Urgent leasing of blocks of seabed for offshore windfarms

1. EXECUTIVE SUMMARY

1.1. Offshore wind power represents the most abundant and commercially viable renewable energy source on the Isle of Man at present. Wind farm developers have already signed an agreement for lease to develop a 700 MW (annual output ~3000 GWh) wind farm on the east coast and have undertaken initial surveys since 2016. There has been no progress since then because renewable energy projects outside UK waters cannot bid in the UK Government contract-for-difference (CfD) auction rounds, the latest of which saw bids to develop offshore wind at a strike price of £39.65 per MWh (2012 prices). There is a barrier to development as there is no route-to-market available for the power generated so the developers are not able to make a final investment decision.

1.2. Until recently, discussions held with Ørsted (the developer, previously DONG Energy) were based on the premise that the power would be exported to the UK. With the ambition to decarbonise the Isle of Man electrical power generation and anticipated increased electrification of domestic heating and vehicular transport, there are several options for the development to consider where some, or all, of the power comes to the Isle of Man.

1.3. These scenarios, which are the result of high-level thinking among the Climate Change Analytical Team (CCAT), Ørsted and Department of Environment, Food and Agriculture (DEFA), are being further investigated. They pose additional economic and technical challenges and costs for the developer and the Manx Utilities Authority (MUA), which would purchase the electricity from Ørsted through a power-purchasing-agreement (PPA). All options will still require a change to the UK CfD legislation to enable the development, unless there is a significant change in the UK electricity market to enable PPAs or merchant agreements for offshore wind power.

1.4. Significant grid reinforcement on the Isle of Man would be required and balancing the intermittent generation from wind with the combined cycle gas turbine (CCGT), a Government owned asset that has significant contributions to the Bond Repayment Fund remaining and due in 2030 and 2034, requires further technical and economic analysis. Alternative balancing and storage solutions exist, such as battery storage and hydrogen production, which will require significant investment and are not evaluated here. Ongoing pilot projects that aim to couple offshore wind power and hydrogen through electrolysis may represent a solution within the next decade, whereby excess electrical energy from wind can be stored in the form of hydrogen. Hydrogen fuel is being used to power CCGT plants in the Netherlands, with 100% hydrogen CCGT power aimed for 2023, suggesting the CCGT can avoid becoming a 'stranded asset' in the context of renewable generation.

1.5. Offshore wind represents an opportunity for public investment with attractive rates of return if sufficient capital can be invested after the construction of the project. Other developments in the Eastern Irish Sea are 50% owned by Danish pension funds, for example.

1.6. The Department of Infrastructure (DOI) and DEFA are in active negotiation about the options for progression presented herein. The Action Plan (AP) resulting from the Climate Emergency Transformation will inform these negotiations going forward. The UK CfD issue is highly unlikely to be influenced by the AP, since it is a UK Government decision.

2. OFFSHORE WIND: OVERVIEW

2.1. Europe is the world leader in offshore wind energy production, with the first offshore wind farm having been constructed in Denmark in 1991 (Wilkes, 2010). Offshore wind energy generation has since accelerated and by 2018 the total installed offshore wind capacity in Europe equated to 18.6 GW (2% of all electricity consumed in the region) (Wind Europe, 2019). This production corresponds to 4,542 connected turbines across 11 nations (Wind Europe, 2019). The continued expansion of offshore wind shows no abatement as the technology develops to maximise economic competitiveness. In 2018, Europe added 2.6 GW of net offshore capacity, 85% of which were within UK and German waters (Wind Europe, 2019). The UK has the largest amount of offshore wind energy production with 44% of all installations in MW. Offshore wind accounts for 39% (c 8.5 GW) of Britain’s total wind capacity and growing due to the end of subsidy schemes for onshore wind farms and continued support from the Contract for Difference (CfD) scheme. To achieve the UK’s new legally binding decarbonisation goal of “net-zero” it is likely that 75 GW of offshore wind will need to be delivered by 2050 contributing to 369 TWh of variable renewables by 2050. The UK Government has already committed to an ambitious target for offshore wind of 30 GW by 2030.

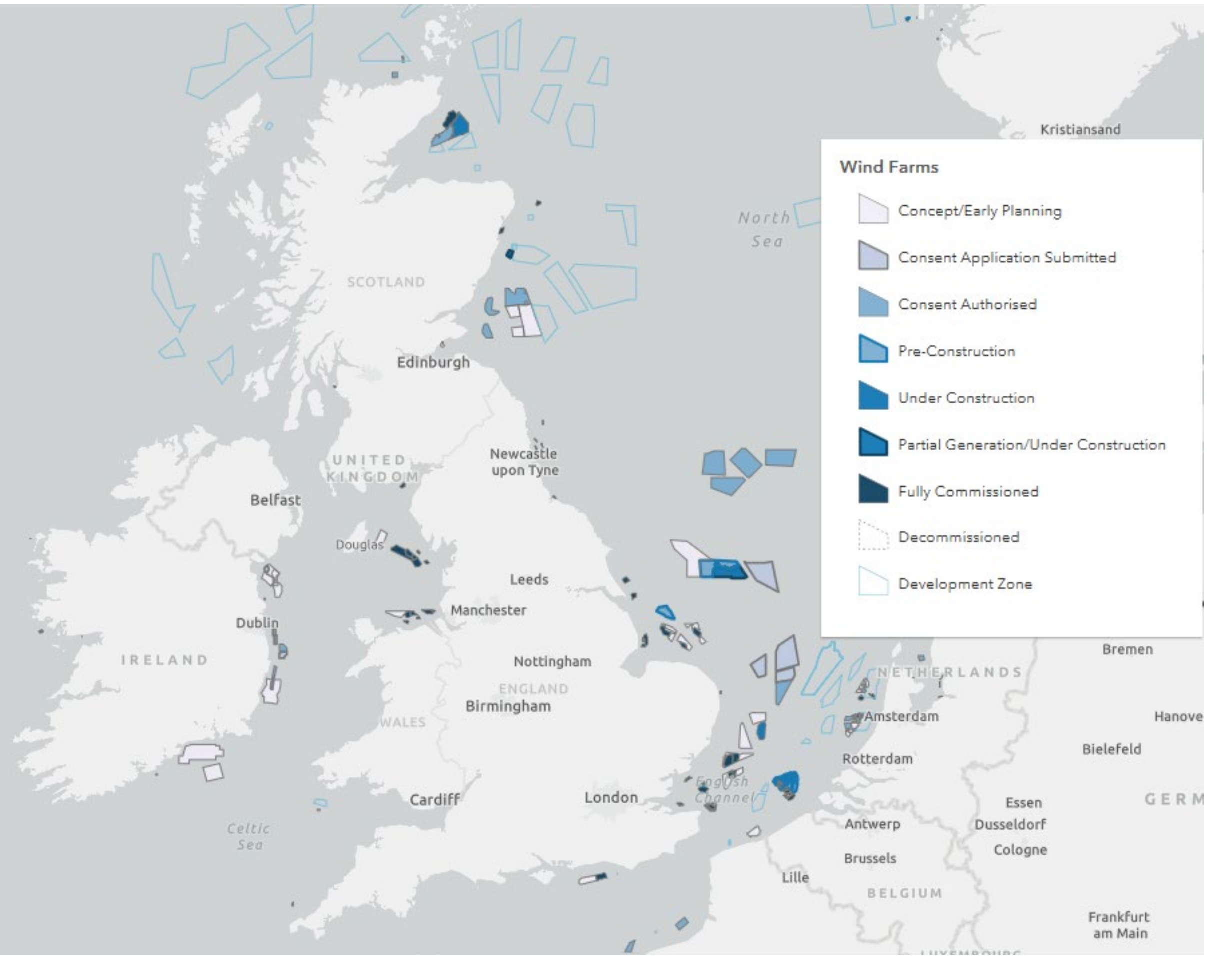


Figure 1. Location of existing and proposed offshore wind farms around the British Isles. (4C Offshore, 2019)

2.2. Overall, wind farms are increasing in size, from an average development size of 79.6 MW in 2007 to 561 MW in 2018. In the UK, construction began on the world's largest offshore wind farm (the Hornsea One project) which will have the generation capacity of 1,200 MW (= 1.2 GW) from 174 turbines once fully operational in 2020 (Ørsted, 2019).

2.3. As well as overall increases in the power output of wind farms, the turbines within them are also increasing in capacity, reflecting the increased economic returns from the increased load factors larger turbines yield. The average size of newly installed offshore turbines in 2018 was 6.8 MW, a 70% increase from 2014 (Wind Europe, 2019).

2.4. New investments in offshore wind energy in Europe in 2018 amounted to €10.3bn, a 37% increase from 2017, as 4.2 GW of additional capacity successfully reached a financial investment decision (FID). Refinancing of offshore wind farms also hit a record level of €8.5bn, bringing total investments, including transmission lines, to €19.6bn (Wind Europe, 2019).

