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Economic and employment impacts of offshore wind for Ireland: a value chain analysis

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Economic and employment impacts of offshore wind for Ireland: a value chain analysis

The imminent development of a number of offshore wind farms in the Republic of Ireland presents a sizable opportunity to stimulate the Irish economy through the growth of an indigenous and globally competitive offshore wind supply chain. The government of Ireland has committed to meet 70% of its electricity needs from renewable sources by 2030 and to achieve net zero carbon emissions by 2050. Separately, Ireland's integrated marine plan, Harnessing Our Ocean Wealth, sets a target to double the value of Ireland's ocean economy by 2030. The deployment of significant offshore wind capacity will be an essential element to meeting these targets. Given the scale of development required to fulfill these objectives, there is the potential to make a significant contribution to the Irish economy through the development of an indigenous and globally competitive offshore wind supply chain. This study uses a value chain analysis to evaluate the economic and employment potential of the offshore wind sector for Ireland. The analysis is based on the expenditure on products and services required to develop an offshore wind farm, the planned capacity of projects in the pipeline, and the ability of Irish companies to supply the sector. Results suggest that by 2030, 2.5-4.5GW of domestic offshore wind development could create between 11,424 and 20,563 supply chain jobs and generate between €763m and €1.4bn in gross value added. ThisIt is the first study to estimate domestic GVA potential for the sector.

Keywords: offshore wind; Ireland; economic impact; employment impact; ocean energy

Introduction

The government of Ireland has committed to meet 70% of its electricity needs from renewable sources by 2030 and to achieve net zero carbon emissions by 2050 (Government of Ireland 2019a). Separately, Ireland's integrated marine plan, Harnessing Our Ocean Wealth, sets a target to double the value of Ireland's ocean economy by 2030 (Inter-Departmental Marine Coordination Group 2012). The deployment of significant offshore wind capacity will be an essential element to meeting these targets. Given the scale of development required to fulfil these objectives, there is the potential to make a significant contribution to the Irish economy through the development of an indigenous and globally competitive offshore wind supply chain. This paper seeks to explore the magnitude of this contribution in terms of employment and gross value added (GVA). This information can help to justify policies or action plans that will support future development of the sector and will allow policymakers to compare the economic impacts of such development with other options.

Ireland has some of the best offshore wind energy resources in Europe. Satellite derived estimates of wind power density show that the majority of Ireland's offshore wind produces over 400 W m^{-2} annually at a height of 10m, placing it within wind power class seven, the highest class of resource potential on the NREL scale for energy potential (Remmers et al. 2019; Elliott et al. 1987). Most of the coastal areas fall in the sixth power class, producing 300-400 W m^{-2} annually (Remmers et al. 2019). While it has been shown that, at the global level, satellite derived estimates of wind resources in near shore areas do not always agree with observational data (C. W. Zheng et al. 2016), in situ measurements in Irish waters showed very good agreement with the satellite data (Remmers et al. 2019). Ireland's wind energy resource also ranks highly on other wind energy classification scales. For example, taking into consideration environmental risk factors and cost factors in addition to wind power, Ireland's offshore wind resource potential as defined by Zheng et al. (2018) remains among the best in Europe.

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Under the EUs climate and energy framework, Ireland must source at least 32% of all its energy needs from renewable sources by 2030 (European Commission 2014). The Irish government has also separately committed, in its Climate Action Plan (CAP), to meet 70% of its electricity needs from renewable sources by 2030 and to achieve net zero carbon emissions by 2050 (Government of Ireland 2019a). Offshore wind will play a significant role in helping Ireland to achieve these targets.

In terms of harnessing the resource, tThere has been limited progress since the deployment of Ireland's first (and only) offshore wind farm at Arklow Bank in 2004. However, , but the government has recently given clear signals of support for future development . For example, in 2014 the publication of the Offshore Renewable Energy Development Plan (OREDP) provided an overarching framework for the development of Ireland's offshore wind and energy resources and indicated a potential 4.5GW offshore wind is achievable by 2030 (DCENR 2014; Government of Ireland 2019b; DCCAE 2020), and t. On the back of that, the 2019 CAP Annex of Actions set out an explicit plan to connect at least 3.5GW of offshore wind to the grid by 2030 (Government of Ireland 2019b). The scale of development required to achieve this has the potential to make a significant contribution to the Irish economy through the development of an indigenous offshore wind supply chain.

Progress in developing Ireland's offshore wind resource has been slow to date. This is due to issues around consenting, route-to-market, and grid connections. Despite this, there is currently over 12.3GW of offshore wind in the development pipeline , with 1.62GW consented and 2.33GW currently in the planning system (Leahy et al. 2020). The majority of these developments are in the Irish Sea. Several floating wind developments are also in the pipeline, although they are in the very early planning (site investigation) stages. Figure 1 contains a map of planned developments.

[Figure 1 here]

Previous research on the employment and GVA impacts of offshore wind development for Ireland is limited. Tsakiridis et al. (2019) estimated that Ireland's offshore renewable energy sector as a whole directly supported only 461 FTEs in 2018.

