Ireland to date.

An equivalent model for offshore wind is needed in the planning process. Work currently underway, facilitated by the Marine Institute, will lead to a national seascape character assessment. This, together with the type of visual sensitivity models developed in EirWind, can help to inform planning guidelines for offshore development. These would have to factor in the differences in visibility of BFOW and FLOW technology as a result of their distance to shore. As set out in the MRIA study of 2018 on marine spatial planning, the visual sensitivity approach is preferable to setting blanket 'no build' buffer zones for offshore renewables which could actually militate against Government policy for offshore wind in light of the proximity to shore of the 50m contour line (relatively high in the context of current offshore wind industry experience for fixed foundations) around the coast of Ireland.

12. A national data strategy for offshore wind

EirWind findings suggest the need for a national data strategy to fill the gaps in data and information, necessary to effective planning for offshore wind development. Action could also be taken to improve accessibility of existing datasets (e.g. automatic identification system data on vessel location and traffic). Key agencies have a role to play, including Marine Institute, Geological Survey of Ireland and the Sustainable Energy Authority of Ireland. Future data collection and standardization efforts could be achieved by directing funding towards research programmes like INFOMAR and MaREI.

13. Supporting adaptation and coexistence with fisheries

The fishing industry is *the* primary stakeholder to consider in the context of offshore wind development. An urgent action to be taken in the gearing-up stage is for the Government to facilitate a meaningful engagement between the fishing and offshore wind sectors. The impact of offshore wind, for example, on fishers, is best understood at a project / site-specific level. Nevertheless, there are macro-level issues that may be addressed via a joint forum with a co-designed agenda (e.g. regulations for fishing vessels to act as guard boats; shared interests in marine conservation; opportunities for co-existence; best practice in compensating against loss of livelihood).

14. Port Capacity Building

Investment is required in ports to support installation and assembly in each of the three Production Zones (e.g. Rosslare, Cork, Shannon Foynes, and in time in the north west). Given the expanse of the west coast of Ireland, and government plans for 30GW of FLOW in the Atlantic, plans also need to be set in motion for port development extending up the west coast in the 2030s (e.g. Killybegs, a new port). This approach would help to ensure the provision of adequate port facilities within operational and cost-effective distances of offshore wind farms. Port Master Plans are important instruments for strategic positioning, as well as opportunities to take stock of existing capital assets, and investment required to service offshore wind within a given region. Offshore wind potential needs to be inculcated into the master-planning and opportunity-scanning processes of the main port actors. Visibility of a pipeline of commercial projects is needed to trigger strategic investment by port companies. Government clearly has a role to play to provide the confidence required for ports to invest in the offshore wind market, either through direct funding in a centralised approach, or by initialising the other incentives and supports described here.

The development of a manufacturing and assembly port facility would be the ‘icing on the cake’ in relation to return on investment via job and value creation. There is likely to be one such facility; and the likelihood of it emerging is entirely dependent on the ambition and clarity of government. Taking a sequential approach to opening up the Atlantic Production Zone would give the lead in time to plan for a strategic partnership (e.g. with Shannon Foynes Port Company).

The potential exists for many small ports and harbours around the coast to act as O&M hubs. In the same way that major port actors may take stock of the opportunity from at an early stage, smaller ports and harbours could follow suit.

15. Cross-cutting and specific actions for OSW Production Zones

A range of cross-cutting actions outlined earlier will have implications for the Production Zones (e.g. investing in port infrastructure, incentivising FLOW and green hydrogen production). However, there are also some actions specific to the Production Zones that need to be addressed in the gearing-up stage: -

Irish Sea Production Zone: This is *de facto* a strategic development area for offshore wind in Ireland, characterised by the consented and relevant and enduring projects to date, and influenced by other developments in the pipeline for BFOW.

Celtic Sea Production Zone: The Celtic Sea needs to be recognised as an important unit or conceptual framing for offshore wind. The Hydrogen Hub kick-starter concept is a unique action specific to this zone. However, a study also needs to commence now, to identify the investment required to reinforce the capacity of the electric grid to absorb electricity generated from offshore wind, assuming the Irish Sea may not deliver on all of the 2030 targets, and factoring in the domestic demand for electricity beyond 2030. Projects of Common Interest (PCIs) have a long lead-in time, making it essential that the question of additional interconnectors to absorb excess energy generated by offshore wind, be examined now (in the context of # 6 above).

