WIND ENERGY IRELAND

July 2021

Revolution

A vision for Irish floating wind energy

WindFloat® being towed away after turbine is installed at Ferrol Outer Harbor, Spain.
Photo courtesy of Principle Power. Artist: DOCK90.

Executive Summary

Rapid developments in floating foundation technology are opening up new markets, where floating foundations can be deployed in waters from circa 50 m to 1000 m deep. **Floating Offshore Wind (FLOW) can add to the benefits of traditional fixed-bottom offshore wind by helping to make Ireland a world leader in producing renewable energy and fighting climate change.** This will allow us to power not just ourselves, but to also export enormous amounts of clean energy to Europe.

Better understanding of the readiness of FLOW technology, the impact the sector can have on job creation and growth, and the contribution it will make to decarbonisation targets, will accelerate progress towards the benefits that FLOW can deliver to our society, our economy and our environment. This report will show how Ireland can seize its opportunity, realise the long-term ambition of 30 GW of FLOW for export set out in the Programme for Government (PfG) and become a leader in the global energy transition.

Ready to Start Delivering

The commissioning of the 48 MW Kincardine Phase 2 project in the UK later this year will bring Europe's installed capacity of floating wind to over 100 MW. By 2030, Europe could have as much as 7 GW. Floating offshore wind is ready to start delivering commercially this decade.

The UK, France and Norway have so far shown the greatest ambition: The UK has set a 2030 target of 1 GW of FLOW and announced plans to design new leasing opportunities for early commercial-scale projects in the Celtic Sea; France has launched its first commercial-scale tender for a floating wind project of between 230 and 270 MW to begin operation this decade, with further tenders planned for the coming years; and Norway has recently opened three areas of up to 500 MW each for FLOW.

With an abundance of wind resources in deep waters off the south and west coasts, investors in Ireland are also poised to progress with stepping-stone FLOW projects this decade, with a view to contributing to the long term goal of net-zero carbon by 2050, in both domestic and European markets.

A major challenge facing FLOW right now relates to misperceptions about the sector's state of readiness. Technology improvements have enabled the rapid maturing of the floating wind market. FLOW has quickly progressed from demonstration to early-stage commercial projects. It can no longer be dismissed as an emerging technology.

FLOW must be considered in the context of decisions being taken in the coming months to put in place a framework for offshore renewable energy development. The attention of policy makers to date has been focused on 'Phase 1' projects. The commissioning of these fixed-bottom projects is crucial to the success of offshore wind in Ireland and achieving our 2030 5 GW ambition. But FLOW can also contribute to this target, and depending on attrition rates of the current pipeline, may be needed to do so. Taking measures to support FLOW now will also help to ensure that the supply chain we urgently need to build for offshore wind can support the development of FLOW towards the end of the decade. This will enable the industrialisation of this whole new sector for Ireland in the 2030s.

Building on the fixed-bottom sector, skills development and the formation of a workforce for FLOW will be key to unlocking the associated benefits. Planning for this must be commenced to ensure that we maximise the potential economic benefit for Ireland, including in coastal communities along the south and west coasts.

Costs are Falling Rapidly

According to WindEurope, by 2030, the cost of new European FLOW projects could be as low as €53 per MWh, with an average of €64 per MWh expected. ORE Catapult predicts that FLOW costs in the UK will reach parity with UK wholesale prices around 2031. Others such as DNV also predict rapid cost reductions. Government support through RESS and the proactive development of the transmission system in the decade ahead will pave the way for a return on investment and value creation. FLOW projects can use 60-70 per cent of the fixed-bottom supply chain; however, FLOW also needs a process to industrialise and standardise floating foundations to further drive down costs. Investment in port capacity is required to facilitate this.

But we have no time to waste. While costs are falling, we must be ready with the right supporting policies and infrastructure in place to capitalise on them.

The Opportunity is There for the Taking

When Ireland built its first offshore wind farm off the coast of Arklow in 2004 an enormous opportunity presented itself. We could have built on this to create a world-leading offshore renewable energy industry, but we missed our chance and for almost two decades we have watched while other countries, who recognised the opportunity available to them, seized it. Investing in offshore wind farms has helped countries like Denmark and the UK to decarbonise their electricity grids, dramatically reduce the cost of renewable electricity to the customer and create thousands of jobs.

Today, we are on the cusp of another opportunity, and actions are needed to fully grasp it. To fully capture the benefits of FLOW, it is important that Ireland builds on the work already being carried out by offshore wind energy developers to become an early mover in FLOW and establish a strong indigenous industry. The window to becoming an early mover is closing quickly as other jurisdictions ramp up their plans for FLOW.

With the Wind Energy Ireland (WEI) developer survey showing a total of circa 8 GW of FLOW projects already proposed for the Celtic Sea and the Atlantic, industry is poised to put the building-block projects in place to ensure FLOW becomes a reality in the coming years. **With the right policy enablers, we are confident we could see a significant volume of floating offshore wind operational by 2030.** Recent public announcements of circa 400 MW projects for the south and the west coasts (including projects seeking to avail of existing grid infrastructure in Moneypoint) are indicators of industry readiness to invest in FLOW, subject to initial supports. If projects can be developed this decade, Ireland will be on the way to becoming a leader in the industry, putting us at the forefront of a global revolution in renewable energy.

Economic Opportunity as well as Critical for Climate and the Environment

With the target of 30 GW of FLOW presenting the possibility of turning Ireland into a major energy exporter, FLOW provides an unprecedented economic opportunity for our country and has the potential to deliver clean, green, sustainable growth and development, whilst facilitating the energy transition.

FLOW can create thousands of jobs by 2050, through staging, installation and the operations and maintenance of wind farms. There may also be opportunities for Ireland to contribute to the manufacturing of floating foundations and smaller components, providing further employment. Floating wind farms, and the new routes to market FLOW unlocks, particularly green hydrogen and electrofuels, and the potential to export vast quantities of renewable electricity via a pan-European Supergrid, will trigger billions of euro in investments in the coming decades. Maximising the portion of this investment captured by the Irish supply chain will depend on how we establish ourselves in the sector this decade. Much of this investment will also be directed to communities on our south and west coasts that may not attract other large industries. For example, FLOW can open new employment opportunities for skilled mariners from the fishing industry.

Few European ports are currently suitable for the manufacturing, assembly and servicing of FLOW projects. **Ireland has multiple ports with ambitious plans to invest in FLOW and we will need a network of ports along our coastlines to support the intricacies and scale of the supply chain.** Redevelopment of these ports can transform coastal communities and allow Ireland to meaningfully contribute to the FLOW supply chain.

However, if measures are not taken by Government now to build on the momentum in the FLOW sector, the opportunity available to us could disappear, and with it many of the associated benefits.

There are Four Main Routes to Market for at least 30 GW

The 'route to market' for FLOW will occur across a wider geographical area and energy system compared to other forms of wind energy in Ireland. Traditional renewable energy support schemes will help FLOW contribute to Ireland's electricity demand, but we need new ways to facilitate FLOW in its other three markets: Ireland's demand for electrofuels; supplying Europe's electricity demand; and Europe's demand for electrofuels. These areas will provide huge demand in the future, with WEI 2050 forecasts outlined below:

- Ireland's electricity demand will grow to over 50 TWh and require 12 GW of wind energy;
- Ireland's electrofuel demand will require 66 TWh of electricity and 15 GW of wind energy;
- European electricity demand will exceed 5,300 TWh and require 680 GW of wind energy; and
- European electrofuel demand will require over 2,500 TWh of electricity and 320 GW of wind energy.

The development of **electrofuels** and the coordinated development and planning for an offshore grid that goes beyond national borders towards a **European Supergrid** can enable Ireland to export clean renewable energy to other European states. Enhanced cooperation between Member States may also provide innovative new financing mechanisms for projects. One way to progress these ideas is to create a '**national route to market strategy for electrofuels**' **with a focus on green hydrogen production**. Targeted policy action, R&D and strategic planning for production facilities is needed if Ireland is to build the requisite supply and demand for this new industry with massive potential.

Although the PfG target of 30 GW may seem an enormous figure, it is realistic in the context of the projected future demand for renewable energy. Innovation in policy formulation will be crucial to lead us on this journey. Resourcing of government departments and agencies with relevant expertise and capacity is critical to this.

Immediate Policy Change is Required to Unlock Ireland's FLOW Potential

Many of the actions needed now apply to offshore wind in general, not just FLOW. These are outlined in WEI's *Building Offshore Wind* report. **The principal recommendations for FLOW are outlined below which can help policymakers to seize the advantage of early-mover status for Ireland, enable FLOW projects to energise for 2030 and foster the development of a FLOW industry for Ireland**:

- The Maritime Area Planning Bill should empower the Minister for Environment, Climate and Communications to grant Maritime Area Consents to Phase Two projects, once they have been identified and designated, and to grant survey licences for beyond the 12 nautical mile limit. Delays to the establishment of the Maritime Area Regulatory Authority (MARA) must not delay projects.
- WEI recommends a floating wind pot in RESS or an "F-RESS" auction in 2025 to support early commercial scale projects for the Celtic Sea and Atlantic production zones. A clear roadmap for future RESS auctions post-2025 should also be put in place;
- Grid upgrades will be needed to facilitate FLOW. EirGrid must identify and plan for these upgrades once it has completed its studies on the grid capacity available on the south and west coasts. Upgrades must also be future-proofed to enable 2050 targets;
- WEI recommends a strategic review of all port facilities with the capability to support FLOW and for future port policy to support investment by the State into this key infrastructure;
- A strategy is needed from Government, encompassing the points above, outlining how we will develop our enormous FLOW resource over the coming years and decades, giving a clear plan on how the 30 GW commitment included in the PfG will be achieved. An action on this should be included in the updated Climate Action Plan, translating the ambition shown in the PfG into a target for industry.

Longer-term, planning for a net-zero electricity system should begin now. Strategic planning of Ireland's electricity grid needs to be progressed to enable us to achieve optimum penetration of renewable electricity, and to export electricity directly to Europe. WEI supports the announcement from DECC that a coordinated, plan-led offshore grid delivery model will be put in place post-2030. This is the most suitable model to unlock our 30 GW potential. This will, however, need to be appropriately consulted on to ensure a smooth transition from the developer-led, which is needed deliver the 5 GW target for 2030, to the longer-term plan-led model.

Realising the export opportunity available to us will require three further critical actions:

- The planned interconnectors from Ireland to Britain and France must be delivered on time and planning should start now for new interconnections in the 2030s;
- The revised TEN-E Regulation should facilitate the development of a European Supergrid and planning should start on Projects of Common Interest (PCIs) and hybrid interconnection; and
- Finally, the opportunity for the production of electrofuels for the Irish and European market requires a national strategy on energy hubs and route to market, including green hydrogen and its derivatives.

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1 Introduction

Wind Energy Ireland (WEI) is the representative body for the Irish wind industry, working to promote wind energy as an essential, economical and environmentally friendly part of the country's low-carbon energy future. We are Ireland's largest renewable energy organisation with more than 170 members who have come together to plan, build, operate and support the development of the country's chief renewable energy resource. WEI works with communities, members and stakeholders to lead the transition to a cost-effective sustainable energy system in Ireland with wind at its heart, through policy development, communication and education.

The COVID pandemic has been a stark warning that nature is a force to be reckoned with and that humankind needs to work together to create resilient and sustainable communities. 2021 will be defined by rebuilding and recovery. The decades ahead will be defined by how green that recovery actually is.

Floating Offshore Wind (FLOW) can make Ireland a world leader in the production of renewable energy, not only in the form of electricity, but also through the production of carbon-free fuels (i.e. electrofuels). By delivering on our significant FLOW potential, we can produce enough power for our own needs but also become a net exporter of clean energy on a truly massive scale. Given the rapid advance of FLOW technology over recent years, it may not be apparent to policymakers just how fast this sector is progressing. This report presents a clear picture of the status of FLOW and communicates the need for urgent action to seize a once-in-a-generation opportunity.

FLOW, as an entirely new industrial sector, has the potential to create thousands of new jobs directly and indirectly in the development, construction and operations & maintenance (O&M) of wind farms. There may also be opportunities for Ireland to contribute to the manufacturing of floating foundations and smaller components, providing further employment. Many more jobs will be created in indirect support services, most of which will be centred around coastal and rural communities along the south and west coasts.