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EurObserv'ER (2019) reported that the onshore and offshore wind sectors together supported 4,800 direct and indirect jobs in Ireland in 2018. It is not clear how many of these jobs can be attributed to the offshore wind sector alone. Looking forward, SEAI (2011) predicted that offshore wind would support over 15,000 direct jobs in installation and O&M by 2040. Other studies of future employment potential related to offshore wind for Ireland (e.g. Pöyry 2014; Siemens 2014; IMDO 2019) group the sector with other related sectors, such as wave energy and onshore wind energy, and model different types of employment over different time periods or different geographical areas under different scenarios. No previous studies have estimated the potential GVA impact of offshore wind development for Ireland, although Pöyry (2014) estimated that the wind sector as a whole for the single electricity market (SEM), which includes Northern Ireland, would be worth between €650 million and €5.02 billion in GVA between 2021-2030. This is the first study to estimate the direct and indirect GVA and employment impacts of the offshore wind sector for the Republic of Ireland. Several floating wind developments are also in the pipeline, although they are in the very early planning (site investigation) stages. Commercial developments are not likely to come on stream until at least 2026. Given the early stage of the technology globally, there is an opportunity for Ireland to place itself in a strategic position to capitalise on the growth of the floating wind market.

There are, at present, limited capabilities within the Irish supply chain for offshore wind due to the lack of a domestic market to date. A recent assessment estimates that current technical Irish supply chain capability stands at 22% across the lifetime of an offshore wind farm project, although the percentage is likely to be lower when market conditions are taken into account (Leahy et al. 2020). For comparison, in the UK, which has emerged as a global leader in offshore wind energy, data from

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projects currently under construction indicate around 50% UK content (Leahy et al. 2020).

The majority of existing Irish capabilities (c.16%) come from vessel provision, vessel services, and associated equipment supply during the operations and maintenance (O&M) stage. More limited opportunities (c. 5%) exist around construction activities. It is estimated that Irish content could increase to 30-35% by 2025 and 48-53% (39-43% for floating wind) up to 2030 and beyond. This could be achieved with sufficient policy support, such as the establishment of offshore wind enterprise zones at ports (Leahy et al. 2020).

Given the massive scale of offshore wind developments, even a small proportion of the value of these projects captured by the domestic supply chain can have a significant economic impact in terms of job creation and value to local communities. In addition, as the domestic market matures, it is expected that Irish companies will gain experience and become competitive in the global market, unlocking a growing export market. This paper explores the scale of this opportunity in terms of job creation and gross value added (GVA).

Approach

There are various methods available for assessing job creation and GVA impacts of renewable energy developments. This paper uses a value chain analysis as it is considered most appropriate for the emerging Irish offshore wind energy sector. Other approaches include employment ratios, input-output (IO) modelling and other complex economic models, such as computable general equilibrium (CGE) models.

Employment ratios (or employment factors) can be used as a first-order estimate of job creation potential. They represent employment generated (in person-years or full-time equivalents) per unit of installed capacity (Jenniches 2018). Using known employment factors, for example from existing developments, employment impact for a similar proposed development can be estimated by multiplying the planned investment or capacity by the employment ratio for the existing development.

The advantage of this approach is that it is relatively simple. The only required inputs are the planned investment or capacity and a known employment ratio. The drawback of this approach, though, is that there can be large differences between ratios, even for the same technologies (Jenniches 2018; Dalton and Lewis 2011). Ratios valid in one geographical area may not necessarily be the same for another, especially in different economies.

In a review of reported ratios of jobs/MW for offshore wind studies across Europe, Dalton and Lewis (2011) found that values can range from 3.9 to 47 jobs/MW. Such variations may arise due to the data used, the modelling method, the size of an economy, technological maturity, technology type, or the types of jobs included (direct, indirect and/or induced).

A more widely employed approach to economic impact assessments is input-output (IO) modelling (for example, Noori, Kucukvar, and Tatari 2015; Faturay et al. 2020; Mukhopadhyay, Chen, and Thomassin 2017; Varela-Vázquez and del Carmen Sánchez-Carreira 2017). Based on the work of Leontief, IO analysis uses tables of use and supply, known as input-output tables, to model the flow of goods and services between the industries of a national economy. In Ireland (and elsewhere), IO tables are only available at high sectoral aggregation level and are not available at sub-national level. Sectoral data are also only available based on traditional official classifications and so may not be appropriate for newly emerging technologies and sectors. For example, construction of an offshore substation for an offshore wind development could be categorised as ‘construction’ in the Irish supply and use tables, so any multipliers used in an IO analysis would include all activities in the construction industry. This is not entirely appropriate, as the construction of an offshore substation is a highly specialised activity that will likely impact the supply chain in different ways than more traditional construction activities. This lack of sectoral specificity can result in over- or under-estimation of economic impacts. For example, Roberts and Westbrook (2017) compared employment impacts calculated for wind turbine tower production in the UK using the IO model versus a value chain approach. They showed how the IO model overestimated employment impacts because the particular type of steel used in turbine manufacture is not produced in the UK. The multipliers in the UK supply and use tables are based on the premise that the UK produces much of the steel it uses domestically. Since the steel for the turbines cannot be produced in the UK, the IO model overestimated the impact.