2.5. The average water depth of developments in 2018 was 27.1 m, with the average distance to shore being 33 km (Wind Europe, 2019). The Hornsea One project is the furthest from shore at just over 100 km. Monopiles represent the preferred option for mounting turbines to the seabed (81.5 % of installations) although several other methods were used in projects in 2018, including a pilot project, the Floatgen project, which is trialling a floating turbine (Wind Europe, 2019).

2.6. On the 11th September 2017, Ørsted were awarded the contract to build the 'Hornsea 2' windfarm in the North Sea at a record low energy price for offshore wind in the UK, with a CfD at £57.50 /MWh (5.7p per kWh). The site will extend the 'Hornsea 1' site, which will be the world's first offshore development to exceed 1 GW in capacity, with a combined output of 3 GW by 2022. More recently, in September 2019, the latest round of auctions in the UK saw contracts awarded at record-low prices again, with several UK projects (Dogger Bank and Sofia) amounting to 2.6 GW achieving a strike price of £39.65 per MWh[1], which is below the wholesale price of electricity in the UK. This means that offshore wind no longer requires subsidisation from the UK government and is competitive against the marginal cost of electricity from the Pulrose CCGT power station[2]. Now offshore wind is competitive in the domestic generation market, the sector may move towards long-term power-purchasing agreements (PPAs) outside the CfD mechanism. This has already been shown to be possible with onshore wind developments. For example, Green Investment Group Ltd (GIG) structured and secured a long-term power purchase agreement (PPA) for the Hornamossen wind farm (Sweden) with Swiss energy utility Axpo Nordic, part of the Swiss energy group Axpo. GIG has now sourced and structured PPAs for almost 1 GW of onshore wind capacity in Sweden, equivalent to over 10% of Sweden's total onshore wind installed capacity.

3. OFFSHORE WIND IN THE NORTHERN IRISH SEA

3.1. In 2018, the North Sea accounted for 70% of all offshore wind production in Europe, followed by the Irish Sea at 16% (Wind Europe, 2019). Much of the Irish Sea developments have been undertaken in the Eastern Irish Sea by Ørsted, near the Lancashire and Cumbrian coasts. A series of projects totalling nearly 1.2 GW of generation capacity are operational (see figure 1). Other developments north of the Welsh coast and the Wirral have also been completed by Stadtwerke München, Greencoat UK and Ørsted along with other stakeholders (total production capacity equal to 271 MW), with an additional capacity of 576 MW in the 'early planning' phase at Stadtwerke München's 'Gwynt y Môr Extension'.

3.2. Offshore wind development opportunities on the western side of the Northern Irish Sea within the Republic of Ireland's waters are also in the early planning

[1] Strike prices are given in 2012 prices so that year-on-year prices are comparable without inflation.
[2] The marginal price of electricity from the Pulrose CCGT is estimated to be £45 per MWh (2018 prices).

phase, with potential power generation capacity of up to 1.8 GW (4C Offshore, 2019a).

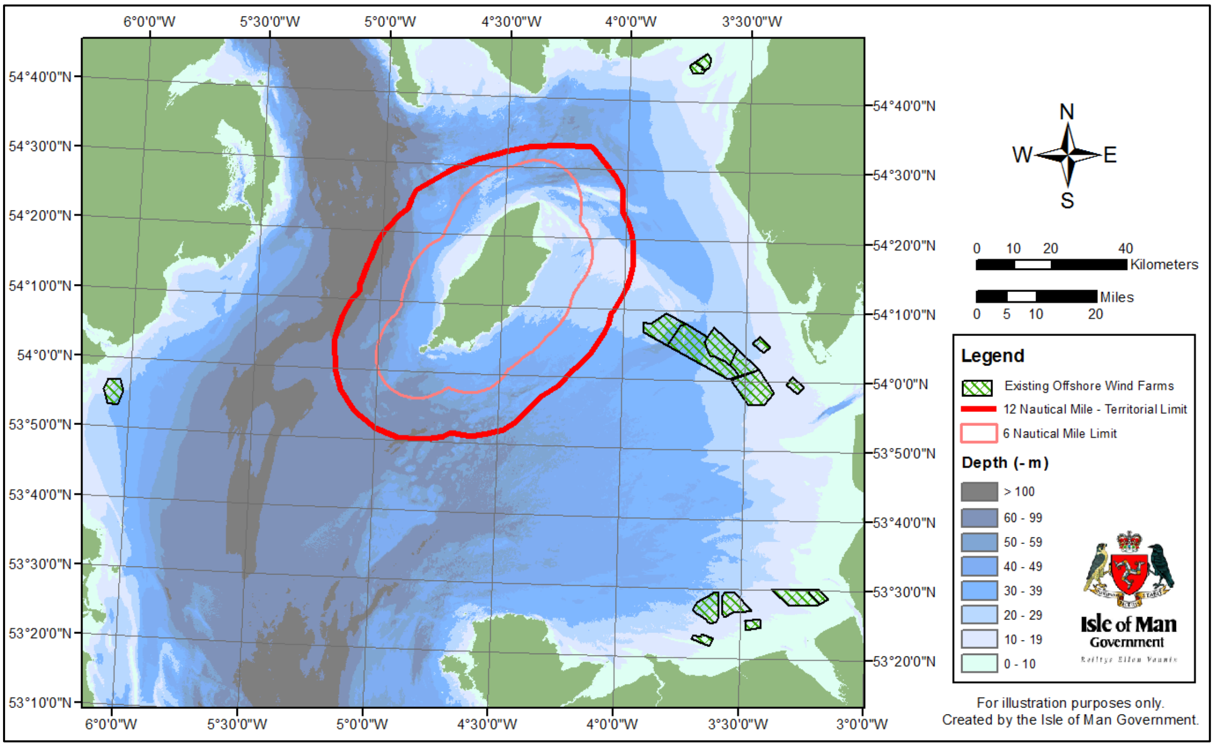


Figure 2. Existing Offshore Wind Farms in the Northern Irish Sea.

3.3. The average minimum depth that these developments occur at is 25 m relative to Mean Low Water Spring (MLWS), with small areas of the Walney extension perimeter being deeper at 55 m, though turbine layout may avoid deeper pockets of seabed (Figure 1). The economics and engineering challenges of construction mean depth is a factor in site-selection, although the UK Crown Estate recently extended pre-selection of areas for the UK's fourth round of auctions to include waters up to 60 m (a 10 m increase on previous proposals) in response to developers feedback and to enable a further development (The Crown Estate, 2018). It is likely that further developments in floating wind farm technology will overcome the depth barrier to development in the future.

4. WALNEY EXTENSION EXAMPLE

4.1. The Walney extension, owned by Ørsted, is situated off the Cumbrian coast and is visible from the Isle of Man. It is the largest operational wind farm in the world (2019) and has a capacity of 659 MW from 87 turbines (40 x MHI-Vestas 8.25 MW turbines and 47 x Siemens Gamesa 7 MW turbines, the largest and most technologically advanced turbines from the respective manufacturers). The power output from the wind farm, together with the adjoining smaller projects ('Walney 1' and 'Walney 2') (see figure 2 & 3), is 1,300 GWh annually, equivalent to the electric power use of 580,000 UK homes each year.

4.2. The Walney Extension was awarded consent in November 2014 following a 4 year agreement process, and offshore works were completed in June 2018 (3 years, 7 months from consent). The extension project created up to 250 new jobs during the operations and maintenance phase, including jobs that are supported through Tier 1 supply chain as well as 'direct' Ørsted employees.

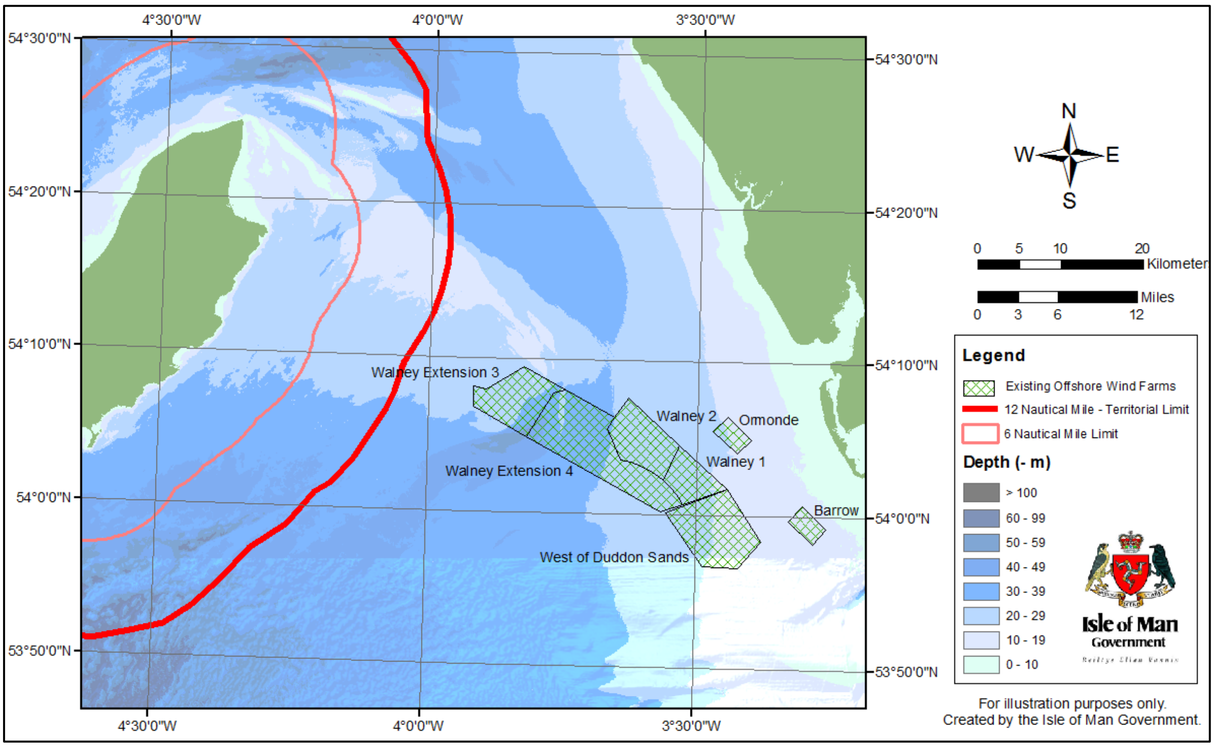


Figure 3. The Walney Extension and surrounding wind farm areas, visible from the Isle of Man.