Companies such as DP Energy, Iberdrola, Equinor, ESB, Simply Blue Energy, Shell and SSE Renewables have all invested in site identification and feasibility studies at risk, giving a clear indication that the industry is poised to make FLOW a reality in the coming years. Other new entrants to the Irish marketplace, such as Ocean Winds, have considerable experience from overseas projects that can be applied here.

The attention of policy makers to date has been focused on 'Phase 1' projects; the initial fixed-bottom projects earmarked for development in Irish waters. **The commissioning of these fixed-bottom projects is crucial to the success of offshore wind in Ireland and achieving our 2030 offshore ambition of 5 GW.** These are the projects that will pave the way for the entire sector to progress and ultimately set Ireland on the pathway towards delivering on our FLOW ambition. FLOW can also contribute to Ireland's 5 GW target by 2030, and depending on attrition rates of the current pipeline, may be needed to do so.

As the offshore wind sector unfolds, however, our energy future will increasingly be a story about FLOW. Decisions and actions in the coming months and years will be crucial to the progression of the immense FLOW opportunity for Ireland.

Our Vision is to make floating offshore wind, a transformative new industrial sector, a commercial reality in Ireland this decade - to realise the long-term climate, jobs and economic benefits from our globally significant offshore wind and deep-water resources off the south, west and east coasts.

The objectives of this report are to: update on the status of FLOW technology and the market; present the opportunity FLOW brings to the local supply chain, jobs, economy and environment; and show how the 30 GW ambition can become a reality. The layout of the report is set out below:

- **Section 2** provides context on the current status of FLOW technology, showing that it is a technology that is ready to deliver, with projects already in the pipeline in Ireland;
- **Section 3** looks at the costs of FLOW and the projected rapid declines which will make it cost-competitive with fixed-bottom offshore wind in the 2030s;
- **Section 4** outlines the opportunity for Ireland to become an early mover as the FLOW industry develops this decade, with reference to recent Irish supply chain initiatives and measures being taken in other jurisdictions to support the development of FLOW;
- **Section 5** assesses the enormous economic opportunity provided by FLOW, and how it can contribute to jobs, growth and regional development while at the same time being critical to climate action;
- **Section 6** focuses on the predicted future demand for energy in Ireland and across Europe and how much wind capacity will be required to supply this; and
- **Section 7** concludes the report and outlines key recommendations.

2 Ready to Deliver

The Programme for Government (2020)[1] set an ambition for 30 GW of FLOW energy. 30 GW may seem an enormous figure for a small nation like Ireland, but it is a very realistic target, given the excellent resource on our doorstep. A resource assessment study showed the potential for the development of up to 50 GW of FLOW capacity in the Celtic Sea alone[2]. Other commentators refer to up to 75 GW of plausible floating wind potential off the west coast[3,4]. The potential scale of development of FLOW is enormous.

This capacity will also be very much needed. There will be huge growth in the demand for clean energy both domestically, and across Europe, over the coming years and decades. This is examined in more detail in chapter 6. The EU has targeted climate neutrality by 2050. If this is to be achieved, the realisation of Ireland's FLOW potential will play an important role by supplying renewable electricity both domestically and to the rest of Europe and aiding the decarbonisation of other sectors.

But FLOW is not just a technology for the future – it is ready to start delivering this decade. The technology has been tested, costs are falling rapidly, and projects are already in the pipeline in Ireland.

2.1 Floating Wind Projects Are Already Underway in Ireland

According to WEI's most recent developer survey, carried out in Q1 2021, **there are approximately 3 GW of FLOW projects in the early stages of development in the Celtic Sea and an additional 5 GW of FLOW proposed for the Atlantic.** These capacities may change when site investigation works are completed, but there is already a significant FLOW pipeline in place.

For example, the ESB and Equinor recently announced their 'Green Atlantic @ Money Point'[5] project, which includes plans for a 400 MW floating wind farm to begin operation by 2028, a wind turbine construction hub, and investment in green hydrogen. Simply Blue Group and Shell[6], and DP and Iberdrola[7] have also publicly announced plans to have FLOW projects in the water before 2030.

Initial commercial scale projects here will take a burgeoning FLOW supply chain to a new level, creating major opportunities for ports, harbours, and local coastal communities along the south and west coasts. Already, significant interest is being shown across the supply chain.

[1] https://assets.gov.ie/94092/50f892b9-a93e-43fc-81d1-778ff9954d9f.pdf
[2] ITP Energised (2019). Assessment of the Floating Offshore Wind Potential in the Irish Sea and UK Waters of the Celtic Sea.
[3] https://www.sfpc.ie/wp-content/uploads/2020/12/20163-R-001-Shannon-Estuary-Offshore-Wind-Rev2.pdf
[4] https://www.irishtimes.com/news/environment/ireland-could-supply-5-of-europe-s-electricity-with-offshore-wind-1.4194310
[5] https://www.esb.ie/our-businesses/generation-energy-trading-new/green-atlantic-at-moneypoint
[6] https://simplyblueenergy.com/emerald/
[7] https://www.dpenergy.com/news/dp-energy-makes-big-splash-with-irish-offshore-deal-2/

Enabling some of these projects already underway to begin operation this decade can put Ireland on the path to becoming a leader in the FLOW industry. **Given the right enabling environment for consenting and supports**, **our members are confident that we could see a significant volume of floating offshore wind operational by 2030.** This would unlock a wealth of opportunities.

It is important to understand that not all projects in the offshore wind pipeline will be realised. The proposed sites for some projects will overlap, some will not get planning permission or grid connections, others will not succeed at auction. There is uncertainty around what attrition rates here will be, but multiples of the 5 GW target set by Government must be allowed to progress through the foreshore investigation and consenting stages if we are to deliver on our 2030 ambition. The higher the volume of capacity which can progress, the lower the risk we will miss our target. FLOW has an important role to play in ensuring Ireland has a sufficient volume of projects in the pipeline and can contribute to our 2030 offshore target of 5 GW.

2.2 Floating Offshore Wind Technology is Proven and Will Bring a Host of Benefits

FLOW projects are already underway in Ireland as technology improvements have enabled the rapid maturing of the market. The first commercial-scale projects in the early 2020s, such as Valorus off Pembroke (300 MW by Total and Simply Blue Group) and the Ulsan project in South Korea (which envisages 500 MW in construction by the end of 2023), will develop supply chains, enable large-scale industrialisation of FLOW, and help FLOW achieve cost-competitiveness with fixed-bottom wind in the 2030s.

Traditional fixed-bottom offshore wind technology is typically in the form of a monopile or jacket/tripod, which can be deployed in water depths of up to approximately 60 m. FLOW foundations float at site and are kept in place by a system of moorings and anchors. Rapid developments in FLOW technology are opening new markets, where floating foundations can be deployed in waters from circa 50 m to 1000 m deep. Figure 2.1 outlines the main floating technologies which are emerging as leaders in the field: the barge platform; the semi-submersible platform; the tension leg platform; and the spar buoy.

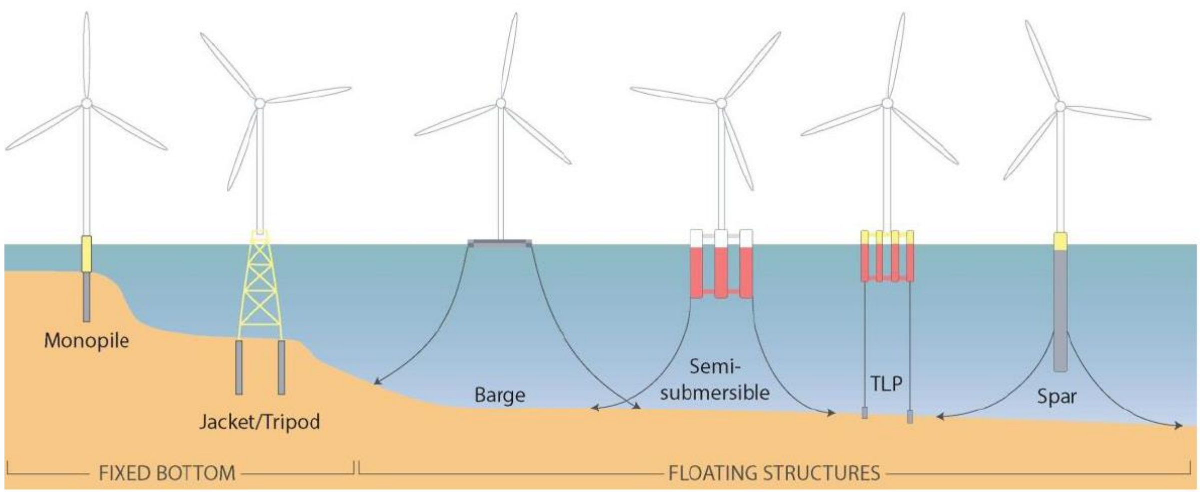

Figure 2.1: The four basic types of FLOW technology are the Barge, Semi-submersible platform, Tension Leg Platform (TLP), and the Spar Buoy, which between them can be deployed in circa 60- 1000m water depths[8]

[8] https://www.marei.ie/wp-content/uploads/2020/07/EirWind-Blueprint-July-2020.pdf

In addition to the many benefits associated with fixed-bottom offshore wind, FLOW technology can bring a host of unique benefits by:

- Unlocking new renewable energy potential in waters that would be unsuitable for fixed-bottom;
- Reaching capacity factors of over 60 per cent due to more consistent winds in deeper waters[9];
- Reducing work offshore as both the substructure and turbine can be assembled and coupled in port and towed to site, as well as towed back to port for some maintenance work;
- Minimising initial environmental impacts due to less invasive installation methods[10];
- Lessening or removing visual impacts from the shore;
- Increasing the efficiency of installation and maintenance due to a lower reliance on large and expensive installation vessels;
- Eliminating the need to customize substructures to the specific features of the site; and
- Creating a huge export potential to the rest of Europe.

[9] https://www.greentechmedia.com/articles/read/worlds-first-floating-offshore-wind-farm-65-capacity-factor

[10] https://acteon.com/blog/benefits-of-floating-offshore-wind/#:~:text=Not%20only%20does%20floating%20wind,accessible%20with%20simply%20fixed%20foundations.

2.3 Installed Capacity will grow rapidly this decade

European installed capacity of FLOW stood at just 62 MW in Dec 2020, 83 per cent of the global installed capacity of 75 MW[11]. This figure is set to increase rapidly in the second half of this decade however (Figure 2.2), as commercial-scale projects come online.

The Carbon Trust predicts up to 13 GW of FLOW globally by 2030, and up to 120 GW by 2040[12] in their 'Accelerated Scenario' and the Global Wind Energy Council forecasts 16 GW FLOW for 2030[13]. DNV predicts there will be 250 GW of FLOW globally by 2050[14], and WindEurope estimates that Europe could have 7 GW[15] by 2030 and 100 – 150 GW by 2050[16].

An interactive map of public FLOW projects in operation and development can be found here[17].