IO table sectors may be disaggregated, where data are available, and some studies such as Lehr *et al.* (2015) have taken this approach, but this requires extensive data gathering where official statistics are unavailable. In Ireland there is an added issue that, because of its size, concerns have arisen about the confidentiality of businesses that may dominate particular sectors, so some sectoral classifications may be unavailable (MacFeely, Moloney, and Kenneally 2011: 70; de Bruin and Yakut 2019: 8). Complex economic models, such as CGEs, can also be employed to model potential economic impacts, but these are often proprietary and computationally complex (de Bruin and Yakut, 2019). CGE models are more data intensive than other approaches and are hampered, similarly to IO approaches, by a lack of sectoral and/or regional disaggregation (Eiser and Roberts 2002; Wittwer and Horridge 2010).

An alternative approach that is perhaps most suited to the nascent Irish offshore wind energy sector is value (or supply) chain analysis. This is a cost-based method for assessing the economic impact of a project (or projects) over a given period (Breitschopf, Nathani, and Resch 2011). It is based on five key elements:

(1) expenditure on all products and services related to a development,

(1) the value breakdown, or the percentage of expenditure on labour, materials, and profits,

(2)(1) the occupational breakdown of the labour expenditure for each element of the project(s),

(3)(1) the cost of labour for each of the occupations, and

(4)(1) the proportion of equipment, components and services supplied by domestic firms (local content).

The supply chain approach has been employed in the UK to model the monetary value and labour content associated with the renewable energy supply chain (DTI 2004) and in the US to model job creation in offshore wind (BVG 2019a). Roberts and Westbrook (2017) argue that this method is best suited to the offshore wind sector because it can take into account the unique and specific requirements associated with the offshore wind supply chain. These requirements may be overlooked when using conventional economic analyses, such as IO models, because they rely on data derived from established industrial sectors.

For this study, a value chain model for the offshore wind sector was developed for Ireland. The model was used to evaluate the economic and employment potential associated with future developments. It was based on the best available information about development costs, wages, and Irish supply chain capabilities. Modelled outputs are sensitive to changing market conditions, which is an important constraint given the dynamic nature of the global offshore wind energy market.

Materials and Methods

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The Irish value chain model developed for this study is based on the breakdown of expenditure into seven sub elements of offshore wind development:

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- Project development and management
- Turbine supply
- Balance of plant supply
- Installation and commissioning
- Wind farm operation
- Turbine maintenance and service
- Foundation and substation maintenance and service

An Excel model was built to calculate annual direct and indirect GVA and employment potential for each sub element for fixed-bottom and floating wind projects, based on specified levels of annual installed offshore wind capacity and the degree of local content. Here, direct impacts refer to those generated by the owners of the wind farm asset and their primary contractors. Indirect impacts are those generated by suppliers and sub suppliers to the owners or their primary contractors. Induced impacts, from personal expenditure of the labour force, have not been considered in this study, although these can be calculated using an induced multiplier (Roberts and Westbrook 2017).

The total expenditure on each sub element of offshore wind development is estimated over the entire period for which associated activities take place. We assume a 5-year period of planning and development. Turbine and balance of plant supply takes place in year 3 of the planning and development period and installation and commissioning takes place in years 4 and 5. Wind farm operation and turbine, foundation and substation maintenance and service take place over a 25-year period. The overall lifetime of the modelled activities for projects installed in any given year is therefore 30 years (5 years of planning and development, including turbine and BOP supply, followed by 25 years of operations and maintenance).

Typical costs for a 1GW project of 100 10MW turbines were provided by BVG (2019b). These are converted to euros and adjusted based on the modelled annual installed capacity. Annual costs are then adjusted to reflect the competing effects of discounting and learning (the reduction in costs due to a combination of economies of scale and learning-by-doing). The default values are a 4% discounting rate and a 2% learning rate, which can be adjusted if necessary. The proportion of annual expenditure on labour is calculated using the value breakdown (the breakdown of expenditure on labour, materials and profits) estimated by DTI (2004) for renewable energy projects. Annual profits are also estimated using this breakdown. The annual GVA impact is taken as the sum of annual expenditure on labour and annual profits (after Roberts and Westbrook 2017).

Only a proportion of the expenditure on supply chain requirements will be sourced domestically. This proportion represents the local content. As the Irish offshore wind sector develops, the proportion of local content is expected to increase. Existing and future Irish capabilities in the offshore wind supply chain have been assessed by Leahy et al. (2020) from consultations with government and industry stakeholders. They scored Irish companies' technical abilities to supply products and services to the offshore wind sector at the time of the research, in the near-term (by 2025) and in the long-term (by 2030) for fixed and floating projects.

Irish supply chain capabilities are categorised as low, medium, or high for each project sub-element. The total GVA content calculated by the model per annum per sub element is broken down according to the potential (low, medium, or high) that products and services for each project sub element can be provided by Irish companies. It should be noted that local content figures represent the technical capabilities of the Irish supply chain, and do not take into account market competition.