Figure 4. View of Walney windfarm with the Isle of Man on the horizon (Source: The Global Warming Policy Forum; www.gwpf.com)

5. ISLE OF MAN OFFSHORE WIND GENERATION POTENTIAL

5.1. An overview of offshore wind potential within the Isle of Man Territorial Sea was commissioned within a report produced by AEA Technology plc (AEA, 2010). The report can now be considered largely out of date, owing to the significant technical and economic advances made within the industry. For example, the turbines considered in the four hypothetical development areas had outputs between 3.6 MW and 5 MW (AEA, 2010), which were considered large turbines at the time, with an aggregated capacity of 2.5 GW. In 2018, Siemens Gamesa announced plans to produce and supply 10 MW turbines for offshore developments in a Dutch offshore windfarm (due for completion in 2023), which are more than twice as powerful in terms of energy output as those considered in the AEA (2010) report. Furthermore, General Electric (GE) has designed a 12MW turbine for offshore development, which generates up to 67 GWh annually with a 63% capacity factor. A single turbine could be expected to generate enough power for 16,000 homes from a typical site in the German North Sea (GE, 2019).

5.2. As a consequence, and in line with decreasing construction costs per MW, the economics of the industry have also changed significantly. AEA (2010) estimated the levelised cost for offshore wind production (with a 10% discount rate) would be £0.180 per kWh. However, recent projects were awarded a contract for difference in the UK for £0.039 per kWh in 2018, supplying energy more than three times cheaper than the AEA (2010) estimates and cheaper than the current (2019) levelised cost for electricity-from-gas (£0.045 per kWh).

5.3. The AEA (2010) report can therefore be considered to greatly underestimate the energy capacity potential of offshore wind in the Isle of Man territorial sea, as well as underestimating the economic competitiveness of offshore wind technology. With that in mind, it is encouraging that offshore wind still scored high in the documents multi-criteria analysis, which weighed energy capacity and output against qualitative criteria such as public acceptance, carbon savings and environmental impacts. Furthermore, public acceptance of offshore wind has generally increased in the UK from 77% acceptance rate in 2012 to 83% in 2018.

6. ØRSTED 'ISLE OF MAN' PROJECT

6.1. In February 2014, the Isle of Man Government took the first step towards exploring the opportunities for the generation of offshore wind (Offshore Energy Strategy; Report GD 2014/0028) and invited expressions of interest from parties seeking to develop offshore energy production in the territorial sea.

6.2. Following a review of several formal tender submissions in 2014, which all identified a similar location for development, the Environment & Infrastructure Committee recommended that DONG Energy (now Ørsted) be selected as the preferred bidder for offshore wind. The site-selection process undertaken by

Ørsted took into account environmental, physical, biological and human constraints and landscape/seascape sensitivities as well as Cost of Energy reduction and wind speed considerations.

6.3. By November 2015, Ørsted had signed an 'Agreement for Lease' (AfL) contract with the Isle of Man Government Department of Infrastructure. The lease allowed Ørsted to carry out preliminary surveys to determine the practicality and commercial viability of siting wind turbines in the development of a 700 MW windfarm within the 12-nautical mile limit. The area deemed most practical by Ørsted is shown in Figure 2. The AfL site covers an area of 253 km^2, with a mean depth of 21 m below MLWS, though the final development layout will be smaller. The site is between the 6 nautical mile limit and the territorial limit, north Douglas Head and south of Maughold Head. The intention was to export the estimated **3,000 GWh yr^{-1}** (based on a 50% capacity factor) to the National Grid in the UK. For comparison, the total amount of electricity consumption in the Isle of Man in 2018, including domestic, commercial and industrial, was **360 GWh** (Isle of Man Government, 2018). Current forecasts anticipate annual electricity demand in 2050 to be approximately 750 GWh following up-take of electric vehicles and heating (MUA, 2019), whilst current total annual energy demand on the island (from all energy sources, including road fuels and domestic heating) is **2,000 GWh**.

6.4. By September 2017, Ørsted had completed a geophysical study, socio-economic study and collected two years of marine mammal and seabird environmental studies, culminating in the submission of an annual AfL report and Socio-economic benefits study. There has been no progress since that point however for the reasons outlined below. The AfL remains an attractive development opportunity for Ørsted providing a secure route to market can be established (see below).

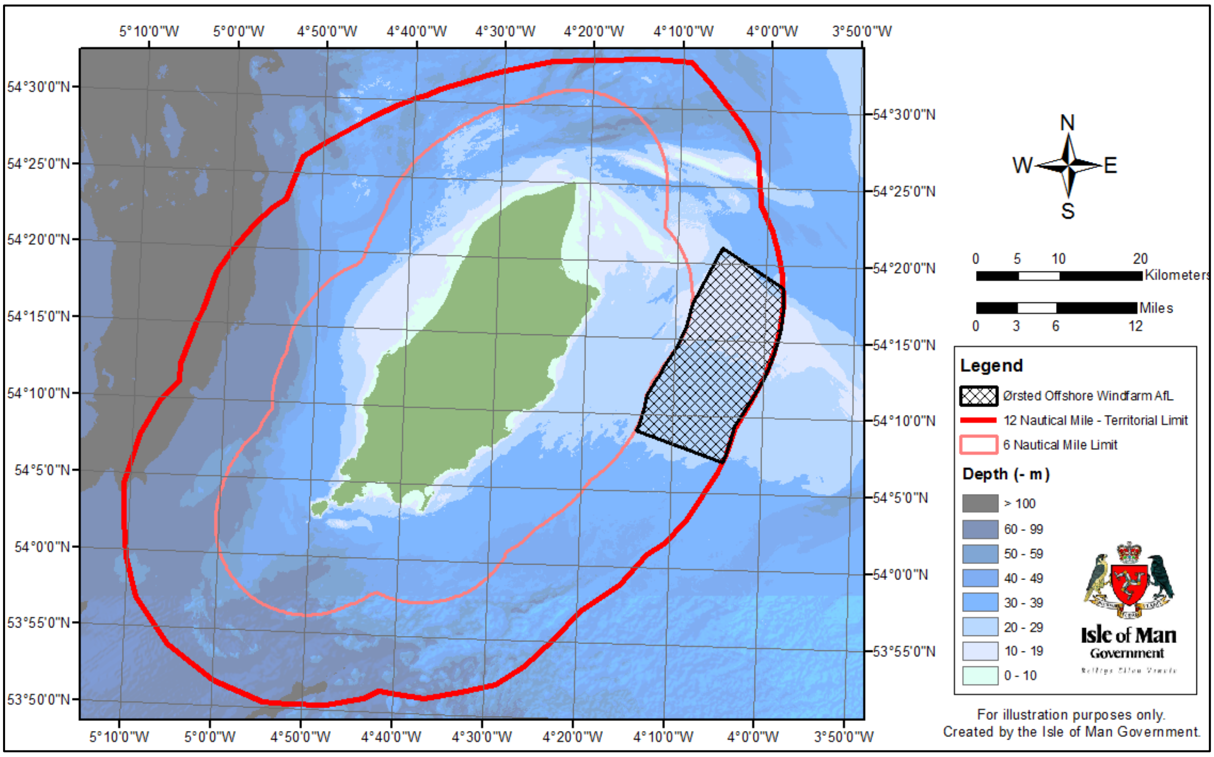


Figure 5. The Agreement for Lease (AfL) area being surveyed by Ørsted.

7. TIMELINE FOR GENERATION

7.1. Following successful consent and an FID, construction of an offshore wind farm could begin within five years following a period of consenting, planning, finalising the turbine array and cable design and a subsequent Environmental Impact Assessment (EIA) and Community Engagement consultation process. Construction is expected to take up to 2.5 years. Likely development time is 7-8 years.