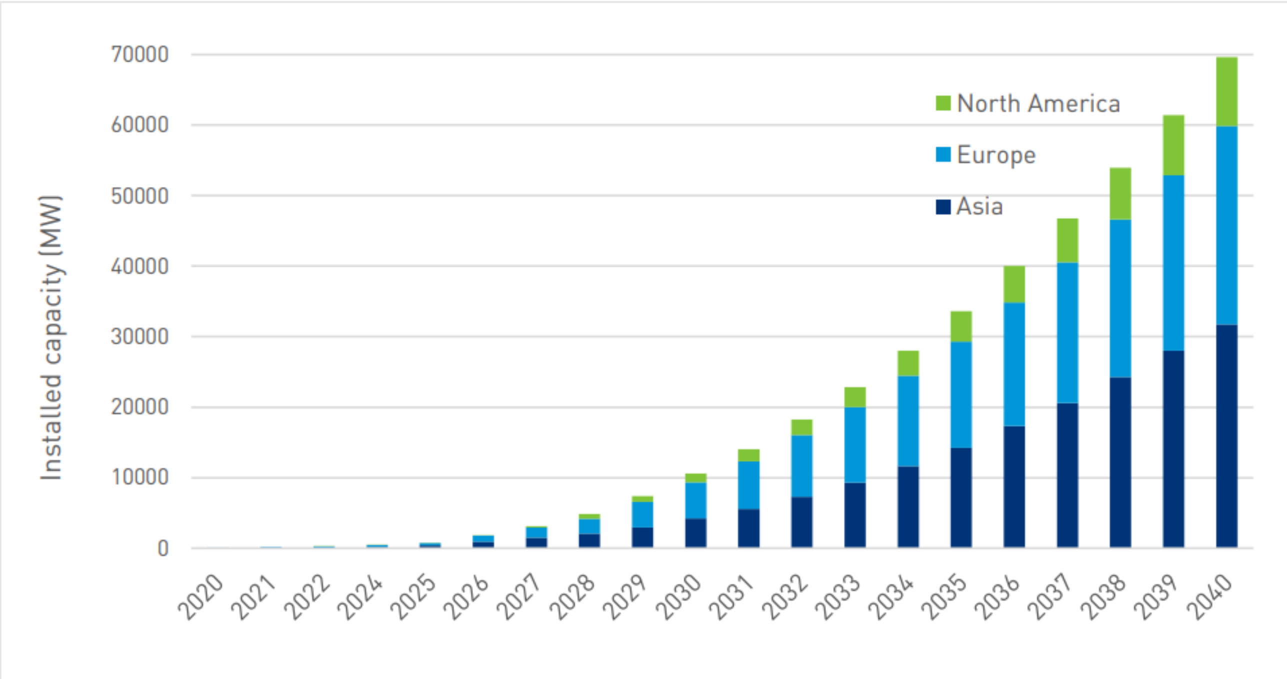

Figure 2.2: Carbon Trust's Projected global FLOW deployment to 2040 (Median Scenario).[18]

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[11] WindEurope, (2021). Offshore Wind in Europe – Key Trend and statistics 2020

[12] Carbon Trust 2020) Floating Wind Joint Industry Project

[13] GWEC Market Intelligence Data January 2021

[14] https://www.dnvgl.com/focus-areas/floating-offshore-wind/commercialize-floating-wind-report.html

[15] https://windeurope.org/intelligence-platform/product/ports-a-key-enabler-for-the-floating-offshore-wind-sector/

[16] https://windeurope.org/wp-content/uploads/files/policy/position-papers/20200610-WindEurope-offshore-renewable-energy-strategy.pdf

[17] https://windeurope.org/data-and-analysis/product/international-floating-wind-projects-public/

[18] https://prod-drupal-files.storage.googleapis.com/documents/resource/public/FWJIP_Phase_2_Summary_Report_0.pdf

3 Costs are Falling Rapidly

Recent reports on FLOW discussed in this section share a common theme: they predict the Levelised Cost of Energy (LCOE) for FLOW will fall significantly this decade. WindEurope predicts the 2030 average LCOE for FLOW projects in Europe will be €64 per MWh[19], as it becomes more cost-competitive with fixed-bottom offshore wind. This is made more impressive when the rapid decline in the cost of fixed-bottom offshore wind to date is considered. The globalised LCOE for fixed-bottom offshore wind fell by 44 per cent in the 10 years up to 2019, reaching €45-79 per MWh[20]. Today, there is 35 GW fixed-bottom offshore wind worldwide, with 25 GW in Europe.

In offshore auctions across Europe, strike prices have also been falling rapidly. The last auction in the UK in 2019 saw an average winning price of just £40.63 per MWh (€46)[21]. This compares to winning bids of £114 (€129) and £119 (€135) in 2015[22] (All 2012 Sterling prices, to be adjusted annually for inflation).

In European jurisdictions where the transmission system operator (TSO) is responsible for the offshore transmission system costs, subsidy-free projects are already being developed[23]. It is important to note here however, that the costs for grid development still need to be covered by the TSO, which will in turn be paid for by the consumer.

The sustained decline in costs for fixed-bottom offshore wind will make it more challenging for FLOW to compete on costs, but recent research suggests that the gap between the two technologies will narrow dramatically this decade, as discussed below.

3.1 Levelised Cost of Electricity Projections

Although the global LCOE for FLOW was estimated to be €135 per MWh in 2020, according to DNV[24], they predict this will fall rapidly to reach approximately €65 per MWh by 2030, and €40 per MWh by 2050 (Figure 3.1). WindEurope predicts the 2030 average LCOE for FLOW projects in Europe will be €64 per MWh, including grid connection costs, constituting a 65 per cent reduction compared to 2020[25].

[19] https://proceedings.windeurope.org/biplatform/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBB

[20] https://ec.europa.eu/energy/sites/ener/files/offshore_renewable_energy_strategy.pdf

[21] https://windeurope.org/newsroom/press-releases/offshore-wind-wins-big-in-worlds-largest-wind-energy-capacity-auction/

[22] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/407059/Contracts_for_Difference_-_Auction_Results_-_Official_Statistics.pdf

[23] https://ieefa.org/vattenfall-to-build-1-5gw-subsidy-free-offshore-wind-farm-worlds-largest-in-north-sea/

[24] https://www.dnvgl.com/focus-areas/floating-offshore-wind/commercialize-floating-wind-report.html

[25] https://etipwind.eu/publications/getting-fit-for-55/

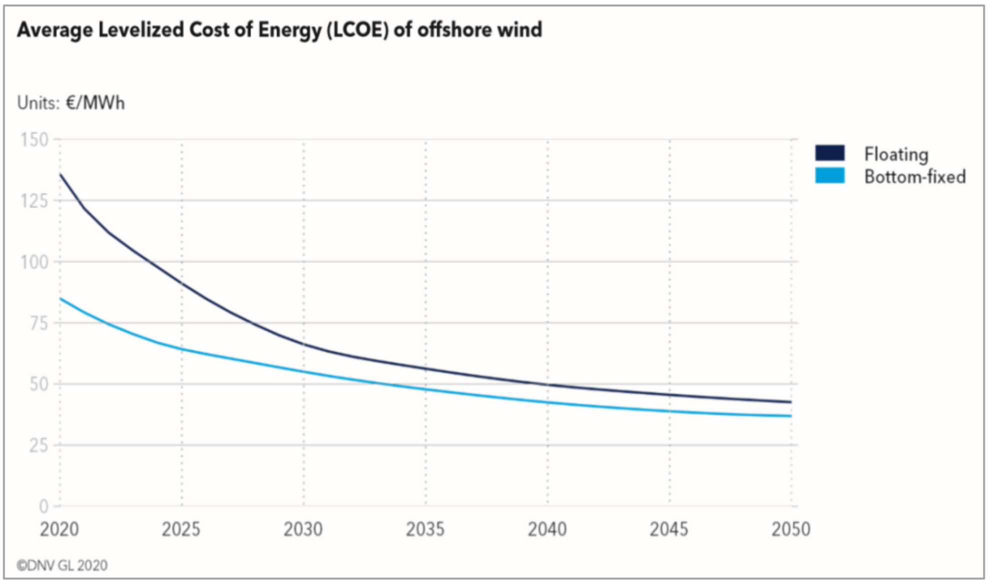

Figure 3.1: DNV projections for the average global LCOE of fixed-bottom and floating offshore wind from 2020-2050, which predict the gap between the costs of fixed-bottom and FLOW will decrease rapidly over the coming decade.[26]

ORE Catapult predicts that FLOW costs in the UK will catch up rapidly with fixed-bottom wind and reach parity with UK wholesale prices around 2031[27]. RenewableUK and Scottish Renewables expect FLOW to be cost-competitive with other energy technologies by 2030[28].

For Irish-specific projections, we can look to the OPFLOW report[29], which carried out financial modelling for two hypothetical 300 MW FLOW projects off our south and west coasts, being delivered in 2028. LCOEs of €77 per MWh and €97 per MWh, respectively, are found. Substation costs were not included in this analysis.

The EirWind team also conducted modelling work for potential Irish FLOW projects in their report[30]. The report looks at two circa. 1 GW projects commissioned in 2035 in the Celtic Sea and Atlantic Ocean, with LCOE ranges of €63 – €90 and €75 – €107 per MWh found, respectively.

It is important to note that these are projections and the input assumptions used have a significant bearing on the results. The EirWind models did not take learning rates into account, for example. It would be expected that a 1 GW project commissioned in 2035 would experience significant cost reductions compared to 300 MW projects commissioned seven years earlier.

All indications are that FLOW will follow a rapid cost reduction path over the coming years and decades. With the costs for fixed-bottom offshore wind expected to continue to decline, FLOW is not expected to become cheaper. The gap should narrow drastically this decade however, and FLOW should become cost-competitive in the 2030s as we start to deliver the scale needed to reach carbon neutrality by 2050.

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26 https://www.dnvgl.com/focus-areas/floating-offshore-wind/commercialize-floating-wind-report.html

27 https://www.crownestatescotland.com/maps-and-publications/download/219

28 https://www.scottishrenewables.com/assets/000/000/475/floating_wind_the_uk_industry_ambition_-_october_2019_original.pdf?1579693018

29 http://www.mria.ie/site/assets/files/1117/opflow_final_report.pdf

30 https://www.marei.ie/wp-content/uploads/2020/07/EirWind-Blueprint-July-2020.pdf

3.2 Potential costs of support

To give an indication of the potential future costs of support for initial Irish FLOW projects, we can again look to the OPFLOW report. This report models the cost of support, assuming a 15-year strike price, for the two hypothetical 300 MW floating wind farms discussed above off the south and west coasts.

To calculate support costs, ORE Catapult modelled four scenarios, ranging from a best case, where strike prices are low and power prices are high during the subsidy period, to a worst-case, where the opposite is assumed. Support costs in the best- and worst-case scenarios are shown in Table 1 below.

Table 1: Average Revenue Support Cost for selected OPFLOW FLOW Case study sites (Adopted from OPFLOW report)

	Best Case		Worst Case	
	Strike Price	**Support Costs**	**Strike Price**	**Support Costs**
Cork (South) Coast 300 MW Project	€80/MWh	€0.53/MWh	€85/MWh	€26.81/MWh
Clare (West) Coast 300 MW Project	€105/MWh	€24.57/MWh	€110/MWh	€51.81/MWh

In a worst-case scenario, the 300 MW Clare Coast project has a total revenue support cost of € 943 million but in a best case, this is circa € 450 million. The cost of supporting the 300 MW Cork Coast project ranges from close to subsidy-free if market prices are sufficiently high to approximately €550 million. For some context, Ireland's State Aid approval for RESS until 2025 is for an estimated budget of €7.2 to €12.5 billion[31].

These early support costs should be seen as an investment that will bring long-term benefits. FLOW will not be able to compete on costs with established technologies initially, but costs will continue to converge, with FLOW becoming cost competitive in the 2030s. However, initial costs need to be viewed in the context of them being a relatively small contribution to overall system costs that can be justified when longer term economic, social and system benefits are considered. As this report outlines, early FLOW projects will be crucial to developing the Irish supply chain and establishing a FLOW sector which will be ready to deliver at scale in the 2030s when FLOW is cost competitive. This will unlock the potential benefits discussed more in chapter 5.

3.3 Key drivers of cost reductions

The pace at which FLOW costs fall will depend mainly on the drivers discussed below:

- **Economies of Scale**: Projects to date have proven concepts and allowed industry and supply chains to better understand the requirements of FLOW. The 2020s will see commercial-scale wind farms become the norm[32], driving down costs. For example, Equinor is aiming for a 40 to 50 per cent reduction in costs per MW for their 88 MW Hywind Tampen project, to be operational next year, compared to the 30 MW Hywind Scotland[33], which was commissioned in 2017.