Atlantic Production Zone: Several of the actions outlined above would influence how this production zone may be unlocked (e.g. #8 and 15). As with the Celtic Sea, the development of this zone needs to focus on the question of infrastructure for electricity and gas (#6). As outlined, there is merit in a FLOW pre-commercial demonstration project; access to the grid at Moneypoint is an important asset for this region. As a natural follow-on from AFLOWT, bringing floating technology on=stream in the challenging metocean conditions of the Atlantic Ocean, would be a pioneering development of international significance. A niche for Ireland is in understanding how to address the associated techno-economic challenges, as well as potential for co-development with other emerging marine technologies, such as wave energy. There is also a need for a hydrogen roadmap to outline the pathway for hydrogen production, storage and distribution in the context of the unique socio-economic profile of the West Coast of Ireland. A long-term plan needs to be developed on how to scale-up to achieve the potential for bulk hydrogen production for export (e.g. this could focus on market drivers such as the International Maritime Organisation target for 40% reduction in GHG emissions from fuel for maritime transport by 2030). Finally, opportunities around manufacturing hubs for turbines and blades can be actioned by the enterprise development agencies and port authorities (#15).

16. Community engagement

Multiple, coordinated actions are needed at the national level to ensure that communities can engage in a meaningful way as Ireland gears-up for offshore wind. A Code of Practice for Wind Development sets the standards for community engagement in onshore wind projects; an equivalent code can be developed for offshore wind. Community co-ownership models for onshore wind, do not transfer to offshore wind development scenarios. As previously discussed, the fishing community is a priority group in the context of offshore wind; this requires additional and specific attention (e.g. through fishing funds allocated through RESS). Other measures that can be facilitated at the national level include coastal partnerships, educational material for schools and public awareness campaigns. At project levels, developers must be open to taking citizen values into consideration and engaging in the provision of collaboratively negotiated community benefits where relevant. Uniquely, as technology progresses, starting with the maturity of FLOW, offshore energy will start to develop over the horizon and out of the orbit of coastal communities.

17. Europe

Ireland is in a unique position to act as a test and demonstration hub for European ambitions and targets related to renewable energy in the European Green Deal, - the roadmap to making the EU's economy sustainable (the European Green Deal is aiming for up to 450GW of offshore wind by 2050 from circa 22GW today). Co-ordinated actions are needed to leverage opportunities for funding available through the EU such (e.g. the ETS Innovation Fund pooling together €10 billion for supporting low-carbon technologies for 2020-2030). This is particularly relevant for investment into infrastructure, including hydrogen demonstration and port related investments. Contributing to policy development is also key, (e.g. the offshore renewable energy strategy due in Q4; the Renewable Energy Directive), as part of Ireland's contribution to the European plan to become the first climate neutral continent by 2050.

18. R&D & Capacity building

Targeted research for offshore wind is needed to inform future planning and policy (e.g. how to take stock of cumulative impact; market activation to boost investments in hydrogen powered vehicles; and co-location with aquaculture), as well as facilitating studies into techno-economic issues (e.g. improving cost reductions for operations and maintenance through technical innovation). The follow-up project to EirWind (the H-Wind project proposal (Dinh and Leahy, 2020) through the MaREI centre) provides continuity for industry-led research to address recommendations arising from the EirWind project. A dedicated research programme for hydrogen technology and innovation is required from Science Foundation Ireland.

4.3 Critical Path – Acting Now

The critical path for the sustainable development of offshore wind has been distilled down to five main points, in the basis that, without these actions, other developments will not ensue. The critical path for offshore wind includes i). Recruitment of additional government resources; ii). Development of a national route to market strategy, including targets for FLOW and green hydrogen; iii). Pre-commercial demonstrations for floating wind; iv). Planning for three offshore wind production zones, and v). Actions for meaningful engagement with coastal communities (Figure 4.3).