8. ECONOMIC BENEFITS ACCRUING FROM SEABED LEASE

8.1. Based on the strike price achieved at recent CfD auctions (2019; £39.65 MWh^{-1}) and an annual generation estimate of 3,000 GWh, the seabed lease derived from 2% of project revenue would result in an economic benefit accruing to the Isle of Man Treasury of £2.4m/yr (DED, 2015).

9. BARRIERS TO PROGRESSION

Contract for Difference outside of UK Waters, for 'UK' projects

9.1. A Contract for Difference (CFD) is a civil contract contract between a low-carbon electricity generator and a government-owned company (such as the Low Carbon Contracts Company (LCCC) in the UK). The idea is that agreeing fixed rates for a certain number of years, settled at auctions, will incentivise companies to commit to producing low-carbon energy.

9.2. The CfD works by guaranteeing a fixed price (strike rate) for energy generation companies (e.g. Ørsted), based on wholesale electricity market rates. The generators will then sell energy to suppliers, and the cost at which they sell it at may be the same as the strike price; below it; or slightly above it.

- If the sales of energy by the generators are the same as the strike price, then there is no further action,
- If the price is below that price, it will trigger top up payments by the suppliers,
- While if the sales by the generators are at a higher price, it will result in generators paying back the difference.

9.3. The CfD allows developers to secure a fixed, pre-agreed price for the low carbon electricity they produce for the duration of the contract. It aims to give greater certainty and security of revenues to electricity generators by reducing their exposure to volatile wholesale prices, while protecting consumers against paying for higher support costs when electricity prices are high. The UK Government Department for Business, Energy and Industrial Strategy (BEIS) is budgeting for 2023-2024 and 2024-2025, and is set to allocate further significant offshore wind energy generation capacity. Strike prices for offshore wind projects delivering 2023-24 have been set at £56 per MWh (4C Offshore, 2019). The most recent auction (2019) results saw developers in the North Sea bid at a record low £39.65 per MWh, which is cheaper than the wholesale price of electricity in the UK and cheaper than the marginal price of generation from CCGT plants.

9.4. However, under secondary legislation in the UK Energy Act (2013), CfD bids from projects outside of UK waters (including the Isle of Man and Channel Islands) are not permitted. Therefore, the Ørsted 'Isle of Man' offshore wind development was not able to bid in previous CfD auctions, the most recent of which was 29 May 2019 with subsequent offshore renewable CfD auctions planned for 2021.

9.5. The development of the Ørsted project, which has outlined the route-to-market as export of power to the UK, is waiting until there is a decision made by the UK Government that the contract for difference (CfD) can be applied to schemes in Crown Dependency waters.

9.6. Isle of Man government officials and Ørsted have remained committed to the development of an offshore wind farm by seeking amendments and/or mechanisms that comply with UK legislation, which has stalled progress to date.

10. OPTIONS TO CIRCUMVENT "BARRIERS"
Await UK legislative change for 'Crown CfD'

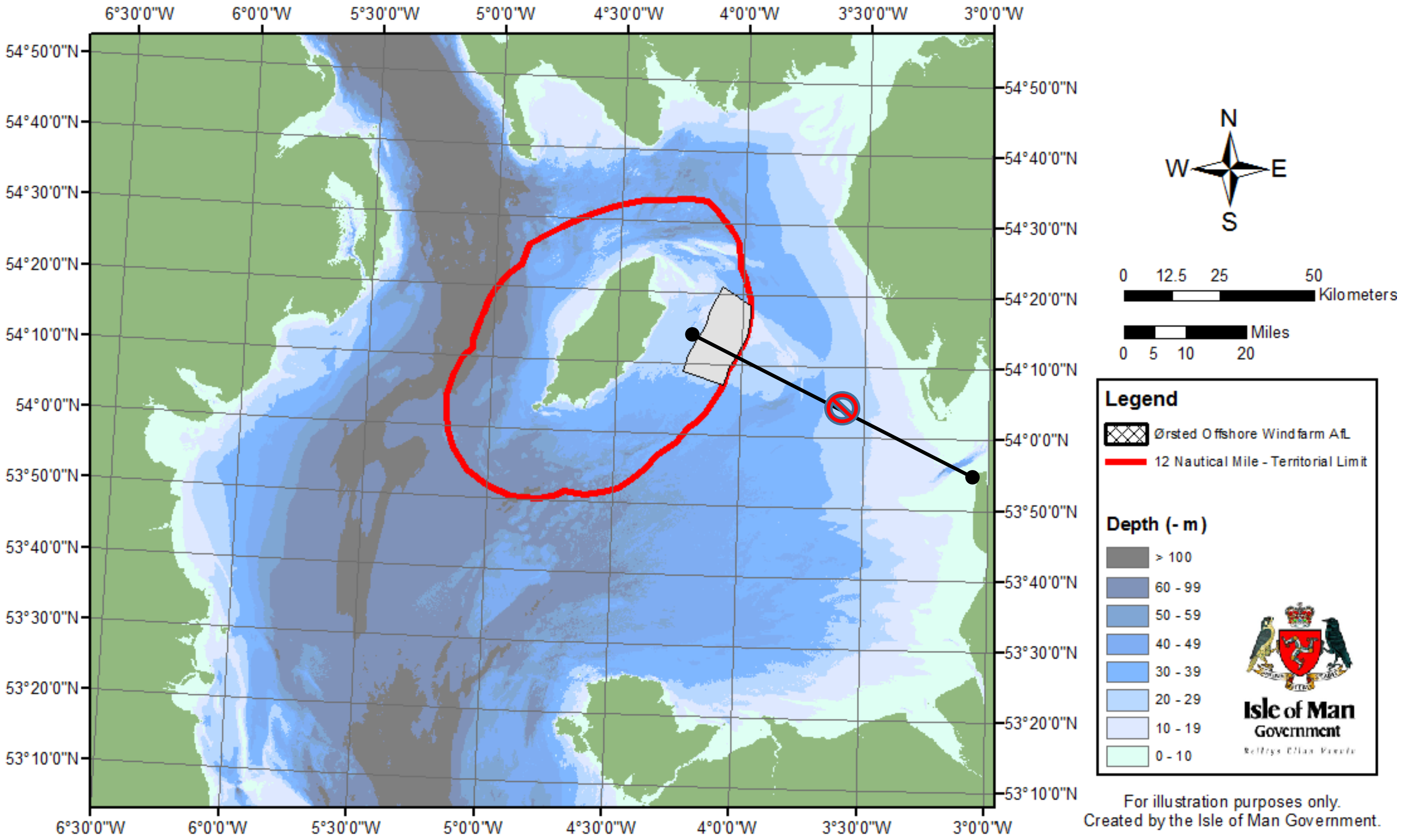


Figure 6. Infographic showing the existing plan for power generation from the Ørsted 'Isle of Man' project. Note: Arrows indicate the direction of power and do not illustrate cable route footprints.

Public sector investment required:	**£ 0**
Private sector investment required (estimate):[3]	**£1,870 m**
Development:	£ 84 m
Turbines:	£ 700 m
Balance of plant:	£ 420 m
Installation:	£ 455 m
Decommission:	£ 210 m
Operation & Maintenance	£52.5 m per annum
Annual Economic benefits to Exchequer:	**£2.4 m**
Seabed Lease:	£2.4 m
Annual Spend into Local Economy	**Commercially sensitive**
Potential net change to annual IOM CO_2e account:	**Increase – not quantified**
Timeline for generation:	**Uncertain**

10.1. Option 1 represents the status quo, which is to await amendments to secondary legislation in the UK to enable bids at CfD auctions for projects in Crown Dependency waters.

10.2. The timeline and probability for development is uncertain. Any changes will require sufficient political will within the UK Government and time to draft amending legislation. Given the prioritisation of Brexit across all Government departments in the UK, it may take several years or longer before any legislative amendments facilitate the Ørsted 'Isle of Man' project, which may or may not occur before the 2021 CfD auction round.

10.3. The most recent results from the BEIS CfD auction round, which showed developments in the North Sea prepared to develop 3GW of capacity at a strike price of £39.65 per MW, suggests that offshore wind may not need a contract-for-difference arrangement in the future, enabled instead with power-purchasing-agreements. These very recent developments suggest that a route-to-market for the Isle of Man offshore wind project may be possible outside the CfD framework. Whilst the national carbon account of the Isle of Man would **not** benefit from the export of green energy directly to the UK (as domestic carbon emissions cannot be 'offset' by such a transaction), the probability of the project going increases as a result of the economic competitiveness of the offshore wind energy market.

[3] These estimates are taken from the BVG Associates (2019) Guide to an offshore wind farm, January 2019. Published on behalf of The Crown Estate and the Offshore Renewable Energy Catapult. Available at: https://www.thecrownestate.co.uk/media/2860/guide-to-offshore-wind-farm-2019.pdf. Estimates presented in 1 GW developments are multiplied by 0.7 to represent the associated prices for 700 MW.

10.4. The annual spend into the local economy was estimated by the developer within the AfL bid. The details therein are commercially sensitive and not published in this report. If the power is exported to the UK, the emissions from the O&M will likely result in an increase in the Isle of Man's CO_2e account.