[31] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1370

[32] https://www.dnvgl.com/focus-areas/floating-offshore-wind/commercialize-floating-wind-report.html

[33] https://prod-drupal-files.storage.googleapis.com/documents/resource/public/FWJIP_Phase_2_Summary_Report_0.pdf

- **Global Deployment:** As discussed in section 2.3, FLOW installed capacity will increase rapidly this decade. This will put strong downward pressures on the global LCOE of FLOW, driving down supply chain costs and encouraging innovation. ORE Catapult estimates a global deployment of 6 GW will reduce FLOW costs in the UK to the same level as the forecast wholesale electricity price and overall offshore wind costs[34].
- **Learning and benefitting from other technologies:** FLOW can benefit from the establishment of the fixed-bottom sector. It will not have to deal with some of the same challenges, and costs can be expected to fall at an even more rapid pace than. For example, FLOW can use 60 – 70 per cent of the existing fixed bottom supply chain[35]. Significant synergies also exist between the oil and gas industry and FLOW.
- **Lower cost of capital:** Due to the confidence built up in the offshore wind sector over the last decade, it is now seen as a much more attractive investment than it once was, and projects should have access to a relatively low cost of capital, which is a key variable to the LCOE. FLOW projects will be able to capitalise on this relatively low cost of capital[36] compared to initial offshore projects.
- **Industrialisation:** The industrialisation of the FLOW supply chain as it develops will be key to driving down costs[37]. This has been seen with offshore wind to date. At present floaters are not industrialised meaning they take longer and are more expensive to produce. Modularisation and standardisation of the manufacturing process will decrease costs.
- **Policy Decisions:** Policy decisions taken in the coming months and years will also have a huge bearing on the costs of developing offshore wind in Ireland. For example, we have recently seen the UK introduce a bidding process using option fees to determine leasing awards for leasing round 4. The results turned out to be far higher than most had anticipated, reaching figures as high as £150,000 per MW per year. This option fee could add 23 – 49 per cent to the LCOE of round 4 projects[38]. Decisions taken here can similarly have a significant impact on the costs of projects here which must be considered.

These are just some of the drivers that should contribute to lower FLOW costs. It will be up to policy makers in Ireland, working with industry, to ensure cost reductions experienced worldwide can be capitalised on here.

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[34] https://www.crownestatescotland.com/maps-and-publications/download/219

[35] https://proceedings.windeurope.org/biplatform/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBaDhDIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--49280b2ed742c3cba9d178d3239bc4f6afdc7185/200922%20Ports%20a%20key%20enabler%20for%20the%20floating%20offshore%20wind%20sector%20FINAL.pdf

[36] https://ore.catapult.org.uk/wp-content/uploads/2021/01/FOW-Cost-Reduction-Pathways-to-Subsidy-Free-report-.pdf

[37] https://proceedings.windeurope.org/biplatform/rails/active_storage/blobs/eyJfcmFpbHMiOnsibWVzc2FnZSI6IkJBaHBBc29DIiwiZXhwIjpudWxsLCJwdXIiOiJibG9iX2lkIn19--b4abbfe7f34467d730433fe94e626d4688098333/ETIPWind-Flagship-Report-Fit-for-55.pdf

[38] https://ore.catapult.org.uk/blog/miriam-noonans-thoughts-seabed-leasing-4/

4 First-Mover Advantage is There for the Taking

Ireland has some of the best wind resources in the world (Figure 4.1Figure 4.1Figure). FLOW technology provides an excellent opportunity to exploit this resource to power ourselves and export to Europe. Becoming a player in the global supply chain for FLOW provides another enormous opportunity for Ireland, and first-mover advantage is there for the taking, given the relatively nascent state of the industry compared to fixed-bottom offshore wind.

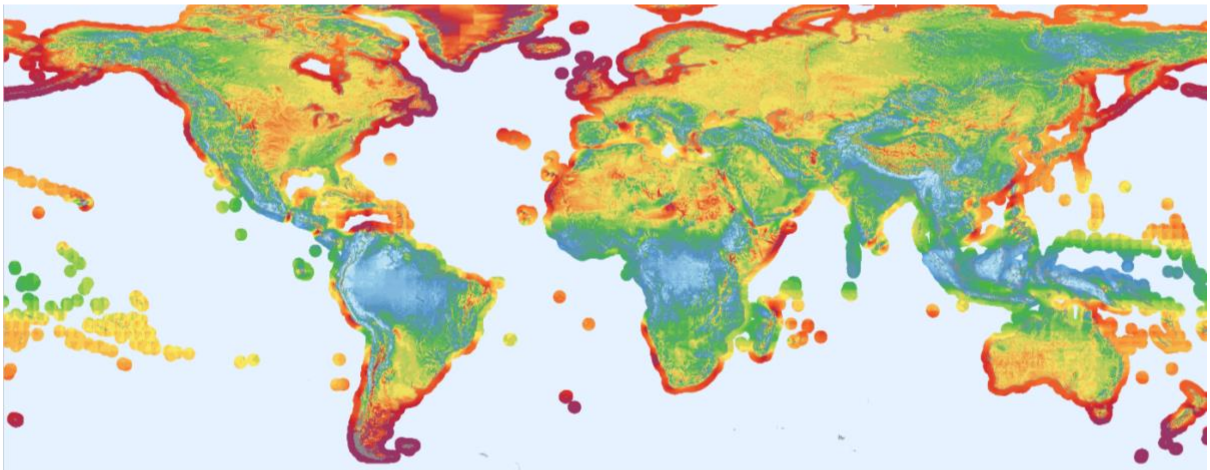

Figure 4.1: The Vortex Global wind speed map shows the excellent wind resources around the coast of Ireland, as among the best resources in the world.

As discussed in section 2.3, installed capacity for FLOW will increase significantly in the coming years and decades. At present, there is no established FLOW supply chain and there are no European or international hubs to service the future needs of the industry. While FLOW can use 60 – 70 per cent of the fixed-bottom offshore wind pipeline, it also has significant unique requirements, such as dynamic cabling, floating platforms and mooring lines. There are also very few ports that can accommodate the various requirements of the industry such as quayside area, wet storage, and draught. This represents an enormous opportunity for Ireland to become a part of the international supply chain for FLOW, which will have a big impact on the benefits that can be captured by Ireland.

4.1 Supply Chain Opportunity

There are four distinct supply chain opportunities presented by FLOW: Component manufacturing (turbines, towers, blades, foundations, cables etc.); assembly; staging; and O&M. Ireland has the potential to contribute to all of these, particularly assembly, staging and O&M. Ireland could also contribute to the manufacturing of floating foundations and smaller components if the right ambition is shown. A key recommendation from the Carbon Trust's Harnessing our Potential report[39] was to progress a development plan for the possible fabrication of FLOW substructures in Ireland, as well as to consider a strategic investment at one or multiple ports on the west coast. An industrial strategy aimed at realising Ireland's full offshore potential including delivering 30 GW of FLOW, with inputs from the IDA and Enterprise Ireland, is needed to facilitate a joined-up approach to unlocking commercial and manufacturing opportunities, including the 'marinisation' of the ICT sector, so that it can pivot to providing solutions for floating projects, in areas such as automation and controls.

[39] https://windenergyireland.com/images/files/final-harnessing-our-potential-report-may-2020.pdf

The pioneering Accelerating market uptake of Floating Wind Technology[40] (AFLOWT) project will facilitate the activation of the supply chain in Ireland, as well as opening up the Atlantic to a new era of offshore wind development.

We have already seen activity from Irish companies in the FLOW supply chain. For example, Dublin Offshore Consultants and Technology from Ideas (TFI) Marine were both recently awarded funding through the Carbon Trust's Floating Wind Joint Industry Project[41]. Dublin Offshore Consultants have developed a load reduction device that sits partway up the mooring line to minimise movement of the floating platform during wave events[42]. TFI Marine has developed a load monitoring system to identify stresses on mooring lines and times when maintenance is needed. They have also partnered with Principle Power to develop this ShallowFloat technology[43]. These examples show how Irish know-how can be harnessed to create value in the FLOW supply chain, with opportunities for enterprise development.

According to The Carbon Trust[44], Ireland is currently placed to capture only 22 per cent of the supply chain arising from fixed-bottom offshore. Ireland's supply chain could grow to capture 48 to 53 per cent of total project value for projects after 2030 with the required supply chain support such as investing in ports and creating offshore wind hubs around them.

For FLOW, The Carbon Trust estimates the potential for the Irish supply chain to grow to capture 39 to 43 per cent of this total project value. This would require significant investment in research and development of FLOW both in terms of costs reduction but also to connect the Irish grid to export markets.

Capitalising on this once-in-a-generation opportunity to establish ourselves as a part of the international supply chain for FLOW will mean we can capture much more of the investment in projects in Ireland, as well as those potentially contributing to projects throughout Europe. This would open up an enormous market.

While the supply chain opportunity afforded to us from offshore wind and FLOW is enormous, measures must be taken to make sure it is not missed.

- FLOW projects must be facilitated to commission this decade to begin to establish a strong FLOW supply chain here, build on the fixed-bottom supply chain in Ireland, and maximise local content for Irish projects;
- A strategic review of all port facilities with the capability to support FLOW should be undertaken and future Ports Policy should support investment by the State into this key infrastructure; and

[40] https://www.marei.ie/project/aflowt/

[41] https://www.carbontrust.com/news-and-events/news/eight-winners-of-scottish-government-funded-floating-wind-competition

[42] https://www.dublinoffshore.ie/2019/07/19/lorem-ipsum-dolor-sit-amet-3/

[43] https://www.principlepowerinc.com/en/news-press/press-archive/2020/10/01/principle-power-partners-with-an-innovative-irish-company-technology-from-ideas-tfi-to-develop-novel-mooring-solutions-for-transitional-waters

[44] https://windenergyireland.com/images/files/final-harnessing-our-potential-report-may-2020.pdf

- Ireland must address the skills shortage faced in trying to maximise local employment opportunities. There are many opportunities for Ireland to develop and implement strategies to address these shortages, as outlined by the Carbon Trust. The Government must coordinate the work of schools and universities, existing training bodies and skills development programmes, to identify the most cost-effective ways to eliminate the skills gap. Central to this must be the development of specialist marine apprenticeship schemes and working with academic institutions to develop a skills development plan for offshore wind.

4.2 Urgency is needed

While FLOW is ready to deliver, urgent action is needed to ensure that Ireland is not left behind as the industry takes off. FLOW is a global industry and if Ireland is not an attractive place to build projects, developers will look elsewhere in the short-to-medium term, and many of the potential benefits of FLOW may be lost to other jurisdictions.

The industry must be established to capitalise on global cost reductions, and the supply chain and supporting policies and infrastructure must be in place. To fully capture the benefits of FLOW, it is important that Ireland looks to become an early mover in the space and to build a strong indigenous industry. We have already seen the benefits that the early adoption of offshore wind has brought to countries like Denmark and the UK, which are now viewed as world leaders.

The time taken to put the frameworks in place to facilitate FLOW also needs to be considered. With Ireland currently working on the consenting, grid and route to market regimes for offshore wind, it has been seen that this is no easy task. Measures that can be taken to facilitate FLOW can be seen as no regret actions and should be carried out as soon as there is capacity to do so.

With interest in the sector growing worldwide, the window to becoming an early mover is closing quickly. Other countries are already taking positive steps to facilitate the development of FLOW and to position themselves to become leaders in the sector and part of the global supply chain. Two examples of countries which are accelerating the development of FLOW rapidly are France and the UK. A brief overview of these jurisdictions is given below.

4.2.1 France

France plans to commission four pilot FLOW projects of approximately 30 MW each in 2022/2023: EFGL; Provence Grand Large; EolMED; and Groix and Belle Ile. These projects will mark France's entry into FLOW.

France has also laid out ambitions plans for FLOW in its National Energy and Climate Plan[45], with three circa 250 MW tenders for FLOW planned in 2021-2022. The first, in the southern waters off Brittany, has recently been launched[46], while the other two in 2022 will be for sites in the Mediterranean. It is expected that this first auction will have a ceiling price of €120/MWh. For comparison, France's 2019 Dunkirk auction for a 600

[45] https://ec.europa.eu/energy/sites/default/files/documents/fr_final_necp_main_en.pdf
[46] https://renewablesnow.com/news/france-awaits-bids-in-270-mw-floating-wind-tender-739812/

MW fixed-bottom offshore wind farm set a ceiling price of €90/MWh[47]. This auction was won by a bid of €44/MWh, with grid costs to be covered by the TSO and the project to receive support for 20 years.

The French government also plans to award 1 GW of offshore wind capacity per year from 2024-2028, which could be fixed-bottom, FLOW, or a mix, depending on the relative competitiveness of the technologies and the convergence of target tariffs with the market price.

4.2.2 The UK

In 2020, the UK Government committed to a target of 1 GW of FLOW by 2030. To pave the way to reach this target, the Department of Business, Energy and Industrial Strategy (BEIS) announced a separate pot of funding for floating wind, wave and tidal energy projects for Allocation Round 4. This will be known as the innovative CfD mechanism and will be the first opportunity for FLOW to bid for contracts in a commercially competitive way. The Crown Estate also recently announced plans to design new leasing opportunities for early commercial scale projects of circa 300 MW in the Celtic Sea[48].