Employment is modelled using the estimated annual expenditure on labour, calculated from the total expenditure and value breakdown per sub element. There are different occupational requirements associated with each sub element of offshore wind development. Occupational breakdowns in the offshore wind sector have been estimated, for example, by BVG (2019a). For each occupation in that report, the total annual cost for one full-time equivalent (FTE) to an employer was estimated. This information was obtained from research by PayScale (2019) and the Central Statistics Office (CSO) (2018). The model then calculates the wage per occupation in a given year, taking into account annual increases in wages, with 3% set as the default. The total number of FTEs per annum per occupation is calculated by dividing the total annual expenditure on labour per occupation by the total annual cost to the employer per occupation, as per equation 1.

$$FTE_a = \frac{L_a}{Y_a + W_a} \qquad (1)$$

Where:

FTE_a = Annual FTE employment

L_a = Annual labour expenditure (€)

Y_a = Average annual wage (€)

W_a = Non-wage average annual cost of employment (includes statutory employers' social insurance, other social costs, benefits in kind, etc.) (€)

The total number of FTEs per annum per sub element is broken down according to the potential (low, medium, or high) for jobs to be created in Ireland by Irish companies, based on the assessment by Leahy et al. (2020).

The modelled outputs are summed into annual GVA and FTE figures, divided into high, medium, or low potential to be supplied domestically, from onshore and offshore projects.

Scenarios for Ireland

Using the model described above, tTwo scenarios were modelled for Ireland, based on installed capacity. The low scenario assumes Ireland's installed offshore wind capacity will reach 2.5GW by 2030 (e.g. after Eirgrid 2019) and the high scenario assumes it will reach 4.5GW by 2030 (e.g. after DCENR 2014). For both scenarios, operations commence in 2024 and the annual installed capacity remains constant until 2040. This is shown in Figure 2. It is assumed that 25% of the annual installed capacity from 2026 onward is from commercial floating projects (e.g. after EU NWE 2019; Eirgrid 2019).

[Figure 2 here]

Table 1 shows the proportion of potential domestic supply for each category of likelihood (high, medium, or low) that supply could be domestically sourced. The proportions are provided in Leahy et al. (2020). They were calculated by dividing the total cost to deliver each project requirement into the proportion of that cost associated with high, medium and/or low capabilities to supply associated products or services.

[Table 1 here]

For example, operations and maintenance costs account for approximately 35% of a project's total lifetime cost. Of this 35%, 46% of the expenditure is spent on vessels and equipment, 43% is spent on monitoring, inspection and maintenance, and 11% is spent on port services. According to Leahy et al. (2020), Ireland currently has strong capabilities in relation to the supply of vessels and equipment, and medium potential to supply services related to monitoring, inspection and maintenance and port services. As such, it is assumed that there is presently a high likelihood that Irish companies can supply 46% of the O&M requirements and a medium likelihood that they can supply the remaining 54%.

Where domestic capabilities are categorised as 'low', it is virtually certain that the corresponding proportion of associated requirements will not be supplied domestically. For example, Ireland currently has limited to no capabilities in relation to turbine and balance of plant supply. As a result, there is a low to medium likelihood that much of the turbine and balance of plant requirements will be sourced domestically for early projects. Domestic capacity in these areas is expected to increase as the supply chain develops, although it will likely remain limited for turbine supply due to the barriers to this market (Leahy et al. 2020).

Where capabilities are categorised as 'high', the proportion of domestic share represents the maximum potential that could be achieved based on current capabilities and future supply chain development. The local content proportions represent technical capabilities and do not take into account market competition.

Results

Figure 3 shows the modelled potential domestic GVA impact under the (a) low and (b) high scenarios. In the near term (pre-2030), there is a high potential that domestically supplied products and services could ~~result in~~generate a domestic GVA impact of between €763m (low scenario) and €1.4bn (high scenario) by 2029, with a mean annual domestic GVA impact of between €76m and €137m. This equates to c. 27% of the total GVA impact for activities carried out in the period 2020-2029. It is contingent on domestic capacity building in the areas of project management and development and operations and maintenance. There is a medium potential for Ireland to ~~secure~~ generate an additional 46% of the total GVA impact, provided domestic companies can supply some products and services related to turbine supply, balance of plant supply, and installation and commissioning. ~~but i~~It is not likely that Irish-based businesses will ~~supply~~ generate the remaining 27%.

[Figure 3 here]

In the longer-term (2030-2035), as capacity builds in operations and maintenance and the provision of products and services for the floating wind market, there is a high potential that ~~domestically supplied products and services~~Irish companies could ~~result in~~generate a domestic GVA impact of between €2.6bn (low scenario) and €4.8bn (high scenario), with a mean annual domestic GVA impact of between €440m and €793m. This equates to c. 66% of the GVA impact for activities carried out in the period 2030-2035. There is a medium potential for Irish-based businesses to ~~supply~~

generate an additional 24% of the total GVA impact, provided domestic companies can provide additional products and services in the areas of turbine supply, balance of plant supply, and operations and maintenance of floating wind farms. but IIt is not likely that they Irish companies will supply generate the remainderremaining 10%.

The increase in domestic GVA impact over time results from an increase in the number of operational projects coming on stream and an increase in the capacity of Irish companies to supply the domestic market with required products and services (as outlined in table 1). Given Irish businesses' strong capabilities in O&M, which accounts for a large share of a project's lifetime cost, there is a high likelihood that Ireland can benefit greatly economically from domestic offshore wind development. This is contingent on installed capacity reaching current targets, continuing to increase beyond 2030, and Irish companiescompanies' ability to secure a significant share of the domestic market.