Multiple DC cables "Splitting the wind farm"

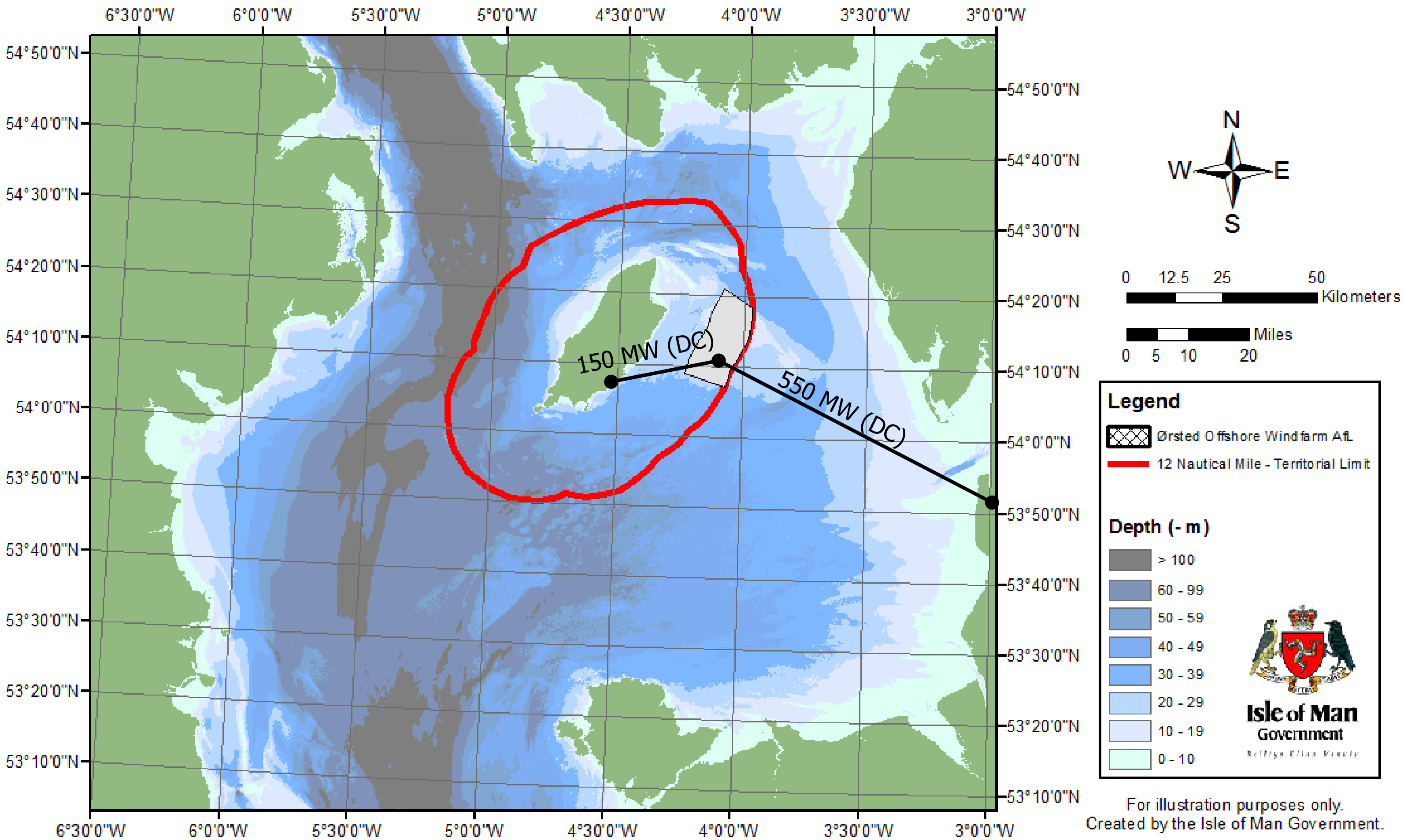


Figure 7. Infographic showing how a two separate power-purchasing agreements (PPAs) or CfD contracts may work for the Ørsted 'Isle of Man' project, exporting the majority of the electricity generated to the UK and importing some to the Isle of Man. Note: Arrows indicate the direction of power and do not illustrate cable route footprints.

Required public sector investment required: **up to £0.5 bn over 30 years** (gradual integration)

% of total IOM demand[1]	Annual MU Integration Costs[2]	Notes:
30%	£1.5M	Based on £12/MWh*
60%	£6.2M	Based on £25/MWh**
100%	£16.4M	Based on £40/MWh**

*Based on 2006 UKER study and price inflated to 2019 levels

**Assumes minimum mitigation from battery storage/load management/dynamic pricing

[1] The % of island demand met by connecting the Isle of Man transmission grid to the Ørsted wind farm.

[2] The annual integration costs are expected to be multi-decadal. The figures provided here are indicative only and a fully evaluated study on large-scale renewables is required to provide a full cost-estimate.

Private sector investment required (estimate): **£2.5 bn**

- Development: £ 84 m
- Turbines: £700 m
- Balance of plant: £420 m
- Installation: £455 m
- Decommission: £210 m
- Operation & Maintenance £52.5 per annum
- Interconnector (150 MW) £100m
- Interconnector (500 MW) £500m

Annual Economic benefits to Exchequer: **£4.4m**

- Seabed Lease: £2.4 m
- Exchequer: local spend £1.6 m
- Jobs: Income tax £0.3 m
- Jobs: National Insurance £0.1 m

Annual Spend into Local Economy **Commercially sensitive**

Potential net change to annual IOM CO_2e account: **199,000 t**

- Emissions from electricity/heat generation: 199,000 t

Timeline for generation: **Uncertain**

10.5. In the absence of a UK CfD, a power-purchasing-agreement (PPA) can provide a route to market for offshore energy projects to corporate buyers in the UK. Although corporate PPAs have not been readily adopted by offshore wind generation projects, they can be 15-25 years long in duration and incorporate sophisticated break-out clauses to factor major changes in wholesale energy markets, introduction of 'floor prices' after certain time-periods and co-ownership of revenue streams with a major 'anchor' customer.

10.6. It is feasible that the Manx Utilities Authority (MUA) could come to a long-term PPA agreement (25 yr) with Ørsted to buy some of the power generated by the offshore wind farm if Isle of Man Government policy required energy to be sourced from renewables (e.g. 30% - 100% of island demand met by offshore wind). Since estimated power output from the wind farm is approximately 8-times more electricity than the Isle of Man currently uses, a larger proportion of the energy could still be exported to the UK via the CfD mechanism. In the future, subject to susbtantial shifts in the economics of the UK electricity market, the export of energy to the UK from the wind farm could also be arranged with PPAs or simple merchant trading agreements.

10.7. If 21% of the turbines installed in the Ørsted 'Isle of Man' project (150 MW capacity) were connected to the Isle of Man electricity grid, the Isle of Man could service the total current electrical energy requirements (in theory). Surplus energy into the island could be stored and/or exported to the UK via interconnectors with additional capacity, particularly overnight when baseload island demand is around 30-40 MW.

10.8. Note that wind-power is not 'baseload' generation as is presently the case with the Pulrose CCGT power plant. The Isle of Man economy is structurally reliant on 24/7 guaranteed power due to significant energy demand profiles from sectors such as financial service, e-gaming, telecoms and precision aerospace engineering featuring in the energy demand profile. At present, the MUAs demand profile is typically 30 MW overnight with winter day-time peak loads of 80 MW.

10.9. Overcoming intermittency issues (see example data of intermittency in the Walney wind farm in Annex B) with wind power would require exisiting infrastructure to accommodate wind but also be able to generate enough power from stable and secure sources in 'island-mode'. Therefore significant reliance and investment will be necessary in long-term battery storage and electricity quality (frequency and voltage) control infrastructure. The level of investment required has been evaluated at a very high-level and requires further detailed technical and economic appraisal.

10.10. This scenario would require a public investment in the existing Isle of Man energy grid transmission infrastructure in order to manage the energy load from 150 MW of offshore energy.

10.11. Public investment in the windfarm could also be expected to make a dividend by claiming a minority ownership of the project. A minority stake in the project is forecasted to make a return on investment of 8-9% over the lifetime of the project, however the cost of investment is significant since the business model typically requires significant liquid capital to inject into the project after the initial risk has been undertaken by the developer.

10.12. This scenario still requires a change to secondary legislation in the UK to allow bids in the CfD auction from projects outside UK waters.

10.13. The greatest benefit is in terms of the Isle of Man's CO_2e account. Unlike scenario 1, which supplies renewable energy to the UK, the renewable energy into the island could offset carbon emissions from the electrial generation sector. The opportunities, barriers and costs to this electricity transition are discussed in more detail in the Annex of this report. This scenario incurs additional cost in the additional cost of an interconnector to the UK compared to scenario 1, which will be reflected in the strike price (LCOE) of the wind farm project, though this has not been determined by the developer.