Scotland is currently considered to be a world leader in the deployment of FLOW, with the success of the Hywind Scotland project (which achieved a UK high average capacity factor of 57.1 per cent in the 12 months to March 2021[49]), and the soon to be completed Kincardine Phase 2 project. Together, these projects account for 80 MW.

The Scottish Government has great ambitions for FLOW due to the vast potential for deployment of such technologies in Scottish marine spaces. The 10 GW Scotwind Seabed Leasing round, which was due to close for applications in March 2021 before a recent delay was announced, will offer great potential for FLOW, with many of the 15 available sites located in waters deeper than 60 m.

The UK can be seen as a great example by setting an ambitious 2030 target for FLOW to kick-start the sector. Industry is also calling for this target to be increased to 2 GW, to accelerate cost-reductions[50].

France and the UK are just two markets that show great promise for FLOW, but there are many others. At the time of writing, Norway has also announced its support for FLOW, with at least three areas being opened for projects of up to 500 MW each at Utsira Nord. The Norwegian Government will support these initial FLOW projects through a system of grant supports. Other jurisdictions to look to include South Korea, Portugal, Japan and the USA. A summary of the status of these FLOW markets and the future FLOW pipeline can be found in the Carbon Trust's Floating Wind Joint Industry Project Report[51].

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[47] https://www.ceer.eu/documents/104400/-/-/f167090e-fb39-84b9-f370-047f5ee6e655

[48] https://www.thecrownestate.co.uk/en-gb/media-and-insights/news/the-crown-estate-to-create-new-floating-wind-leasing-opportunity-in-the-celtic-sea/

[49] https://renews.biz/67378/hywind-scotland-capacity-factor-hits-57/

[50] https://cdn.ymaws.com/www.renewableuk.com/resource/resmgr/ruk_raising_the_bar_0521_v3_.pdf

[51] https://www.carbontrust.com/resources/floating-wind-joint-industry-project-phase-2-summary-report

5 Economic Opportunity as well as Critical for Climate and the Environment

FLOW provides an unprecedented opportunity to simultaneously help Ireland's economy and environment. It can deliver clean, green, sustainable growth and development, whilst facilitating the energy transition. It can help to meet the needs of current and future generations with regards to civil society requirements for transformative initiatives that facilitate the delivery of the Sustainable Development Goals[52].

5.1 Investment and Local Content

As discussed in section 4, FLOW could attract tens of billions of euro in investment to Ireland. WindEurope estimates that every new offshore wind turbine installed generates €15 million in economic activity[53] and the Carbon Trust estimates that post 2030, delivering on a development potential of 24.1 GW would involve a total spend of €102 billion over the assumed 25-year lifetime of the capacity. There is great potential for the Irish supply chain to maximise the portion of this investment it can capture if supportive measures are put in place and Ireland can become an early adopter of the technology.

5.2 Port Development

Ports are a key enabler for FLOW[54] and port development could attract massive investment to Ireland. The importance of investment in port infrastructure to service the offshore wind industry in Ireland has been highlighted as a priority in WEI's Harnessing our Potential report[55]. Port infrastructure and services required by the offshore wind sector span a range of activities. These include:

- Large, strategic ports designated as manufacturing hubs (such as Green Port, Hull);
- Ports for pre-assembly and installation (Port of Esbjerg, Denmark); and
- Small ports and harbours for O&M (such as the Port of Wick, Scotland).

FLOW development requires ports with the right mix of water depths, quayside bearing capacity, landbanks, cranage, vessels, berthage, and transport links. Only a few European seaports are currently suitable for FLOW manufacturing, assembly and servicing. The logistics around the assembly and deployment of a large volume of components coming in by sea will require investment in port infrastructure on the south and west coasts.

Ireland already has multiple ports that have shown an interest in offshore wind, and FLOW. Redevelopment of these ports can transform coastal communities. Multiple ports will be needed in Ireland to service the requirements of the FLOW industry, whether they be for manufacturing, assembly and installation or maintenance. This has been seen in the UK and Europe. The UK recently announced £95 million Government investment for two new offshore wind ports to be constructed, creating 6,000 jobs[56].

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52 https://sdgs.un.org/goals

53 https://renewablesnow.com/news/europes-offshore-wind-sector-pours-eur-263bn-in-new-capacity-in-2020-730657/

54 https://windeurope.org/intelligence-platform/product/ports-a-key-enabler-for-the-floating-offshore-wind-sector/

55 https://windenergyireland.com/images/files/final-harnessing-our-potential-report-may-2020.pdf

56 https://www.gov.uk/government/news/second-wind-for-the-humber-teeside-and-uk-energy-industry

Recent announcements have earmarked Irish ports such as Rosslare[57], Shannon Foynes[58] (Figure 5.1) and the Port of Galway[59] (Figure 5.2) for offshore wind development. The Cork Harbour: Ready to Float by 2025[60] document outlines recent and future plans for investment in the supply chain in Cork Harbour, including the development of the former Cork Dockyard by Doyle Shipping Group as an assembly and installation hub (Figure 5.3). If a clear plan is put in place for the development of the FLOW industry in Ireland, continued announcements from Irish ports hoping to service the industry can be expected.

Figure 5.1: Shannon Foynes Port, which has announced ambitious plans to upgrade the port to service the FLOW industry.

Figure 5.2: Port of Galway, which has lodged plans to redevelop the port to increase capacity and potentially service offshore wind[61].

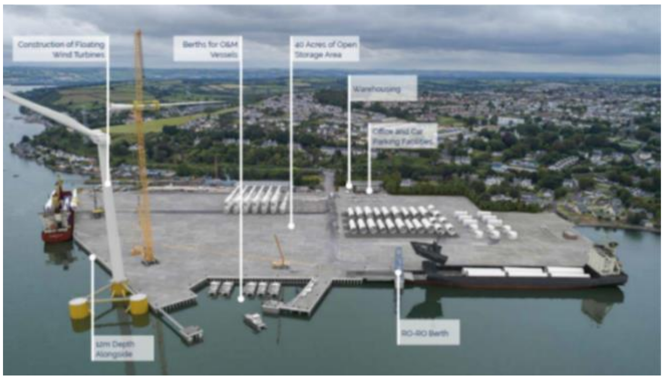

Figure 5.3: Doyle Shipping Group's vision for Cork Dockyard as a hub for assembly and deployment of offshore wind.

57 https://www.rosslareeuroport.ie/en-IE/news/rosslare-welcomes-offshore-wind-base
58 https://www.sfpc.ie/wp-content/uploads/2020/12/20163-R-001-Shannon-Estuary-Offshore-Wind-Rev2.pdf
59 https://bvgassociates.com/cases/the-floating-offshore-wind-opportunity-for-the-port-of-galway/
60 https://www.corkchamber.ie/wp-content/uploads/2021/02/Cork-Harbour-2025-Ready-to-Float-Offshore-Wind.pdf .
61 https://theportofgalway.ie/new-port-proposal/

5.3 Jobs and growth

FLOW provides a unique opportunity for local job creation.

Research by The Carbon Trust[62] indicated that developing just 3.5 GW of offshore wind by 2030 will create 675 permanent jobs over the lifetime of the projects, as well as 2,532 direct jobs during the development and construction and a further 1,312 jobs during decommissioning. The manufacturing of components for these projects will also create 16,000 employment opportunities which will be based internationally but for FLOW there may be an opportunity to capture some of these manufacturing jobs.

Eirwind[63] research indicates that in 2030, 6.5 – 7.3 GW of domestic offshore wind development would support between approximately 12,000 and 13,500 direct and indirect jobs in the domestic supply chain. To put these figures in context, the same report notes that the number of direct employees in sea fisheries, aquaculture and seafood processing in 2019 totalled 9,178. The potential for FLOW to create multiples of this 6.5 – 7.3 GW capacity shows the potential job creation that it can also bring.

5.4 Facilitating Regional Development

Ports and offshore wind projects can be a locus for regional development too. The port of Wick, Scotland, provides a great example of this. £20 million was invested in Wick to renovate two largely derelict port buildings for O&M facilities and to ready the port. The renovated port will serve as the O&M base for the Beatrice Offshore Windfarm, guaranteeing the Harbour Authority 25 years of rental and harbour fees, as well as supporting up to 90 full-time personnel, and more support staff.

As FLOW opens up new areas for the development of projects. It 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.[64]

5.5 Utilisation of renewable marine resources

Ireland's vast marine resources have been under-developed since the foundation of the State. The tide is turning with the opportunity opened by offshore wind and FLOW.

Ireland traditionally gets less than 2 per cent of its GDP from the marine economy. The Harnessing Our Ocean Wealth strategy[65] aimed to double this, however, progress has been slow. FLOW will help to meet and surpass this target, enhancing Ireland's status as a maritime nation.

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62 https://windenergyireland.com/images/files/final-harnessing-our-potential-report-may-2020.pdf

63 https://www.marei.ie/wp-content/uploads/2020/07/EirWind-Blueprint-July-2020.pdf

64 https://www.sfpc.ie/wp-content/uploads/2020/12/Shannon-Estuary-Offshore-Wind-GDG-November-2020.pdf

65 https://www.ouroceanwealth.ie/sites/default/files/sites/default/files/Harnessing%20Our%20Ocean%20Wealth%20Report.pdf

5.6 Co-existence with marine users

FLOW can impact on the triple bottom line of sustainability. In other words, as well as the economic benefits outlined above, FLOW will also provide benefits to society and environment. The societal benefits are linked to job creation and stemming the tide of coastal depopulation, as outlined previously. However, the development of FLOW should also achieve co-existence with fellow users of the sea though the support and promotion of scientific research, education and training. It is important to co-design projects using early engagement with key stakeholders including fishers and fishing communities. Government plans to facilitate a forum for engagement between the fishing and offshore wind sectors need to factor in the unique attributes of FLOW projects, to enhance understanding of how co-existence, where possible, can produce mutual benefits.

5.7 Conservation of the marine environment

Floating projects in deeper waters are characterised by ecosystems that differ from marine habitats closer to shore. An opportunity exists to explore the potential for floating wind farms to become *de facto* Marine Protected Areas (MPAs), and/or to explore the development of biodiversity hotspots through the deployment of artificial structures that can act as reef systems to enhance fisheries productivity. Science Foundation Ireland has a role to play in supporting research through MaREI to enhance understanding of such opportunities.

6 Size and Potential Policies for the Four Main Routes to Market

The EU has made firm commitments to transition to a zero-carbon economy by 2050. The demand for renewable electricity to achieve these enormous cuts in carbon emissions in only a few decades will be multiples of what it is today. Due to the scale of renewable electricity required, FLOW will be a vital technology to ensure we can deliver on our future low carbon targets. In this section we quantify the scale of the electricity that will be required to demonstrate the critical role of FLOW, which leads to two critical conclusions:

1. **The PfG target of 30 GW is a very realistic target in the context of what will be required in the future, both domestically and at EU level.** Ireland alone will require circa 27 GW of wind energy by 2050, and Europe could need more than 1000 GW. How well we position ourselves to contribute to this European demand will be key to maximising FLOW potential.

2. **The 'route to market' for FLOW will occur across a wider geographical and energy system context compared to other forms of wind energy in Ireland**. FLOW will depend on a pan-European Supergrid and electrofuels for energy-dense applications as routes to market. This will create new opportunities for policy to support the growth of wind energy in Ireland.

The basis for these conclusions is the scale of demand in a zero-carbon energy system across four potential routes to market for FLOW: Ireland's future electricity demand; Ireland's future electrofuel demand; Europe's future electricity demand; and Europe's future electrofuel demand.

As outlined above, an important new route to market for FLOW and renewables will be green hydrogen and other electrofuels such as ammonia or methanol. These will be needed to decarbonise sectors where direct electrification is not feasible, such as aviation and shipping, and enable net-zero emissions energy systems. A useful ranking of the sectors that are expected to provide future demand for green hydrogen can be seen in Figure 6.1, but the exact role electrofuels will play in the future energy system is still to be determined.