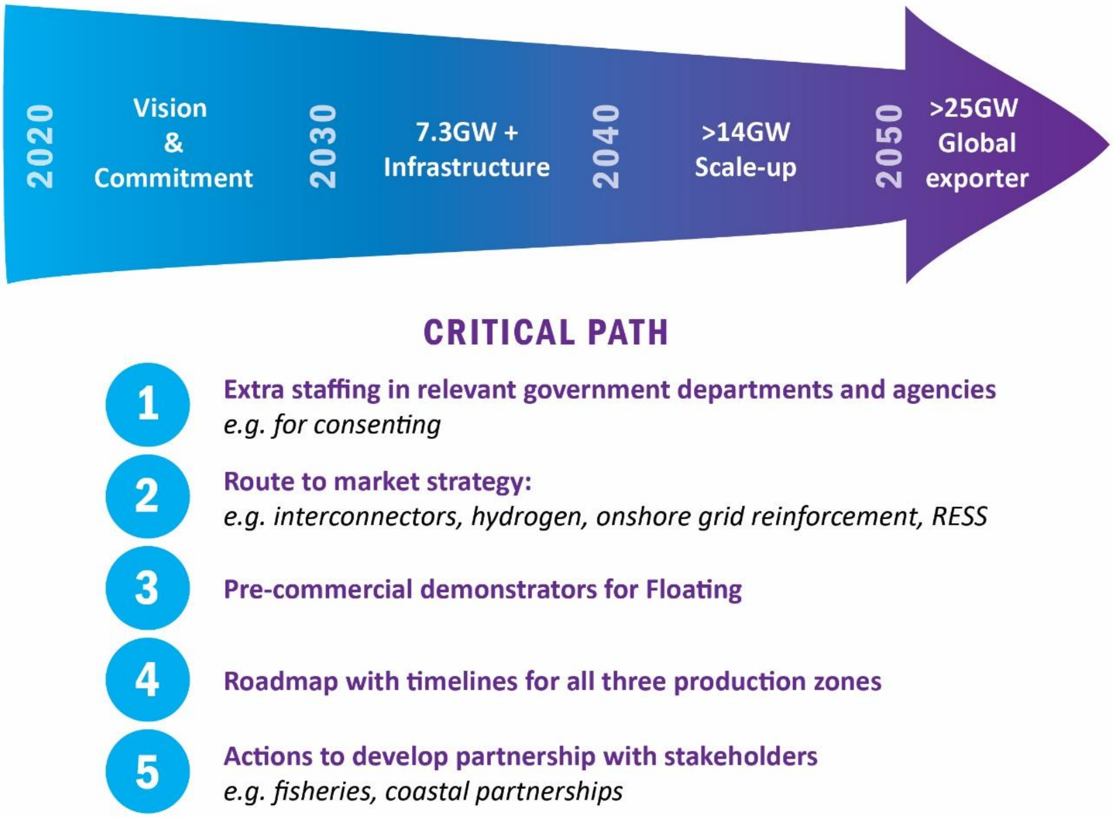


Figure 4.3: Critical path for the sustainable development of offshore wind.

4.4 Conclusion

The new government has indicated a scale of ambition for the offshore wind sector that positions Ireland as one of the most exciting emerging markets globally. Delivery of BFOW in the first half of the 2020s in line with the Climate Action Plan and Programme for Government commitments is critical to kick-start an offshore wind industry in Ireland. Ireland needs to make rapid progress to sustain confidence in the industry and lay the foundation for the future where Ireland has the opportunity to be a world leader. While offshore generation forecast for the 2020s will be needed to satisfy domestic demand, beyond this, Ireland will need to export the excess energy that can be produced, requiring an unprecedented level of investment by the State in critical energy infrastructure. In order to maintain momentum, there is an urgent need for decisions on where, when and how different scaling-up of production and distribution activities may occur, aligned with market activation for electricity, heat, transport, domestic industry and bulk hydrogen export. The development of offshore wind and the recommendations for actions on green hydrogen production outlined above, are not without challenges. Government must set new targets and commit to revenue support schemes to encourage investment, as part of the New Green Deal. Government must also invest now, in ensuring that communities are informed about what is at stake. This synthesis report, underpinned by detailed technical studies, provides a roadmap for development that will hopefully inform these decisions on Ireland's energy future. The recommendations contained in this report suggest sequencing around three production zones; and propose plausible pathways for specific markets for electricity and hydrogen generated by Ireland's abundance of offshore wind. The implementation of these recommendations will require partnership with sea-users, industrial actors and civil society.

5. Appendices

Appendix 1

Table 5.1 provides a summary of the publicly available reports and studies at www.marei.ie/eirwind that underpinned this report.

Table 5.1: Summary of the technical reports produced in the EirWind project, as input to the Synthesis Report

Deliverable Title	Year	Authors
EirWind: Data Resources Assessment Phase 1: Data Requirements, Gap Analysis and Strategic Plan	2018	J. Peters, A. Wheeler, T. Remmers & V. Cummins
EirWind: Field Measurement Plan 1	2018	J. Peters and A. Wheeler
EirWind: Data Resources Assessment Phase 2	2018	J. Peters, A. Wheeler & V. Cummins
EirWind: Initial Issues Report on Offshore Wind farm Development in Ireland	2018	R. Chester, J. Murphy, V.N. Dinh & V. Cummins
EirWind: Offshore Development Zones and Pathways Interview Summary	2020	C. Desmond & F. Butschek
EirWind: Recommended Innovation and Best Practice in Stakeholder Engagement	2018	Y. Cronin & V. Cummins
EirWind: Comparative Analysis of Regulatory Regime Ireland and Scotland	2019	Z. O'Hanlon & V. Cummins
EirWind: Public Perception of Offshore Wind Farms Report: Part 1	2019	Y. Cronin & V. Cummins
EirWind: Marine Installation Conservation Areas	2020	M. Sweeney & V. Cummins

EirWind Research Methodology: Fishers' and Offshore Wind Developers' Perceptions of Trust Building Mechanisms,& Community Benefits	2019	M. Kami Delivand & V. Cummins
EirWind: Public Perception of Offshore Wind Farms Report Part 2	2020	Y. Cronin, E. Wolsztynski & V. Cummins
EirWind: Media Content Analysis	2020	Y. Cronin, V. Cummins & G. Mullally
EirWind: Study on State Bandwidth for Offshore Wind	2020	F. Judge, V. Cummins, A O Hagan & J. Murphy
EirWind: An Investigation of Co-existence between the Fishing and Offshore Wind Sectors, and the Perceptions of Benefit Sharing	2020	M. Kami Delivand & V. Cummins
EirWind: Socio-economic Study	2020	S. Kandrot, V. Cummins & D. Jordan
EirWind: Initial Results for the Assessment of Seabird Vulnerability to Offshore Wind Farms in Ireland	2019	E. Critchley & M. Jessopp
EirWind: Impacts from Offshore Wind Farms on Marine Mammals and Fish – A Review of the Current Knowledge	2019	W. Hunt & M. Jessopp (2019)
EirWind: Final Report on Impacts of Offshore Wind Farms on Seabirds and Marine Mammals	2019	E. Critchley, W. Hunt & M. Jessopp
EirWind: Evaluating Offshore Wind Governance in the Irish Sea using the Policy Arrangements Approach - Lessons for the Republic of Ireland	2020	T. Rhiannon Evans, R. Ballinger & V. Cummins
EirWind: Identification of New and Future Markets for Offshore Wind and Hydrogen Energy	2018	V.N. Dinh, P. Leahy, V. Cummins & E. McKeogh
EirWind: System Services Report 1	2019	J. Laguipo, P. Leahy, V.N. Dinh& Mc Keogh

EirWind: Projections for Future Levels of Wind Curtailment for Market Arrangements	2020	B. Bambury, P. Leahy, V.N. Dinh & E. Mc Keogh
EirWind: Review of Electrolyser and Power-to-gas Technologies with a Focus on Variable Operation and System Services	2019	P.H. Todesco Pereira, P. Leahy, V.N. Dinh & E. Mc Keogh
EirWind: Recommendations on Role of Government and Funding Mechanisms for Infrastructure Development	2020	J. Laguipo, P.H. Todesco Pereira, B. Bambury, P. Leahy, V.N. Dinh & E. Mc Keogh
EirWind Report on the Existing and Developing Interconnectors and their Capacity Strategies	2020	P.H. Todesco Pereira, P. Leahy, V.N. Dinh & E. Mc Keogh
EirWind: Full Economic Analysis.	2020	J. Laguipo, B. Bambury, P. Leahy, V.N. Dinh & E. Mc Keogh
EirWind: Demonstration Pilots Design and Recommendations	2020	P.H. Todesco Pereira, V.N. Dinh, P. Leahy & E. Mc Keogh
EirWind: Literature and Methodology for a Blueprint of Sustainable Development of Offshore Wind in Ireland	2019	V.N. Dinh, V. Cummins, J. Murphy and E. McKeogh
EirWind: Synthesis/Blueprint for Phased Approach to Sustainable Development of Offshore Wind in Ireland	2020	V. Cummins & E. McKeogh

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