One interconnector "Isle of Man as an offshore substation & exporter"

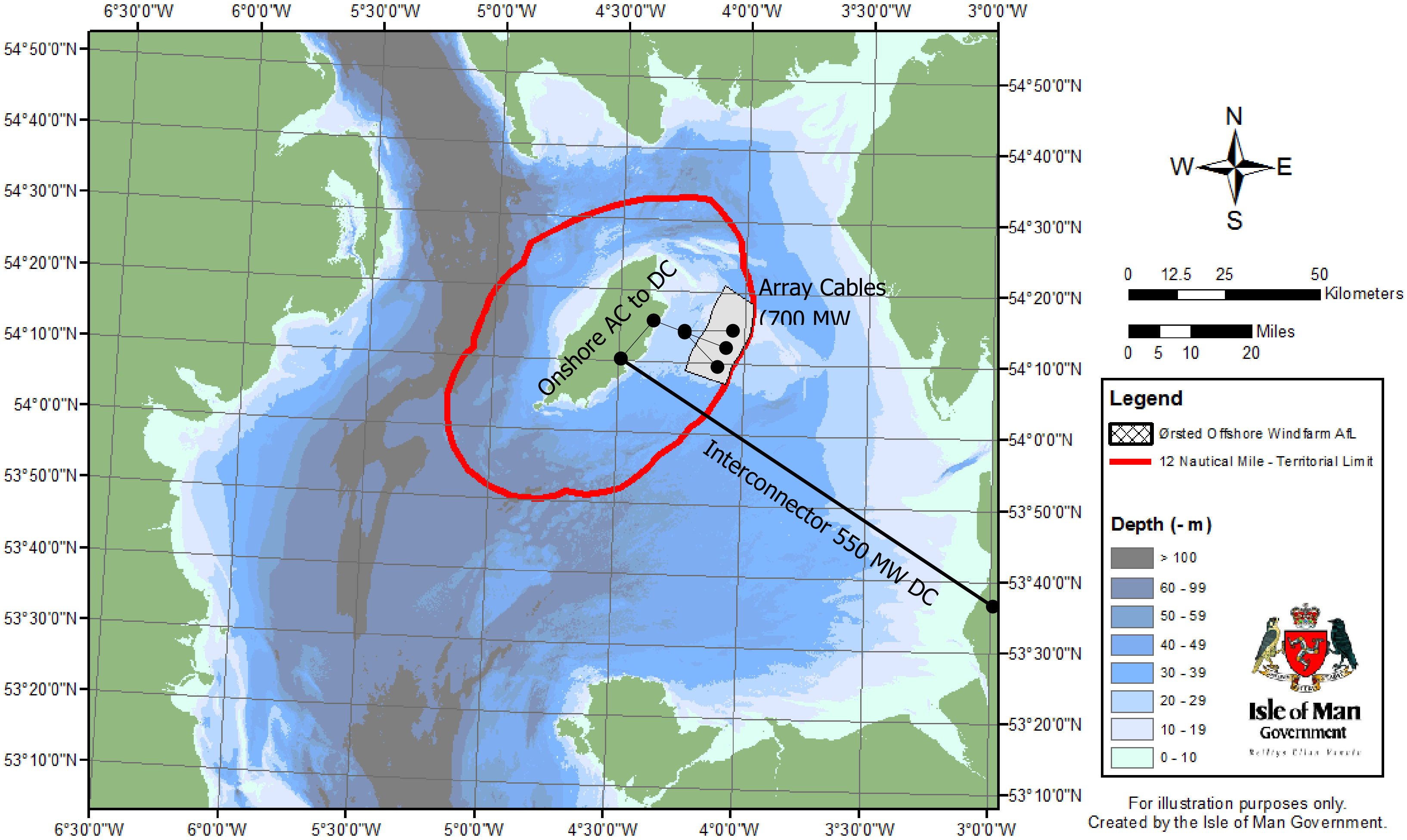


Figure 8. Infographic showing a third option for the Ørsted 'Isle of Man' project, with the wind farm connected to a large (>700 MW) interconnector between the Isle of Man to the UK. Note: Lines indicate the international interconnector links and do not illustrate cable route footprints.

Required public sector investment required: **up to £0.5 bn over 30 years** (gradual integration)

% of total IOM demand[1]	**Annual MU Integration Costs[2]**	**Notes:**
30%	£1.5M	Based on £12/MWh*
60%	£6.2M	Based on £25/MWh**
100%	£16.4M	Based on £40/MWh**

**Based on 2006 UKER study and price inflated to 2019 levels*
***Assumes minimum mitigation from battery storage/load management/dynamic pricing*
[1] The % of island demand met by connecting the Isle of Man transmission grid to the Ørsted wind farm.
[2] The annual integration costs are expected to be multi-decadal. The figures provided here are indicative only and a fully evaluated study on large-scale renewables is required to provide a full cost-estimate.

Private sector investment required (estimate):[3] **£2.4 bn**
Development: £ 84 m
Turbines: £700 m
Balance of plant: £420 m
Installation: £455 m
Decommission: £210 m
Operation & Maintenance £52.5 per annum
Additional interconnector £500 m
Annual Economic benefits to Exchequer: **£4.4 m**
Seabed Lease: £2.4 m
Exchequer: local spend £1.6 m
Jobs: Income tax £0.3 m
Jobs: National Insurance £0.1 m
Annual Spend into Local Economy **Commercially sensitive**

Potential net change to annual IOM CO_2e account: **301,000 t** (-36% Total 2018 Emissions)
Emissions from electricity/heat generations: 199,000 t
Car emissions: 99,000 t
Light Duty Vehicle emissions: 2,000 t
Motorcycle emissions: 1,000 t[4]
Certainty of development: **Medium**
Timeline for generation: **Uncertain**

10.14. This scenario brings all of the electrical power to the Isle of Man via an AC cable array, which will have multiple landing points (this may face significant planning barriers). The cable array will feed into an onshore AC to DC substation, where a

[4] Subject to the island taking increasing amounts of power from the wind farm that can be used to support the transition from internal combustion engines to EVs.

portion (150 MW) could be available for transmission into the Isle of Man grid. The remaining power could then be sold to the UK via an additional 550 MW DC interconnector. The export of up to 550 MW via an interconnector will still likely require a CfD from the UK Government for the generator, unless alternative PPA or merchant agreements can be arranged, which at present is said to be unlikely in the context of the UK electricity market.

10.15. This option has the added benefit compared to option 2 by allowing some flexibility, subject to grid reinforcements and upgrades, to take increasing amounts of power from the wind farm as the Isle of Man electrical demand grows. Additionally, a 550 MW interconnector to the Isle of Man can be used to import power in times of low generation when the island relies solely on renewables – this will be important as the existing interconnector becomes unable to support the high-demand electrical profile of the island as a backup. Hypothetically, as demand increases on the island and increasing amounts of power are drawn from the wind farm, the high capacity DC interconnector provides an opportunity for further development of renewable energy on the island in the future, such as tidal. Tidal development in Orkney, where global R&D of the technology is undertaken at the European Marine Energy Centre, is currently being limited by the capacity of the interconnector to the UK. When tidal energy becomes cost-effective (see tidal report), the additional asset of a high-capacity DC interconnector may be important in facilitating development.