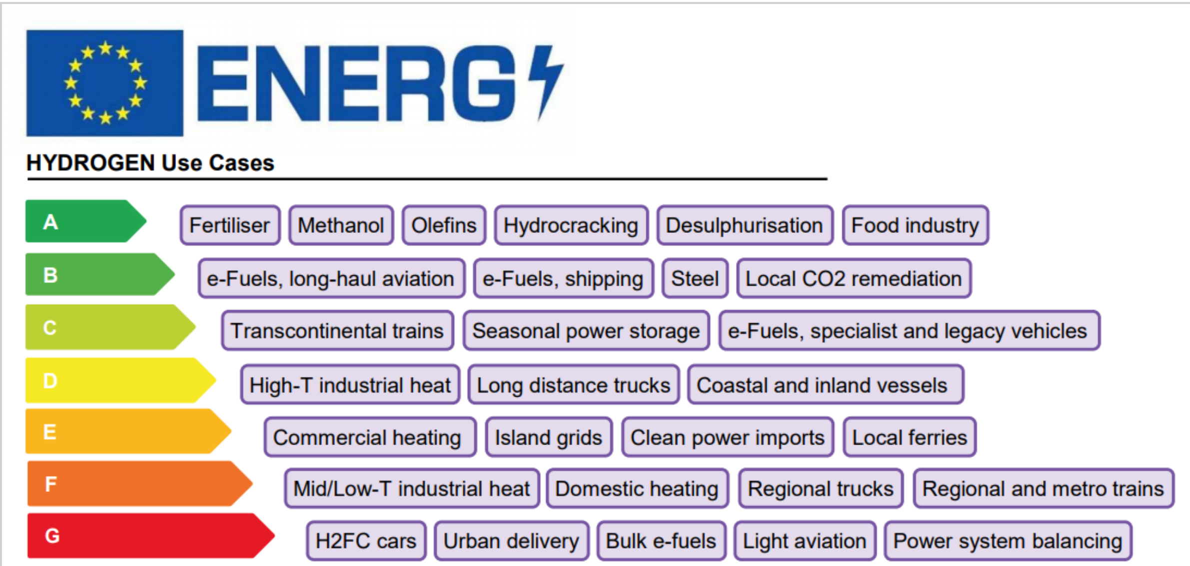

Figure 6.1: Hydrogen demand side merit order by sector (Michael Liebreich/Liebreich Associates, Concept Adrian Hiel/Energy Cities)[66]

[66] https://twitter.com/MLiebreich/status/1391439223727824896

It is important to distinguish between the different types of hydrogen, typically referred to as grey, blue or green. The first two use fossil fuels to produce hydrogen which emits CO_2, with the advantage of blue over grey being the CO_2 emitted is captured and stored. Green hydrogen, however, uses renewable electricity sources to produce hydrogen from water via electrolysis. This ensures the whole process, from production to use, is emissions free. More information on Hydrogen and electrofuels can be found in the references below[67,68,69].

Offshore wind, and FLOW will be key to the production of green hydrogen in the future, with the EU's Hydrogen Strategy targeting the production of up to 10 million tonnes by 2030 (330 TWh).[70] Similarly, green hydrogen can provide an innovative route to market for FLOW.

A summary of projected future electricity demand for Ireland and Europe is presented in Table *2*, which indicates that Ireland will need ~27 GW of wind energy by 2050 and Europe will need ~1,000 GW. The assumptions behind each of these are elaborated upon later in this section and in the Appendix, but importantly the scale of wind energy required calculated here is similar to those reported by others:

- The Zero by 50 Report[71] by MaREI in UCC calculated that Ireland would need 21 GW of wind energy for its domestic needs by 2050 and up to 8.5 GW to provide electrofuels for shipping and aviation;
- The European Commission expects the demand for wind energy to be up to 1,200 GW by 2050[72] and has set an offshore wind target of 300 GW[73]. Ambition to 2030 will also increase as the EU translates its *Fit for 55* energy and climate package into clear actions;
- EirWind predicted up to 24.9 GW in Ireland[74];
- An analysis by Siemens Gamesa forecast the need for wind energy to be 1,000-4,000 GW[75]; and
- The peer-reviewed 'Smart Energy Europe' study forecasted 3,700 GW of wind power would be needed for Europe to become 100% renewable[76].

Based on these future demands, the 30 GW target in Ireland's PfG will only reflect 3% of the ~1,000 GW of wind capacity required across Europe in the coming decades. Considering Ireland's huge wind resource compared to other EU countries, 30 GW is unlikely to be a sufficient contribution to the wider EU transition to

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67 http://dconnolly.net/wp-content/uploads/2014/05/GreenPlanIreland-Connolly.pdf
68 https://ramboll.com/partner-for-change/power-to-x
69 https://www.energyplan.eu/smartenergyeurope/
70 10 million tonnes equates to 330 TWh assuming 33 kWh per ton of hydrogen.
71 https://www.marei.ie/wp-content/uploads/2021/03/Our-Climate-Neutral-Future-Zero-by-50-Skillnet-Report-March-2021-Final-2.pdf
72 https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf
73 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0741&from=EN
74 https://www.marei.ie/wp-content/uploads/2020/07/EirWind-Blueprint-July-2020.pdf
75 https://www.siemensgamesa.com/en-int/newsroom/2021/01/210113-siemens-gamesa-press-release-siemens-energy-agreement-green-hydrogen
76 https://www.sciencedirect.com/science/article/abs/pii/S1364032116002331

a low-carbon economy by 2050. This was also the conclusion of a Wind Europe's analysis which suggested the Atlantic and Irish sea areas will need to supply 85 GW to Europe by 2050.[77]

Table 2: Estimated demand for renewable electricity and renewable fuel in Ireland and Europe in 2050.

Estimated Demand in a low carbon 2050 energy system	Electrofuel Demand (TWh)	Electricity Demand (TWh)	Wind Energy Required (% of total demand)	Wind Energy Required (TWh)	Wind Energy Required (GW)^	Total Wind Energy Required (GW)
Ireland's Electricity	-	52	90%[+]	47	12	27
Ireland's Electrofuels[#]	39	66*	90%[+]	59	15	
EU's Electricity	-	5350	50%[=]	2675	680	1000
EU's Electrofuels[#]	1525[∞]	2540*	50%[=]	1270	320	

[+]UCC 0by50 study concluded that wind energy can provide >90% in a zero-carbon energy system due to the flexibility created by upgrading the electricity grid, increasing interconnection and electrifying other sectors.

[#]Includes the fuel required for aviation, shipping, high-temperature industry heat demands (i.e. >200°C), decarbonised gas for power plants, heavy duty transport and heat for buildings which are uneconomical to upgrade for heat pumps. All of these applications will be very challenging to electrify directly as they require fuels with high energy densities.

*Assuming an average power-to-fuel conversion efficiency of 60%.

[=]A 50% wind share is relatively conservative. For example, Smart Energy Europe had a wind share >80% when assessing how the EU could become 100% renewable: https://www.sciencedirect.com/science/article/abs/pii/S1364032116002331

[∞]It is assumed here that electrofuels only supply 50% of the demand for energy dense fuels in Europe with the other 50% coming from biofuels. Biofuels are very unlikely to supply all of these demands to the limited resource available so electrofuels will be a critical solution in these sectors.

^An average capacity factor of 45% was used to reflect a blend across onshore, fixed-bottom offshore and FLOW.

These new routes to market for Ireland's wind energy open up new challenges and opportunities. These are briefly presented in the sections below, with further details contained in the Appendix. Further research is needed on the policies that can unlock FLOW's potential across each of these areas.

6.1 Ireland's direct electricity demand expected to be 52 TWh

MaREI's Zero by 50 study[78] projects an almost doubling in domestic demand from 27 TWh in 2018 to 52 TWh in 2050 (excluding electricity for electrofuels for power plants). This growth will mainly be driven by industrial productivity, development of new data centres and the electrification of heat and transport, most notably significant uptake in electric vehicles and domestic heat pumps.

Using the assumptions expanded on in the Appendix i.e that wind energy will provide over 90% of the electricity required in a zero-carbon energy system, we have calculated in Table *2* that **~12 GW of wind energy will be required by 2050 for Ireland's domestic electricity demand alone**. For context, there is currently ~4.3 GW of wind capacity installed today so wind energy will need to almost triple for our own domestic requirements alone in the coming three decades. Given demands for space on land and constraints on suitable sites for more fixed-bottom wind, FLOW will play a critical role in delivering this wind energy for Ireland by 2050.

[77] https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Our-Energy-Our-Future.pdf

[78] https://www.marei.ie/wp-content/uploads/2021/03/Our-Climate-Neutral-Future-Zero-by-50-Skillnet-Report-March-2021-Final-2.pdf

It is anticipated regular RESS auctions and to a lesser extent CPPAs will facilitate a route to market for developers to deliver the 12 GW of wind energy required for Ireland's domestic electricity needs. If the Irish electricity market is redesigned appropriately, for example by moving to a market based on zero-marginal cost power, then market forces could drive investment rather than support schemes. However, considering the time required for such changes, RESS is going to be the key driver of delivering FLOW for Ireland's domestic electricity demands in the coming decade.

6.2 Ireland's electrofuel demand expected to be 39 TWh and require 66 TWh of electricity

Using 2050 electrofuel demands outlined in the Appendix means Ireland's demand for electrofuels in 2050 will be 39 TWh. It should be noted that this figure could be viewed as conservative as 2019 levels of demand for aviation and shipping are used. UCC analysis underlying these figures also assumed Ireland consumes its entire sustainable bioenergy resource, including its sustainable import share from Europe. If this level of sustainable bioenergy cannot be obtained, then electrofuel demand will likely increase.

The **resulting electricity demand required to supply these electrofuels is 66 TWh, which assuming a 90% wind share and 45% capacity factor, means that 15 GW of wind energy will be needed to supply this** as presented earlier in Table *2*.

Due to the international nature of aviation and shipping, the route to market for these is likely to be heavily reliant on EU policy as well as Irish policy, but there are measures Ireland could take at a domestic level. For example, Ireland could implement a Public Service Obligation (PSO) levy on airline tickets, similar to the PSO currently applying to the bills of electricity consumers, with the funds gathered to fund the production of electrofuels for aviation in Ireland. Similarly, a PSO levy could be placed on all ships that dock in Irish ports to fund electrofuels for the maritime sector.

For high-temperature heating for industry (>200^{O}C), electrofuels could be added as an eligible solution under the Support Scheme for Renewable Heat (SSRH), while for power plants in the electricity sector, a technology specific pot could be created in RESS for power plants which use electrofuels. Also, the Biofuel Obligation Scheme could be broadened into a '**Clean Fuel Obligation Scheme**, which could encourage the update of electrofuels in heavy-duty transport. There are many other policy levels in heat and transport which could accommodate electrofuels, so this is an area which warrants a specific focus in future research.

One way to progress these ideas is to create '**national route to market strategy for electrofuels**' with a focus on green hydrogen production, targeted policy action and R&D. Strategic planning for production facilities is needed if Ireland is serious about building the requisite supply and demand for this new industry with massive potential. Macroeconomic scenarios need to be developed to outline the role of green hydrogen relative to electricity for achieving domestic targets and gearing up for the export opportunity. We have already seen exciting announcements from industry such as EI-H2's plans to set up the county's first green hydrogen plant in 2023[79] or the ESB and dCarbonX's partnership on green hydrogen storage development[80]. Policy making

[79] https://www.siliconrepublic.com/innovation/green-hydrogen-facility-cork

[80] https://esb.ie/tns/press-centre/2021/2021/05/26/esb-and-dcarbonx-to-partner-on-green-hydrogen-storage-development

must keep pace with these announcements. This will require Government intervention across multiple departments, and a strategy, which should consider:

- A 100 MW pilot hydrogen facility, linked to FLOW, to demonstrate how green hydrogen can be produced and used in Ireland; and
- Scaling-up of green hydrogen production to facilitate a cost-effective route to market for FLOW and to support innovations in heat and transport fuel.

6.3 Europe's electricity demand expected to be >5,000 TWh

The PfG highlights the Government's intention to make Ireland a major contributor to a pan-European renewable energy system. The total demand for electricity in Europe using the assumptions outlined in the Appendix would be **5,350 TWh** of electricity. As outlined in Table 2, **if wind energy supplied half of Europe's electricity needs in 2050, then Europe would need approximately 680 GW of wind energy to meet this demand alone**. This is an enormous opportunity for Ireland to export its vast wind resource directly to the rest of Europe via interconnectors or a Supergrid , as demand for clean electricity in continental European Member States will likely exceed what it can deliver via their own resources.