Figure 4 shows potential domestic employment impact under the (a) low and (b) high scenarios. In the near term (pre-2030), there is a high potential that offshore wind development could create between 11,424 (low scenario) and 20,563 (high scenario) FTEs by 2029, supporting an average of 1,142 to 2,056 FTEs per annum. This equates to c. 33% of the total employment impact for activities carried out in the period 2020-2029. There is a medium potential for Ireland to secure an additional 46% of the total employment impact, but it is not likely that Ireland will secure the remaining 21%.

[Figure 4 here]

In the long term (2030-2035), there is a high potential that offshore wind development could create between 34,952 (low scenario) and 62,914 (high scenario) FTEs, supporting an average of 5,825 to 10,486 FTEs per annum. This equates to c.

76% of the total employment impact for activities carried out in the period 2020-2029. There is a medium potential for Ireland to secure an additional 16% of the total employment impact, but it is not likely that Ireland will secure the remaining 8%.

Overall, the greatest proportion of GVA likely to be generated and jobs likely to be created by domestic companies is in operations and maintenance. These jobs are mostly permanent and often sourced locally, whereas long-term employment in activities related to CAPEX depend on the growth of the domestic market or demand from the export market.

Discussion

Irelands marine renewable energy sector accounted for 1.4% of Ireland's ocean economy in 2018 (Tsakiridis et al. 2019). Direct and indirect GVA for the sector amounted to c. €57m, and the sector directly employed 467 FTEs. Compare this to the largest contributor to Ireland's ocean economy, the shipping and maritime transport sector, which generated c. €1.7bn in direct and indirect GVA and directly employed 5,055.

If the scenarios modelled in this study were to be realised and current trends for other ocean economy sectors were to remain constant, direct and indirect GVA from offshore wind development could exceed that of the marine advanced technology products and services sector, the marine manufacturing, construction and engineering sector, the sea fisheries sector and marine retail services sector by 2030. This would contribute significantly to Ireland's Harnessing Our Ocean Wealth target of doubling the value of Ireland's ocean economy by 2030 (Inter-Departmental Marine Coordination Group 2012).

The modelled results suggest that the return on initial investment for offshore wind development in Ireland would be positive. Leahy et al. (2020) estimated that an initial total investment of €8.6 billion would be required to deliver the 3.5GW of offshore wind energy required under the Climate Action Plan. In return for this investment, the offshore wind industry could support c. 10,000 direct and indirect jobs per annum by 2035 and generate €4.8bn in GVA, according to our model, provided 3.5GW is installed by 2030. If a quarter of the initial investment requirement came from public support, the return for this investment would represent €2 of GVA for each €1 invested, although the return on investment is likely to be higher if induced impacts are considered.

Given this enormous potential, it is important to consider the reliability of the estimates of economic impact generated by the model presented in this study. The modelled outputs are broadly in line with those referenced in the existing literature. The UK Office of National Statistics estimated that in 2017, at which time there was a cumulative installed capacity of 6,988 MW in the UK, there were 13,500 directly or indirectly employed in the UK offshore wind sector (Office of National Statistics 2019; UK Government 2020). This equates to an employment ratio of 1.93 jobs/MW. Our model results in employment ratios in 2030 of 1.81 jobs/MW (low scenario) and 1.85 jobs/MW (high scenario). Although small, differences in the ratios may be due to methodological differences and differences in the UK and Irish economies.

-It is difficult to compare our findings to other Irish studies due to differences in methodology, modelled timeframes, types of employment, and geographical extent. Nonetheless, assuming an installed capacity of 4.5GW by 2030, SEAI (2011) predicted installation and O&M would support c. 4,000 direct jobs in 2030. Our model, under the 4.5GW scenario, shows installation and O&M would support 6,843 direct + indirect jobs in 2030. We have included employment in supply chain activities, which may explain why our employment figures are higher than that of SEAI (2011). IMDO (2019) assumed the installed capacity of offshore wind farms would reach between 1GW and 5GW by 2030. The outputs of their model suggest that this would create 8,700 person years of direct employment between 2020-2030 for the 1GW scenario and 39,800 person years of direct employment from 2020-2030 for the 5GW scenario. Running our model using the same installed capacity scenarios, we obtain results of 6,418 person years of direct and indirect employment for the 1GW scenario and 32,088 person years of direct and indirect employment for the 5GW scenario. The higher numbers in their model reflect the fact that it covers employment in offshore wind on the island as a whole (including Northern Ireland). The port of Belfast already has a greater capacity to serve the sector than ports in the Republic of Ireland. As a result, some proportion of the total employment impacts presented by IMDO (2019) would come from outside the geographical scope of this research. Based on international data from IRENA, With regard to employment, our modelled figures are in line with estimates of Irish workforce requirements presented by Leahy et al. (2020). Based on international data from IRENA, they estimated that a workforce comprised of 210,380068 FTEs would be required to deliver 3.5GW of offshore wind by 2030 for Ireland. This includes jobs created in planning and development, manufacturing, transport and logistics, installation and connection, and operations and maintenance. Compare this with our model, which estimates a requirement of 22,462 FTEs to deliver 3.5GW of offshore wind. Leahy et al.'s estimates are based on workforce requirements for a typical offshore wind farm and the share of domestically supplied content from their assessment of Irish supply chain capabilitiesDifferences between our results and those of Leahy et al. (2020), while small, are likely due to methodological differences, such as the use of estimated wage data, which was not a feature of Leahy et al.'s work. Our model differs in that it takes wage data, discounting, and technological learning into account.

It is not possible to directly compare modelled outputs with those reported in these studies, though, because they are based on different ranges of assumptions and use different methods, models, and timeframes to estimate impacts.

There are also differences in how activities associated with offshore wind development are categorised, the types of employment considered (direct, indirect or induced; permanent or temporary), the types of developments considered (onshore and/or offshore; fixed or floating), and the Irish content share. Since this is the first study to estimate the potential domestic GVA impact of offshore wind development for Ireland, there are no Irish benchmarks from which to compare figures. However, some inferences can be drawn from the UK experience.

Our model suggests that the GVA impact for Ireland could grow from c. €261m per GW in 2025 to €1.6bn per GW in 2035, at which time cumulative installed capacity would range from 4.2GW (low scenario) to 7.7GW (high scenario) and local content (with a high likelihood to be sourced domestically) would be 37%. Noonan and Smart (2017) estimated that the total direct + indirect GVA impact to the UK from offshore wind in 2017 was £1.8bn per GW. At that time, the cumulative installed capacity in the UK was 5.1GW and UK content was 32%. Our modelled GVA ratio is only slightly lower than that of Noonan and Smart (2017) and our local content figures are slightly higher. This can be explained by differences in the breakdown of the value of the products and services for different project sub elements that could be captured by Irish companies versus that of UK companies. For example, blade manufacturing in the UK is already established. Our model does not assume that there is a high likelihood that Irish companies will manufacture any turbine components by 2035. Nevertheless, the similarity of the GVA figures for somewhat comparable situations suggests that the model may be reasonably able to simulate GVA impact for the Irish case.

~~With regard to employment, our modelled figures are in line with estimates of Irish workforce requirements presented by Leahy et al. (2020). Based on international data from IRENA, they estimate that a workforce comprised of 20,068 FTEs would be required to deliver 3.5GW of offshore wind for Ireland. This includes jobs created in planning and development, manufacturing, transport and logistics, installation and connection, and operations and maintenance. Compare this with our model, which estimates a requirement of 22,462 FTEs to deliver 3.5GW of offshore wind. Leahy et al.'s estimates are based on workforce requirements for a typical offshore wind farm and the share of domestically supplied content from their assessment of Irish supply chain capabilities. Our model differs in that it takes wage data, discounting, and technological learning into account.~~

It is important, though, to acknowledge the limitations of the model presented. First and foremost, the modelled outputs are sensitive to changing market conditions. For example, changes in the discounting rate, technological learning rate, or wage increases could affect modelled output. The inputs are based on the best available information, but if this should change, the model can be easily updated to reflect these changes or a sensitivity analysis could be undertaken to explore how such changes might affect modelled outputs.

It is also important to consider what is being modelled and what is not. This model does not take into account decommissioning, as there is limited information about this and, given the lifetime of upcoming projects, it would not be reflected in the modelled timeframe anyway. Information about the costs of commercial floating wind projects is also limited. As such, these are treated like fixed bottom projects in the model except for differences in the potential domestic capabilities to supply products and services to the floating projects. Differences in costs and occupational breakdowns between fixed and floating projects may affect modelled outputs.

Finally, GVA and employment are only modelled for the domestic market for offshore wind, and thus represent a lower boundary on the likely overall impact of offshore wind development on the Irish supply chain. KPMG (2018) and SEAI (2011) expect that the export market will far exceed that of the domestic market for offshore wind for Ireland. However, this can only materialise if companies have an opportunity to gain experience in the domestic market.

Conclusion

Given the recent policy developments and the level of interest from offshore wind developers, there is a growing public interest in what benefits offshore wind will bring to the Irish economy and to local communities. For public consumption, a robust and transparent assessment of the potential economic impacts of the sector is needed. This study helps to fulfil this requirement. The value chain model can easily be adjusted to fit changing conditions. Modelled outputs can be used by developers and policy makers to evaluate the socio-economic impacts of offshore wind development and to design community benefits schemes, tailored to coastal communities specific needs. Further research could include an assessment of sensitivity of modelled outputs to changing conditions, use of the model to explore the export market (assuming the Irish supply chain could capture a share of the European or global market offshore wind markets), or an assessment of the induced GVA and employment impacts of modelled development.

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Declaration of Interest Statement

In accordance with Taylor & Francis policy and my ethical obligation as a researcher, I am reporting that I receive funding from Eirwind's 10 industry partners, DP Energy Ireland, Equinor ASA, Enerco Energy, Statkraft Ireland, Brookfield Renewable Ireland, EDP Renewables, SSE Ireland, Simply Blue Energy, ENGIE, and Electricity Supply Board (ESB), companies that may be affected by the research reported in the enclosed paper. I have disclosed those interests fully to Taylor & Francis, and I have in place an approved plan for managing any potential conflicts arising from that involvement.

References

Breitschopf, Barbara, Carsten Nathani, and Gustav Resch. 2011. "Review of Approaches for Employment Impact Assessment of Renewable Energy Deployment." *EID (Economic and Industrial Development)–EMPLOY* 99.

BVG. 2019a. *U.S. Job Creation in Offshore Wind: A Report for the Roadmap Project for Multi-State Cooperation on Offshore Wind*. https://www.nyserda.ny.gov/-/media/Files/Publications/Research/Biomass-Solar-Wind/Master-Plan/US-job-creation-in-offshore-wind.pdf.

BVG. 2019b. *Guide to an Offshore Wind Farm*. https://bvgassociates.com/publications/#GOWF.

CSO. 2018. "EARNINGS AND LABOUR COSTS ANNUAL DATA 2018." https://www.cso.ie/en/releasesandpublications/er/elca/earningsandlabourcostsannualdata2018/%0A.

Dalton, G.J., and T. Lewis. 2011. "Metrics for Measuring Job Creation by Renewable Energy Technologies, Using Ireland as a Case Study." *Renewable and Sustainable Energy Reviews* 15 (4). Pergamon: 2123–2133. doi:10.1016/J.RSER.2011.01.015.

DCCAE. 2020. "Ministers English and Bruton Announce the Transition of Offshore Renewable Energy Projects." https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Ministers-English-and-Bruton-Announce-the-Transition-of-Offshore-Renewable-Energy-Projects.aspx.

DCENR. 2014. *Offshore Renewable Energy Development Plan: A Framework for the Sustainable Development of Ireland's Offshore Renewable Energy Resource*. Dublin.

DTI. 2004. *Renewable Supply Chain Gap Analysis*. https://www.slideshare.net/TheSupplychainniche/renewable-supply-chain-gap-analysis-summary-report.

Eirgrid. 2019. *Tomorrow's Energy Scenarios 2019 Ireland: Planning Our Energy Future*. http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-TES-2019-Report.pdf.

Eiser, David, and Deborah Roberts. 2002. "The Employment and Output Effects of Changing Patterns of Afforestation in Scotland." *Journal of Agricultural*

Economics 53 (1). Wiley Online Library: 65–81.

Elliott, D L, C G Holladay, W R Barchet, H P Foote, and W F Sandusky. 1987. *Wind Energy Resource Atlas of the United States*. Pacific Northwest Lab., Richland, WA (USA).

EU NWE. 2019. "AFLOWT - Accelerating Market Uptake of FLoating Offshore Wind Technology." *Interreg North-West Europe Programme*. https://www.nweurope.eu/projects/project-search/aflowt-accelerating-market-uptake-of-floating-offshore-wind-technology/.

EurObserv'ER. 2019. *The State of Renewable Energies in Europe, 19th EurObserv'ER Report*. https://www.eurobserv-er.org/pdf/19th-annual-overview-barometer/.

Faturay, Futu, Venkata Sai Gargeya Vunnava, Manfred Lenzen, and Shweta Singh. 2020. "Using a New USA Multi-Region Input Output (MRIO) Model for Assessing Economic and Energy Impacts of Wind Energy Expansion in USA." *Applied Energy* 261. Elsevier: 114141.

Government of Ireland. 2019a. *Climate Action Plan 2019: To Tackle Climate Breakdown*.

Government of Ireland. 2019b. *Climate Action Plan 2019 To Tackle Climate Breakdown - Annex of Actions*. https://www.dccae.gov.ie/documents/Climate Action Plan 2019 - Annex of Actions.pdf.

IMDO. 2019. *IPORES 2018 A Review of Irish Ports Offshore Renewable Energy Services*. https://www.imdo.ie/Home/sites/default/files/IMDOFiles/13390 IMDO IPORES Report 2018 FA.PDF.

Inter-Departmental Marine Coordination Group. 2012. *Harnessing Our Ocean Wealth: An Integrated Marine Plan for Ireland*. https://oar.marine.ie/handle/10793/810.

Jenniches, Simon. 2018. "Assessing the Regional Economic Impacts of Renewable Energy Sources–A Literature Review." *Renewable and Sustainable Energy Reviews* 93. Elsevier: 35–51.

KMPG. 2018. *Offshore Wind: Ireland's Economic and Social Opportunity*. https://assets.kpmg/content/dam/kpmg/ie/pdf/2018/11/ie-offshore-wind-nov-2018.pdf.

Leahy, L., D.K. Spearman, R. Shanahan, E. Martins, E. Northridge, and G. Mostyn. 2020. *Supply Chain Study for Offshore Wind in Ireland*.

Mukhopadhyay, Kakali, Xi Chen, and Paul Thomassin. 2017. "Economy Wide Impacts of Ethanol and Biodiesel Policy in Canada: An Input–Output Analysis." *International Journal of Green Energy* 14 (4). Taylor & Francis: 400–415.

Noonan, M., and G. Smart. 2017. *The Economic Value of Offshore Wind: Benefits to the UK of Supporting the Industry*. https://ore.catapult.org.uk/app/uploads/2017/12/SP-0012-The-Economic-Value-of-Offshore-Wind-1.pdf.

Noori, M, M Kucukvar, and O Tatari. 2015. "Economic Input–Output Based Sustainability Analysis of Onshore and Offshore Wind Energy Systems." *International Journal of Green Energy* 12 (9). Taylor & Francis: 939–948.

Office of National Statistics. 2019. *Low Carbon and Renewable Energy Economy, UK: 2017*. https://backup.ons.gov.uk/wp-content/uploads/sites/3/2019/01/Low-carbon-and-renewable-energy-economy-UK-2017.pdf.

PayScale. 2019. "Salary Data & Career Research Center (Ireland)." https://www.payscale.com/research/IE/Country=Ireland/Salary.

Pöyry. 2014. *The Value of Wind Energy for Ireland*. http://www.poyry.co.uk/sites/www.poyry.co.uk/files/41x187872_economicbenefitsofwind_v7_0.pdf.

Remmers, Tiny, Fiona Cawkwell, Cian Desmond, Jimmy Murphy, and Eirini Politi. 2019. "The Potential of Advanced Scatterometer (ASCAT) 12.5 Km Coastal Observations for Offshore Wind Farm Site Selection in Irish Waters." *Energies* 12 (2). Multidisciplinary Digital Publishing Institute: 206. doi:10.3390/en12020206.

Roberts, A., and S. Westbrook. 2017. *A New Economic Impact Methodology for Offshore Wind*. https://bvgassociates.com/publications/#GVAWP.

SEAI. 2011. *SEAI Wind Energy Roadmap 2011-2050*. https://www.seai.ie/resources/publications/Wind_Energy_Roadmap_2011-2050.pdf.

Siemens. 2014. *An Enterprising Wind: An Economic Analysis of the Job Creation Potential of the Wind Sector in Ireland*. https://www.esri.ie/system/files?file=media/file-uploads/2015-

07/BKMNEXT250.pdf.

Tsakiridis, Andreas, Murat Aymelek, Daniel Norton, Ryan Burger, Jenny O'Leary, Rebecca Corless, and Stephen Hynes. 2019. *Ireland's Ocean Economy 2019*. https://www.nuigalway.ie/media/researchsites/semru/files/Online_Irelands-Ocean-Economy-Report_for-web_final.pdf.

UK Government. 2020. "Renewable Electricity Capacity and Generation (ET 6.1 - Quarterly)." Department for Business, Energy and Industrial Strategy. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/875409/ET_6.1.xls.

Varela-Vázquez, Pedro, and María del Carmen Sánchez-Carreira. 2017. "Estimation of the Potential Effects of Offshore Wind on the Spanish Economy." *Renewable Energy* 111. Elsevier: 815–824.

Wittwer, Glyn, and Mark Horridge. 2010. "Bringing Regional Detail to a CGE Model Using Census Data." *Spatial Economic Analysis* 5 (2). Taylor & Francis: 229–255.

Zheng, Chong-wei, Zi-niu Xiao, Yue-hua Peng, Chong-yin Li, and Zhi-bo Du. 2018. "Rezoning Global Offshore Wind Energy Resources." *Renewable Energy* 129: 1–11. doi:https://doi.org/10.1016/j.renene.2018.05.090.

Zheng, Chong Wei, Chong Yin Li, Jing Pan, Ming Yang Liu, and Lin Lin Xia. 2016. "An Overview of Global Ocean Wind Energy Resource Evaluations." *Renewable and Sustainable Energy Reviews* 53: 1240–1251. doi:https://doi.org/10.1016/j.rser.2015.09.063.

Table 1 - Proportion of potential domestic supply for each category of likelihood that supply can be domestically sourced.

		Project development and management	Turbine supply	Balance of plant supply	Installation and commissioning	Operations and maintenance
Fixed-bottom + Floating projects 2020-2024	Low	-	90%	47%	17%	-
	Medium	100%	10%	53%	42%	54%
	High	-	-	-	42%	46%
Fixed-bottom + Floating projects 2025-2029	Low	-	76%	32%	-	-
	Medium	-	24%	68%	100%	43%
	High	100%	-	-	-	57%
Fixed-bottom projects 2030 and beyond	Low	-	66%	-	-	-
	Medium	-	34%	100%	100%	-
	High	100%	-	-	-	100%
Floating projects 2030 and beyond	Low	-	100%	-	-	-
	Medium	-	-	100%	64%	7%
	High	100%	-	-	36%	93%

[To give an example of how to read the table, for turbine supply for a fixed-bottom wind farm built between 2020-2024, there is a low likelihood that 90% of the supply could be sourced domestically and a medium likelihood that 10% of the supply could be sourced domestically. There is a high likelihood that none of the supply could be sourced domestically. Figures represent technical capabilities, and do not take into account market competition. Proportions have been calculated from research conducted by Leahy et al. (2020). Where capabilities are categorised as ‘low’, it is virtually certain that the corresponding proportion of associated requirements will not be supplied domestically.]

[Figure 1. Existing and planned offshore wind developments in Ireland. While current installed capacity stands at only 25MW, there are 12.3GW of offshore wind energy projects at various stages of planning. The only fully commissioned project is the Arklow Bank Wind Farm. Floating wind projects the very early planning (site investigation) stages, with commercial developments not likely to come on stream until at least 2026.]

[Figure 2. Forecast annual and cumulative offshore wind capacity in Ireland under the low and high scenarios.]

[Figure 3. Potential GVA impact associated with the domestic supply of products and services for Irish offshore wind projects for (a) low and (b) high cumulative installed capacity scenarios. GVA impact is broken down by the potential for domestic suppliers to supply the required products and services.]

[Figure 4. Potential employment impact associated with the domestic supply of products and services for Irish offshore wind projects for (a) low and (b) high cumulative installed capacity scenarios. Employment impact is broken down by the potential for domestic suppliers to supply the required products and services.]