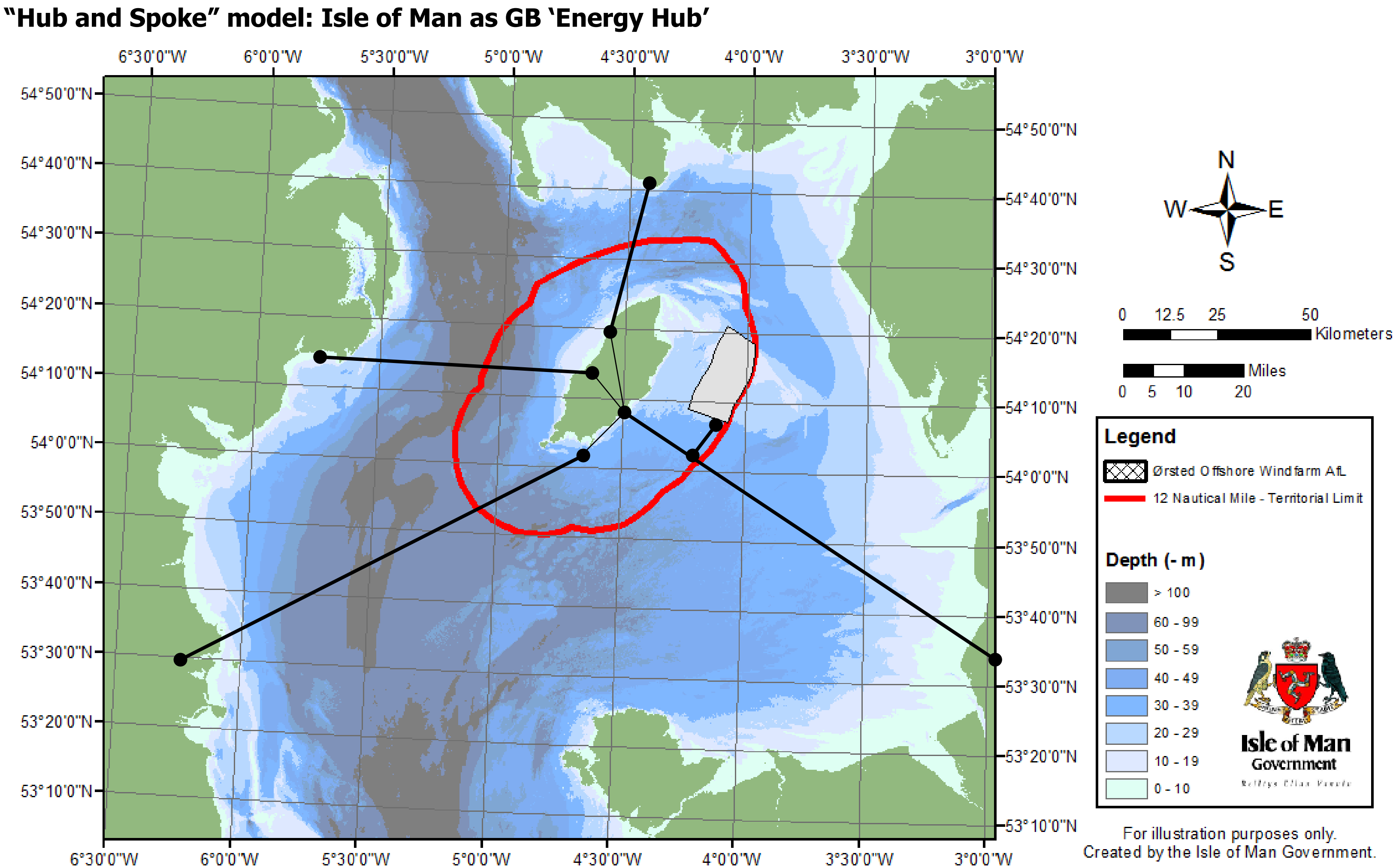


Figure 9. Infographic showing how a 'Hub and spoke' model may utilise the Isle of Man as a regional distributor of energy between Great Britain and Ireland via interconnectors in the Northern Irish Sea. Note: lines indicate international interconnector links and do not illustrate cable route footprints.

10.16. A fourth option is more conceptual and less island-centric. A multi-ended HVDC network, using the Isle of Man as a hub in the northern Irish Sea, which is optimised for future wind developments, has been previously explored to a small extent.

10.17. The benefits of a large-scale multi-ended HVDC network include:

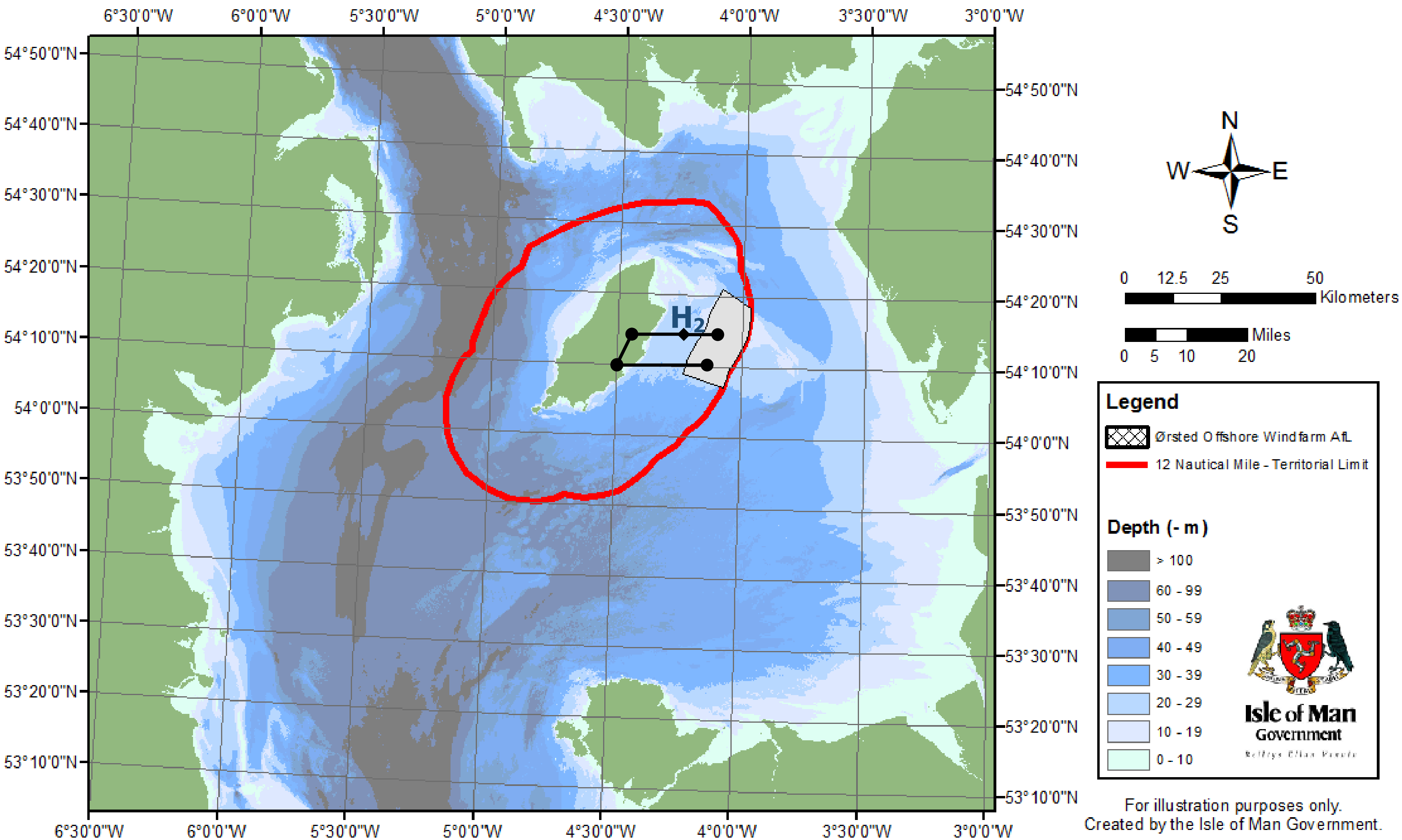
- Potential to provide an increased offshore wind bootstrap in the western Irish Sea
- Providing increased trading capacity between Ireland and GB
- Cost-optimised versus project-specific cable developments
- Increase in asset utilisation

10.18. The potential risks and challenges of this concept include:

- Increased stranding risk if all potential offshore projects do not proceed
- A fault on any of the converters / cables will result in a loss of all links until the fault is isolated
- More complex commercial arrangements required to underpin multi-purpose international projects
- More complex technology
- Commercial and technical solution required to manage largest feed-in loss as seen by the transmission system

10.19. The timeline for this option is uncertain as multi-jurisdictional and commercial arrangements would have to be extensively researched. The concept, whilst ultimately providing environmental and cost-optimising benefits, is potentially limited by the complexity of the proposal.

Ørsted-Gigastack. Hydrogen (H^2) production using windhydrogen



10.20. In August 2019, ITM Power, the energy storage and clean fuel company, announced that they had received funding from the UK Government BEIS for the 'Gigastack' feasibility study with Ørsted and Element Energy.

10.21. Gigastack, funded by the BEIS Hydrogen Supply Competition, aims to demonstrate the delivery of bulk, low cost and zero-carbon hydrogen (H_2) through gigawatt scale polymer electrolyte membrane (PEM) electrolysis. ITM have committed to:

- Development of a new 5MW stack module design to reduce material costs
- A new semi-automated manufacturing facility with an electrolyser capacity of up to 1GW / year to increase throughput and decrease labour costs (200 5MW units)
- Deployment of very large scale and low cost 100MW+ electrolyser systems using multiple 5MW units
- Innovations in the siting and operation of these large electrolysers to exploit synergies with large GW scale renewable energy projects

10.22. The deployment of PEM electrolysers on such a large scale has not been possible to date, as it requires low-cost stack modules which are easily integrated into larger electrolyser systems, and much larger automated manufacturing facilities (the largest electrolyser factories globally are capable of less than 30MW of capacity output per annum). ITM Power's proposed innovations in stack design and manufacturing techniques aims to address these issues and reduce the cost of installing an electrolyser such that the capital cost contribution to the eventual cost of hydrogen becomes less significant, being dominated by the cost of electricity.

10.23. Ørsted have committed to demonstrating the synergy between GW scale offshore wind energy deployments and hydrogen that will enable the continued decarbonisation through renewables and a continued cost out of offshore wind power projects.

10.24. Experts note hydrogen, the most abundant and lightest of elements, is odourless and nontoxic, and it has the highest energy content of common fuels by weight, which means it can be used as an energy carrier in a full range of applications, from power generation to transportation and industry. Though it is not found freely in nature and must be extracted (produced, or "reformed") via a separate energy source (such as power, heat, or light), the hydrogen industry is today well-established in sectors that use it as a feedstock. Increasingly, however, hydrogen is being considered the missing link in the energy transition as key technologies to produce it using renewable electricity, such as proton exchange membrane electrolysers and fuel cells, reach technical maturity and economies of scale.

10.25. Mitsubishi Hitachi Power Systems (MHPS) is currently piloting a project to convert one of three units at Vattenfall's 1.3-GW Magnum combined cycle plant in the Netherlands to renewable hydrogen by 2023. The project in Groningen, which entails modifying a 440-MW M701F gas turbine, will refine the combustion technology "to stay within the same NO_x envelope as a natural gas power plant but do it burning 100% hydrogen," without steam or water injection, which will likely be achieved "in the next decade", claims MHPS President and CEO Paul Browning.

10.26. Theoretically, the Isle of Man could adopt ITM H_2 Gigastack technology within the offshore wind farm development and import both electricity and hydrogen as zero-carbon fuel. The hydrogen could be used to run the Pulrose CCGT power station as well as in use in public transport. The quantities and costs of production relating to H2, which would be able to be produced from electricity from an offshore wind farm. The technology is in the very early stages of development, with a clearer picture of the state of technology and economic context being ~10 years away.

11. RECOMMENDATIONS

11.1. Isle of Man Government will to continue to encourage the UK government to amend secondary legislation so that Crown Dependencies can bid in the UK BEIS Contract for Difference support mechanism.

11.2. Maintain watching brief on floating wind turbines, which are expected to achieve cost-parity with monopile developments.

11.3. Conduct a full technical and economic appraisal of the options highlighted in this report with Ørsted, taking into account the immediate and forecasted electrical demand and generation potential of the Isle of Man.

11.4. Maintain watching brief on modular gigastack electrolysis technology coupled with offshore wind and explore the technical and economic feasibility of using hydrogen in the existing generating assets (CCGT) on the island.

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Annex A

1. INTEGRATING VARIABLE RENEWABLES INTO MANX UTILITIES ELECTRICITY SYSTEM

1.1. Manx Utilities – the Island's sole electricity supplier - currently operates as a vertically integrated utility with ownership of the full supply chain from generation to transmission to supply to the Isle of Man's domestic, commercial and Industrial customer sectors. It currently operates with a large 80MW natural gas-fired Combined Cycle Gas Turbine (CCGT) plant meeting the majority of the Island's electricity requirements with surplus power exported to the UK's electricity system on a daily basis via a marine AC 65MW interconnector to the UK. Additional generation support is provided by low sulphur gas oil fired diesel plant located at Douglas and Peel, SITA's Energy from Waste (EfW) plant and a hydro generation station at Sulby. Assuming the EfW plant is generating 'green' electricity, renewable energy presently represents c8% of net retail electricity sales.

1.2. During the last decade, a number of proposals for onshore wind and solar PV farms have been investigated by Manx Utilities but the economics of potential Power Price Agreements (PPA) with third party renewable developers have been discounted as they would have resulted in an increase in energy procurement costs. This would inevitably have resulted in higher electricity tariffs for commercial and industrial sectors on the Island and potentially have an onerous commercial impact on the sustainability of key and growing business sectors such as Finance, E-gaming and Aerospace manufacturing. This would reduce the Island's attractiveness and competitiveness to inward investment in the medium to long term and potentially reduce its future economic growth and excellent employment opportunities.

1.3. However the transition to a low carbon economy and eventually to the decentralisation of generation and the substitution of existing fossil-fuelled power plant with renewable alternatives will significantly influence future network planning and design standards. In addition the excellent quality and security of electricity supplies that the Island has benefitted from during the last two decades needs to be maintained as a priority. Going forward this consequently demands that there is sufficient back-up generation and/or large scale battery storage to ensure new intermittent generation source such a wind and solar PV can be cost effectively accommodated without compromising existing quality of electricity supplies on the Island.

1.4. The Isle of Man has the opportunity to procure variable renewable electricity from a potential 700MW offshore wind farm that could be commissioned by Ørsted by the middle of the next decade. Alternatively Manx Utilities could develop joint ventures to co-own a range of onshore wind and solar PV farm schemes at different locations across the Island.

1.5. It is assumed that decarbonising the electricity sector must be conducted cost – effectively to mitigate the risk of losing public acceptance and leading to substantial increases in power prices for industry, businesses and residents on the Isle of Man.

1.6. The levelised cost of generation from renewable energy technologies has declined in recent years to a position where wind and solar are equivalent to that of conventional fossil fuel and nuclear power in many parts of the world.

1.7. Although the cost of generation between these technologies maybe similar, they differ significantly when considering their ability to supply power on demand, with wind and solar having a problem with intermittency due to the nature of the technology. Therefore, these technologies require careful integration to enable reliable and cost effective interaction between renewables and other conventional generation or equivalent. When operating with a major interconnector to the UK, MU will need to minimise exposure to system imbalance prices when exporting as existing generation is considered base-load and therefore more predictable. Apart from potential significant reductions in the output of renewable generation, consideration will need to be also given to excess renewable generation when the Island electricity demand is low.

1.8. Calculating the cost of integrating renewables into the Manx Utilities grid requires the analysis of a variety of complicating factors; however two of the main factors are as follows:

- Grid Reinforcement Costs - wind and solar are generally located away from where the demand is the greatest, this means new transmission infrastructure will be required. This is less relevant for Islands because of their relative smaller size and where the highest electricity demands can be concentrated in just a few localised areas. However the lack of economies of scale and ready access to sufficient numbers of specialist engineers/technicians on an Island tends to accentuate both material and labour costs resulting in a degree of inflation of network reinforcement costs;
- System Integration Costs – costs relating to the interaction between new renewable power and existing conventional power generation, where the utilisation of existing plants is changed or reduced which can increase their specific generation costs. To maintain the resilience and reliability of electricity supplies, it will be necessary to pull back the maximum output from existing generation plant to provide sufficient levels of reserve capacity to cover the unexpected loss of renewable generation. In addition conventional plant can respond very quickly to variations in demand or renewable generation maintaining key security parameters such as system frequency within standard limits;

- **Factors reducing integration costs in the future –** significant reduction in average integration costs can be achieved by a number of factors including: widespread deployment of utility scale and behind-the-meter electrical battery storage as well as combining thermal storage with heat pumps; use of dynamic pricing structures with the rollout of smart meters to aggressively encourage off-peak electricity usage; demand management services via vehicle to grid/home technological advances and aggregator services providing demand side response.

1.9. The above costs are variable considering the quantity of renewable energy to be integrated, with the general rule of thumb the higher the amount of renewable energy the higher the integration costs. Note that surplus integration costs will be incurred due to spilling of excess renewable generation when output is greater than demand which is more likely to occur when renewables represent a larger percentage of the total overall generation mix. However as the levelised unit cost of renewables falls the monetary value of 'spilled' generation becomes less material and therefore does not require expensive incremental transmission to avoid. The increasing load factor of large offshore wind farms and more sophisticated smart predictive software will make the output of these renewable sources more certain.

2. INTEGRATION COSTS: [OFF SHORE WIND FARMS]

2.1. The tabled figures of the network reinforcement costs for integrating different ranges of renewable generation are based on a number of historic studies carried out in the UK and EU by reputable consultancies and universities. Some additional adjustments are made to reflect the MU position to incorporate the underlying cost multiplication factor for Islands due to lack of economies of scale and maintaining existing high levels of security standards on the Isle of Man. Depending on the speed of decarbonisation, these network integration costs could be even higher if other load management technologies have not developed at the same rate.

% of total IOM demand[1]	**Annual MU Integration Costs[2]**	**Notes:**
30%	£1.5M	Based on £12/MWh*
60%	£6.2M	Based on £25/MWh**
100%	£16.4M	Based on £40/MWh**

**Based on 2006 UKER study and price inflated to 2019 levels*

***Assumes minimum mitigation from battery storage/load management/dynamic pricing*

[1] The % of island demand met by connecting the Isle of Man transmission grid to the Ørsted wind farm.

[2] The annual integration costs are expected to be multi-decadal. The figures provided here are indicative only and a fully evaluated study on large-scale renewables is required to provide a full cost-estimate.

3. FUTURE CHALLENGES AND OPPORTUNITIES

3.1. Maintaining network system integrity will become more paramount as we transition to a digital economy with increasing levels of artificial intelligence, smart grids and IoT sensors in homes and businesses. Therefore system parameters traditionally provided by thermal plant such as frequency regulation, voltage management and system inertia will need to be provided by other flexible plant and devices such as flywheels, synchronous condensers, etc. However this is counterbalanced by new vehicle to grid developments in EV batteries, collective load control of heat pumps and domestic battery storage allowing DC operation of key devices in the home at winter peaks and consequently alleviating electricity peak demands and delaying the need for network reinforcement.

3.2. In the future renewable technologies will incorporate the ability to deliver ancillary services to the grid such as fast frequency response, reactive power for voltage support and inertia control.

Annex B

1. WALNEY (367.5 MW) OFFSHORE WIND FARM GENERATION OUTPUT MAY 2019 (RED) AGAINST ISLAND ELECTRIC DEMAND (BLUE)