Ireland has significant potential to contribute to EU Climate targets, mainly through FLOW deployment which will be a key driver for facilitating electricity exports. Ireland has access to a greater offshore wind resource than it will ever need domestically and therefore the export of electricity to other European countries with high electricity demand will be a key route to market for Irish electricity out to 2050 and beyond.

A strong pan European transmission system alongside a re-designed European electricity market will be key to opening up and maximising the routes to market for Ireland's wind energy as an export. The amount of electricity Ireland is looking to export will depend upon the right interconnection infrastructure being planned and delivered on time alongside of hybrid connection methodologies. To achieve Ireland's target of 70 per cent renewable electricity by 2030, all-island interconnection will need to increase from almost 1,000 MW today to at least 2,200 MW in 2030. WindEurope estimates that for 2030 Europe needs an additional 85 GW of interconnection on top of today's 50 GW[81].

A pan-European **Supergrid** will be required beyond this to ensure we can deliver upon the 30 GW ambition, inclusive of new hybrid connections using innovative new technologies such as super conductivity. FLOW projects could even be directly connected from Irish waters into neighbouring countries to help decarbonise their energy systems, either by using a proportion of their renewable electricity auctions for Irish wind farms in line with Article 5 of the Renewable Energy Directive on the opening of support schemes to cross-border participation, or by creating new policy levers, such as pan-EU support schemes.

The **new market design** should further encourage cross-border trading, including the commercial provision of ancillary services from renewables as a fundamental feature, and increased transparency and appropriate safeguards on curtailment practices. It should also be supported by a stable regulatory framework that will secure the price of electricity years in advance, benefitting society and security of supply by allowing the free

[81] https://windeurope.org/intelligence-platform/product/getting-fit-for-55-and-set-for-2050/

flow of electricity between member states. Additionally, an effective carbon price is a crucial element to an efficient EU-wide market based on renewable electricity, and the EU's July 2021 *Fit for 55* package presents an important opportunity to increase ambition in the Emissions Trading System (EU-ETS), the Union's flagship cap-and-trade mechanism. One example of a policy which would send a strong signal for all sectors would be the introduction of an EU-wide carbon floor price, similar to what is already in place in the UK.

Ireland could also capitalise on **EU funding** to support its offshore wind sector. The European Commission estimates that the investment needs for a large-scale deployment of offshore renewable energy technologies by 2050 will be circa €800 billion, around two thirds of which is for associated grid infrastructure and a third for offshore generation[82]. While it expects the bulk of the investment to come from private investment (also potentially fostered by the EU's sustainable finance taxonomy), EU public funding will be made available for some projects. This will mainly come through the InvestEU programme, among others, and "Green Deal" programmes from the EU's COVID-19 recovery fund. It is key for Ireland to take advantage of this opportunity to ensure we are world leaders in grid delivery and interconnection to facilitate the deployment of FLOW.

6.4 Europe's electrofuel demand to be >1,500 TWh and require >2,500 TWh of electricity

Following the same principles as outlined for Ireland earlier, and using the assumptions outlined in the Appendix it is assumed here that the demand for electrofuel in Europe in 2050 would **equate to a wind energy capacity of 320 GW**. This creates a huge opportunity for Ireland to produce clean electrofuels at scale which can be exported to Europe. For example, Agora Energiewende predicts that Germany will have a total Hydrogen demand in 2050 of around 270 TWh, but that 68 per cent of the demand will need to be met by imports[83]. It doesn't only open new markets for wind energy but also new opportunities for policy to support the development of wind energy by incentivising the use of electrofuels in other sectors rather than supporting electricity generated by wind energy directly.

The EU will have a major role to play in creating new routes to market for FLOW in parts of the energy sector which span multiple countries, particularly in hard-to-electrify sectors, such as international aviation, international shipping and for large energy consumers who participate in the EU-ETS.

Right now there are enormous indirect subsidies provided to international aviation and shipping fuel by excluding these sectors from the taxes which other parts of the transport sector pay, particularly road transport for cars, trucks and busses. The lack of taxation on international aviation and shipping mean that these sectors only pay ~€12/GJ and ~€8/GJ for their fuel, while road transport pays ~€25/GJ for trucks and ~€40/GJ for cars. These low fuel costs for aviation and shipping make it challenging to provide zero-carbon alternatives, but if these sectors were subject to the same taxation as road transport, then some electrofuels would become economically viable immediately: for example, ammonia for shipping could be produced at €20-25/GJ today for shipping, the same price as trucks pay for fuel, but it is not economically viable in the shipping sector as the lack of taxation means the fuel price for ships is only €8/GJ. **EU policy should aim to equalise the cost of aviation and shipping fuel with road transport.**

[82] https://ec.europa.eu/energy/sites/ener/files/offshore_renewable_energy_strategy.pdf

[83] https://static.agora-energiewende.de/fileadmin/Projekte/2020/2020_10_KNDE/A-EW_193_KNDE_Executive-Summary_EN_WEB_V111.pdf

The European Commission is currently revising the Energy Taxation Directive to end these tax emptions, and outlined in its 2020 Communication: 'Sustainable and Smart Mobility Strategy – putting European transport on track for the future' that " *As part of the ongoing impact assessment, it is looking closely at current tax exemptions, including for aviation and maritime fuels, and will make proposal on how best to close any loopholes in 2021*".[84] Ireland should support this initiative as ending these subsidies will help stimulate the electrofuel sector and thus the wind energy sector.

To stimulate electrofuels for power plants and large energy users in industry, the EU could consider a carbon floor price in the ETS system, with a projected forecast out to 2050 of what this minimum price will be, ideally increasing each year. This was mentioned earlier in section 6.2, as individual Member States can do this on their own also if they wish.

A higher Linear Reduction Factor, which defines the pace at which the number of emissions allowances is reduced, would also help to align the EU-ETS with the EU's climate ambitions.

In the European Commission's 2020 proposal for a **revision of the TEN-E Regulatio**n[85], Ireland has been included in the Hydrogen Interconnections in Western Europe ('HI West') Priority Corridor for Hydrogen and Electrolysers. There is a significant opportunity for Ireland to contribute to wider EU demand for green hydrogen through scaling up the deployment of electrolysers, developing a hydrogen manufacturing and export economy and contributing to the interconnection of hydrogen within the region.

Similar to the proposal covered in section 6.2, the *Fit for 55* package, and specifically the upcoming Revision of the Renewable Energy Directive (REDII) presents an important opportunity to increase the ambition level for Renewables in transport by **increasing the blending obligation on fuel suppliers** and ensuring that electrofuels are given the needed incentives, alongside electrification, to contribute meaningfully to the decarbonisation of the EU transport fleet.

The EirWind Blueprint[86] recommends that a 100 MW pilot hydrogen facility, linked to FLOW, be developed to demonstrate how green hydrogen can be produced and used in Ireland. There will be numerous **EU funding** opportunities for electrolysers and two example programmes of interest include:

- H2020 Green Deal call on Electrolysers. This was a call to demonstrate electrolyser technology. Up to €30 million per grant available, with further details available here.
- The ETS Innovation Fund. A new instrument to help innovative technologies break the market and scale up. There will be annual calls. The next one opens in September 2021. There is no fixed limit to the grant. 60 per cent of the relevant cost of innovation can be covered, and some OPEX too.

Key stakeholders are now financing green hydrogen projects in various locations across Europe with its identification as a key technology within the green recovery. Again, the policy proposals here should be view as suggestions and exploring these in more detail will be a key area of further research going forward.

84 EUR-Lex - 52020DC0789 - EN - EUR-Lex (europa.eu)
85 EUR-Lex - 52020PC0824 - EN - EUR-Lex (europa.eu)
86 https://www.marei.ie/wp-content/uploads/2020/07/EirWind-Blueprint-July-2020.pdf

6.5 Wind Energy in Ireland and Europe forecasted to be 27 GW and 1,000 GW respectively

Taking the demand for domestic electricity and electrofuels together, it is estimated here that **Ireland will need 27 GW of capacity for our domestic needs alone**.

For Europe, the analysis indicates that >5,000 TWh of 'direct electricity' and >2,500 TWh of electricity for electrofuels will be required by 2050. Assuming wind energy can provide 50% of this electricity, **then this analysis indicates that Europe will need ~1,000 GW of wind energy by 2050**.

As explained earlier, these figures are in line with other reports, but at this point the exact figure is not critical. **Instead, the critical thing is the scale of the opportunity – Europe will very likely exceed 1,000 GW of wind energy by 2050 if a zero-carbon energy system is to be achieved and this creates a huge opportunity for Ireland**.

The PfG target to export 30 GW of wind energy is only 3 per cent of the future potential market in Europe. In this context, 30 GW should be viewed as an absolute minimum for Ireland to achieve as the true potential is much greater and could create a whole new economic pillar for Ireland. For example, the Offshore Wind Energy Council and ORE Catapult[87] in the UK indicated that green hydrogen could be worth as much as £320 billion to the UK and support up to 120,000 jobs by 2050. The UK plan aims to integrate 75 GW of offshore wind into the energy system as green hydrogen making the case for a national hydrogen network there and building on the significant offshore wind capacity and level of innovation that has built up.

Ireland has a much larger wind resource than it needs domestically, something most other EU countries are not fortunate to have. BVG Associates estimates Ireland has the second largest gross offshore wind resource potential in Europe[88], but it is nowhere near the top for electricity consumption[89]. Therefore, **not only does Ireland have the opportunity to export its clean electricity – it must do so if the EU is to deliver on its ambitions of becoming the world's first climate-neutral continent by 2050.**

[87] https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2020/09/07105124/Solving-the-Integration-Challenge-ORE-Catapult.pdf

[88] https://9tj4025ol53byww26jdkao0x-wpengine.netdna-ssl.com/wp-content/uploads/Offshore-wind-in-the-North-Seas-from-ambition-to-delivery-report.pdf

[89] https://ec.europa.eu/eurostat/databrowser/view/nrg_cb_e/default/map?lang=en

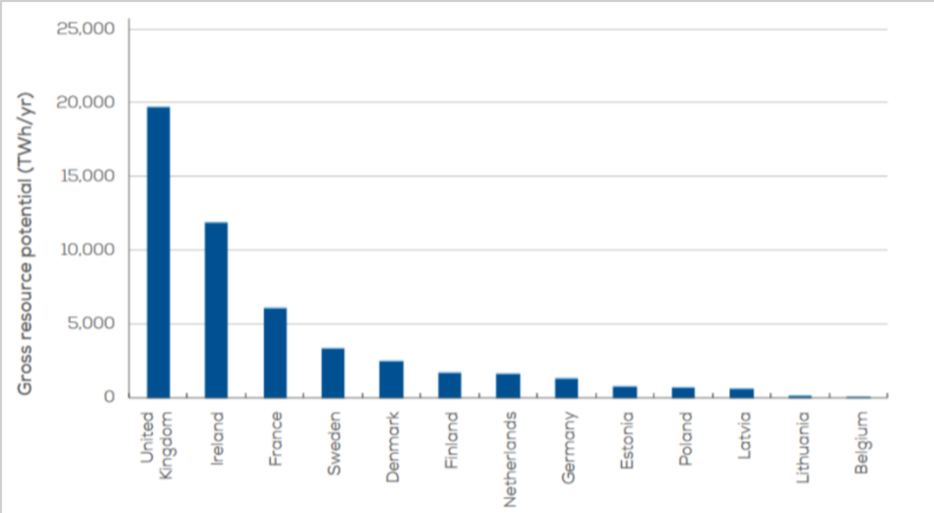

Figure 6.2: Gross resource potential in 2030 by country[90]

In closing, the two critical conclusions from this section are:

1. The PfG target of 30 GW is a very realistic target in the context of what will be required in the future, both domestically and at EU level. Ireland alone will require circa 27 GW of wind energy by 2050, and Europe could need more than 1000 GW. If Ireland is to significantly contribute to a European net-zero energy system, much more than this 30 GW will be required.

2. The 'route to market' for FLOW will occur across a wider geographical and energy system context than other forms of wind energy in Ireland. FLOW will depend on a pan-European Supergrid and electrofuels for energy-dense applications as routes to market. This will create new opportunities for policy to support the growth of wind energy in Ireland so more research is required to identify what these exact policies should be.

90 https://9tj4025ol53byww26jdkao0x-wpengine.netdna-ssl.com/wp-content/uploads/Offshore-wind-in-the-North-Seas-from-ambition-to-delivery-report.pdf

7 Conclusions and Recommendations

FLOW provides an opportunity for Ireland to achieve energy security, to play its part in the energy transition in Europe, and to develop an entirely new industrial sector for the Irish economy, with a focus on the south and west coasts. It is an extraordinary and unique opportunity for a small island nation.

FLOW is no longer an emerging technology. It is not something for the future, it is a choice available to us today. Many of the actions needed now to facilitate FLOW apply to offshore wind in general. These are outlined in WEI's Building Offshore Wind report[91] and include the enactment of the Maritime Area Planning Bill and the requisite provisions for Marine Area Consenting, and grid development.

The principal recommendation for FLOW is for policymakers to pave the way for FLOW projects to energise for 2030. This will place Ireland in the best position to unlock the unique benefits of FLOW in terms of the scale of the opportunity outlined in this report and become part of a global energy revolution.

Recommendations specific to the routes to market defined in this report are outlined below.

Ireland's Electricity Demand will grow to over 50 TWh and require ~12 GW of wind energy

- There are a number of Irish FLOW projects on track to deliver and contribute to the 5 GW target for 2030. To enable this, provisions must be made by Government to facilitate the development and grid connection processes and a route to market in RESS auctions. WEI recommends a specific 'floating wind pot' in 2025 to ensure these commercial scale projects can progress. A roadmap for future RESS auctions also needs to be defined to start preparing for regular auctions post 2025.
- The pending Maritime Area Planning Bill should empower the Minister for Environment, Climate and Communications to grant Maritime Area Consents to Phase Two projects, once they have been identified and designated, and to grant survey licences for beyond the 12 nautical mile limit. Delays to the establishment of the Maritime Area Regulatory Authority (MARA) must not delay projects.
- South and west coast grid connection capacity needs to be enabled for FLOW projects as part of the 2030 capacity building process. Steps must also be taken in the next couple of years to plan for the development of grid infrastructure to optimise the transmission of electricity generated from larger scale FLOW projects to meet domestic needs.
- A strategic review of all port facilities with the capability to support FLOW should be carried out by the Department of Transport and relevant agencies to establish how future port policy can provide support and investment by the State into this key infrastructure.

[91] https://windenergyireland.com/images/files/20201203-final-iwea-building-offshore-wind-report.pdf

- An industrial strategy supporting the delivery of Ireland's 5 GW and 30 GW offshore targets set out in the PfG should be enabled by the Department of Enterprise Trade and Employment together with the development agencies.

Ireland's electrofuel Demand will require ~66 TWh of electricity and ~15 GW of wind energy

- A national route to market strategy including a focus on green hydrogen production with targeted policy action, R&D and strategic planning for production facilities is needed if Ireland wishes to build the requisite supply and demand for this new industry. Macroeconomic scenarios need to be developed to outline the role of green hydrogen relative to electricity for achieving domestic targets and gearing up for export opportunity. Government intervention is required across multiple departments to make this a reality. Such a strategy should consider:
    - Supports for pilot hydrogen facilities, to demonstrate how green hydrogen can be produced and used in Ireland, and ultimately linked to FLOW.
    - Scaling-up of green hydrogen production to facilitate a cost-effective route to market for FLOW and to support innovations in heat and transport fuel.
    - Broadening the Biofuel Obligation Scheme into a 'Clean Fuel Obligation Scheme.

European Electricity Demand is forecast to grow to > 5,000 TWh and require 680 GW of wind energy

- The current rate of build of the transmission system is too slow EU targets, and will need to be improved. The grid will also need to be adapted so the vast offshore wind resources in the Atlantic Ocean and the Northern Seas can be fully exploited. Increased interconnection will be needed to ensure the electricity generated in these areas with a lower cost of production can be sent to high demand areas with limited access to affordable renewable electricity.
- It is recommended that the Irish Government (DECC) pushes for an integrated renewable electricity market at a European level to facilitate our FLOW ambitions. Additionally, further interconnector infrastructure should be planned and designed around realistic export figures and efficient flows of power. Cost reduction drivers for FLOW should be facilitated by the Irish Government (DECC) to ensure Ireland becomes a net exporter of power.
- Ireland could also capitalise on EU funding to support its offshore wind sector. It is essential that this work commences now and grid infrastructure in Ireland's marine area is included as part of this investment.

European demand for electrofuels will require > 2,500 TWh of electricity and over 300 GW of wind energy

- Aviation and shipping fuel costs should be brought in line with other parts of the transport sector .
- In the European Commission's 2020 proposal for a **revision of the TEN-E Regulatio**n[92], Ireland has been included in the Hydrogen Interconnections in Western Europe ('HI West') Priority Corridor for Hydrogen and Electrolysers. There is a significant opportunity for Ireland to contribute to wider EU demand for green hydrogen through scaling up the deployment of electrolysers, developing a hydrogen manufacturing and export economy and contributing to the interconnection of hydrogen within the region.
- Broadening the Biofuel Obligation Scheme into a 'Clean Fuel' Obligation Scheme so electrofuels are also included.

[92] EUR-Lex - 52020PC0824 - EN - EUR-Lex (europa.eu)

8 Appendix – Calculation of expected demand for each route to market

8.1 Ireland’s direct electricity demand expected to be 52 TWh

EirGrid has projected significant growth in domestic demand for electricity here of up to 47% over the next 10 years.[93] Beyond this, the MaREI’s Zero by 50 study, which outlined what a zero-carbon energy system could look like in Ireland by 2050, projected an almost doubling in domestic demand from 27 TWh in 2018 to 52 TWh in 2050 (excluding electricity for electrofuels for power plants). This growth will mainly be driven by industrial productivity, development of new data centres and the electrification of heat and transport, most notably significant uptake in EVs and domestic heat pumps.

The same study found that wind energy can provide over 90% of the electricity required in this zero-carbon energy system given strong investment in our electricity grid, additional interconnection, and increased flexibility on the demand side some of which is created particularly to the electrification of heat and transport.

Using this 52 TWh demand as proxy for Ireland’s domestic needs in 2050 and assuming that wind energy will provide 90% of electricity demand, we have calculated in Table *2* that ~12 GW of wind energy will be required by 2050 for Ireland’s domestic electricity demand alone.

8.2 Ireland’s electrofuel demand expected to be 39 TWh and require 66 TWh of electricity

The following areas typically require energy-dense fuel and therefore are likely to require electrofuel of some nature in a zero-carbon energy system (Demand figures taken from Zero by 50):

1. MaREI’s 0by50 study forecasted a domestic electrofuel demand (assumed to be hydrogen) across power plants, industry, buildings and transport of almost **24 TWh in 2050**.
2. Aviation: **today’s (2019) fuel demand is 12 TWh** with a forecasted demand of **18 TWh in 2050**.
3. Shipping: **today’s (2019) fuel demand is almost 3 TWh** with a similar demand forecasted in 2050.

To ensure the forecasted demands here are relatively conservative for electrofuels, the 2020 levels of demand are used here for international aviation and shipping fuel, which are 12 TWh and 3 TWh respectively. Combining these above demands means the total demand for electrofuels will be 39 TWh.

Assuming an average power-to-fuel conversion efficiency of 60%. The **resulting electricity demand required to supply these electrofuels is 66 TWh, which assuming a 90% wind share and 45% capacity factor, means that 15 GW of wind energy will be needed to supply this** as presented earlier in Table *2*. This forecasted demand for electrofuels is likely to be conservative. The demands for shipping and aviation are based on 2020 figures and the UCC analysis found that Ireland consumed its entire sustainable bioenergy resource, both domestically and its sustainable import share from Europe, to decarbonises its domestic carbon footprint. If this level of sustainable bioenergy cannot be obtained then more electrofuel will likely be required.

[93] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-All-Island-Generation-Capacity-Statement-2019-2028.pdf

8.3 Europe's electricity demand expected to be >5,000 TWh

Europe has already declared its ambition to move to a zero-carbon energy system by 2050[94] and to do so, it will need to undergo a rapid increase in the electrification of heat and transport. The following metrics from the 2020 EU Energy Balance provide a benchmark for the scale of 'direct electricity' demand that is likely in a zero-carbon energy system from Europe:[95]

- 2020 EU Electricity Demand of **3,350 TWh**
- 2020 EU Oil Demand for Private Cars of 2,200 TWh
  - If converted to electric cars they would need **~780 TWh** of electricity, assuming a typical efficiency of 30% for internal combustion engines compared to 85% for electric cars.
- 2020 EU Heat Demand in Buildings ~3,000 TWh
  - If converted to heat pumps they would need **~1,000 TWh** of electricity, assuming a typical Coefficient of Performance (COP) of 3.[96]
- 2020 EU Heat Demand in Industry for Heat <200^{O}C is ~660 TWh[97]
  - If converted to heat pumps this would require **~220 TWh** of electricity, assuming a typical COP of 3, which is conservative as some of this industrial demand will need direct electric heating which is more likely to have an efficiency of 1 rather than a COP of 3.

The total demand for electricity in Europe using the above as indicators would be **5,350 TWh** of electricity. As outlined in Table 2, **if wind energy supplied half of Europe's electricity needs in 2050, then Europe would need approximately 680 GW of wind energy to meet this demand alone**. This is an enormous opportunity for Ireland to directly export its vast wind resource directly to Europe via interconnectors or a Supergrid, as Europe's demand for clean electricity will likely exceed what it can deliver via its own resource.

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[94] https://ec.europa.eu/clima/policies/strategies/2050_en#:~:text=The%20EU%20aims%20to%20be,action%20under%20the%20Paris%20Agreement.

[95] https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

[96] It may be too expensive to retrofit some buildings with a heat pump, and where this occurs in urban areas there may be an opportunity to use electrofuels (i.e. power to methane).

[97] https://heatroadmap.eu/heating-and-cooling-energy-demand-profiles/

8.4 Europe’s electrofuel demand expected to be >1,500 TWh and require >2,500 TWh of electricity

Offshore wind and FLOW in particular will be key to the production of green hydrogen in the future, with the EU’s Hydrogen Strategy targeting the production of up to 10 million tonnes by 2030 (330 TWh).[98] Similarly, green hydrogen can provide an innovative route to market for FLOW.

Following the same principles as outlined for Ireland earlier, it is assumed here that electrofuels will be required in sectors which need high-density fuel such as aviation, shipping and high-temperature applications in industry (i.e. >200^{O}C). Again, the following demands from the 2020 EU Energy Balance are used here to build a proxy for the level of electrofuels that will potentially be required in Europe in 2050[99]:

- EU 2020 Aviation Fuel Demand: 700 TWh
- EU 2020 Shipping Fuel Demand: 600 TWh
- Head Demand in Industry for Applications >200^{O}C: 850 TWh
- Power plants in the electricity sector: quantifying this would require a full energy system analysis for a zero-carbon energy system in 2050, so it is not considered here.
- EU 2020 Heavy-duty transport such as trucks and busses: 950 TWh
- Heat demand for buildings which cannot be electrified: quantifying this would require a detailed understanding of the building stock, particularly the building fabric and what proportion are located in urban settings where gas grids are used for domestic heating, so this is not considered here.

Even without including all of the sectors above, the total demand for energy dense fuel in Europe is ~3,050 TWh. Using a conservative assumption that only 50 per cent of these demands will need to be met by electrofuels in 2050, with the other 50% coming from alternatives such as biofuels[100,101], the demand for electrofuel in Europe in 2050 is likely to be at least ~1,525 TWh, as presented in Table 2. Assuming a typical power-to-fuel efficiency of 60% for electrofuels, this means the corresponding demand for electricity to produce this electrofuel demand would be ~2,540 TWh. Again, taking a very conservative approach and assuming that wind energy would be 50% of the electricity mix an EU zero-carbon energy system by 2050, then **the wind energy required to supply its share of electricity for electrofuels would be ~1,270 TWh which equates to a capacity of 320 GW**.

[98] 10 million tonnes equates to 330 TWh assuming 33 kWh per ton of hydrogen.

[99] https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf

[100] Smart Energy includes a review of the EU’s bioenergy resource which demonstrates how this is likely to be a limited resource in a future low-carbon energy system. The results from the analysis outline how wind energy could reach over 80% of electricity supply in a 100% renewable energy scenario for Europe: https://www.sciencedirect.com/science/article/abs/pii/S1364032116002331

[101] EU Commission have estimate the bioenergy resource available for various scenarios to 2050 in Figure 84 of this report: https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf