Final report: Offshore grid delivery models for Ireland

Options paper for offshore wind

Submitted by:
Sil Boeve, Barry Vree, Carmen Wouters, Lennard Sijtsma, Ainhoa Villar Lejarreta, Anna Pulo and Wolfgang Schlez
Navigant Netherlands B.V.
Stadsplateau 15
3521 AZ Utrecht
The Netherlands

030 662 3300
navigant.com

Reference No.: 210668
ORDER NO: EIR-010347
31 March 2020

DISCLAIMER

This report (“report”) was prepared by Navigant Netherlands B.V. (Navigant)[1] and is protected by copyright. Navigant’s conclusions are the results of the exercise of its reasonable professional judgment and the information available at the time this report was prepared. The reader hereby agrees and acknowledges he is bound by the disclaimers and/or limitations on liability set forth in the report. Navigant does not make any representations or warranties of any kind with respect to (i) the accuracy or completeness of the information contained in the report, (ii) the presence or absence of any errors or omissions contained in the report, (iii) any work performed by Navigant in connection with or using the report, or (iv) any conclusions reached by Navigant as a result of the report. Any use of or reliance on the report, or decisions to be made based on it, are the reader’s responsibility. Navigant accepts no duty of care or liability of any kind whatsoever to you, and all parties waive and release Navigant from all claims, liabilities and damages, if any, suffered as a result of decisions made, or not made, or actions taken, or not taken, based on this report.

[1] On October 11, 2019, Guidehouse LLP completed its previously announced acquisition of Navigant Consulting Inc. In the months ahead, we will be working to integrate the Guidehouse and Navigant businesses. In furtherance of that effort, we recently renamed Navigant Consulting Inc. as Guidehouse Inc.

DEVELOPING AN OFFSHORE GRID DELIVERY MODEL FOR IRELAND – KEY MESSAGES

Ireland has ambitious climate targets towards 2030, including the addition of at least 3.5 GW of offshore wind capacity as stated in the Climate Action Plan (CAP) and supported by a Renewable Energy Support Scheme (RESS). Criteria have been identified to define "Relevant Projects" from the large pipeline of offshore wind projects in Ireland to be included in a transitional scheme to facilitate a fast build-out of offshore wind.

A suitable grid delivery model needs to be adopted to develop the targeted offshore wind capacity in Ireland. Navigant carried out a comprehensive review of international approaches and developed four delivery model options that are tailored to the Irish context. The two main classes of grid delivery models in the international context are plan-led and developer-led models[2], representing both ends of a spectrum of model options:

Developer-led model	Plan-led model
Developers prepare the requirements for consents, select and pre-develop wind farm sites and develop and build both offshore wind farm and transmission assets (offshore substation, export cables and onshore connection assets). This model is applied in e.g. the United Kingdom.	A State Body and/or the TSO is the responsible party for the complete process of wind farm site selection and pre-development and offshore grid connection development. This model is applied in e.g. the Netherlands.

Source: Navigant.

Seven key drivers in Ireland impact the model design. These drivers include cost levels, environmental impact, future proofing of policies and technologies, required infrastructure, compatibility with Relevant Projects, social acceptance and timely achievement of the 2030 targets.

Four enduring grid delivery models tailored to the Irish context were assessed, ranging from a fully developer-led model to a fully plan-led model. The models represent a set of options, each with their advantages and disadvantages, to indicate a spectrum of options fit for the Irish context. The constituent elements of the four models presented could be combined in a variety of ways to form a wide range of additional model options. It follows that the model option or options ultimately chosen will not necessarily be set out in the report and could contain elements of two or more options. A brief description of these grid delivery models is as follows:

Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Fully developer-led grid delivery model	State defines minimum distance from shore for wind farms, as well as onshore grid connection points and available onshore grid capacity for RESS auctions; EirGrid pro-actively plans and coordinates onshore grid reinforcements	Developers responsible for offshore wind farm transmission asset construction, ownership, operation and maintenance in plan-led model	Fully plan-led grid delivery model

Source: Navigant.

The advantages of the developer-led model include compatibility with the Relevant Projects that can be developed quickly and that are more likely to be compatible with existing legislative and policy frameworks and leveraging existing developer experience in the delivery of offshore wind farms. The disadvantages include minimal onshore-offshore transmission asset coordination, the likelihood that any public acceptance campaign will be focused on a single project rather than multiple projects, greater risk of additional infrastructure with associated environmental

[2] Plan-led and developer-led can also be referred to as centralised and decentralised grid delivery models, respectively.

impact and more complexity involved in future proofing of offshore transmission assets. Option 2 provides mitigation to some of these disadvantages compared to option 1.

The advantages of the plan-led model include long-term onshore-offshore transmission coordination with the potential for reduced infrastructure, the ability to craft a coordinated public acceptance process covering multiple projects and ease of future proofing of technology. The disadvantages include the time needed to develop new governmental capabilities, and policy, regulatory, licence and legislative frameworks which are likely required, challenges with state bodies simultaneously developing multiple offshore and onshore renewable energy and transmission projects, and incompatibility with Relevant Projects. Option 3 gives developers control of the construction of both the offshore wind farm and transmission assets, reducing potential risks as perceived by the offshore wind industry.

A transition towards a more plan-led model option (3 or 4) could offer a pathway to leverage the timing advantages of more developer-led models in the short term and allows greater coordination of onshore-offshore grid development in the medium to long-term. As always, the overall suitability of each model option in the Irish context highly depends on the emphasis and relative weighting of certain criteria to reflect key stakeholder interests.

It is important that a timely decision is made to determine which grid delivery model will be adopted in Ireland, to ensure preparations for this model can commence in time such that the 2030 renewable targets are achievable.

EXECUTIVE SUMMARY

Ongoing developments Ireland

Ireland has ambitious climate targets towards 2030, including the addition of at least 3.5 GW of offshore wind capacity as stated in the Climate Action Plan (CAP) and supported by a Renewable Energy Support Scheme (RESS). Criteria for "Relevant Projects" have been defined to qualify some projects from the large pipeline of offshore wind projects in Ireland to be included in a transitional scheme to facilitate a fast build-out of offshore wind.

To support the roll-out of offshore wind capacity, various developments are ongoing in Ireland that are relevant for the choice of grid delivery model for offshore wind:

- A Climate Action Plan has been developed with ambitious targets of achieving at least 3.5 GW of offshore wind capacity in 2030; currently only 25 MW is operational;
- The RESS support scheme is under development with multiple auction rounds planned by 2030. The RESS 1 design foresees a technology-neutral auction scheme (except for the solar preference category) in which offshore wind competes against other technologies. Future RESS rounds are expected to offer offshore wind specific support, as outlined in the CAP;
- An update in marine spatial planning is being conducted with the development of the National Marine Planning Framework (NMPF) and Marine Planning and Development Management (MPDM) Bill, which will impact marine spatial planning and the consenting process for offshore wind developments. These updates are compatible with both a plan-led and developer-led grid delivery model;
- Several legacy offshore wind projects in Ireland have progressed further in development than others by e.g. acquiring a lease or grid connection offer. The Department of Housing, Planning and Local Government (DHPLG) together with the Department of Communications, Climate Action and Environment (DCCAE) has defined criteria to qualify some of these as Relevant Projects, which can continue their development under a "transition protocol" prior to enactment of the MPDM Bill;
- The current onshore transmission grid could potentially integrate ~1.5 GW[3] of offshore wind capacity on the Irish East Coast without any significant transmission capacity expansion but would require additional onshore grid reinforcements with significant lead times to integrate the targeted 3.5 GW of offshore wind.

Offshore wind grid delivery models

A suitable grid delivery model should be adopted to facilitate the build-out of offshore wind in Ireland in order to meet the target of at least 3.5 GW by 2030. Navigant carried out a comprehensive review of international approaches and developed four delivery model options that are tailored to the Irish context.

The two main classes of grid delivery models in the international context are plan-led and developer-led models[4], representing both ends of a spectrum of model options:

[3] This is based on a high-level assessment of cumulative available capacity informed by the East Coast Study – more detailed analysis would be required to more accurately assess this figure.

[4] Plan-led and developer-led can also be referred to as centralised and decentralised grid delivery models, respectively.

Developer-led model	Plan-led model
Developers prepare the requirements for consents, select and pre-develop wind farm sites and develop and build both offshore wind farm and transmission assets (offshore substation, export cables and onshore connection assets). This model is applied in e.g. the United Kingdom.	A State Body and/or the TSO is the responsible party for the complete process of wind farm site selection and pre-development and offshore grid connection development. This model is applied in e.g. the Netherlands.

Source: Navigant.

Figure 1 illustrates the roles and responsibilities within the spectrum of grid delivery models across North-Western Europe. Ownership, operation and maintenance of the offshore wind transmission assets is under all models the responsibility of the party constructing them, with the exception of the UK where the ownership and maintenance is the responsibility of an OFTO and the operation the responsibility of the TSO.

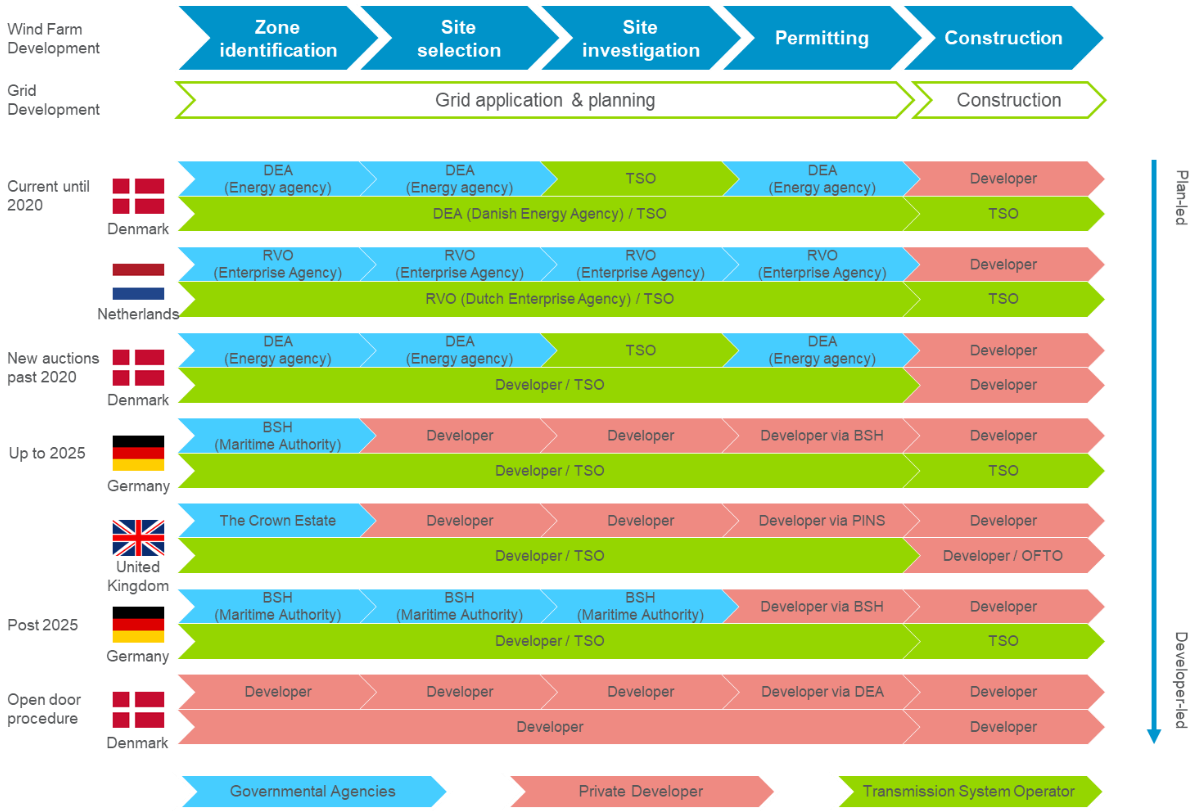


Figure 1. Allocation of roles and responsibilities within the grid delivery models across North-Western Europe. *Source: adapted from WindEurope, 2019.*[5]

The Climate Action Plan specified that an Options Paper on Offshore Grid Models be developed on the Framework for Offshore Electricity Grid to support the decision regarding a suitable enduring model option for Ireland. This report assessed the performance of the main grid delivery models in comparison to each other and tailored the models to the Irish context to support the development of at least 3.5 GW of offshore wind over the coming decade and the development of offshore wind in the longer term.

[5] Wind Europe, 2019. Industry position on how offshore grids should develop. https://windeurope.org/wp-content/uploads/files/policy/position-papers/WindEurope-Industry-position-on-how-offshore-grids-should-develop.pdf

In a first step, the two main grid delivery models were analysed based on economic/financial, technical, regulatory/policy and international parameters. Subsequently, they were assessed against seven key drivers in the Irish context.

These seven key drivers, which impact the choice of model, include: cost levels, environmental impact, future proofing of policies and technologies, required infrastructure, compatibility with Relevant Projects, social acceptance and facilitating the timely development of offshore wind capacity to achieve the 2030 targets.[6] It should be noted that this report does not apply any weighting to the various drivers – clearly appropriate weighting would be key to any policy decision on the choice of model.

Next to the ongoing developments in the Irish context, several key stakeholders (EirGrid, DCCAE, CRU, ESB Networks[7] and offshore wind industry representatives) were interviewed to identify and understand the key drivers that might impact the expected performance and resulting choice for a more developer-led or more plan-led grid delivery model for offshore wind.

Model options for Ireland

Based on the analysis, four enduring grid delivery models for Ireland are assessed ranging from a fully developer-led model to a fully plan-led model. The models represent a set of options, each with their advantages and disadvantages, to indicate a spectrum of options fit for the Irish context. The constituent elements of the four models presented could be combined in a variety of ways to form a wide range of additional model options. It follows that the model option or options ultimately chosen will not necessarily be set out in the report and could contain elements of two or more options. A brief description of these grid delivery models is as follows:

Option 1. Developer-led	**Option 2. Plan-defined, developer consents and builds**	**Option 3. Plan-led, developer builds**	**Option 4. Plan-led**
Fully developer-led grid delivery model	State defines minimum distance from shore for wind farms, as well as grid connection points and available onshore grid capacity for RESS auctions; EirGrid pro-actively plans and coordinates onshore grid reinforcements	Developers responsible for offshore wind farm transmission asset construction, ownership, operation and maintenance in plan-led model	Fully plan-led grid delivery model

Source: Navigant.

Figure 2 details the grid delivery model options assessed for Ireland following the phases of a project timeline:

[6] This includes consistency with existing and proposed legislation/regulations.

[7] ESB Group comprises various separate, ring-fenced, regulated businesses. For ease of reference, in this report we collectively use the term “ESB Networks” to describe the ESB licensed Distribution System Owner (referred to as the Distribution Asset Owner or “DAO”) and the ESB licensed Transmission System Owner (referred to as the Transmission Asset Owner or “TAO”) functions, both of which are operated through the ring-fenced ESB Networks business unit.

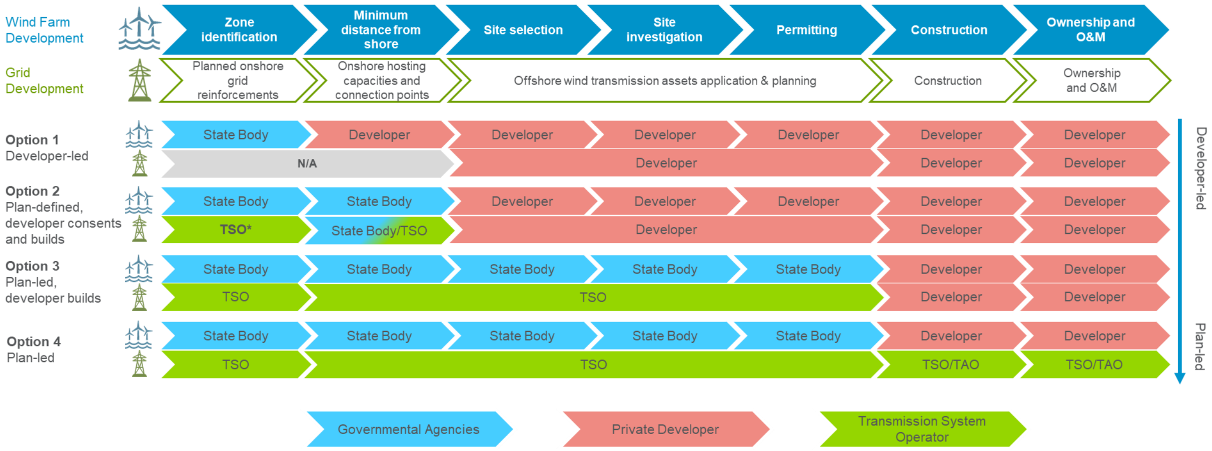


Figure 2. Grid delivery model options for Ireland following the phases of a project timeline.
* In option 2 the TSO will pro-actively plan and communicate the timeline for onshore grid reinforcements early in the development process. *Source: Navigant.*

Option 1, developer-led, presents the full developer-led model as a variation on the current "onshore" grid delivery model. Developers have the responsibility for offshore wind farm site selection and pre-development, and – following successful participation in an auction – development of the wind farm and offshore wind farm transmission assets. Developers are responsible for securing the required consents, financing, construction and operation and maintenance of both wind farm and transmission assets. The grid connection point lies onshore. Required onshore grid reinforcements are undertaken by EirGrid and ESB Networks in a reactive manner based on the announcement of the successful projects.

Option 2, plan-defined, developer consents and builds, the State defines a minimum distance from the wind farm to shore to enhance public support for offshore wind developments. In addition, EirGrid pro-actively plans and coordinates onshore grid reinforcements and for each RESS auction, identifies the locations, capacities and timelines for the onshore connection points. In this way EirGrid can optimise the upgrades of the onshore grid such that the connection capacity to meet the CAP targets is made available in a timely manner. The developer remains responsible for site selection and pre-development, and the consenting and construction of the offshore wind farm transmission assets.

Options 3 and 4 adopt a more central offshore planning and coordination approach by shifting responsibilities from the developers to a State Body and EirGrid / ESB Networks. A single State Body for ORE developments will manage the planning and the site pre-development processes for offshore wind farms. Planning of onshore grid reinforcements and offshore developments could be optimised, and shared asset development[8] could be prescribed for offshore wind farm sites, where appropriate.

Under **Option 3, plan-led, developer builds,** the developer winning the auction for a pre-developed site receives the responsibility for construction, financing and operation and maintenance of both the wind farm and offshore wind transmission assets.

Option 4, plan-led, follows the fully plan-led model, shifting even more responsibilities to EirGrid and ESB Networks compared to option 3. Alongside site (pre-)development, the construction, ownership, operation and maintenance of the offshore wind transmission assets are now centrally planned by EirGrid and ESB Networks.

A common set of assumptions underpins all four options**:**

- A Government auction scheme is in place specific to offshore wind but with a different auction design depending on the grid delivery model; an auction amongst wind farm sites that are

[8] If shared assets are adopted under this model, issues might arise due to unbundling requirements (Directive on common rules for the internal market for electricity (EU) 2019/944) that restrict generation and operation by a single party, in this case the developers. The ownership and operation of shared assets may then have to fall under the responsibility of the TAO/TSO.

pre-developed by developers for options 1 and 2, and a site-specific auction for sites pre-developed by a State Body for options 3 and 4;

- EirGrid chooses the onshore connection point and defines the connection method (note that the extent of connection method specification (e.g. the cable route) differs between the model options);
- EirGrid and ESB Networks design and build onshore grid reinforcements and costs are recovered through network tariffs;
- Zones are large areas, and typically include several sites (e.g. the Irish East Coast area could be one zone);
- All offshore assets are built to TSO transmission standards and compliant with Grid Codes (i.e. minimal standards must be met) with appropriate oversight by TSO/TAO;
- Whoever builds the transmission assets organises financing;
- Connection charging policy will follow the onshore model;
- EirGrid can seek to transfer grid connection ownership to the TAO in any option where the developer builds the asset; This would need to appropriately balance ownership of risk and cost of risk;
- Under option 4, current outturn availability rules are assumed to apply for offshore wind transmission assets where the developer bears the responsibility for a defined period in case the offshore wind transmission assets owned by ESB Networks and operated by EirGrid experience an outage.[9] Under options 1, 2 and 3 the offshore wind transmission assets are owned and operated[8] by the developer, who manages and bears the risk of outages to its transmission assets;
- Currently no compensation from EirGrid or ESB Networks to developers is defined under the first competition of the RESS scheme (RESS 1) for delayed delivery of either onshore or offshore grid connections. Because this is out of the control of the developers for options 1, 2 and 3 (onshore grid reinforcements) and option 4 (onshore grid reinforcements and offshore grid connection), this poses a risk from the developer's perspective. To address this risk of delayed delivery, developer compensation arrangements could be included in offshore RESS competitions, similar to e.g. the Netherlands.[10]

Table 1 presents the responsible parties for each project phase per option.

[9] EirGrid, 2017. The EirGrid and SONI Implementation Approach to the SEM Committee Decision Paper SEM-15-071. http://www.eirgridgroup.com/site-files/library/EirGrid/The-EirGrid-and-SONI-Implementation-Approach-to-the-SEM-Committee-Decision-Paper-SEM-15-071-Version-2.pdf

[10] TenneT, 2020. Compensatieregeling. https://www.netopzee.eu/borssele/zo-werkt-de-netaansluiting-borssele/compensatieregeling

Table 1. Overview of responsibilities for the four model options assessed for Ireland.

Project phase	Responsibility	Description	Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Pre-development	**Zone selection**	Selection of location of offshore zone wherein wind farm sites (including transmission assets) could be developed as well as identification and appointment of exclusion zones (e.g. military, shipping, fishing etc.)	DHPLG/ DCCAE	DHPLG/ DCCAE	DHPLG/ DCCAE	DHPLG/ DCCAE
	Site selection	Selection of location of offshore wind farm site (including transmission assets) within the selected offshore zone	Developer	Developer	State Body	State Body
	Timing wind farm roll-out	Timing of wind farm site development (roll-out plan)	Developer	Developer	State Body	State Body
	Offshore wind farm trans-mission asset planning	Timing of offshore wind transmission asset development	Developer	Developer	EirGrid	EirGrid
Development	**Wind farm consents – application**	Consents for the offshore wind farm site (including surveys, wind resource and environmental assessments, and any required leases or licences)	Developer	Developer	State Body	State Body
	Offshore wind farm trans-mission asset consents – application	Consents for the offshore wind transmission assets (including environmental assessment and any required leases or licences)	Developer	Developer	EirGrid	EirGrid
	Financing	Financing of offshore wind transmission assets	Developer	Developer	Developer	ESB Networks
	Final selection of onshore grid connection point	Final decision on onshore grid connection point	EirGrid	EirGrid	EirGrid	EirGrid
	Functional design offshore transmission assets	High-level design of the functional requirements and specs of transmission assets beyond grid codes and applicable standards (e.g. voltage level, capacity, cable corridor, offshore substation location, landing points, shared assets if applicable[8]…)	Developer	EirGrid and Developer	EirGrid and ESB Networks	EirGrid and ESB Networks
Construction	**Detailed design offshore wind transmission assets**	Detailed design of offshore wind transmission assets (e.g. full technical definition of transmission assets, installation methodology, construction timeline etc.)	Developer	Developer	Developer	EirGrid and ESB Networks
	Offshore wind transmission asset construction	Construction and commissioning of transmission assets	Developer	Developer	Developer	ESB Networks

Project phase	Responsibility	Description	Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
O&M	**Ownership and maintenance**	Ownership and maintenance of offshore wind transmission assets (including decommissioning)	Developer[8]	Developer[8]	Developer[8]	ESB Networks
	Operation	Operation of offshore wind transmission assets	Developer[8]	Developer[8]	Developer[8]	EirGrid
Onshore grid reinforcements	**Responsibility onshore grid reinforcement**	Planning, specification, consenting (EirGrid) and construction (ESB Networks) of required reinforcements in the onshore grid to facilitate the infeed of offshore wind energy	ESB Networks/ EirGrid Reactive	ESB Networks/ EirGrid Pro-Active	ESB Networks/ EirGrid Pro-Active	ESB Networks/ EirGrid Pro-Active
Auction design	**Auction type**		Amongst sites	Amongst sites	Site-specific	Site-specific
	Definition of offshore capacity in RESS auctions		DCCAE	DCCAE	DCCAE	DCCAE
	Selection and definitions of onshore connection points (stations, capacity, timing) for RESS auctions		N/A	EirGrid and DCCAE	EirGrid and DCCAE	EirGrid and DCCAE
Ownership boundary	Ownership boundary assuming assets do not transfer to TAO in options 1, 2 and 3		Onshore	Onshore	Onshore	Offshore

Note that offshore wind farm transmission assets include the offshore substation, export cables and onshore connection assets.
Source: Navigant.

Pros and cons of grid delivery models assessed

Mapping the advantages and disadvantages of each model option assessed shows that in the longer term, options 3 and 4 have specific advantages and a lower risk profile compared to options 1 and 2. It should be noted that these advantages, disadvantages and risks have not been weighted in this report – clearly this would be key to any policy decision on the optimum model for Ireland.

The advantages of the **developer-led model** include compatibility with the Relevant Projects that can be developed quickly and that are more likely to be compatible with existing legislative and policy frameworks and leveraging existing developer experience in the delivery of offshore wind farms. The disadvantages include minimal onshore-offshore transmission asset coordination, the likelihood that any public acceptance campaign will be focused on a single project rather than multiple projects, greater risk of additional infrastructure with associated environmental impact and more complexity involved in future proofing of offshore transmission assets. Option 2 provides mitigation to some of these disadvantages compared to option 1.

The advantages of the **plan-led model** include long-term onshore-offshore transmission coordination with the potential for reduced infrastructure, the ability to craft a coordinated public acceptance process covering multiple projects and ease of future proofing of technology. The disadvantages include the time needed to develop new governmental capabilities, policy, regulatory, licence and legislative frameworks which are likely required, challenges with state bodies simultaneously developing multiple offshore and onshore renewable energy and transmission projects and incompatibility with Relevant Projects. Option 3 gives developers control of the construction of both the offshore wind farm and transmission assets, reducing potential risks as perceived by the offshore wind industry.

Figure 3 summarises the advantages and disadvantages of the grid delivery model options assessed for Ireland.

<table>
<tr><th>Key drivers</th><th></th><th>Option 1
Developer-led</th><th>Option 2
Plan-defined, developer consents and builds</th><th>Option 3
Plan-defined, developer builds</th><th>Option 4
Plan-led</th></tr>
<tr><td rowspan="5">Cost</td><td rowspan="3">+</td><td colspan="2">Competitive pressure can reduce cost levels transmission assets
No sunken costs associated with Relevant Projects</td><td colspan="2">Optimised transmission asset costs through standardised and holistic planning, and synergies
Optimised cost for onshore grid reinforcements through effective coordination of on- and offshore asset developments
Central pre-development and de-risking of offshore wind sites</td></tr>
<tr><td rowspan="2"></td><td>Potential cost upside due to pro-active onshore grid reinforcement</td><td></td><td>Further optimisation of transmission costs through economies of scale on programme level</td></tr>
<tr><td colspan="3">Potential upside from economies of scale on a project level through hubs and shared infrastructure</td></tr>
<tr><td rowspan="2">-</td><td>Suboptimal costs onshore grid reinforcements through misalignment on- and offshore developments</td><td>Less optimal onshore grid co-ordination with offshore wind capacity compared to options 3 and 4</td><td rowspan="2"></td><td rowspan="2">State exposed to compensating developers for lost revenue in event of fault on offshore transmission connection</td></tr>
<tr><td colspan="2">Sunken costs for pre-development of sites unsuccessful in auction</td></tr>
<tr><td rowspan="2">Environ-ment</td><td>+</td><td></td><td>More optimal onshore-offshore grid coordination compared to option 1 by definition of grid connection point with potential to reduce environmental impact</td><td colspan="2">Lower cumulative environmental impact by coordinating onshore-offshore transmission works, minimising the need for new transmission infrastructure</td></tr>
<tr><td>-</td><td colspan="2">Limited potential to take onshore-offshore transmission asset coordination into consideration resulting in greater environmental impact due to potential need for more transmission infrastructure</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Future proofing</td><td>+</td><td></td><td>Potential upside as EirGrid can specify technologies and connection methods including shared assets</td><td colspan="2">High potential for future-proofing of technology and shared assets due to long planning horizon and societal incentives of State Body
Potential to adopt innovative technologies if not yet cost-effective</td></tr>
<tr><td>-</td><td colspan="2">Limited developer incentive for future-proofing of technology
Only cost-effective technologies and incremental innovations</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Infra-struc-ture</td><td rowspan="2">+</td><td colspan="3">Leverages developer experience and expertise in delivery of offshore infrastructure
Less complex onshore interface
One party (developer) for development, construction and O&M windfarm and transmission assets</td><td>Leverages experience of EirGrid and ESB Networks with delivery of offshore infrastructure</td></tr>
<tr><td></td><td>Increased on- and offshore grid coordination compared to option 1 through pro-active planning and communication of onshore development timeline and alignment with RESS auctions</td><td colspan="2">Long-term planning horizon allows to coordinate and optimise on- and offshore developments and between ORE projects
Reduced procedural complexity with limited stakeholders in consenting process</td></tr>
<tr><td rowspan="2">-</td><td>No coordination and optimisation on- and offshore grid and across ORE projects</td><td>Less coordination potential and optimisation of on- and offshore grid and across ORE projects compared to options 3 and 4</td><td colspan="2">Planning phase by new State Body for ORE development could introduce bottleneck since multiple large-scale projects with similar timelines being developed by a small number of bodies</td></tr>
<tr><td colspan="2">Procedural complexity with more stakeholders and potentially more projects in consenting process grid and across ORE projects</td><td></td><td>Developers perceive a risk as they do not have control of site pre-development and offshore wind transmission infrastructure development
More complex offshore interface</td></tr>
<tr><td rowspan="2">Relevant projects</td><td>+</td><td colspan="2">Compatible with Relevant Projects, and leverages work already completed by developers on Relevant Projects</td><td colspan="2"></td></tr>
<tr><td>-</td><td colspan="2"></td><td colspan="2">Incompatible with Relevant Projects</td></tr>
<tr><td rowspan="3">Social accep-tance</td><td rowspan="2">+</td><td></td><td colspan="3">Prescription of minimal distances from shore</td></tr>
<tr><td colspan="2">Targeted and specific campaigns have the potential to improve social acceptance of some projects</td><td colspan="2">Central public acceptance campaign
Coordination of sites and minimisation of landing points and visibility to increase public acceptance</td></tr>
<tr><td>-</td><td colspan="2">Social acceptance campaign on project-by-project basis</td><td colspan="2">Offshore wind farm developers less likely to be supportive of plan-led model</td></tr>
<tr><td rowspan="3">Timing</td><td>+</td><td colspan="2">Relevant Projects can be developed quickly to commence offshore wind developments in the short-term, leveraging work already completed by developers providing a programme advantage</td><td colspan="2">Controlled and coordinated onshore-offshore transmission asset roll-out plan to timely achieve targets</td></tr>
<tr><td rowspan="2">-</td><td rowspan="2">No control and coordination of onshore-offshore transmission assets roll-out to achieve targets</td><td rowspan="2">Proactive planning of programme for onshore capacity and auctions but less coordination of offshore wind roll-out compared to options 3 and 4</td><td></td><td>Capacity needs to be built up in EirGrid and ESB Networks</td></tr>
<tr><td colspan="2">Transitioning to a plan-led model takes time to develop new governmental capabilities, and policy, regulatory, licence and legislative frameworks, which are likely required
Challenges with state bodies simultaneously developing multiple ORE projects</td></tr>
</table>

Figure 3. Pros and cons of grid delivery model options for key drivers in Ireland. The pros and cons have not been weighted – clearly this would be key to any policy decision.
Source: Navigant.

Developing an offshore grid delivery model for Ireland

A transition towards an enduring grid delivery model would be required to leverage the development of the Relevant Projects in the short term and to implement any required regulatory, policy and legislative changes.

A transition towards option 1 would require limited actions but has a higher risk of misalignment between onshore and offshore developments. A transition to option 2 increases the onshore and offshore coordination and requires action by EirGrid to assess in detail the availability of onshore capacity and align this with auctions. A transition to options 3 and 4 would require significant changes and actions that would need to be implemented as soon as possible but ensures onshore and offshore developments are fully aligned. The overall suitability of each model option in the Irish context highly depends on the emphasis and relative weighting of certain criteria to reflect key stakeholder perspectives.

A possible high-level roadmap with key actions and milestones towards 2030 for options 1 and 2 is given in Figure 4. Significant uncertainty remains regarding the timing and duration of the actions as some are sequentially dependent (e.g. assessment, planning and construction of onshore grid reinforcements). The actions to transition from the current "onshore" model to options 1 and 2 are limited.

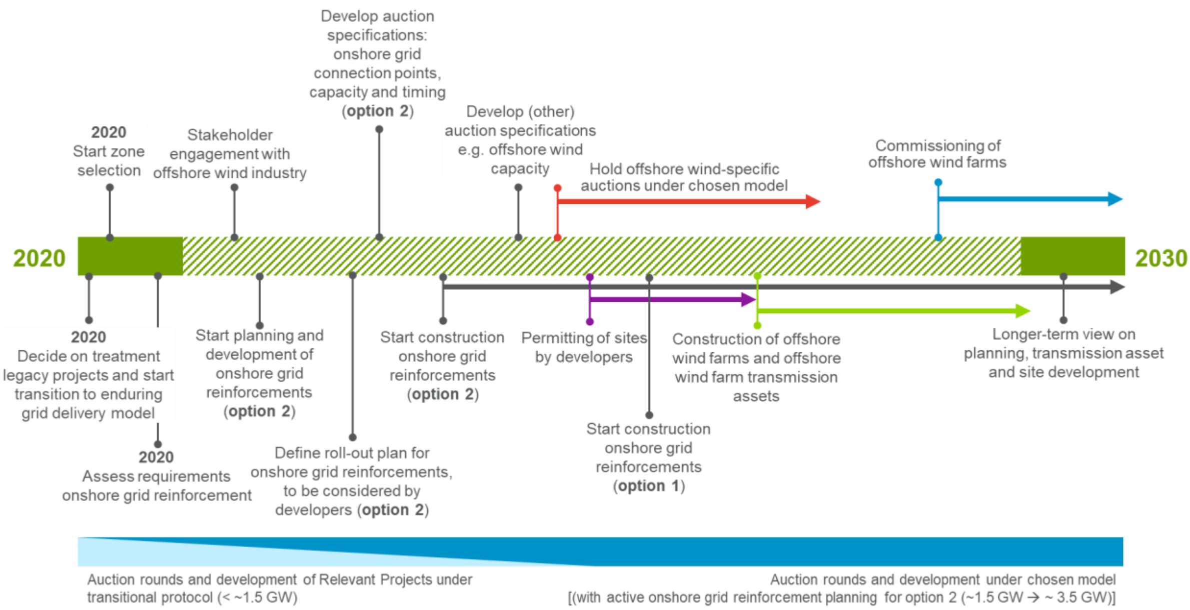


Figure 4. Possible high-level roadmap with key actions and milestones towards 2030 for options 1 and 2. *Source: Navigant.*

Options 1 and 2 share a start-up phase with options 3 and 4, which presents common no-regret actions that should start as soon as possible in line with the planning and development of required onshore grid reinforcements, namely:

- Offshore zone selection;
- Decision on enduring model option;
- Assessments on current hosting capacity of onshore grid.

A possible high-level roadmap for options 3 and 4 with key actions and milestones towards 2030 is given in Figure 5. Some milestones (*) have a different interpretation depending on the option. The exact timing and duration of the actions depends on the time required by the involved stakeholders to perform the required actions.

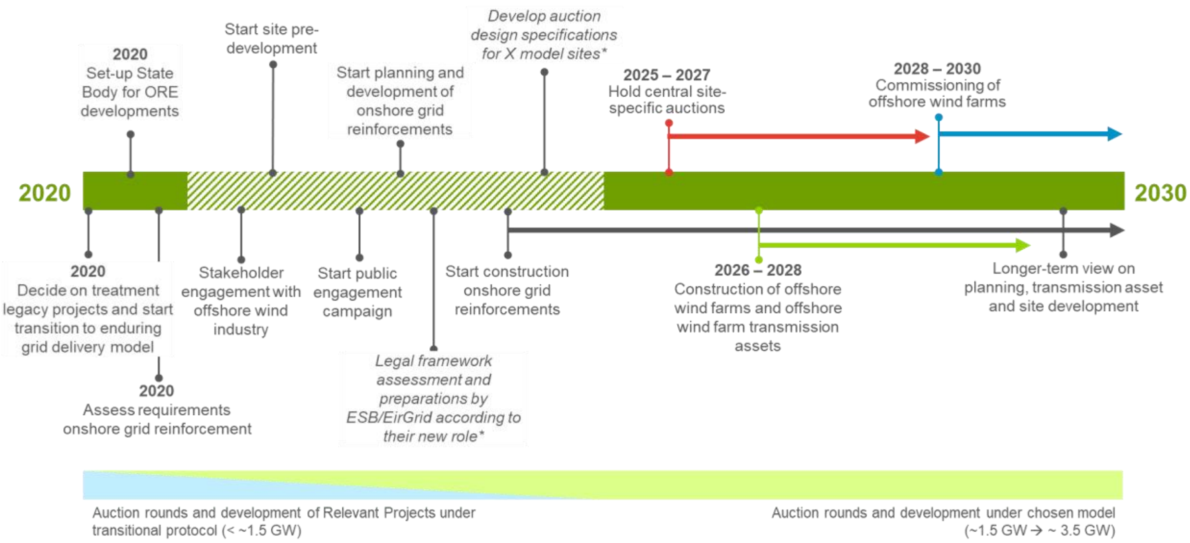


Figure 5. Possible high-level roadmap with key actions and milestones for options 3 and 4 towards 2030. *These milestones will have a different interpretation depending on the selected model option.
Source: Navigant.

Whilst the pre-development of the new enduring model is taking place, the assumed roll-out towards ~1.5 GW (based on expected current available onshore grid capacity) is expected under an interim model to allow some Relevant Projects to be developed. If a different enduring option is chosen, this model could be gradually phased out to be replaced with the chosen enduring model. Due to the tight timeline, the next couple of years should focus on the pre-development actions as shown above.

The yearly capacity additions should be decided based on yearly targets, planned roll-out timeline, onshore grid developments and wind resource potential at the identified sites.

It is important that a grid delivery model decision is made to determine which grid model will be adopted in Ireland to ensure preparations for the enduring model can commence in time such that the 2030 RES-E targets are achievable.

Note that this report was not intended to provide a decision on the best available option, but rather to present evidence that informs the decision for a grid delivery model suitable for offshore wind development in Ireland. All models assessed have their advantages and disadvantages from the various stakeholder perspectives and the decision for the grid delivery model for Ireland will require careful consideration of the key drivers in the Irish context.

TABLE OF CONTENTS

Developing an Offshore Grid Delivery Model for Ireland – Key Messages 1

Executive Summary 3

Table of Contents 13

1. Introduction 15

1.1 Climate action and offshore renewable energy in the Irish market 15
1.2 Developments in offshore grid models 15
1.3 Objective and goals of the report 16
1.4 Content and structure of the report 16

2. Overview of developments in the Irish offshore context 17

2.1 Climate ambitions and targets 17
2.2 Support schemes 18
2.3 Marine spatial planning 20
2.4 Offshore renewable energy developments 23
2.5 Transmission infrastructure 26
2.6 Stakeholders 28

3. Approach and assessment framework 30

3.1 Approach 30
3.2 Assessment framework 31
3.3 Synthesis of the results 34

4. Grid delivery model assessment in the Irish context 35

4.1 Overview 35
4.2 General overview of offshore grid technologies and delivery models 35
4.3 Economic and financial assessment 45
4.4 Technical assessment 56
4.5 Regulatory and policy assessment 65
4.6 International context assessment 79
4.7 Summary 82

5. Grid delivery model options for Ireland 85

5.1 Overview 85
5.2 Assessment of key drivers 85
5.3 Grid delivery options for Ireland 89
5.4 Advantages and disadvantages of model options for Ireland 97
5.5 Risk analysis 99
5.6 Roadmap and key milestones for Ireland towards 2030 102
5.7 Summary 106

6. Discussion and conclusion 107

6.1 Discussion 107
6.2 Conclusions 108

Appendix A. Economic financial assessment A-1

ABBREVIATIONS

AC	Alternating Current	**MVA**	Megavolt Ampere
AER	Alternative energy requirement	**MW**	Megawatt
BE	Belgium	**NGO**	Non-governmental organisation
BSH	Federal Maritime and Hydrographic Agency Germany	**NI**	Northern Ireland
CAP	Climate Action Plan	**NL**	The Netherlands
CAPEX	Capital expenditures	**Nm**	Nautical miles
CfD	Contract for difference	**NMPF**	National Marine Planning Framework
CRU	Commission for Regulation of Utilities	**NSWPH**	North Sea Wind Power Hub
DCCAE	Department of Communications, Climate Action and Environment	**O&M**	Operation and maintenance
DE	Germany	**OFTO**	Offshore transmission owner
DEA	Danish Energy Agency	**OHVS**	Offshore high-voltage substation
DEVEX	Development expenditures	**OPEX**	Operational expenditures
DHPLG	Department of Housing, Planning and Local Government	**ORE**	Offshore renewable energy
DK	Denmark	**OS**	Onshore substation
EEZ	Exclusive Economic Zone	**OSS**	Offshore substation
ENTSO-E	European Network of Transmission System Operators for Electricity	**OWF**	Offshore wind farm
EU	European Union	**PPA**	Power purchase agreement
FCR	Frequency Containment Reserves	**PSO**	Public Service Obligation
FOU	Foundation	**REFIT**	Renewable energy feed in tariff
GW	Gigawatt	**RESS**	Renewable energy support scheme
GWh	Gigawatt hour	**RVO**	Rijksdienst voor Ondernemend Nederland
HVDC	High Voltage Direct Current	**SEA**	Strategic Environment Assessment
IE	Ireland	**SEAI**	Sustainable Energy Authority of Ireland
IEA	International Energy Agency	**T&C**	Terms and Conditions
km	kilometre	**TAO**	Transmission asset owner
kV	Kilovolt	**TSO**	Transmission asset operator
LSI	Largest Single Infeed	**TWh**	Terrawatt hour
MAC	Marine area consent	**UK**	United Kingdom
MCCAE	Minister of Communications, Climate Action and Environment	**WACC**	Weighted average cost of capital
MPDM	Marine planning and development management	**WTG**	Wind Turbine Generator
MPPS	Marine Planning Policy Statement		

1. INTRODUCTION

1.1 Climate action and offshore renewable energy in the Irish market

In order to significantly increase renewable production by 2030, Ireland has set a target to develop at least 3.5 GW of offshore wind energy, as published in the Climate Action Plan by the Department of Communications, Climate Action and Environment (DCCAE) in June 2019. To connect this significant amount of offshore wind power to the Irish grid, transmission asset investments are required. Throughout North-Western Europe different grid delivery models are in place to develop these transmission assets (offshore substation, export cables and onshore connection assets). It is EirGrid's responsibility to develop an options paper on different offshore grid delivery models, which will be presented to a working group of DCCAE, the Commission for the Regulation of Utilities (CRU), EirGrid and ESB Networks.[11] The Government decision on the offshore grid model for Ireland will be aligned with the National Marine Planning Framework (NMPF) and the development consent regime for the maritime area as set out in the Maritime Planning and Development Management Bill (MPDM).

1.2 Developments in offshore grid models

A dramatic cost reduction trend for offshore wind is evident across Europe. This trend is driven by technological innovation, economies of scale and reallocation of cost and risks to national governments. The first subsidy-free projects were awarded in Germany and the Netherlands in 2017/2018, where it should be noted that these projects excluded the cost for grid connections. Cost reduction potential for offshore wind transmission assets (transmission assets) is lower[12], which makes it an increasingly important element in the total cost of offshore wind electricity and therefore important to provide more insight into the grid delivery models. Various "grid delivery models" are currently used for offshore wind developments. The two main classes of grid delivery models in the international context are plan-led and developer-led models[13], representing both ends of a spectrum of model options.

Table 1-1 gives a brief overview on how the main offshore grid delivery models differ. Note that "grid delivery models" refer to the governance of the offshore wind transmission assets, i.e. the connection between the wind farm and the connection point to the mainland grid and excludes the wind farm array cables.

Table 1-1. Main characteristics of grid delivery models.

Aspect	Developer-led model	Plan-led model
Site selection, planning and development	Government selects zone where wind farm can be developed, developer responsible for all other development activities of wind farm site within appointed zone	Government selects, plans, pre-develops and obtains consents for wind farm sites
Responsibility transmission assets	Developer	Transmission System Operator (TSO) and Transmission Asset Owner (TAO)
Tender process	Amongst multiple sites	For single pre-selected sites

[11] ESB Group comprises various separate, ring-fenced, regulated businesses. For ease of reference, in this report we collectively use the term "ESB Networks" to describe the ESB licensed Distribution System Owner (referred to as the Distribution Asset Owner or "DAO") and the ESB licensed Transmission System Owner (referred to as the Transmission Asset Owner or "TAO") functions, both of which are operated through the ring-fenced ESB Networks business unit.

[12] Navigant, 2019. Connecting offshore wind farms. https://www.navigant.com/-/media/www/site/downloads/energy/2019/2019-navigant-comparison-offshore-grid-development.pdf?la=en

[13] Plan-led and developer-led can also be referred to as centralised and decentralised grid delivery models, respectively.

Aspect	Developer-led model	Plan-led model
Investment and cost recovery	The offshore wind farm developer (or Offshore Transmission Owner (OFTO)) finances the grid connection. Costs are recovered through energy tariffs and a consumer levy. An OFTO recovers asset costs through a Tender Revenue Stream.	The TSO or TAO finances construction of onshore grid reinforcements and offshore wind transmission assets. Costs are recovered through government funding or via regulated transmission tariffs for electricity consumers
Example countries	UK	NL, DK, DE (new regime-EEG 2017)

Source: Navigant.

Some European offshore wind markets have transitioned from a developer-led to a plan-led grid delivery model. Governments see benefits in the plan-led model and have taken on a larger share of the development risk and costs. This could mean that a larger share of offshore wind will be financed with public money. It is therefore important to understand the differences between each grid delivery model and assess their pros and cons.

1.3 Objective and goals of the report

The objective of this report is to provide ample evidence to inform the government decision on the offshore grid delivery model for Ireland, within the margins established by the National Marine Planning Framework and the Maritime Planning and Development Management Bill (MPDM); and within the forthcoming consultation process of the CRU on the regulatory framework for connections of offshore renewable energy to the electricity grid.

The focus of this report is the roll-out of offshore wind energy in Ireland over the next decade and beyond. This report intends to provide a detailed analysis regarding possible options for offshore grid delivery models as applicable to the Irish electricity grid and market and, to support the assessment of the most appropriate model and framework for further offshore renewable developments in Ireland.

1.4 Content and structure of the report

This report is structured to provide the required evidence in a logical manner. The current state of affairs in Ireland and developments in climate ambitions, support schemes, offshore renewable energy, transmission infrastructure, and stakeholders are described in Chapter 2, to feed the grid model assessment in the Irish context in Chapter 4.

The methodology for assessing grid delivery models within the Irish context is presented in Chapter 3, thereby introducing the approach to the further research performed in this report. An assessment framework is created to compare the grid delivery models within the Irish context along economic, technical, regulatory and international criteria.

The assessment, analysing the plan-led and developer-led grid delivery models, is detailed in Chapter 4. Aspects of these models may be combined to form a range of model options that are suited to the Irish context. The results of the assessment are presented in Chapter 5 together with grid delivery model options assessed for Ireland. The models represent a set of options, each with their advantages and disadvantages, to indicate a spectrum of options fit for the Irish context. The final chosen model option for Irish offshore wind development could include a combination of elements from across the spectrum. This report, however, does not provide a decision on the best available option, but presents all evidence required to make an informed decision in this regard. A reflection on the report and recommendations are presented in Chapter 6.

2. OVERVIEW OF DEVELOPMENTS IN THE IRISH OFFSHORE CONTEXT

2.1 Climate ambitions and targets

The EU ratified the Paris Agreement, coming into effect on the 4th of November 2016. This agreement commits Member States to significantly reduce greenhouse gas emissions by 2030 and beyond to limit global warming well below 2 degrees Celsius above pre-industrial levels. An important pillar of greenhouse gas emission reduction is promoting the use of renewable energy. At the EU level, the renewable energy target for 2020 is set at 20% of gross final energy consumption, increasing to at least a 32% target by 2030. The EU 2020 target translates to an Irish national target of 16% by 2020, as indicated in Figure 2-1. In 2018, Ireland was still 4.9 pp below its target.[14] The renewable electricity target for Ireland in 2020 is set at 40% under the National Renewable Energy Action Plan.[15] The renewable energy generation as a percentage of electricity consumption in Ireland was 35.7% in 2019 (all-island was 36.4% in 2019).[16] Ireland has set a 70% renewable electricity production target for 2030.[17]

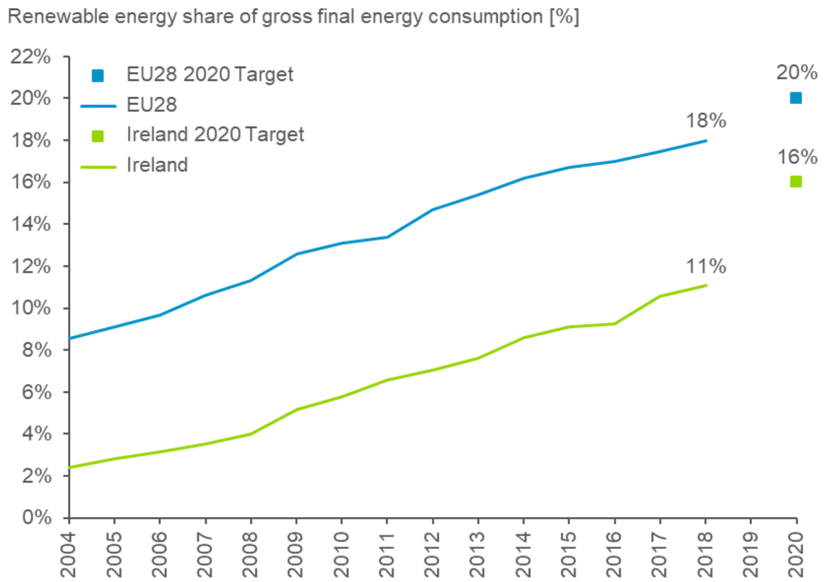


Figure 2-1. Renewable energy share of gross final energy consumption for EU28 and Ireland.
Source: Eurostat, 2020.[14]

In order to significantly increase renewable energy production by 2030, the DCCAE in Ireland has developed a Climate Action Plan (CAP) that was released in June 2019.[17] The CAP aims at reducing greenhouse gas emissions in the period between 2021 and 2030 by 58.4 $MtCO_{2eq}$. outside the EU emission trading system (ETS), by 17 $MtCO_{2eq}$. within the ETS, and by 26.8 $MtCO_{2eq}$. from land use. A large share of emission reductions should come from renewable power production as the share of renewable power production is aimed to ambitiously increase from 30% in 2017 to 70% in 2030 through the addition of 12 GW of renewables.[17]

[14] Eurostat, 2019. 2020. Share of renewable energy in gross final energy consumption. https://ec.europa.eu/eurostat/databrowser/view/t2020_31/default/table?lang=en

[15] EC, 2020. National renewable energy action plans 2020. https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020

[16] Communications with EirGrid

[17] Government of Ireland, 2019. Climate Action Plan 2019. https://www.dccae.gov.ie/documents/Climate%20Action%20Plan%202019.pdf

Figure 2-2 shows the development of the power generation mix in Ireland and Northern Ireland. Both countries show a large dependency on fossil fuel generation (mainly gas, coal and peat), with a share of wind energy that grew over time to 28% in 2018 for Ireland, and 31% for Northern Ireland. Currently wind power generation primarily consists of onshore wind power generation but offshore renewable energy (ORE) sources, and specifically offshore wind, are foreseen to be a major contributor to renewable power production in Ireland in the near future as it should contribute to at least 3.5 GW of additional capacity by 2030. Next to ORE, grid-scale solar (up to 1.5 GW) and onshore wind (up to 8.2 GW) capacities are the main candidates for providing growth in renewable power generation. Note that the exact level of offshore wind, onshore wind, solar and other renewable technologies are foreseen to be determined by a competitive auction system. The ramp-up of offshore wind for Ireland will be substantial as the current offshore wind power capacity is only delivered by the 25 MW Arklow Bank wind farm that was commissioned in 2004.

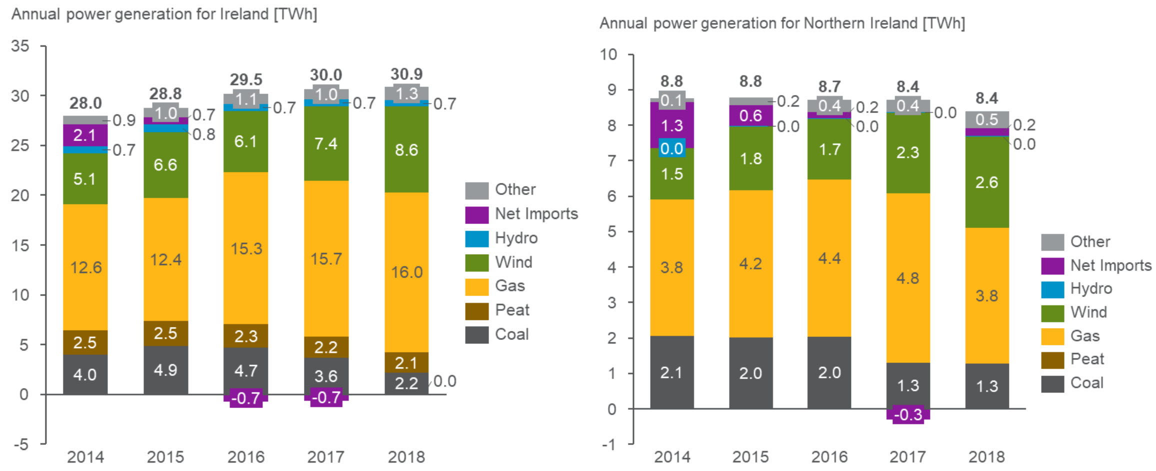


Figure 2-2. Power generation mix in Ireland and Northern Ireland. *Source: EirGrid, 2018.*[18]

2.2 Support schemes

Renewable power generation in Ireland was historically supported through the alternative energy requirements (AER) support scheme that ran from 1995 until 2003. Under the AER scheme, bidders competed for a 15-year power purchase agreement (PPA) with Electric Ireland (an ESB supply entity, then called ESB Customer Supply) at the winning bid price.19,20 For each technology (wind, hydro, biomass etc.) a quota was set. Electric Ireland is entitled to receive a compensation from the public service obligation (PSO) levy, which is paid by all electricity consumers, if the power is sold at a lower rate than it had to pay to the renewable generators. Vice versa, it has to return any income that it received above the rates for the renewable generations. This scheme is very similar to a 2-way contract for difference (CfD) scheme as is employed in Great Britain. A total of six competitions were held and currently there are two wind projects (30 MW) remaining under the AER scheme with support lasting until the end of 2021. The amount for the PSO levy for the 2018/2019 period is -829 k€, i.e. Electric Ireland returns income to the PSO.

The AER scheme was superseded by the renewable energy feed in tariff (REFIT) scheme, which was introduced in 2006 (REFIT 1) and was followed by REFIT 2 and 3 in 2012. The aim of REFIT was to contribute to Ireland's 2020 target of 40% of electricity consumption from renewable sources. The main difference with the AER scheme is that REFIT was open to all electricity suppliers who engaged in a 15-year PPA with off takers, and not just to Electric Ireland. Technologies supported under this

[18] EirGrid, 2019. System & Renewable Summary Report. http://www.EirGridgroup.com/site-files/library/EirGrid/System-and-Renewable-Data-Summary-Report.xlsx

[19] IEA, 2013. Renewables-Based Electricity Generating Capacity to be Installed - AER VI. https://www.iea.org/policiesandmeasures/pams/ireland/name-21887-en.php

[20] CRU, 2018. Decision paper – Public Service Obligation Levy 2018/19. https://www.cru.ie/wp-content/uploads/2018/03/CRU18148-2018-19-PSO-Decision-Paper.pdf

scheme include wind, hydro, biomass, landfill and anaerobic digestion. The total REFIT payment for 2018/2019 is 237.8 M€ supporting 3,805 MW of capacity, representing a 16% growth in capacity compared to 2017/2018.[20] The REFIT payment is also recovered through the PSO levy.

The new scheme for meeting the 2030 targets is the Renewable Electricity Support Scheme (RESS), which aims to support meeting Ireland's contribution to the 2030 EU target of 32% renewable energy of gross final energy consumption. Primary policy objectives that support the RESS design are (i) contributing to the EU-wide renewable energy target, (ii) increasing community participation in and ownership of renewable electricity projects, (iii) ensuring value for money for electricity consumers, and (iv) enhancing security of supply.[21]

The RESS auctions are envisioned to consist of five competitive auction rounds, which will be frequently scheduled.[21] The rationale behind the outlined roadmap for RESS auctions is to take advantage of falling cost of renewables while providing developers with an outline to progress their project developments prior to the RESS auction rounds. Technologies will compete amongst each other in the auction rounds, with targeted auction interventions aiming at finding the right balance between technology diversity and ensuring sufficient competition.

The draft terms and conditions of the first RESS scheme were published in December 2019 for consultation and the final version published in February 2020.22,23,24 The RESS 1 auction round is now foreseen to take place in 2020 with a maximum auction volume of 3000 GWh subject to the competition ratio set by the CRU. Further planning is still to be finalised.

A number of intervention levers are considered for the RESS to ensure the multiple policy goals are delivered. These levers can be adapted and fine-tuned for each auction by the relevant body, in line with national policies as set out by the DCCAE. The following conditions have been set out in the RESS 1 Terms and Conditions:[24]

- RESS 1 support is structured as a 2-way Contract for Difference based on a strike price and a variable or non-variable day-ahead market reference price resulting in either income or costs to the Irish government and the wind farm operator based on the relation between the prices.
- Qualified Applicants that submit eligible Offers will compete against each other (technology neutral with the exception of solar) on the basis of three Preference Categories with each minimum and maximum offer requirements, namely: (i) the Community Preference Category; (ii) the Solar Preference Category; and (iii) the All Projects Preference Category.
- A volume of renewable energy is targeted in the auction with minimum and maximum quantities per Preference category.
- Curtailment Compensation Arrangements are possible for projects that identify a curtailment issue during operation (>10% curtailment).
- Full planning permission is a condition to be eligible to submit an offer into the RESS 1 auction. In the case of offshore wind, the equivalent planning permission from the relevant planning body and or planning authority is required.
- Changes to the plant or equipment within any individual RESS 1 Project may be agreed by the Minister subject to a set of conditions.

[21] DCCAE, 2019. Renewable Electricity Support Scheme (RESS) High Level Design. https://www.dccae.gov.ie/documents/RESS%20Design%20Paper.pdf

[22] DCCAE, 2020. Renewable Electricity Support Scheme (RESS). https://www.dccae.gov.ie/en-ie/energy/topics/Renewable-Energy/electricity/renewable-electricity-supports/ress/Pages/default.aspx

[23] DCCAE, 2019. Minister Bruton announces scheme to reach 70% renewables. https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Minister-Bruton-Announces-Scheme-to-Reach-70-Renewables.aspx; DCCAE, 2019. Public Consultation on the Draft RESS Terms and Conditions. https://www.dccae.gov.ie/en-ie/energy/consultations/Pages/Public-Consultation-on-the-Draft-RESS-Terms-and-Conditions.aspx

[24] Government of Ireland, 2019. Terms and Conditions of the First Competition under the Renewable Electricity Support Scheme, RESS 1: 2020. https://www.dccae.gov.ie/en-ie/energy/consultations/Pages/Public-Consultation-on-the-Draft-RESS-Terms-and-Conditions.aspx

- Projects should be individually metered, and the maximum Offer Quantity is 600 GWh/year
- Successful Projects will be required to submit performance security to ensure delivery against a set of milestones and maximise project realisation rates.

Community ownership and participation in renewable electricity projects plays an important role in the RESS 1 design with the community preference category and the community benefit fund requirements. The RESS 1 design is currently under consultation. Future RESS rounds are foreseen to include offshore-specific measures as stated in the Climate Action Plan.[16]

2.3 Marine spatial planning

Offshore wind projects are subject to several legislative and consenting considerations, which must be satisfied for a site to progress through planning and development, construction and commissioning. There are several legislative and other policy initiatives underway, which will significantly update and enhance the Irish marine planning system.

The European Marine Spatial Planning Directive (Directive 2014/89/EU) dictates that countries should develop national maritime spatial plans, which in Ireland will be known as the National Marine Planning Framework (NMPF).[25] This framework should be the key consideration for decision makers and should serve as an overarching framework for decision-making in the marine area that is consistent, evidence-based and secures a sustainable future for the marine area. It is under consultation between November 2019 and April 2020 and a final plan will be prepared for submission to the Government in 2020. The deadline for submitting the final plan to the European Commission is 2021, as set out under the European Marine Spatial Planning Directive. It is important to note that the NMPF does not replace existing regimes or legislate requirements and any projects that are currently submitted for a consent, or are already in the system, prior to the adoption of the NMPF will be dealt with on the basis of applicable regulatory requirements and sectoral plans.[26]

In addition, the Marine Planning and Development Management Bill (MPDM) general scheme was approved by Government in December 2019. Note that this primary legislation alone is not sufficient to bring the new regime into operation, and development work is required on e.g. administrative procedures and requirements.[27] The MPDM evolved from the Maritime Area and Foreshore Amendment Bill into a new, more comprehensive and holistic regime to govern developments and activities in the marine area.

Prior to the enactment of the MPDM, the Foreshore Acts 1933 - 2014 (the Foreshore Act) are the core legal instruments for managing the marine and coastal environment and the statutory basis on which an area of the seabed could be leased to a developer of an offshore wind farm. The Foreshore Act granted the appropriate Minister at the Department of Housing, Planning and Local Government (DHPLG) the authority to lease or licence foreshore land belonging to the Irish State where it would be in the public interest to do so. Offshore generators applying for a network connection under the Enduring Connection Policy – 1 were required to provide evidence of a valid Foreshore Lease. In practice though, under this process various difficulties existed to get projects approved, leased and consented as the developer had to interact with multiple parties simultaneously and decisions by one entity could impact on the outcome of other processes.[28]

[25] Department of Housing, Planning and Local Government, 2019. Draft National Marine Planning Framework. https://www.housing.gov.ie/planning/marine-planning/public-consultation-draft-national-marine-planning-framework

[26] Department of Housing, Planning and Local Government, 2019. General Scheme of the Marine Planning and Development Management (Bill) – Frequently asked questions The Marine Planning and Development Management Bill. https://www.housing.gov.ie/planning/legislation/other/marine-planning-and-development-management-bill-faqs

[27] Department of Housing, Planning and Local Government, 2019. The Marine Planning and Development Management Bill. https://www.housing.gov.ie/planning/marine-spatial-planning/foreshore/marine-planning-and-development-management-bill

[28] A Great Leap Forward? Offshore Wind in Ireland A joint Cornwall Insight Ireland, ORE Catapult and Pinsent Masons paper 2018. https://ireland.sse.com/media/539571/Cornwall-Insights-Report.pdf

The MPDM Bill updates this Foreshore Act 1933 and addresses the absence of a regulatory framework to regulate offshore renewable energy developments beyond the limits of the foreshore (12 nautical miles). The MPDM Bill also provides a coherent mechanism to facilitate and manage developments in the exclusive economic zone (EEZ) and on the continental shelf, including for the first time a comprehensive regime for the regulation of Offshore Renewable Energy (ORE).

The MPDM Bill mainly impacts the consenting process for ORE developments. The aim of the Bill is to streamline the consenting process and the Bill is underpinned by a statutory Marine Planning Policy Statement[29] (MPPS) and guided by the NMPF. The MPDM Bill streamlines procedures by a single consent principle: one state consent (Maritime Area Consent: MAC) to enable occupation of the Maritime Area and one development consent (planning permission), with a single environmental assessment.[30] MACs for offshore renewable energy developments are awarded by the Minister of Communications, Climate Action and Environment (MCCAE). At this moment it is not clear which grid delivery model (developer-led/decentralised or plan-led/centralised) will be selected for ORE development and the MPDM allows the flexibility for developments under both a 'plan-led' and 'developer-led' approach, as described by the Department of Housing, Planning and Local Government (2019):[30]

- *"The decentralised approach closely follows the general process set out in the MPDM with the addition of (1) the identification of Strategic Maritime Area Zones for ORE development in line with the National Marine Planning Framework (NMPF) prior to the planning interest stage and (2) a competitive process for subsidy support to occur prior to granting a Maritime Area Consent."*[30]
- *"Under the centralised approach, zones will also be identified for ORE development however the MCCAE may designate an entity to undertake grid development, which may include site selection and securing necessary permissions in relation to the grid connection to facilitate further ORE development by third party developers."*[30]

For both models, a competitive process is foreseen to provide financial support (such as the RESS) to ORE developments. The financial support process takes place before a MAC is awarded by the MCCAE.

Table 2-1 details the proposed ORE consent sequence for both the decentralised and centralised grid delivery models as planned to operate under the MPDM Bill. Note that in the centralised model approach, the offshore wind farm development consent is obtained by a designated State Body for ORE development, similar to e.g. the government agency RVO in the Netherlands. At this point it is not known which development body would be responsible in Ireland.

[29] Department of Housing, Planning and Local Government, 2019. Government launches Marine Planning Policy Statement. https://www.housing.gov.ie/planning/marine-spatial-planning/government-launches-marine-planning-policy-statement

[30] Department of Housing, Planning and Local Government, 2019. General Scheme of the Marine Planning and Development Management (Bill) – Frequently asked questions The Marine Planning and Development Management Bill. https://www.housing.gov.ie/planning/legislation/other/marine-planning-and-development-management-bill-faqs

Table 2-1. Overview of proposed ORE Consent Sequence for both decentralised (developer-led) and centralised (plan-led) grid delivery models as foreseen under the MPDM Bill.

Aspect	Decentralised	Centralised
1. National Marine Planning Framework (NMPF)	• Strategic Maritime Area Zones are established by Government	• Strategic Maritime Area Zones are established by Government.
2. Planning interest	• Marine Planning Scheme is developed by the Minister (subject to public consultation) • The Minister receives applications of Planning Interest for ORE from Developers	• Marine Planning Scheme is developed by the Minister (subject to public consultation) • The Minister/ORE Development Body selects sites for ORE development and does not receive applications for individual planning interests
3. Development Consent	• Following receipt of Planning Interest from Minister, the Developer may seek leave to apply to An Bord Pleanála for Development Consent. Applications are subject to public consultation.	• ORE Development Body/TSO submits application for sites to ABP for Development Consent.
4. Competitive Process	• The Minister may establish a competitive process for support for projects who have received a Planning Interest and Development Consent by ABP. • The T&C's of the process will consider arrangements for access to and the charging mechanism for connection to and use of the electricity transmission/ distribution system as set out under section 35 of the Electricity Regulation Act 1999.	• The Minister may establish a competitive process for support for the right to develop and operate an ORE installation within the designated zone. Successful bidders win right to construct and operate ORE site. • A competitive process would award a portion of the public service obligation levy for their ORE development as provided for under Section 39 of the Electricity Act 1999. • The T&C's of the process will consider arrangements for access to and the charging mechanism for connection to and use of the electricity transmission/ distribution system as set out under section 35 of the Electricity Regulation Act 1999.
5. Marine Area Consent	• Marine Area Consent is granted by the Minister only to projects that; 1. Have received a grant of Planning Interest, 2. Have received Development Consent, and; 3. Are successful in the competitive process established by the Minister under Section 39 of the Electricity Regulation Act	• Marine Area Consent is granted by the Minister only to projects that 1. Have received Development Consent, 2. Are successful in the competitive process established by the Minister under Section 39 of the Electricity Regulation Act 1999.

Source: DCCAE, 2019.[30]

Terrestrial planning in Ireland is governed by the National Planning Framework, which also defines how the interface with maritime spatial planning and ORE developments is addressed. A number of common aims for both planning regimes are defined including sustainable, forward-looking long-term use and management of areas, co-ordination of Departments and Sectoral issues in a plan-led manner, and consistency between maritime and terrestrial planning in areas of common interest. The Planning and Development Act 2000 forms the foundation for overall planning in Ireland and covers an extensive range of planning issues and combines a wide range of different legislation (including consenting) in one place.[31]

2.4 Offshore renewable energy developments

Although Ireland hosts a significant coastline along the Atlantic Ocean, and Irish and Celtic Seas, offshore renewable energy (ORE), and specifically offshore wind, developments have not taken off as in other North West European countries such as the UK, Germany, Denmark, the Netherlands and Belgium. The main focus area for fixed bottom offshore wind development in Ireland up to 2030 is the Irish Sea off the East Coast due to the relatively favourable bathymetry (a relevantly large offshore area within the 50 meters water depth contour as indicated in Figure 2-3), sea conditions (Figure 2-4), and the presence of the main load centre in Dublin. The Irish South and West Coasts would in general be more suitable for floating offshore wind development as the available area within 50 meters water depth is more limited.

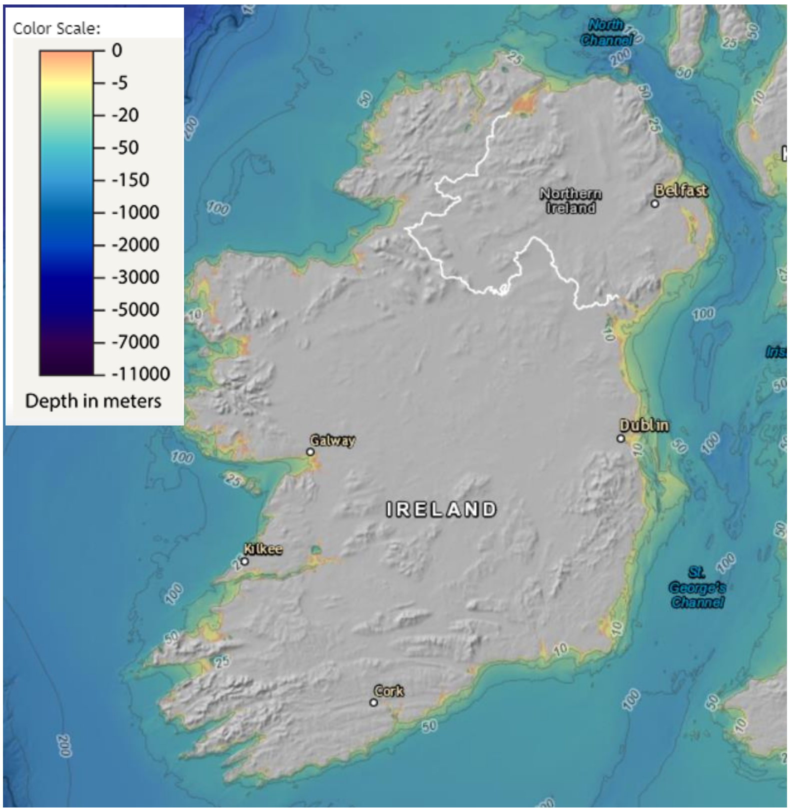


Figure 2-3. Bathymetry around Ireland. *Source: NOAA, 2020.*[32]

[31] Department of Planning, Housing and Local Government, 2020. Planning legislation. https://www.housing.gov.ie/planning/bord-pleanala/planning-legislation

[32] NOAA, 2020. Bathymetry. https://maps.ngdc.noaa.gov/viewers/bathymetry/

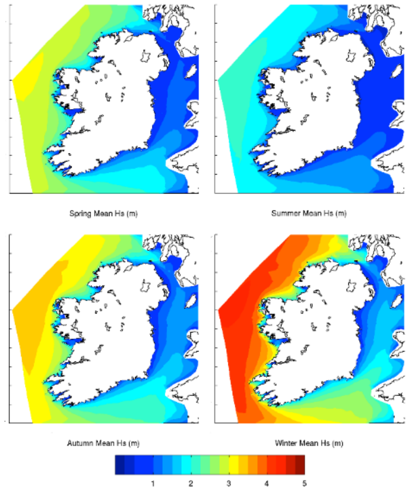


Figure 2-4. Seasonal average significant wave height (Hs) around Ireland.
Source: The Irish Meteorological Service, 2019.[33]

The only operational offshore wind project in Ireland is the Arklow Bank project consisting of seven 3.6 MW wind turbines, which was commissioned in 2004. Reasons quoted for the stall of offshore wind development in Ireland include complex consenting and permitting regimes, uncertain network connection agreement processes and uncertainty on support schemes.[34] The lack of growth in operational offshore wind projects does not imply offshore wind project development is absent in Ireland. The offshore wind pipeline for Ireland consists of over 10 GW[35] of offshore projects, as presented in Table 2-2. Approximately 5.6 GW of this capacity has applied for a grid connection (i.e. an onshore connect point).[36]

Table 2-2. The offshore wind pipeline for Ireland consists of more than 10 GW of projects.

Project, location	Capacity (MW)	Developer
Arklow Bank 2, Wicklow	520	SSE Renewables
Braymore Point, Dublin	800	SSE Renewables
Celtic Sea Array, Waterford	800	SSE Renewables
Clogherhead, Louth	500	ESB[37], Parkwind
Codling Bank 1, Wicklow	1100	Fred Olsen, Hazel Shore
Codling Bank 2, Wicklow	1000	Fred Olsen, Hazel Shore
Cooley Point, Louth	500	ESB[37]
Dublin Array, Dublin	600	Innogy, Saorgus
Helvick Head, Waterford	1000	Energia
Inis Ealga, Cork	400	DP Energy
Kilmichael Point, Wexford	500	ESB[37]

[33] The Irish Meteorological Service, 2019. Marine meteorology. https://www.met.ie/science/marine-meteorology

[34] Irish Examiner, 2019. Ireland emerging as attractive market for offshore wind. https://www.irishexaminer.com/breakingnews/ireland/ireland-emerging-as-attractive-market-for-offshore-wind-929987.html A joint Cornwall Insight Ireland, ORE Catapult and Pinsent Masons, 2018. A great leap forwards? Offshore wind in Ireland. http://alerts.pinsentmasons.com/rs/emsimages/pdf/Great-leap-forward-Offshore-wind-in-Ireland.pdf

[35] IWEA, 2019. New Horizons: Ireland's Offshore Wind https://www.iwea.com/images/Article_files/1._9.15_David_Connolly_IWEA_Offshore_Conference_12_Sept.pdf

[36] EirGrid, Offshore Wind-substation and Cable Functional Specification Revisions, 2019. http://www.eirgridgroup.com/customer-and-industry/becoming-a-customer/generator-connections/offshore-wind-substation/

[37] As noted above, ESB comprises various ring-fenced, regulated businesses. References to ESB in this table are references to ESB's generation business which is strictly ring-fenced from the ESB Networks business.

Project, location	Capacity (MW)	Developer
NISA, Louth/Meath	750	Statkraft
Oriel, Louth	330	Oriel, Parkwind, ESB[37]
Skerd Rocks, Galway	400	Fuinneamh Sceirde Teoranta
Unnamed project, tbc	1000	Energia

Source: IWEA, 2019.[35]

Many of these projects are still in an early stage of development while other projects made more progress by e.g. obtaining a lease and/or grid connection offer. The lease is a key element of any project and specifies the project characteristics including number of turbines for a project, tower height and rotor diameter. The MPDM general scheme specifies that existing foreshore leases and licences will remain in force. Any consents granted under existing regimes will be manged under the relevant existing legislation until expiry, termination, assignment or any material change is proposed - at which time a new application will have to be made under the new regime.[30] This implies that changes to existing consents would be possible, but that any material change would result in having to file a new application under the new regime.

While Ireland is preparing and implementing the new offshore grid delivery model and marine planning and development framework, it is important that some of the more advanced projects in the pipeline are developed to meet the targets as set out under the CAP. Therefore, the DHPLG together with the DCCAE has defined criteria to qualify some of these as “Relevant Projects”, which can continue their development under a “transitional protocol” which is to be legislated under the MPDM Bill 2020.[38] The Relevant Projects are defined as:[30]

- “*offshore wind projects which applied for (and substantially advanced) or were granted a lease under the Foreshore Act 1933, as amended (the Foreshore Act) in respect of which material changes are proposed to that which was originally applied for and assessed under the Foreshore Acts, which changes require further assessment; and/or*
- *offshore wind projects which have a valid connection agreement from the TSO or are confirmed by the TSO as eligible to be processed to receive a valid connection offer;*”

EirGrid are developing a plan for assessing the onshore network reinforcements once the number, scale and status of Relevant Projects has been confirmed through engagement with the relevant government departments and developers.[39]

In the past, offshore projects were offered contracts under a “contested grid model” where the developer would choose their offshore location and would have the right to build the offshore wind transmission assets, and ESB Networks could acquire the assets at a nominal fee after commissioning.[40] This model is used for the transmission assets of onshore wind projects as well (i.e. the “onshore” model) and would be more in line with a developer-led grid delivery model approach, than a plan-led approach.

In terms of other offshore renewable energy technologies, Ireland focusses on ocean energy (wave, tidal, floating wind), which will actively be supported under the Climate Action Plan. Off the Atlantic Coast in Mayo, the Atlantic Marine Energy Test Site is being developed for testing more mature technologies (Technology Readiness 7-9) at full scale. In Galway Bay, there is a facility aimed at testing Technology Readiness 4-6 technologies. In Cork, there is the Lir National Ocean Test Facility, which is a custom designed test facility for laboratory testing of offshore wind, wave, and tidal energy for smaller devices.

[38] DHPLG, 2019. The Marine Planning and Development Management Bill. https://www.housing.gov.ie/planning/marine-spatial-planning/foreshore/marine-planning-and-development-management-bill

[39] https://www.cru.ie/document_group/offshore-grid-connection/

[40] EirGrid, 2002. Contestability and Connection Assets. http://www.EirGridgroup.com/site-files/library/EirGrid/Contestability-and-Connection-Assets.pdf

2.5 Transmission infrastructure

The transmission grid in Ireland (IE) is planned and operated by EirGrid (transmission system operator, TSO), while ESB Networks builds and owns the network and carries out maintenance (transmission asset owner, TAO). EirGrid also supplies the distribution network that is planned, operated and owned by ESB Networks.

Figure 2-5 shows the Irish and Northern Irish transmission system at 110 kV and above. The transmission system in Northern Ireland (NI) is operated by SONI (System Operator Northern Ireland) at 275 kV and 110 kV. The transmission system in Ireland is operated at 400 kV, 220 kV and 110 kV. The two transmission systems are connected by means of one 275 kV double circuit, from Louth station in Co. Louth (Irl) to Tandragee station in Co. Armagh (NI). There are also two 110 kV connections at Letterkenny in Co. Donegal (Irl) to Strabane station in Co. Tyrone (NI); and at Corraclassy station in Co. Cavan (Irl) to Enniskillen station in Co. Fermanagh (NI).

The two extra high voltage (400 kV) transmission arteries in Ireland run from east to west across the Island, connecting Dublin and the west coast area around Kilrush, which hosts the Moneypoint coal fired power station, Ireland's largest power plant (915 MW). A ring of 220 kV circuits runs around Ireland with a 275 kV ring in Northern Ireland, with 110 kV connections transmitting power to more remote areas of the island.

Two interconnectors currently connect the Island of Ireland to Great Britain: the East-West interconnector between the Dublin area and Wales (500 MW HVDC) and the Moyle interconnector between the Belfast area and Scotland (500 MW HVDC). Onshore wind power production is relatively spread across the country while thermal generation is mostly concentrated in the South.

The increasing levels in renewable generation capacity in Ireland must be integrated into the onshore power system, posing several challenges, which are to be addressed under the DS3 programme of EirGrid.[41] Phasing out conventional generation plants in combination with increased renewable capacity will reduce available system inertia, making it challenging to maintain system stability. Other grid services, such as black start capabilities, are currently supplied by conventional power plants. These services could be supplied by (offshore) wind farms and industry is investigating solutions for wind farms to provide these capabilities.[42] ENTSO-E network codes (RfG and HVDC) already specified "black start" and "island operation" as optional requirements, allowing TSOs to request these requirements.[42] ENTSO-E grid codes also specify requirements for fault ride-through, and operational control and protection of offshore wind farms.[43] Further research is required to investigate the impact on the power system of increasing the share of renewable power in the system to 70% by 2030.

[41] EirGrid, 2019. What is the DS3 Programme? http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/

[42] Göksu, 2017. Black Start and Island Operation Capabilities of Wind Power Plants. https://www.promotion-offshore.net/fileadmin/PDFs/Conference_Paper_Black_Start_and_Island_Operation_Capabilities_of_Wind_Power_Plants_with_note.pdf; National Grid ESO, 2019. Black start from non-traditional generation technologies https://www.nationalgrideso.com/document/148201/download

[43] ENTSO-E, 2016. Establishing a network code on requirements for grid connection of generators. https://www.entsoe.eu/network_codes/rfg/

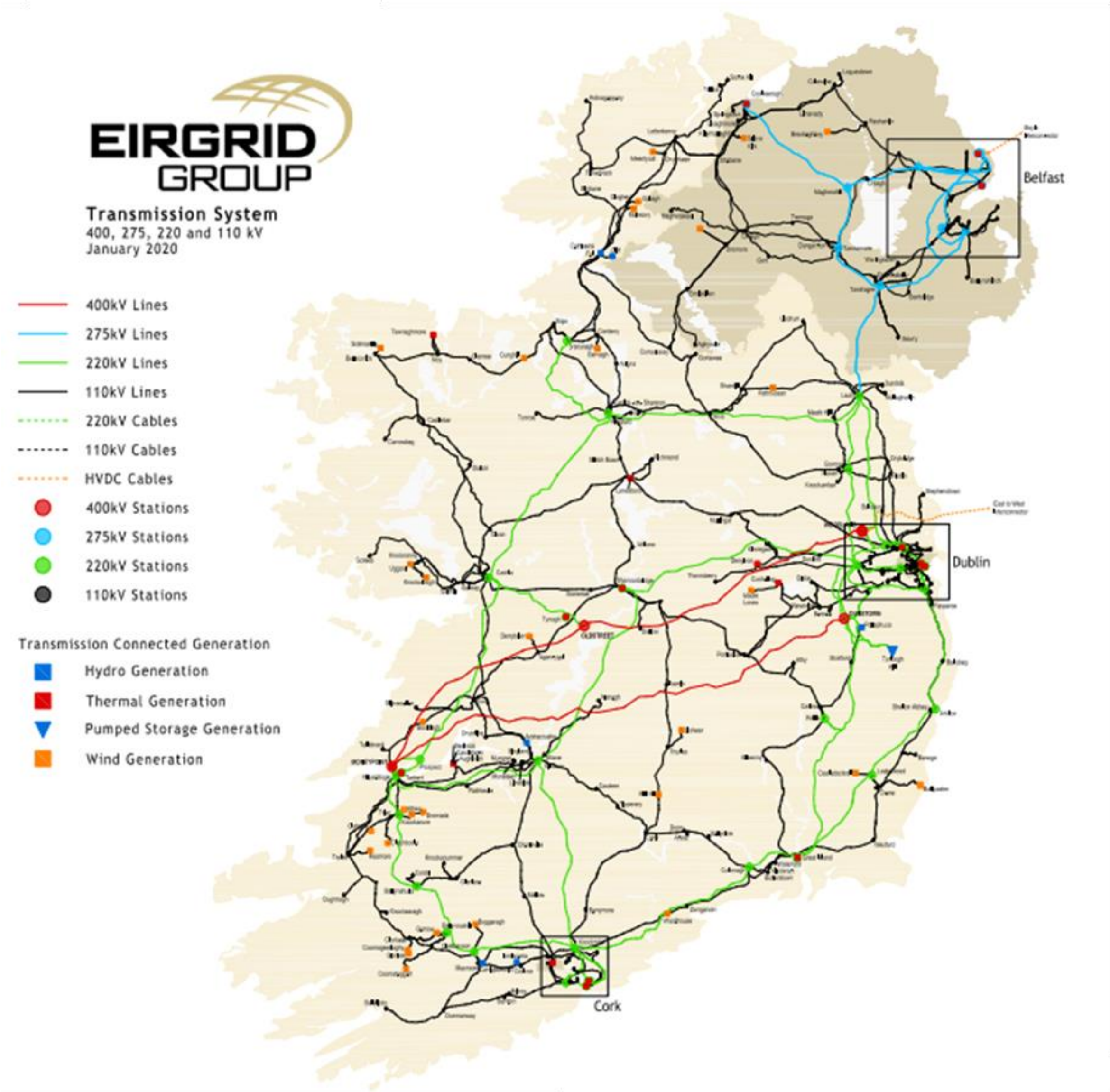


Figure 2-5. Map of transmission system in Ireland and Northern Ireland.
Source: EirGrid, status January 2020.

To assess the opportunities for physically integrating large amounts of ORE, EirGrid conducted an "East Coast Generation Opportunity Assessment" in February 2019.[44] The study specifically focussed on the integration potential of generation capacity for the east coast power system, as main focus area for offshore wind development up to 2030. Furthermore, demand in the Dublin area is expected to increase significantly due to a growing number of data centres. Several 220 kV grid connection points are assessed along the east coast and considerable capacity appears to be available, as is indicated in Figure 2-6. Note that these capacities should not be treated cumulatively. A new generator connection may use up some or all of the capacity available at other locations in the region.

[44] EirGrid, 2019. East Coast Generation Opportunity Assessment. http://www.EirGridgroup.com/site-files/library/EirGrid/East-Coast-Generation-Opportunity-Assessment.pdf

Substation	Opportunity for Offshore Wind Before significant works (MW)	Space at Substation
Louth	450	4 x bay space
Oriel (New 220kV substation)	400	New Substation
Woodland	>800	2 x bay space
Poolbeg North	600	2 x bays
Poolbeg South	>800	2 x bays
Finglas	>800	1x bays
Carrickmines	650	3 x bays
Ballybeg (New 220kV substation)	500	New Substation
Arklow	350	2 x bay Space

Figure 2-6. Assessment of opportunities for East Coast grid integration for offshore wind in Ireland. Note that stated capacities are not cumulative. *Source: EirGrid, 2019.*[44]

The arrangement of the Dublin 220 kV transmission network in North and South sections brings a degree of electrical separation between North and South Dublin. It is therefore expected that the available grid connection capacity for offshore wind is approximately 1.5 GW (50/50 split between areas North and South of Dublin) along the east coast. Further analysis is required in order to substantiate this expectation.[45] This means that the foreseen offshore wind capacity of at least 3.5 GW cannot readily be integrated into the existing onshore grid.

Reinforcement, and potentially expansion, of the onshore grid will be required, which poses a risk of stranded offshore assets if the onshore grid development is not coordinated and aligned with offshore wind developments. EirGrid will investigate the available cumulative capacity that can be connected, and the level of grid reinforcements required for meeting the renewable energy targets.

The main legislation governing the Irish electricity sector is the Electricity Regulation Act 1999[46], which established the CRU and made provision for the CRU to issue licences for generating electricity.[47] The act defines a transmission system as *"a system which consists, wholly or mainly, of high voltage lines and electric plant and which is used for conveying electricity from a generating station to a substation, from one generating station to another, from one substation to another or to or from any interconnector or to final customers but shall not include any such lines which the Board may, from time to time, with the approval of the Commission, specify as being part of the distribution system but shall include any interconnector owned by the Board."*

2.6 Stakeholders

Multiple stakeholders will influence and be impacted by offshore wind development and grid integration in Ireland. The key stakeholders are elaborated on in Table 2-3.

[45] Interview with EirGrid planning department on 22nd of October 2019.
[46] DCCAE, 2018. Electricity Regulation Act 1999. http://www.irishstatutebook.ie/eli/1999/act/23/enacted/en/print#sec34
[47] Mason, Hayes & Curran, 2019. Electricity regulation Ireland. https://gettingthedealthrough.com/area/12/jurisdiction/14/electricity-regulation-ireland/

Table 2-3. Key stakeholders for offshore wind development and grid integration in Ireland.

Stakeholder	Impact of offshore wind development on stakeholder
Wind farm developers	Responsible for developing the wind farm including wind turbines, foundations, array cables, and potentially the transmission connection assets.
Electricity consumers	Offshore wind developments, and on- and offshore grid developments will be recovered through grid tariffs, PSO levies and energy tariffs impacting expenditures of electricity consumers (including private persons, businesses and industry). Electricity consumers are represented by the regulator (CRU) in the discussions regarding the grid delivery model for Ireland.
People and businesses in coastal areas	Offshore wind farms closer to shore will be visible from shore and could impact local residents and businesses.
Fisheries	Offshore wind developments could impact fishing grounds.
Department of Agriculture, Food and the Marine (DAFM)	DAFM has a consenting role in fisheries under the Foreshore Act.
Non-governmental organisations (NGOs)	Offshore wind farm and transmission assets will impact the environment both offshore and onshore.
TSO EirGrid	EirGrid is responsible for planning and operating the electricity grid, and potentially the offshore wind transmission assets.
TAO ESB Networks	ESB Networks is responsible for constructing, owning and maintaining onshore grid, and potentially the offshore wind transmission assets.
Department of Housing, Planning and Local Government (DHPLG)	DHPLG is responsible for awarding leases under the Foreshore Act.
Department of Communications, Climate Action and Environment (DCCAE)	DCCAE is responsible for support mechanisms and the award of MACs under the new MPDM bill. DCCAE in conjunction with CRU are responsible for a decision on grid delivery model.
Commission for Regulation of Utilities (CRU)	Responsible for regulating TSO/TAO expenditures and recovering support scheme expenditures through consumer electricity bills (PSO levy). Electricity customers are represented by the CRU.
Planning Authorities (local authorities) on the seaboard	Responsible for regional economic and strategic plans and processes in coastal areas that might impact landing points for offshore wind, local jobs through offshore wind developments, harbour activities, tourism etc.
An Bord Pleanála	Independent national body responsible to ensure that physical developments and major infrastructure projects in Ireland respect the principles of sustainable development, including the protection of the environment.
Elected Representatives	Relevant Parliamentary members and committees that would be key stakeholders in the grid delivery model selection.

Source: Communications with Working Group.

3. APPROACH AND ASSESSMENT FRAMEWORK

3.1 Approach

The assessment of the grid delivery models within the Irish context is approached through four tasks, as illustrated in Figure 3-1, combined with continuous interaction with and feedback from the Working Group. The four tasks provide a detailed analysis of both developer-led and plan-led grid delivery models, their suitability to the Irish context as well as their robustness regarding existing and future developments.

The focus of the assessment is the developer-led and plan-led grid delivery models for offshore wind, as defined in section 4.2. This analysis highlights the full spectrum of options. Grid delivery models can come in many forms and shapes, and often combine elements of both developer-led and plan-led models in terms of advantages and disadvantages. Specific grid delivery models well-suited within the Irish context are assessed and detailed in Chapter 5.

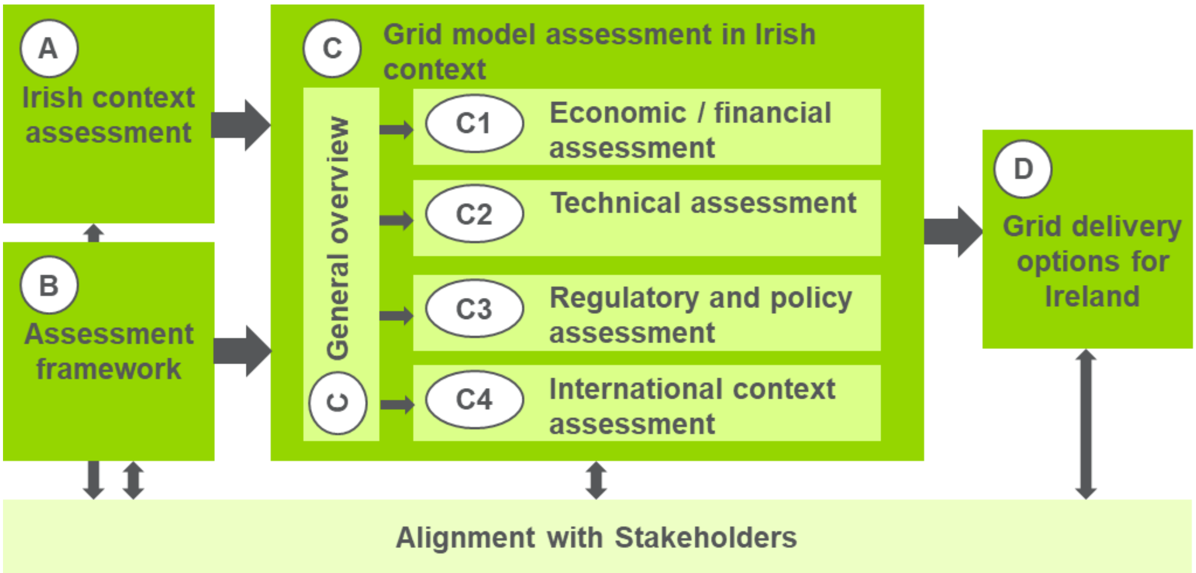


Figure 3-1. Overview of approach and tasks of the study. *Source: Navigant.*

A. Assessment of the Irish context

The developer-led and plan-led grid delivery models need to be evaluated with regards to their applicability to the Irish context. Chapter 2 provided an overview of the Irish grid, market, and regulatory framework to set the stage for the assessment and highlight the main regulatory, technological and economical drivers in the Irish context.

B. Assessment framework

To facilitate the assessment of the grid delivery models and their applicability to the Irish market, a clear and transparent framework is defined to structure the comparison. This framework forms the basis of the study and identifies the different categories and criteria that will be used for the comparison in C. Section 3.2 details the assessment framework.

C. Grid delivery model assessment in the Irish context

Task C combines various sub-tasks to facilitate the assessment of the developer-led and plan-led grid delivery models in the Irish context. First, a general overview of offshore grid technologies and existing grid delivery models is provided, including an overview of the roles and responsibilities of the various parties involved. Second, the grid delivery models are investigated within the Irish context for economic/financial, regulatory, technical and future-proofing criteria as defined in the assessment framework. The assessment of the grid delivery models in the Irish context is presented in Chapter 4 for each of the assessment topics.

D. Grid delivery model options for Ireland

Finally, the results of the assessment are summarised, resulting in a specific assessment of the key drivers in the Irish context and an overview of the advantages and disadvantages of the developer-led and plan-led grid delivery models in the Irish context. Chapter 5 synthesises the results of the assessment and assesses four grid delivery model options for Ireland to facilitate the roll-out of at least 3.5 GW of offshore wind capacity by 2030. The models represent a set of options, each with their advantages and disadvantages, to indicate a spectrum of options fit for the Irish context. The outcomes of the assessment will guide the DCCAE towards the selection of a suitable grid delivery model for the development of offshore wind in the Ireland. The final chosen model option for Irish offshore wind development could include a combination of elements from across the spectrum.

3.2 Assessment framework

3.2.1 Overview

The assessment framework forms the basis of this study and is therefore based on objective criteria to compare the developer-led and plan-led grid delivery models within the Irish context. Figure 3-2 gives an overview of the structure of the assessment framework.

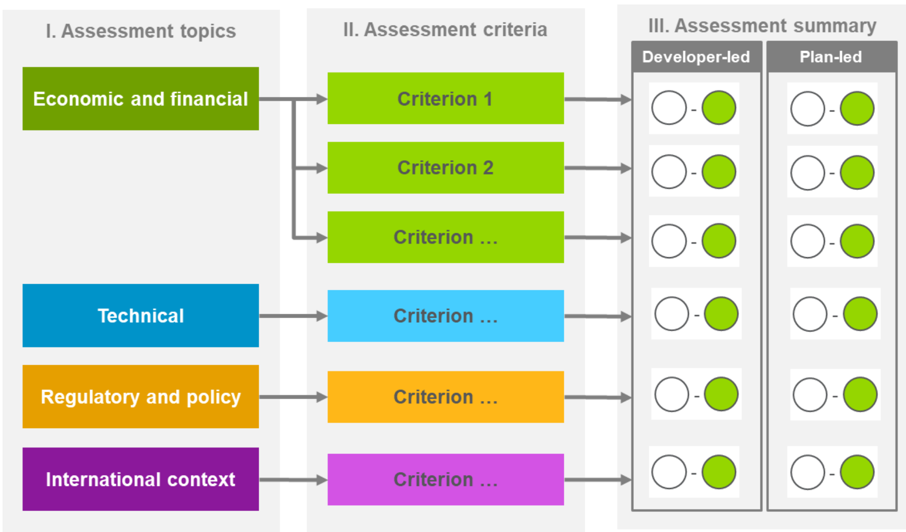


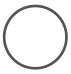
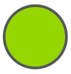
Figure 3-2. Schematic of assessment framework. *Source: Navigant.*

The assessment is conducted along various topics, including economic and financial aspects, a technical assessment, a regulatory and policy analysis (including social and environmental considerations) and future proofing for developments in the international context.

The topics are translated into various assessment criteria. Each assessment criterion is assessed on a quantitatively, semi-quantitative or qualitative basis. Finally, the grid delivery models are assessed in the assessment summary as indicated in Table 3-1.

Note that “performance” of a delivery grid model with respect to each criterion depends on the definition of that criterion as detailed in Chapter 4. Scoring is done using a three-point scale as the current assessment does not allow for further differentiation. This implies that a similar assessment summary does not necessarily imply that the two models have exactly the same characteristics.

Table 3-1. Assessment methodology for assessment criteria.

Indicator	Description
	Indicating that the grid delivery model has a poor performance with respect to the criterion.
	Indicating that the grid delivery model has a moderate performance with respect to the criterion.
	Indicating that the grid delivery model has a good performance with respect to the criterion.

Source: Navigant.

3.2.2 Key drivers in the Irish context

The assessment framework is developed along four overarching topics: economic/financial, technical, regulatory and policy aspects (including social and environmental considerations) and future proofing for developments in the international context. A list of assessment criteria is defined for each topic (section 3.2.3). The key drivers in the Irish context that impact the choice for grid delivery model in Ireland, are considered in defining the set of criteria. Table 3-2 summarises the key drivers in the Irish context as identified based on interviews with key stakeholders in the Irish market (EirGrid, DCCAE, CRU, ESB Networks and offshore wind industry representatives).

Table 3-2. Key drivers in the Irish context based on stakeholder interviews.

Key drivers	Description of topics
Cost	• Minimising infrastructure costs • Minimising cost impact on Irish consumers
Environment	• Minimising cumulative effect on the environment • Reducing the impact of the power system on the environment by achieving targeted renewable developments
Future proofing	• Decisions today should not cause issues post 2030
Infrastructure	• Effective use and coordination of onshore and offshore grid development • Minimising onshore grid reinforcement needs (interface/planning/coordination) (see section 2.5) • Limitations related to largest single infeed requirements
Relevant projects	• Compatibility with Relevant Projects of offshore wind in Ireland (see section 2.4)
Social acceptance	• Increasing social acceptance and public engagement
Timing	• Achieving climate ambitions as stated in the Climate Action Plan and the timely realisation of at least 3.5 GW of offshore wind capacity by 2030 (see section 2.1) • Ensuring speed of delivery of offshore wind projects • Ensuring capacity to deliver from involved parties

Source: Navigant.

It should be noted that this report does not apply any weighting to the various drivers – clearly appropriate weighting would be key to any policy decision on the choice of model.

3.2.3 Criteria and metrics

Based on expert insight, validation through analysis and discussions with Navigant subject matter experts and stakeholder experts, a list of assessment criteria was developed as summarised in Table 3-3. These criteria are used to assess the developer-led and plan-led grid delivery models in the Irish context. The criteria include both quantitative and qualitative aspects.

Table 3-3. Overview of assessment criteria per topic.

	Assessment criteria
	Economic and financial
1a	Impact on cost level transmission assets - offshore wind transmission assets
1b	Impact on cost level transmission assets - onshore grid reinforcements
2a	Impact on consumer electricity prices - PSO levy
2b	Impact on consumer electricity prices - network tariffs
2c	Impact on consumer electricity prices - consumer energy tariffs
3	Impact on State support scheme income/expenditure - offshore wind scope
4	Impact on State support scheme income/expenditure - transmission assets scope
5	Impact on financeability of transmission assets
6	Impact on financeability of offshore wind assets
7	Impact on level of risk of lost revenue for the wind farm developer
	Technical
1	Technological advancement of offshore wind technology (2020-2030)
2	Technological advancement of other offshore renewable energy technologies (ORE) (2020-2030)
3	Speed of delivery – offshore wind farm transmission asset development
4	Compatibility of multiple project developments
5	Maximising offshore resources - technical aspects
6	Technical challenges
7	Technical complexity of interface
8	Ease of enforcing maximum infeed requirements
	Regulatory and policy
1	Compatibility with RESS auction design
2a	Impact on State - meeting RE targets through offshore wind projects in planning stage
2b	Impact on State - meeting RE targets through offshore wind projects in auction stage
2c	Impact on State - meeting RE targets through offshore wind projects in realisation stage
2d	Impact on State - scalability of grid capacity to achieve higher targets
3	Capacity to deliver offshore wind transmission assets and site pre-development
4a	Complexity of grid planning procedure - developer perspective
4b	Complexity of grid planning procedure - consenting body
4c	Complexity of grid planning procedure - TSO perspective
5	Coordinated onshore integration of renewables
6	Compatibility with Relevant projects
7	Social acceptance
8	Environmental impact
	International Context
1	Consistency with future offshore grid technology
2	Consistency with future policy of offshore renewable energy

Source: Navigant.

The criteria are detailed further in Chapter 4, where the assessment is presented per criterion or group of criteria. The assessment follows structured templates for each criterion or group of criteria to systematically address the criteria and ensure readability and structure of the report.

Table 3-4 gives an example of the assessment template. The assessment is grouped per topic and provides a definition and general description of each criterion or group of criteria. In addition, the characteristics of the criteria are described for both a developer-led and plan-led grid delivery model. Lastly, each grid delivery model is reviewed based on their performance with respect to the criterion as explained in Table 3-1. The descriptions and review are based on industry reports, experiences of North-Western European offshore developments, consultations with working group members and further augmented with literature and Navigant's in-house experience.

Table 3-4. Example assessment template for criteria.

Financial/economic				
1	**Impact on cost level of transmission assets**			
Definition of criterion				
Information	General description of the criterion, its characteristic and how it fits in the Irish context.			
Grid delivery model	**Developer-led**		**Plan-led**	
	Description of characteristics of the criteria for the developer-led grid delivery model		Description of characteristics of the criteria for the plan-led grid delivery model	
Score	◐	Description of scoring developer-led model	◐	Description of scoring plan-led model

Source: Navigant.

3.3 Synthesis of the results

The results of the assessment include a score per criterion for both the developer-led and plan-led grid delivery model. Chapter 5 summarises the findings of the assessment based on a description of the key drivers in the Irish context, combining the assessment results for the developer-led and plan-led grid delivery models. In addition, four grid delivery model options are presented suitable to support offshore wind development in Ireland. An analysis is presented of the key advantages and disadvantages as well as the key risks for each option. Finally, roadmaps with key actions are proposed to transition from the current "onshore" model to one of the four model options assessed for Ireland. The overall suitability of each grid delivery model assessed in the Irish context will highly depend on the emphasis on certain criteria to reflect the main interest of the involved stakeholders.

This report does not apply any weighting to the various assessment criteria – clearly appropriate weighting would be key to any policy decision on the choice of model.

4. GRID DELIVERY MODEL ASSESSMENT IN THE IRISH CONTEXT

4.1 Overview

This Chapter presents the results of the assessment of the developer-led and plan-led grid delivery models in the Irish context. First a general overview of offshore grid technologies and grid delivery models is provided in section 4.2, highlighting the definition and scope of the fully developer-led and plan-led grid delivery models. The definition includes:

- the allocation of roles and responsibilities for each grid delivery model; and
- the key stakeholders in the decision-making process in Ireland.

Once the scope of the developer-led and plan-led grid delivery models is defined, the assessment is presented in sections 4.3 to 4.6 for the economic/financial criteria, the technical criteria, the regulatory and policy criteria and the international context criteria, respectively.

4.2 General overview of offshore grid technologies and delivery models

4.2.1 Offshore wind transmission asset technology

The offshore wind farm location and its distance to the onshore connection point have a large influence on the technical grid connection concept. Various technical grid connection concepts have been applied across Northwest Europe to optimise local transmission and onshore grid integration.

Figure 4-1 provides an overview of cumulative installed capacity of offshore wind capacity in Europe, per connection type. The installed capacity numbers in each country highly depend on the national planning objectives, including offshore wind targets and scheduled tender timelines, as well as permitting and grid connection processes, and onshore grid planning and reinforcement needs, rather than the adopted grid delivery model.

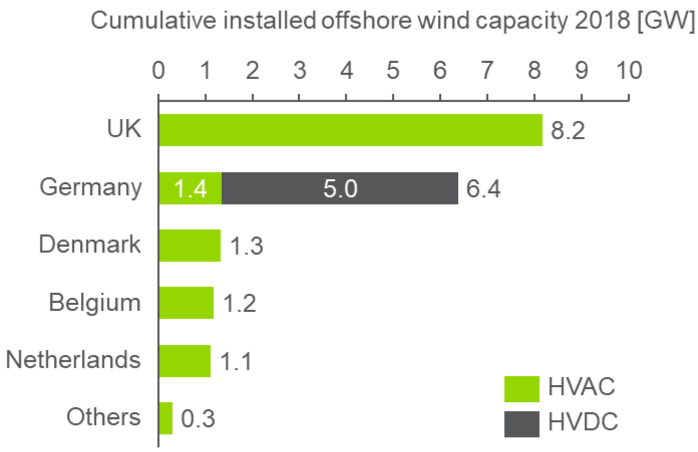


Figure 4-1. Cumulative installed offshore wind capacity in Europe in 2018.
Source: WindEurope[48] and Foundation Offshore Wind Energy Germany.[49]

Most of the installed offshore wind capacity to date is located relatively close to shore and connected to the onshore grid via alternating current (AC). Offshore connections over long transmission distances in Germany (as offshore wind sites are located beyond the Waddensea) have been

[48] WindEurope Annual Offshore Statistics 2017 & 2018. https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2017.pdf, https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2018.pdf

[49] Foundation Offshore Wind Energy Germany, 2020. https://www.offshore-stiftung.de/en/status-quo-offshore-windenergy

connected via direct current (DC) to optimise the transmission system in terms of costs and electrical losses. The “tipping point” for cost-efficient application of HVDC technology is determined by the transmission distance to the onshore connection point (~80 km-100 km) and capacity level (typically above 800 MW, although there are HVDC connections in Germany with a lower capacity, e.g. Borwin1 (400 MW and 200 km of export cable length50)).

Figure 4-2 provides an overview of currently applied and planned grid connection configurations and technologies for offshore wind. These configurations are detailed further below.

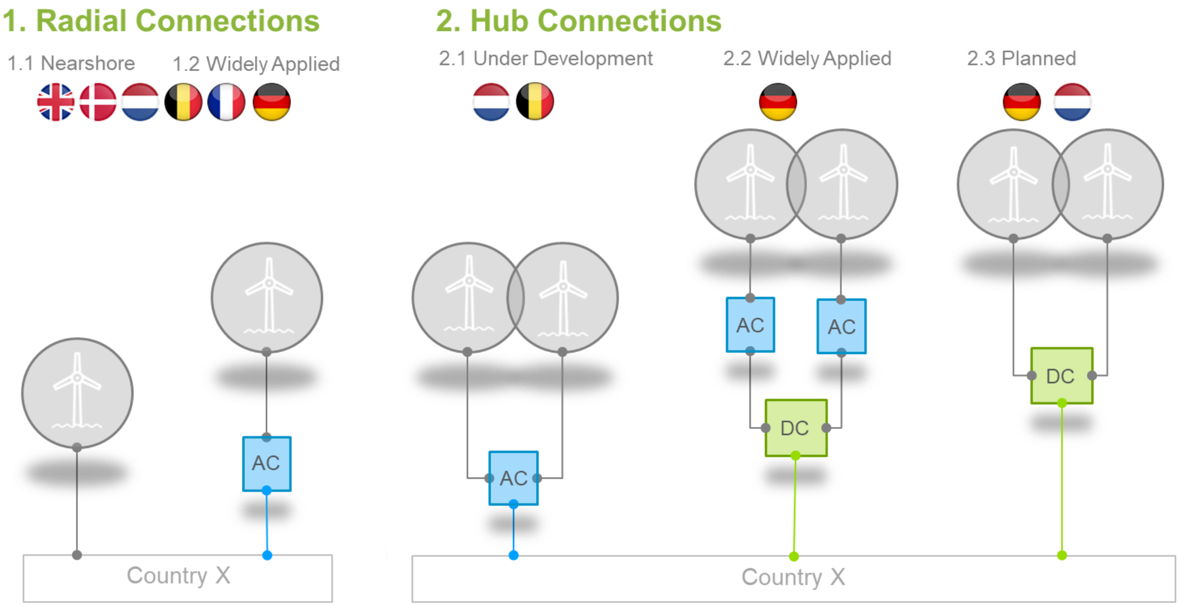


Figure 4-2. Overview of currently applied and planned grid connection configurations.
Source: Navigant.

Wind farms with lower capacities located close to shore were historically connected through direct AC array cable connections to shore without using an offshore substation e.g. the Arklow Bank wind farm in Ireland (25 MW, 13 km offshore, commissioned in 2004[51]), the OWEZ wind farm in the Netherlands (108 MW, 18 km offshore, commissioned in 2007[52]) or the Middelgrunden offshore wind farm in Denmark (40 MW, 4 km offshore, commissioned in 2001[53]).

With increasing distances from shore and increasing wind farm power ratings, it became technically more challenging and more costly to directly connect turbines through array cables to shore. Array cables typically have a maximum length of 20 km due to the build-up of reactive power along the length of the cable. In addition, with an increase in wind farm power ratings, the number of array cables (and thus the potential cable crossings, landfall points and drillings) also increases. Most offshore wind farms that are currently operational in the UK, Belgium, the Netherlands and Denmark use HVAC offshore substations at export voltages of 130, 150 or 220 kV.[54]

[50] TenneT, 2020. Borwin 1. https://www.tennet.eu/our-grid/offshore-projects-germany/borwin1/

[51] SSE Ireland, 2020. Arklow Bank Wind Park. https://ireland.sse.com/what-we-do/our-projects-and-assets/renewable/arklow-bank-wind-park/

[52] Noordzeewind, 2008. Offshore Windfarm Egmond aan Zee General report https://www.noordzeewind.nl/nl_nl/kennis/bedrijfsvoering/_jcr_content/par/expandablelist/expandablesection.stream/1554282176475/334aa72f20805ebcbe44c1bdfc2cae19539d1e59/owez-r-141-general-report.pdf

[53] Copenhagen Environment and Energy Office and The Middelgrunden Wind Turbine Cooperative, 2002. The Middlegrunden Offshore Wind farm. http://base.socioeco.org/docs/a118_doc1.pdf

[54] Examples include Gwynt y Mor, Westermost Rough, Humber Gateway, Burbo Bank Extension, Dudgeon Offshore Wind Farm, and many others. See also Navigant, Connecting offshore wind farms report[1], or Navigant Dutch Offshore Wind Market Update 2019. https://www.navigant.com/-/media/www/site/downloads/energy/2019/navigant-dutch-offshore-wind-market-update-2019.pdf

Higher export voltages (e.g. 420 kV) have not been used to date as the main challenge lies in the installation of three phase 420 kV cables. At higher voltages, thicker insulation is required which increases the diameter of the export cable, making it more challenging to install. Next to the installation challenge of a 420 kV cable, also a thermal challenge exists within the cable design itself. Technology is however developing as cable manufacturer NKT recently announced that it will supply a 420 kV subsea cable for crossing a six kilometre sea distance near Stockholm.[55]

In addition, HVAC connections are further developing towards hub concepts where multiple wind farms are routed through a single offshore substation, such as the current 700 MW grid connection concept of TenneT in the Netherlands (e.g. Borssele Alpha connects two 350 MW wind farms[56]), and the Modular Offshore Grid concept of Elia in Belgium (note that additional HVAC collector platforms are used in Belgium[57]). Using hub concepts reduces the number of cable corridors and landfall locations, and increases redundancy compared to individual connections.

HVDC technology for offshore transmission assets has currently only been applied in Germany where wind farms are connected to HVDC offshore substations through HVAC collector platforms. As mentioned, HVDC is used because of the significant export cable lengths and offshore wind capacities required in the German North Sea.[58] The typical export voltage level for the HVAC collector platforms is 150 kV while the HVDC substations use 150, 250 or 320 kV export voltage levels. To reduce costs, TenneT has recently announced a new, more standardised, HVDC platform concept for the Netherlands and Germany where wind farms would directly connect their array cables to the HVDC platform. This would eliminate the HVAC collector platforms and reduce societal costs.[59]

Defining landing points and cable routes for offshore wind farms is a balancing act between costs (cable length/distance to connection point), environmental impact and social acceptance. Available onshore grid capacity is an important prerequisite. In the Netherlands, the roll-out of 10.6 GW of offshore wind farm capacity by 2030 is foreseen at landing points where sufficient onshore grid capacity is available in a timely manner. In Germany, large HVDC corridors are planned between North and South Germany to enable the integration of the continued roll-out of offshore wind. The use of hub concepts can limit the number of landing points required, as connections can be combined. However, largest single infeed requirements should be considered when planning and coordinating offshore transmission systems and landing points.

4.2.2 Offshore transmission assets in the international context

The trend of moving further from shore and adopting increasing capacity ratings results in increased adoption of HVDC and hubs for the connection of offshore wind farms. These developments also increase interest in international cooperation and sharing of offshore energy between countries. An example of this is currently being investigated by the North Sea Wind Power Hub (NSWPH) consortium. The consortium is working on a modular Hub-and-Spoke infrastructural concept to connect offshore wind through multiple central hubs of approximately 10 GW, which can be interconnected to the Netherlands, Germany and Denmark to scale up offshore wind deployment whilst combining this with offshore interconnections.[60] The NSWPH is an example of so-called “offshore hybrid assets” that combine the functions of offshore wind transmission assets and cross-border interconnection. Hybrid assets, such as WindConnectors, combining more than one function,

---

[55] NKT, 2019. NKT to deliver 420 kV high-voltage turnkey offshore power cables system to strengthen the grid in Stockholm https://www.nkt.com/news-press-releases/nkt-to-deliver-420-kv-high-voltage-turnkey-offshore-power-cables-system-to-strengthen-the-grid-in-stockholm

[56] TenneT, 2019. Programme 2023. https://www.tennet.eu/our-grid/offshore-grid-netherlands/programme-2023/

[57] Elia, 2019. Modular Offshore Grid. https://www.elia.be/en/infrastructure-and-projects/infrastructure-projects/modular-offshore-grid

[58] TenneT, 2019. Offshore Projects Germany. https://www.tennet.eu/index.php?id=2130&L=0

[59] TenneT, 2020. Dolwin 5. https://www.tennet.eu/our-grid/offshore-projects-germany/dolwin5/

[60] North Sea Wind Power Hub, 2019, The Vision; The Hub-and-Spoke concept as modular infrastructure block to scale up fast. https://northseawindpowerhub.eu/wp-content/uploads/2019/07/Concept_Paper_2_The-Vision.pdf. Navigant has performed multiple studies for the NSWPH Consortium over the last few years: Navigant, Supporting the North Sea Wind Power Hub, 2019. https://www.navigant.com/experience/energy/2019/supporting-the-north-sea-wind-power-hub

are also in line with ENTSO-E's objectives of integrating a high degree of renewable energy in Europe's energy system.[61] A recent example of a hybrid connection is the AC grid system linking the Kriegers Flak (DK) (see Figure 4-3) wind farm, which is currently under construction,[62] and the Baltic 2 (DE) wind farm. The North Sea region is considered to have a strong potential for hybrid assets.[63]

In 2016, countries in the North Sea region, including Ireland, signed the North Seas Energy Cooperation declaration aiming to facilitate more cost-effective deployment of offshore renewables.[64] Several potential hybrid projects were identified in the North Sea.[64] In the North Sea region there is also interest in joint development of hybrid projects allowing for instance a Dutch wind farm to connect to both the British and Dutch grids, or the proposed Project Irish Sea that would combine an Irish offshore wind farm with an interconnector between Ireland and the United Kingdom.[64]

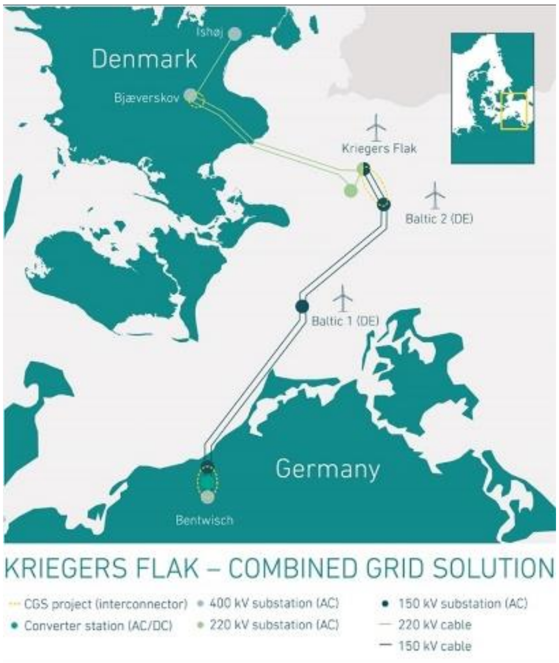


Figure 4-3. Kriegers Flak Combined Grid Solution. *Source: Energinet.dk, 2019.*[62]

The PROMOTioN project investigates another alternative typology where these trends of increased interconnection and offshore wind deployment is further integrated on a larger scale: an offshore meshed HVDC grid in the Northern Seas.[65] Similar projects for meshed grids were investigated in the Baltic Integrid[66] project for the Baltic Sea area and the ISLES project for Ireland, Northern Ireland and Scotland[67]. Meshed grids would allow large shares of offshore wind energy to connect to load centres but would also include the benefit of balancing this renewable electricity over a large geographical area through the interconnection function between countries bordering the sea area.

[61] ENTSO-E, 2019. ENTSO-E objectives. https://www.entsoe.eu/about/inside-entsoe/objectives/

[62] Vattenfall, 2019. News: construction of Kriegers Flak Offshore Wind Farm has started. https://group.vattenfall.com/press-and-media/news--press-releases/newsroom/2019/construction-of-kriegers-flak-offshore-wind-farm-has-started; Energinet.dk, 2019. Kriegers Flak – Combined Grid Solution. https://en.energinet.dk/Infrastructure-Projects/Projektliste/KriegersFlakCGS

[63] European Commission, 2014. Study on the benefits of a meshed offshore grid in the Northern Seas Region – final report. https://ec.europa.eu/energy/sites/ener/files/documents/2014_nsog_report.pdf

[64] Roland Berger, 2018. Hybrid Projects: How to reduce costs and space of offshore developments; North Seas Offshore Energy clusters study. https://op.europa.eu/en/publication-detail/-/publication/59165f6d-802e-11e9-9f05-01aa75ed71a1

[65] PROMOTioN, 2016, Deliverable 1.1, Detailed description of the requirements that can be expected per Work Package. https://www.promotion-offshore.net/fileadmin/PDFs/160415_PROMOtioN_WP1_D_1.1_V1.0.pdf

[66] Baltic Integrid. 2019. http://www.baltic-integrid.eu/

[67] ISLES, 2015. http://islesproject.eu/

4.2.3 Grid delivery models

From international practices, several types of grid delivery models can be distinguished: a developer-led model, a plan-led model, and model options that combine aspects of developer-led and plan-led grid delivery models. The developer-led and plan-led models provide two extremes of a spectrum of model options. Each model includes specific choices with regard to methods and responsibilities for auctioning, pre-development and grid connection.

This report aims to provide an assessment of these two extremes (developer-led and plan-led) grid delivery models to understand the main differences across the spectrum. Selecting a single model within the spectrum is not sensible as there are many options available. For most criteria, a model within the spectrum would be equally suited to either the developer-led or plan-led grid delivery model in the assessment framework. The definitions of developer-led and plan-led grid delivery models used in this report are defined below and in Figure 4-4.

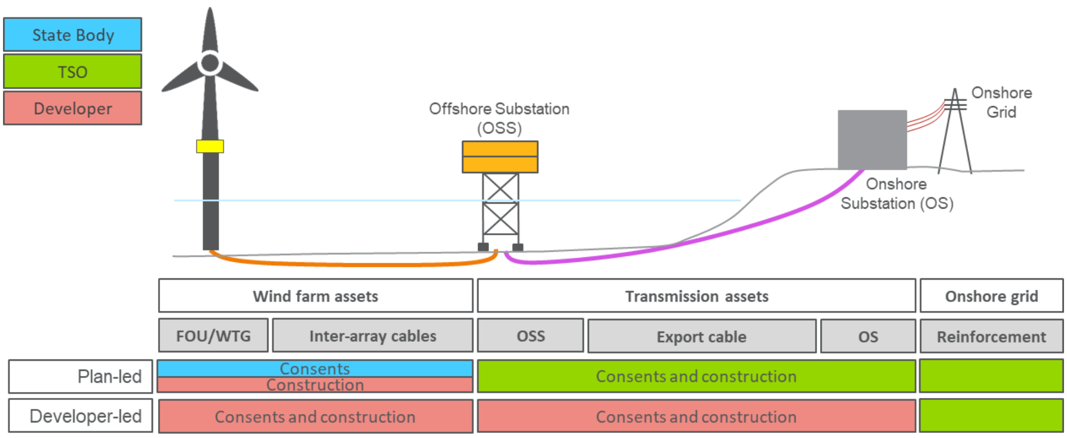


Figure 4-4. Allocation of development responsibilities of offshore wind farm and transmission assets. (FOU = foundation, WTG = wind turbine generator). *Adapted from: Navigant, 2019.*[12]

In the **developer-led grid delivery model**, commercial developers carry out consents and the (pre-) development and construction of both the offshore wind farm and the offshore wind transmission assets. The development and construction of the radial grid connections can be undertaken either by a wind farm developer or an independent Offshore Transmission Owner (OFTO). After construction, the transmission assets can be sold to an OFTO through a competitive auction as is the case in the UK. National governments could announce tenders for offshore wind projects where pre-developed sites by different developers would compete (i.e. amongst sites). The developer-led grid delivery model is, for example, applied in the United Kingdom.

Under the **plan-led grid delivery model**, a State Body and/or national TSO/TAO[68] is the responsible party for the complete process of wind farm site pre-development (including consents) and offshore wind grid connection development. In most cases, the TSO/TAO is responsible for all stages of the offshore wind transmission asset's life cycle, from development to construction and operation. This model is therefore also commonly referred to as the TSO-Built grid delivery model.[12] National governments announce tenders for offshore wind projects of a specific size within a specified geographical area (i.e. site-specific auctions), potentially as part of a planned and coordinated roll-out to meet renewable energy or wind energy targets. In this model, the government or TSO could be liable for damages suffered by the project developer if the TSO fails to fulfil its obligations to the grid connection. This obligation could include timely delivery of the grid connection and operational availability (potentially incentivised by penalties). The plan-led grid delivery model is, for example, used in the Netherlands, Denmark, Belgium and France.

Figure 4-5 presents the allocation of the roles and responsible parties within the European context. A distinction is made between governmental agencies or State Bodies (such as the DEA in Denmark

[68] In the Netherlands, Denmark and Germany, the TAO is also the TSO. In Ireland, the transmission ownership and operating responsibilities are divided between ESB and EirGrid, respectively.

and RVO in the Netherlands), private developers and transmission system operators (TSO). Ownership, operation and maintenance of the offshore wind transmission assets is under all models the responsibility of the party constructing them, with the exception of the UK where the ownership and maintenance is the responsibility of an OFTO and operation the responsibility of the TSO.

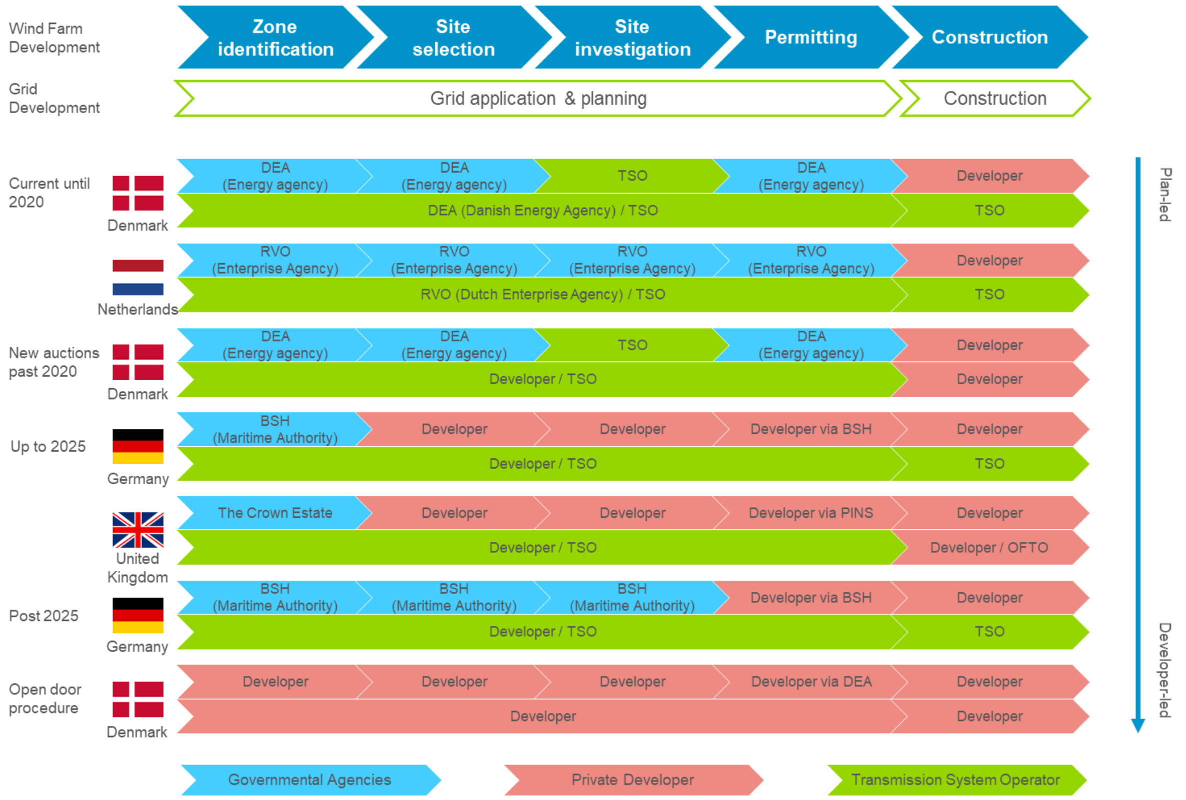


Figure 4-5. Allocation of roles and responsibilities within the grid delivery models throughout Europe. *Source: adapted from WindEurope, 2019.*[69]

While the offshore energy market has been around for nearly 30 years in Europe, the roles and responsibilities are still shifting between governmental agencies, government owned parties and commercial parties in established markets. A recent example is the Thor offshore wind farm in Denmark, which allows the wind farm developer to develop the wind farm's transmission assets (offshore substation and export cable), contrary to previous tenders for wind farms, such as Kriegers Flak and Horns Rev 3, where Energinet developed the offshore wind transmission assets. This change would provide more transparency to the costs associated to offshore wind farm projects.[70] Another example is the expanded role of TSO RTE in France where RTE, instead of the developer, develops the offshore grid connection for the Dunkirk offshore wind farm.

A government is free to decide upon and revise their adopted grid delivery model, and their decision is likely to be influenced by a range of different considerations. For example, in the UK Ofgem announced in February 2020 that it will explore whether a more coordinated offshore transmission system could reduce both financial and environmental costs, as it does not deem individual radial connections sensible and acceptable for consumers to allow for projected growth of offshore wind capacity.[71]

The same stakeholders are involved in the planning, (pre-)development and operation of offshore wind farms and transmission assets in both grid delivery models. However, the roles taken on by each

[69] Wind Europe, 2019. Industry position on how offshore grids should develop. https://windeurope.org/wp-content/uploads/files/policy/position-papers/WindEurope-Industry-position-on-how-offshore-grids-should-develop.pdf

[70] Source: DCCAE input from North Sea Energy Cooperation Countries

[71] Ofgem, 2020. Ofgem decarbonization programme action plan. https://www.ofgem.gov.uk/system/files/docs/2020/02/ofg1190_decarbonisation_action_plan_web.pdf

stakeholder can differ between the models. Table 4-1 presents the roles and responsibilities in the process of offshore wind farm and transmission asset development. The key stakeholders which hold responsibilities within the Irish context, are:

- Offshore wind farm developer;
- EirGrid, the Transmission System Operator (TSO);
- ESB Networks, the Transmission Asset Owner (TAO);
- State Body: e.g. Department for Communications, Climate Action and Environment (DCCAE), the Department of Housing, Planning and Local Government (DHPLG) or a dedicated State Body for ORE development.

Table 4-1. Definition of scope and allocation of roles and responsibilities for the developer-led and plan-led grid delivery models.

Project phase	Responsibility	Description	Developer-led model	Current "Onshore" model	Plan-led model
Pre-development	**Zone selection**	Selection of location of offshore zone wherein wind farm sites (including transmission assets) could be developed as well as identification and appointment of exclusion zones (e.g. military, shipping, fishing etc.)	DHPLG/ DCCAE	DHPLG/ DCCAE	DHPLG/ DCCAE
	Site selection	Selection of location of offshore wind farm site (including transmission assets) within the selected offshore zone	Developer	Developer	State Body
	Timing wind farm roll-out	Timing of wind farm site development (roll-out plan)	Developer	Developer	State Body
	Offshore wind farm transmission asset planning	Timing of offshore wind transmission asset development	Developer	Developer/ EirGrid*	EirGrid
Development	**Wind farm consents – application**	Consents for the offshore wind farm site (including surveys, wind resource and environmental assessments, and any required leases or licences)	Developer	Developer	State Body
	Offshore wind farm transmission asset consents – application	Consents for the offshore wind transmission assets (including environmental assessment and any required leases or licences)	Developer	Developer/ EirGrid*	EirGrid
	Financing	Financing of offshore wind transmission assets	Developer	Developer/ ESB Networks*	ESB Networks
	Final selection of onshore grid connection point	Final decision on onshore grid connection point	EirGrid	EirGrid	EirGrid
	Functional design offshore wind farm transmission assets	High-level design of the functional requirements and specs of transmission assets beyond grid codes and applicable standards (e.g. voltage level, capacity, cable corridor, offshore substation location, landing points, shared assets if applicable[72]…)	Developer	Developer	EirGrid and ESB Networks

[72] If shared assets are adopted under this model, issues might arise due to unbundling requirements (Directive on common rules for the internal market for electricity (EU) 2019/944) that restrict generation and operation by a single party, in this case the developers. The ownership and operation of shared assets may then have to fall under the responsibility of the TAO/TSO.

Project phase	Responsibility	Description	Developer-led model	Current "Onshore" model	Plan-led model
Construction	**Detailed design offshore wind farm transmission assets**	Detailed design of offshore wind transmission assets (e.g. full technical definition of transmission assets, installation methodology, construction timeline etc.)	Developer	Developer	EirGrid and ESB Networks
	Offshore wind farm transmission asset construction	Construction and commissioning of transmission assets	Developer	Developer/ ESB Networks*	ESB Networks
O&M	**Ownership and maintenance**	Ownership and maintenance of offshore wind transmission assets (including decommissioning)	Developer[72]	ESB Networks	ESB Networks
	Operation	Operation of offshore wind transmission assets	Developer[72]	EirGrid	EirGrid
Onshore grid reinforcements	**Responsibility onshore grid reinforcement**	Planning, specification, consenting (EirGrid) and construction (ESB Networks) of required reinforcements in the onshore grid to facilitate the infeed of offshore wind energy	ESB Networks/ EirGrid Reactive	ESB Networks/ EirGrid Reactive	ESB Networks/ EirGrid Pro-Active
Auction design	**Auction type**		Amongst sites	Amongst sites	Site-specific
	Definition of offshore capacity in RESS auctions		DCCAE	DCCAE	DCCAE
	Selection and definitions of onshore connection points (stations, capacity, timing) for auctions		N/A	N/A	EirGrid and DCCAE
Ownership boundary			Onshore	Onshore (developer*) / Offshore (ESB Networks*)	Offshore

*Developer has a choice to contest transmission asset development under the current "onshore" model.
Note that offshore wind farm transmission assets include the offshore substation, export cables and onshore connection assets.
Source: Navigant.

The key characteristics of developer-led and plan-led grid delivery models are summarised through four key questions to provide more context:

- **Who plans the location of the offshore wind farms including the location of offshore substations and the requisite offshore and onshore transmission assets?**

Developer-led grid delivery model	Plan-led grid delivery model
The developer determines the offshore wind farm sites and the location of the substation in the wind farm area. EirGrid would specify the onshore connection point. This is a more reactive approach to onshore grid integration as the winning site and corresponding connection point would only be known after the RESS auction.	The State Body appoints specific sites and, together with EirGrid, can decide on the location of the offshore substation inside the wind farm area. EirGrid can then determine the cable route and location for the onshore connection. The timing and order of sites can be structured such that onshore grid integration can be optimised.

- **Who funds the offshore wind transmission assets?**

Developer-led grid delivery model	Plan-led grid delivery model
The developer funds the offshore wind transmission assets. The costs are recovered through the PSO levy (RESS support) and network tariffs.	The TSO/TAO funds the offshore wind transmission assets. The costs are recovered through the network tariffs, paid by the energy companies and consumers for the use of the power grid.

- **Who is responsible for securing consents and building the offshore wind farm and transmission assets?**

Note that onshore grid reinforcements are not part of the offshore wind transmission assets or wind farm and would be developed under the current regime.

Developer-led grid delivery model	Plan-led grid delivery model
Securing consents for the offshore wind farm and transmission asset is the responsibility of the developer. Consents would be granted by the DCCAE through the Marine Area Consent. The (offshore wind farm) developer builds the offshore wind farm as well as transmission assets (offshore substation, export cable and onshore interface).	Securing consents for the offshore wind farm would be the responsibility of the State Body for ORE development. Securing the consents for the transmission asset would be the responsibility of EirGrid. Consents would be granted by the DCCAE through the Marine Area Consent. The developer builds the offshore wind farm and ESB Networks builds the offshore wind transmission assets. These transmission assets are operated by EirGrid upon completion of the project.

- **Who owns, operates and maintains the offshore wind transmission assets?**

Developer-led grid delivery model	Plan-led grid delivery model
The developer owns the offshore wind transmission assets. The assets are also maintained, owned and operated by the developer.	The offshore wind transmission assets are owned and maintained by ESB Networks and operated by EirGrid.

4.2.4 Auction design and support scheme

In addition to the plan-led and developer-led grid delivery model definitions as presented in Table 4-1, support scheme and auction design can vary per model. In a developer-led grid delivery model as employed in the UK, a 2-way CfD (contract-for-difference) support scheme is offered through technology neutral auctions. In the plan-led grid delivery models in the Netherlands, Belgium and Germany, a plan-led auction per offshore wind farm site is offered, with a sliding feed-in premium support scheme. This division is summarised in Table 4-2.

Table 4-2. Typical auction mechanism under developer-led and plan-led grid delivery models based on international practices.

Support aspect	Developer-led	Plan-led
Auction scheme	Technology-neutral (inclusive auction) auction amongst sites	Plan-led site-specific auction

Source: Navigant.

Note that auction schemes and support scheme mechanisms are not necessarily allocated in this way. A developer-led model could also make use of a sliding feed-in premium, and a plan-led model could make use of a 2-way CfD.

However, it would be unlikely for a plan-led grid delivery model to tender offshore wind farm sites in a technology neutral auction amongst sites as there should be competition amongst developers for a single site, or for a developer-led grid delivery model to have plan-led auctions per site as there is only one developer per site.

As the RESS 1 design defines a 2-way CfD support scheme, this is assumed for the assessment in sections 4.3 to 4.6 for both the developer-led and plan-led grid delivery models. For the auction design, an auction amongst sites is assumed for the developer-led model and a site-specific auction for the plan-led model, both with offshore wind specific support as stated in the CAP. Note that site-specific auctions could include multiple sites in one combinatorial auction.

4.3 Economic and financial assessment

Financial/economic

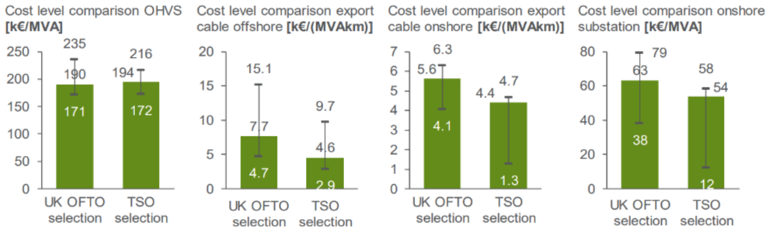
1a-b Impact on cost level of transmission assets

Cost level assessment for the offshore grid models including impact on investment and operational costs of offshore wind transmission assets, for single projects and across grid roll-outs.

Information

Cost levels for offshore wind transmission assets may vary per grid delivery model and are an important decision-making criterion for selecting a grid delivery model. Ultimately, electricity consumers are impacted by these costs through network tariffs and the PSO levy components of the electricity bill. The most important cost components of offshore wind transmission assets are the CAPEX and OPEX (typically 1-2% of the CAPEX).[73]

A cost level comparison performed by Navigant shows that CAPEX levels are generally lower for each main component in an offshore transmission system in a plan-led grid model compared to a developer-led model.[12] However, recent UK offshore wind tender results showed that strike prices (including transmission costs) have gone down considerably to levels around 40 £2012/MWh[74], comparable to overall levels under plan-led delivery grid models.



UK selection represents a developer-led model, TSO selection represents a plan-led model. Offshore High Voltage Station = OHVS. Source: Navigant, Connecting Offshore Wind Farms.[12]

The total investment required for the offshore wind transmission assets (offshore substation, export cabling and onshore connection assets) of 3.5 GW offshore wind capacity in Ireland can be estimated to be between EUR 1.5 and 2 billion, for "typical" Irish wind farm conditions.[75] The current hosting capacity of the Irish grid is estimated to be approximately 1.5 GW. To allow the integration of an additional 2 GW of offshore wind capacity, grid reinforcements will be required. The required investment for these onshore grid reinforcements will depend on the extent to which offshore wind farms are connected in a plan-led manner.

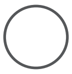
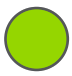
The total societal costs will be mainly determined by the costs for the wind farm, transmission assets and onshore grid reinforcements.[76] At this point, based on the considerations above, it is not possible to provide a total quantitative societal cost comparison mainly due to the uncertainty in cost differences in transmission assets and onshore grid reinforcements under both models. Ireland, as an emerging market, might benefit from a developer-led grid delivery model where experienced developers could deploy offshore wind transmission assets at more optimal cost levels right away. A plan-led model, however, has the potential to deploy infrastructure more efficiently from a system perspective, especially considering the foreseeable onshore grid challenges ahead.

[73] DNV GL, 2019. Cost of offshore transmission. https://www.tennet.eu/fileadmin/user_upload/Company/News/Dutch/2019/20190624_DNV_GL_Comparison_Offshore_Transmission_update_French_projects.pdf

[74] Department for Business, Energy & Industrial Strategy, 2019. Contracts for Difference Allocation Round 3 Resultshttps://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/838914/cfd-ar3-results-corrected-111019.pdf

[75] The range is given by using cost parameters for "UK OFTO selection" and "TSO selection" from the Navigant report on Connecting Offshore Wind Farms. A total offshore wind capacity of 3.5 GW (4 GVA), and export cable lengths of 20 km offshore, and 10 km onshore are assumed. See also Appendix A.

[76] Note that typical offshore wind farm investment costs are approximately 1.8 to 2.0 M€/MW (https://www.shell.nl/media/persberichten/2018-media-releases/blue-wind-consortium-reaches-financial-close.html, https://group.vattenfall.com/press-and-media/news--press-releases/pressreleases/2016/vattenfall-wins-tender-to-build-the-largest-wind-farm-in-the-nordics). Grid connection investment costs for the Dutch roll-out are approximately 0.7 M€/MW (https://www.parlementairemonitor.nl/9353000/1/j9vvij5epmj1ey0/vjskeuzrc0yz).

	Developer-led	Plan-led
Grid delivery model	Recent tender results in developer-led grid delivery models, like in the UK, have proven that it is possible to achieve low strike prices when transmission assets are included in the developer's scope. It allows for more innovation and increased competitive pressure, which control cost levels.[77] However, due to unavailability of data, it is unknown how the share of transmission costs in these bids would compare to transmission asset cost levels under plan-led models like in the Netherlands and Germany. In addition, the zero subsidy bids make it hard to compare combined cost levels of transmission assets and wind farm scope between developer-led and plan-led models. From a system perspective, a developer-led model could increase costs resulting from a more uncoordinated, ad-hoc and less holistic approach towards the planning and design of offshore grid connections. This could lead to suboptimal system solutions and an increased risk of higher costs for onshore grid reinforcements. In the case of Ireland, this would be a key aspect to consider and evaluate. In addition, developers are currently not incentivised to cooperate and develop e.g. shared assets as they are inclined to limit risks for their individual project. Many of the offshore wind farm developers in Ireland are developing multiple offshore wind farm in projects across Europe and further afield. They could expect to benefit from economies of scale for CAPEX costs, some standardisation of asset designs across multiple jurisdictions as a result of this – thus reducing costs.	In plan-led delivery grid models, TSOs face in practice less competition to deliver at cost optimal levels and in a timely manner. In the absence of competition, TSO performance is controlled by regulation. Plan-led delivery grid models, however, can benefit from standardised designs and processes: reduced DEVEX[78] from standardised asset designs, reduced CAPEX from scalability of assets, economies of scale, project pipeline (buying power) and synergies from shared operational and maintenance activities between assets. Redundancy between transmission assets would increase availability in case of grid outages and the use of back-up power technologies (e.g. diesel generators) would be avoided. From an overall system perspective, investment and operating costs would be reduced. Also, cost savings could be achieved when offshore wind transmission asset roll-out is coordinated with onshore grid reinforcement needs. This is particularly relevant where significant onshore grid reinforcements are foreseen.
Assessment summary	 **Cost levels offshore wind transmission assets:** Recent offshore wind tender results demonstrated that competitive pressure can bring down cost levels of offshore wind farm projects that include transmission assets and can achieve comparable ranges as offshore wind cost levels under a plan-led model.	 **Cost levels offshore wind transmission assets:** Standardised design and processes, together with scalability, pipeline and O&M synergies of multiple assets, allow for offshore wind transmission assets cost reduction.
	 **Cost levels onshore grid reinforcements:** Broader system inefficiencies due to a lack of coordination between offshore and onshore developments could still be a risk under this delivery grid model.	 **Cost levels onshore grid reinforcements:** Coordination between offshore and onshore grid planning will result in lower onshore grid reinforcement cost levels.

[77] IEA, 2019. Offshore Wind Energy Outlook 2019, page 26, figure 8. https://webstore.iea.org/offshore-wind-outlook-2019-world-energy-outlook-special-report

[78] DEVEX, development expenditures that occur pre-financial close related to site (pre-)development.

Financial/economic	
2	**Impact on number of consumers and consumer electricity prices**

Consumers' electricity prices are impacted by the choice of offshore grid delivery model as the tariffs consist of different components (network tariffs, PSO levy, energy tariff, etc.), which are impacted differently by each model.

Information

The consumers' electricity bill reflects the components through which the financing parties recover the cost of the investments incurred, related to the offshore wind farm and transmission assets. The same number of consumers would be impacted under both grid delivery models, but the difference lies in the weight of each component relative to the grid model choice. The electricity tariff consists of the following components:

- **PSO (public service obligation) levy** – a regulated component of the tariff, designed to recover the costs linked to the funding mechanism under the RESS auctions. It is determined by the regulator and it is ultimately paid to the generators through the suppliers with which they have Power Purchase Agreements. For residential customers, the PSO levy is €2.84 per month (from October 2019 onwards[79]). Taxes (non-VAT) are approximately 3% of the total electricity price in Dublin.[80]
- **Network tariffs** – a regulated component through which the TAO earns back the investment and operational costs of onshore and offshore transmission investments, when applicable. Grid costs are approximately 30% of the total electricity price to residential customers in Dublin.[80]
- **Energy tariff** – the liberalised component of the electricity bill, paid to energy suppliers based on energy consumption and mainly subject to retail competition. Energy tariffs are approximately 55% of the total electricity price to residential customers in Dublin.[80]
- **VAT** – approximately 12% of the total electricity price to residential consumers in Dublin.[80]

Similar to the PSO levy, the ODE subsidy in the Netherlands is paid for by consumers. In the Netherlands, €4 billion of subsidies are reserved for offshore wind farms that will be built by 2023.[81] In addition, TenneT also receives a correction in its Allowed Tariff incomes related to wind offshore development.[82]

[79] Electricity Ireland, 2019. What is the PSO levy and how much is it? https://www.electricireland.ie/residential/help/billing/is-the-pso-levy-increasing

[80] Household Energy Price Index, 2020. www.energypriceindex.com

[81] Algemene Rekenkamer, 2018. Focus op kosten windenergie op zee. https://www.rekenkamer.nl/publicaties/rapporten/2018/09/27/focusonderzoek-kosten-van-windparken-op-zee

[82] ACM, 2015. Besluit tot vaststelling van de maximum transporttarieven voor TenneT TSO B.V. voor het jaar 2016 en wijziging van de rekenvolumina. https://www.tennet.eu/fileadmin/user_upload/The_Electricity_Market/Customers/besluit-tarieven-tennet-2016.pdf

	Developer-led	Plan-led
Grid delivery model	All consumers would be impacted through the different components of the electricity bill, as described below: A higher increase in **PSO levy** would be expected in a developer-led model since it would need to cover investments in offshore wind transmission assets as well as the regular offshore wind farm cost. **Network tariffs** in a developer-led model could be potentially higher mainly due to an increased risk of a lack of coordination between the offshore and onshore grid development activities. There is no increase in network tariffs expected from offshore wind transmission assets in a developer-led model, since these would be taken care of by the developer. Retail competition would play the biggest role in setting **energy tariffs**. However, compared to a plan-led model, offshore wind electricity consumers could potentially be somewhat impacted due to higher costs that need to be recovered (for both offshore wind farm and transmission assets). The impact is expected to be limited as the offshore wind farm is likely to be part of a wider portfolio of the retailer, and the cost would be mostly covered by the PSO levy.	All consumers would be impacted through the different components of the electricity bill, as described below: The increase in **PSO levy** would only account for the offshore wind transmission assets and therefore would be lower than in a developer-led model. The development of the offshore wind transmission assets lies under the TAO's scope. In comparison to the developer-led model, **network tariffs** would see a higher increase to account for the TAO's development of offshore wind transmission assets. In contrast, a potentially more efficient and coordinated TAO investment plan for both onshore and offshore assets would lead to a lower increase resulting from onshore grid reinforcements. It does not seem likely that this impact would offset the increase in network tariffs through the inclusion of offshore wind transmission assets. The **energy tariff**, purely attributable to the energy consumed, is determined by the energy supplier and it is mainly subject to retail competition. Energy tariffs might also be somewhat impacted due to offshore wind farm developments but not due to transmission assets, as these are not part of the developer's scope. The impact, however, is expected to be limited, similar to the developer-led model.
Assessment summary	**Impact on PSO levy:** Higher PSO levy accounting for offshore wind farms and transmission assets.	**Impact on PSO levy:** Lower PSO levy accounting only for offshore wind farms.
	Impact on network tariffs: Potentially higher increase in network tariffs from onshore grid reinforcements. No impact from offshore wind transmission assets.	**Impact on network tariffs:** Potentially lower increase in network tariffs from onshore grid reinforcements. Higher network tariffs due to offshore wind transmission assets.
	Impact on consumer energy tariffs: Limited impact expected on energy tariffs for offshore wind electricity consumers.	**Impact on consumer energy tariffs:** Limited impact expected on energy tariffs for offshore wind electricity consumers.

Financial/economic

3-4 Impact on State support scheme expenditure and income – transmission assets and offshore wind scope

The choice for an offshore grid delivery model and support scheme will impact State expenditure (and potential income) for the offshore wind farm and the transmission asset scope.

Information

In plan-led grid delivery models like in the Netherlands, the support scheme mostly corresponds to a sliding feed-in premium system. A maximum payment is received by the developer per kWh. This payment guarantees the difference between the developer's bid price and the market price. The developer will not receive a support payment if the market price goes above the bid price. A floor price is in place to set a maximum to the subsidy payment and is determined by the government. Tenders with sliding feed-in premium support schemes in plan led models have already led to zero subsidy bids for offshore wind farms in the Netherlands and Germany. Note that in these tenders the grid connection was not part of the developer's scope.

In a developer-led grid delivery model, as in the UK, a 2-way CfD scheme is in place where a successful developer in the tender rounds will be allocated with a strike price. The 2-way CfD scheme is based on a difference between the market price and the agreed strike price. The developer will receive a payment when the strike price goes above the market price and will pay back the difference to the government agency when the market price goes above the strike price. Note that the choice for a support scheme is independent on the grid delivery model, as explained in section 4.2. Ireland's proposed new financing structure for successful developers under the RESS auction scheme is based on a 2-way CfD. This support scheme will be funded through the PSO levy.[21] The draft terms and conditions of the RESS 1 scheme were published in December 2019 for consultation.[24]

Grid delivery model

Developer-led assuming 2-way CfD support scheme[83]	Plan-led assuming 2-way CfD support scheme[83]
Offshore transmission assets fall under the developer's scope and therefore under the RESS auction scheme. Bid prices in a developer-led model ruled by a CfD support mechanism would then need to account for both the offshore wind farm and transmission assets. Total State support scheme expenditures are hence expected to be higher than under a plan-led model. However, there is high uncertainty on the expenditure levels since these are largely dependent on auction bid prices and the evolution of power market prices. Similarly, any potential State income coming from a 2-way CfD support scheme is possible, but income levels remain highly uncertain.	Under a plan-led model, offshore wind transmission assets would be developed by the TAO and therefore only the wind farm assets, falling under the RESS scheme, would impact the bid price. Since the offshore wind transmission assets are not part of the developer's scope, no support scheme expenditures or income are expected. Compared to the developer-led model, total State support scheme expenditures are therefore expected to be lower.

Assessment summary

	Developer-led		Plan-led
	Impact on State support scheme income/expenditure – offshore wind assets: Impact on State support scheme expenditures/income uncertain due to high uncertainty on cost levels. Both expenditures and income are possible.		**Impact on State support scheme income/expenditure – offshore wind assets:** Impact on State support scheme expenditures/income uncertain due to high uncertainty on cost levels. Both expenditures and income are possible.
	Impact on State support scheme expenditure/income – transmission assets: Impact on State support scheme expenditures or income uncertain due to high uncertainty on cost levels. Both expenditures and income are possible.	**N/A**	**Impact on State support scheme expenditure – transmission assets:** No State support scheme expenditures or income possible as offshore wind transmission assets outside developer's scope.

[83] Note that the 2-way CfD support scheme .is assigned to both grid delivery models in line with the RESS.

Financial/economic

5 Impact on financeability of transmission assets

Ease at which the developing party can attract finance for offshore wind transmission assets, impact on risk and interest rates

Information

In plan-led delivery grid models, offshore wind transmission assets are financed by the TSO/TAO. These assets follow established regulated remuneration schemes determined by the national regulators. Regulation plays a big role in facilitating the investments, especially by ensuring sufficiently high regulated rate of returns to allow the financial viability of the TSO/TAO in the long run. The Irish regulatory model characteristics are compared to those in Germany and Netherlands, where some TSOs are also state-owned.

	Germany[84]	Netherlands[84]	Ireland[85]
Pre-tax return on equity	6.91%	5.02%	6.86%
Cost of debt	N/A	2.19%	2.90%
Gearing	60%	50%	55%
WACC pre-tax	N/A	3.0%	4.95%

To date, in the developer-led grid delivery model in the UK developers have opted to develop and finance offshore wind transmission assets themselves. Once completed, transmission assets are transferred to the successful OFTO bidder in exchange for a lump-sum determined by Ofgem (Final Transfer Value) based on the efficient costs, which the developer ought to have incurred for the development of the assets. Developers' hurdle rates may differ largely, subject to their risk appetite. A bottom level indication of their equity returns is revealed through the OFTO tenders: OFTO parties have required equity returns ranging between 9-10% (post-taxed), and recently 7% in tender round 5.[86]

[84] PROMOTioN, 2017. Deliverable 7.5: Financing framework for meshed offshore grid investments. https://www.promotion-offshore.net/fileadmin/PDFs/D7.5_-_Financing_framework_for_meshed_offshore_grid_investments.pdf

[85] ESB, 2016. ESB Price Control 2016-2020. https://esb.ie/docs/default-source/investor-relations-documents/esb-networks-pr4-price-review-determination---investor-presentationc083592d46d164eb900aff0000c22e36.pdf?sfvrsn=4

[86] Ofgem, 2018. RIIO-2 Sector Specific Methodology Annex: Finance, page 46-47. https://www.ofgem.gov.uk/system/files/docs/2018/12/riio-2_finance_annex.pdf

	Developer-led	Plan-led
Grid delivery model	Developers generally require higher returns on equity since their appetite for risk is higher than that of a government-backed TSO. In a developer-led grid delivery model, UK experience shows there is a diverse pool of private capital available (infrastructure funds, insurance companies) for investments in generation and transmission assets.[84,87] Changing trends in financial markets could, however, impact the appetite of investors to finance transmission assets as part of the offshore wind farm scope. Financing costs may differ substantially depending on the developers' portfolio size, investment rating, and their project financing approach, i.e. corporate loans, project finance, bonds, etc. Developers with a sufficiently large investment portfolio, generally can spread risk across it, will be more willing to be aggressive on their returns and will likely have more favourable financing terms with lenders. Overall, in the UK a diverse set of international financing sources are available to fund these assets, both at the developer's construction phase and at the OFTO's takeover phase. It is likely that these sources of finance will be available in Ireland as they are also available in other developing offshore wind markets such as Taiwan.[88]	Generally, lower allowed returns on equity are set by regulators for regulated investments. On the one hand, the regulatory framework can provide stability and certainty to investors attracted to inherently low-risk transmission assets. On the other hand, regulation should also be flexible and timely reflect changing trends in financial markets, i.e. decreasing interest rates, to allow TSOs to attract capital that matches market conditions. TSOs could otherwise face limitations or lose opportunities in raising funding. State-owned TAO/TSOs are generally seen as more creditworthy than developers. ESB Networks, 95% state-owned, can probably access relatively cheaper sources of financing than most private developers. However, governments are reluctant to include additional external equity compared to privately-owned TSOs or developers. Most of the financing is in the form of corporate or EIB[89] loans or bonds[84]. Increasing debt financing could impact creditworthiness and investment rating, ultimately impacting interest rates at which TSOs can lend from financiers. It is thus key that regulators set not too high leverage levels. Enabling private capital would contribute to better balancing the TSOs' overall corporate financing structure, especially considering the investment volumes required in the near-term to meet investment plans.
Assessment summary	Large variety of financing sources available. Financing costs may vary subject to developer's portfolio, rating and financing approach. Higher equity returns than government backed TSOs. There is no experience to date of how risk in an Irish context would be priced by developers.	Potentially less diverse financing sources available. Potentially cheaper financing for government-backed TAO investments with good credit ratings. Regulated assets have lower allowed returns on equity.

[87] PwC, 2018. Offshore Transmission Market update, page 20. https://www.ofgem.gov.uk/system/files/docs/2018/10/pwc_ofto_tr6_market_update.pdf

[88] OffshoreWind.biz, 2019. Formosa 2 Reaches Financial Close. https://www.offshorewind.biz/2019/10/29/formosa-2-reaches-financial-close/

[89] EIB: European Investment Bank.

Financial/economic

6 Impact on financeability of offshore wind farm assets

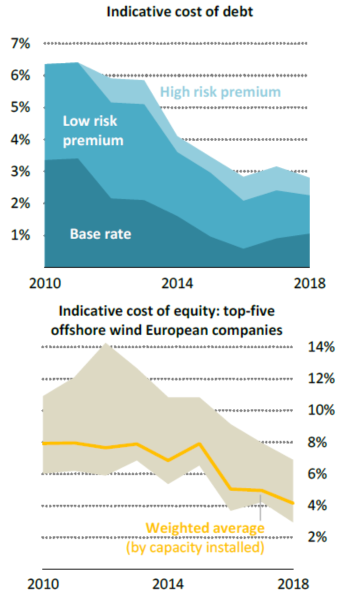
Ease at which the developing party can attract finance for offshore wind farm assets, impact on risk and interest rates.

Information

In developer-led grid delivery models, wind farm site development (zone identification, site selection, investigation and consents) and offshore wind transmission infrastructure developments become part of the wind farm scope. With increased risk in the project's scope, equity return rates will generally be higher. Higher risk generally results in higher financing costs, but it is subject to the developer's experience, its investment portfolio and its project financing structure.

In plan-led grid delivery models, transmission infrastructure and site pre-development, are taken care of by the TAO/TSO and a state agency. This contributes to de-risking of the project and possibly attracting smaller more risk-averse developers to invest, with more varying hurdle rates. By de-risking the project scope, financing costs will inherently go down.

In mature offshore wind markets, there are active investors for almost every risk profile and stage of the project, and hurdle rates are consistent with the risks taken at each stage. Cost of debt and cost of equity have drastically gone down, reflecting the ease at which financiers now lend money to offshore wind projects and how competitive investors have become in their expected rates of returns. In the Irish context, as with other recent emerging markets, an additional premium to account for the new market risk could be required by debt providers. Equity investors will probably also account for this in their equity return rates.



Source: IEA, Wind Offshore Outlook, 2019.

Grid delivery model

Developer-led	Plan-led
Wind farm site and offshore wind transmission infrastructure developments add to the project risk profile, impacting financing costs of the overall project for a given specific developer and compared to a plan-led grid delivery model. An increasing trend in interest rates can also impact developers' appetite to invest in additional grid developments on top of regular offshore wind farm developments. Also, developers' expertise in site and offshore grid developments will be assessed by financiers and premiums in the financing terms will be added accordingly to account for a higher risk of delays or issues. Developer-led grid delivery models will favour experienced developers and/or developers with large investment portfolios capable of taking on the additional risk, and therefore a more limited number of developers will likely be willing to invest.	Wind farm site (pre-)development is partly undertaken by the government and offshore wind transmission infrastructure is developed by the TAO/TSO. The project profile is de-risked and, compared to a developer-led grid delivery model, financing costs and returns on equity will be lower for a given developer. De-risking the project's profile can attract various types of equity sources that may have been reluctant to invest in a developer-led grid delivery model. Also, it will be easier for developers to agree on more attractive terms with debt providers, i.e. lower interest rates in project-financed deals. However, in an emerging offshore market like Ireland, a minimal additional premium in investors' equity return rates and projects' financing costs can be expected to capture the additional risk to the wind farm project related to the setup and development of the transmission space, compared to the levels in more mature markets.[90]

[90] Green Giraffe, 2018. Profitability and financeability of offshore wind. https://www.offshore-energy.biz/uploads/images/sub_producten/Offshore%20Wind%20Conference%20-%20Profitability%20and%20financeability%20of%20offshore%20wind%20-%20Barbara%20Zuiderwijk.pdf

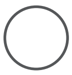
Assessment summary	◐	Increased perceived risk profile of offshore wind farm projects by some investors. Potentially more expensive financing costs from debt providers, subject to developer's investment portfolio, investment rating and financing approach. Potentially somewhat more limited investor pool interested in providing equity financing due to increased project risk.	●	Lower perceived risk profile of offshore wind farm projects by some investors but developers perceive a risk as they do not have control of site pre-development and offshore wind transmission infrastructure development. Potentially cheaper financing costs due to lower project risk, subject to developer's investment portfolio, investment rating and financing approach. Potentially somewhat more diverse investor pool interested in providing financing.

Financial/economic		
7	**Impact on level of risk of lost revenue for the wind farm developer**	
Impact and allocation of risks of potential wind farm lost revenues during the delivery and operational stages (e.g. late delivery of offshore wind transmission assets, delays of onshore grid reinforcements, constraints due to forced grid outages).		
Information	The risk of lost revenue for a wind farm developer is defined as the developer's exposure to a situation when a component or a part of the offshore wind transmission asset is unavailable for the delivery of power, causing revenue losses and a negative economic impact on the developer's wind farm business case. This risk can take place before the grid's commercial operations date, potentially causing a delay in the delivery of the grid, or during the operation phase due to a grid outage or curtailment. The developer's perception is that EirGrid and ESB Networks have limited experience in developing offshore transmission assets for wind farms and therefore the offshore wind industry may perceive the delayed delivery of offshore transmission assets as a greater risk in a plan-led grid delivery model. Nonetheless, ESB Networks also has vast experience in developing onshore transmission assets as well as international experience with offshore transmission assets and wind farm development through their subsidiary ESB International.[91] EirGrid has successfully delivered the East-West interconnector project to the UK on time and within budget.[92] In addition, the Celtic interconnector is under way, currently in early development[93]. This experience may contribute to reducing the perceived risks by developers. An important point to note is that delays in onshore transmission assets are not generally representative for offshore grid development as the onshore environment is more challenging in terms of permits and landowners.	

[91] Projects ESB international supported include the Moyle and East West HVDC interconnectors, a subsea AC cable project in Tanzania and AC cable projects in Cork-Harbour. Source: ESBI, 2020. https://www.esbinternational.ie/our-solutions/transmission.

[92] The Irish Times, 2012. East-West interconnector is opened. https://www.irishtimes.com/news/east-west-interconnector-is-opened-1.737858

[93] DCCAE, 2019. Minister Canney bears witness to historic grant agreement signing ceremony in Brussels – Celtic Interconnector to proceed with €530m grant secured and signed. https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Minister-Canney-bears-witness-to-historic-grant-agreement-signing-ceremony-in-Brussels---Celtic-Interconnector-to-proceed-w.aspx

	Developer-led		Plan-led	
Grid delivery model	In a fully developer-led model where the developer would be responsible for the development of the offshore wind transmission assets, the risk of delayed delivery of the transmission assets is borne and managed by the developer. It could therefore be argued that there is a reduced probability this risk will materialise since the developer is incentivised to ensure timely delivery of the offshore wind transmission assets, and developers have gained experience in other markets. Also, during the operational phase, a developer would be incentivised to maximise grid availability to prevent lost revenue. However, if the risk event occurs, the developer would miss out on potential compensation payments under a plan-led model. Also an OFTO could develop and finance the offshore wind transmission assets but this has not happened so far as the risk of late delivery is considered too high by developers.[69] When the developer transfers ownership to an OFTO, appropriate incentives should be in place to ensure OFTOs are sufficiently incentivised to ensure availability of offshore wind transmission assets. However, in the UK OFTO scheme, developers consider this risk is not evenly allocated between developer and OFTO, as the developer is exposed to a risk that is managed by the OFTO.[69] An additional risk is the absence of compensation in case of onshore grid reinforcement delays under the current RESS 1 design, which are more likely in case of a developer-led model (see also plan-led model description).		In a plan-led model, the TSO/TAO has the responsibility to deliver the offshore wind transmission assets in a timely manner and ensure their availability during the operational phase. The developer, however, bears the risk of delayed delivery while the TAO/TSO manages this risk. The developer could, nevertheless, receive compensation payments for non-availability of the offshore wind transmission assets.[94] In the operational phase, the developer receives compensation after a specified period per outturn availability rules. However, the current RESS design does not include any compensation for delayed delivery of offshore wind transmission assets, only an option for the DCCAE to delay specified deadlines. Unavailability during the operational phase is covered under the outturn availability rules[95]. This grid model's setup would specifically benefit those developers whose core business strictly focuses on offshore wind farm developments and not offshore grid development. Absence of compensation could increase perceived risk of wind farm investors as the risk of lost revenues due to stranded assets is increased. From the developer's perspective the risk could be perceived as higher when compared to a developer-led model as the risk for this critical component of an offshore wind farm is out of their control. An additional factor is the absence of compensation under the current RESS 1 design.	
Assessment summary		Offshore transmission assets under developer's control, so reduced perceived risk. However, no compensation payments received if risk materialises. Increased risk perceived when TSO/TAO and developer need to efficiently coordinate transmission asset developments with onshore grid reinforcements, and no compensation in place for delays in onshore grid reinforcements.		Increased perceived risk by developer as offshore wind transmission assets are not within their control. Risk largely depends on availability of compensation in case of delays although under outturn availability developers get paid after a specified period of time. Currently no compensation for delayed grid delivery in place under the RESS design. Reduced risk perceived when it is the TSO/TAO's responsibility to coordinate offshore wind transmission assets with onshore grid reinforcements only.

[94] CMS, 2018. Compensation for delay and unavailability, section 4.4. https://cms.law/en/int/expert-guides/cms-expert-guide-to-offshore-wind-in-northern-europe/netherlands

[95] EirGrid, 2017. The EirGrid and SONI Implementation Approach to the SEM Committee Decision Paper SEM-15-071. http://www.eirgridgroup.com/site-files/library/EirGrid/The-EirGrid-and-SONI-Implementation-Approach-to-the-SEM-Committee-Decision-Paper-SEM-15-071-Version-2.pdf

4.4 Technical assessment

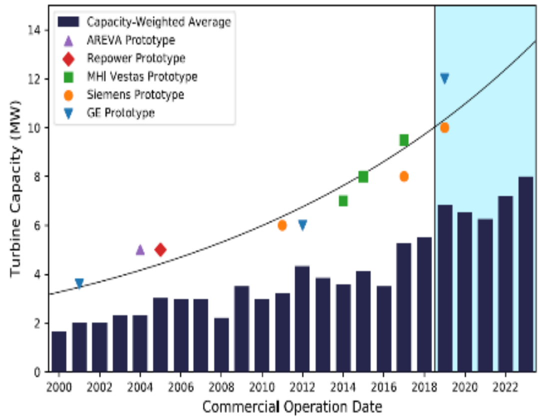
Technical	
1	**Technological advancement of offshore wind technology (2020-2030)**

A projection of technologies that can be deployed at scale within the next 10 years.

Information

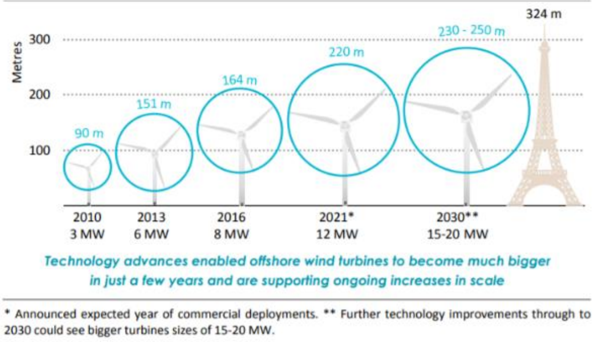
Offshore wind is a cost-effective mature technology; technology development over the next 5-10 years is expected to be incremental.

Turbine diameter and rated capacity - Larger turbines come with reduced Balance of Plant[96] cost per MW, a benefit that is partly offset by increased costs per unit and cost for construction. Over the next decade, it is expected that, based on current prototypes, the dominant class of turbines will have around 8-12 MW rated power and a rotor diameter of 150-225 m. Offshore turbine tower heights are expected to increase, in line with increases in rotor diameters.[97] A recent study by the IEA indicates that further technology improvements to 2030 could see the introduction of bigger turbines of 15-20 MW.[77]



Turbine capacity development by year.[97]

Capacity and capacity factor - Offshore wind projects usually have a higher capacity factor than onshore wind projects. Gross capacity factors (excluding wake losses) are reported at around 40% and are projected to increase above 50%.[77] This is due to technological choices and developments that are triggered by the proportionally higher costs of maintenance, construction and grid connection. No major change to the installed capacity per planning area is to be expected, as the inter-turbine distances scale with the rotor diameter. The typical range was 3.5-8.8 W/m² for past offshore projects[98], NREL uses conservative 3 W/m² as standard[97]. The planning of the grid connection is thus considered technology neutral with respect to future turbine diameter and rated capacity



Average commercial wind turbine rating compared to prototype deployment by year.[77]

Foundation and water depth - Fixed bottom foundation designs (i.e. monopile, gravity, tripod) are typically deployed for water depths up to 30-40 m, and up to a maximum of 50-60 m. Moored floating foundations have been used in one wind farm. It is expected that the use of floating foundations will become more routine for projects with water depths exceeding 60 m. This allows a wider planning area to be considered for offshore wind farms, which is necessary for unlocking more of Ireland's offshore wind potential in the longer term.

---

[96] The 'Balance of Plant' refers to all engineering, supporting components and auxiliary systems for offshore wind development *aside* from the installation of the wind turbines.

[97] US Department of Energy, 2018. Offshore Wind Technologies Market Report. https://www.energy.gov/eere/wind/downloads/2018-offshore-wind-market-report

[98] NREL, 2013. Assessment of Offshore Wind Energy Leasing Areas for the BOEM Massachusetts Wind Energy Area, https://www.nrel.gov/docs/fy14osti/60942.pdf

Grid delivery model	Developer-led		Plan-led	
	Developers are incentivised to develop (incremental) innovations that deliver commercial benefit.		The government could create room for targeted areas of innovation.	
Assessment summary	◑	A developer-led model might allow for faster and more incremental innovations, but only if cost-effective.	◑	A plan-led model can prescribe innovations, but standardisation might hinder progress.

Technical

2 Technological advancement of other offshore renewable energy technologies (ORE) (2020-2030)

A consideration of new ORE technologies that may enter the market within the next decade.

Information

New offshore renewable energy (ORE) technologies (excluding offshore wind) include the conversion of power from waves, tidal flows, ocean currents, differences in salinity and temperature. Offshore wind will be the main contributor towards the 2030 renewable electricity targets but R&D and demonstration of other ORE technologies will be pursued due to their vast potential in Ireland.[17] Auxiliary technologies that support the scaling up of new ORE technologies include storage, and power-to-X solutions.

Tidal Range - Tidal range technology is well established with several plants in operation around the world. There are a few technically suitable sites in Ireland,[99] but there is currently little or no active or planned development of a tidal barrier in Ireland.

Tidal Flow - Tidal (and ocean) currents are highly predictable and well-suited for power generation. Substantial flows could be exploited along the north and east coasts of Ireland (see figure). The technology is promising, although it is still in the early stages of development. It is not expected that there will be significant deployment in Ireland by 2030.

Power-to-X - describes the storage of electrical energy in a chemical product, X. Hydrogen (H_2) is one product option being discussed. Power-to-X technology can serve as buffer storage for excess power, as well as become an independent route of channelling power produced offshore to shore. The additional fuel, X, could offset natural gas which could then remain underground. Power-to-Hydrogen technology is available at scale, but commercially not viable if required to compete with Natural Gas.

	Developer-led	Plan-led
Grid delivery model	New ORE technologies will not thrive in direct commercial competition with other renewable technologies, such as onshore and offshore wind. A developer-led solution would need to be accompanied by project-specific ORE support. Transmission assets are likely to be built on a project-by-project basis.	Although potentially not as relevant for 2030 targets, new ORE can be supported easier by preferential access to the central grid or by technology-specific auctions. A plan-led solution would need to be accompanied by project-specific ORE support. Transmission assets could be coordinated and shared amongst different ORE technologies (including offshore wind) potentially increasing speed of deployment of ORE technologies.
Assessment summary	Developers are incentivised in a developer-led model to use the most cost-effective ORE technology and develop transmission assets for individual projects.	Transmission assets could be shared between offshore wind and other ORE technologies in a plan-led model, thereby potentially increasing speed of development of other ORE technologies. This is more relevant post 2030.

[99] SEI, 2010. Sustainable Energy Ireland: Tidal and Current Energy Resources in Ireland. https://www.seai.ie/publications/Tidal_Current_Energy_Resources_in_Ireland_Report.pdf

Technical

3 Speed of delivery – offshore wind farm transmission asset development

The expected challenges regarding the speed of delivery of offshore wind transmission assets development.

Information

The development and deployment of offshore wind farm transmission assets can take several years, and time required differs per grid delivery model. This section focusses mainly on the development phase of the wind farm, as the construction phase itself would not differ significantly between the grid delivery models. In the Irish context it is important to distinguish between the impact of grid delivery models on ongoing and new offshore wind farm developments.

Ongoing offshore wind farm developments - There are several ongoing offshore wind farm developments in Ireland, the majority located along the east coast of Ireland, of which some could become Relevant Projects that could be allowed to progress under a transitional protocol (see section 2.4). As some of these Relevant Projects have already progressed significantly in their development activities, a more developer-led approach would be more compatible with these and lead to a faster project delivery which could speed-up the roll-out of offshore wind on a programme level. In addition, some of these projects could avail of the existing onshore capacity as identified by the East Coast Study.

Future offshore wind farm developments - Future projects could benefit more from a plan-led approach for their transmission asset development as this would ensure certainty for the parallel development of onshore transmission reinforcements resulting in earlier delivery of system capacity compared to a developer-led model. This is particularly relevant when there is limited capacity onshore.

	Developer-led	Plan-led
Grid delivery model	The development phase (developing a project up to construction start) in the developer-led model can take more time as each developer has to submit its own individual project development consent applications and grid connection agreements. Development periods of offshore wind farm projects (incl. offshore wind transmission assets) in the UK can take up to 7-9 years.[100] However, this general argument is not valid for some Relevant Projects in Ireland as the development phase is already well progressed.	In the plan-led model, pro-active wind farm and transmission asset roll-out, planning and pre-development by government and TSO (see section 4.2.3) can ensure faster development procedures for offshore wind transmission assets and required onshore reinforcements. This is due to the earlier commencement of the required onshore reinforcements and greater potential to parallel pre-development activities in a plan-led model compared to a developer-led model. However, there are potentially longer phases for coordination and planning upfront. The development period for offshore wind transmission assets in the Netherlands within the current roll-out programme is approximately 3 years.[101] The model is likely better suited for future offshore wind farm developments.
Assessment summary	The developer-led approach is likely more favourable in the shorter term as it benefits from development works already underway in Relevant Projects, is better suited for scaling up the development in the short term and for projects close to the shore. However, developer-led project development (incl. transmission assets) can take longer, as observed in the UK: project development involves more consecutive stages for each project including obtaining a Crown Estate lease, a planning consent and a grid connection date.	The adoption of a plan-led approach would take a significant period of time to put the necessary frameworks in place and requires significant pre-development and (roll-out) planning of wind farms and transmission assets. However, execution of the grid development can be relatively fast: offshore wind farm transmission asset development in the Netherlands takes approximately 3 years. A plan-led model is likely more favourable in the longer term as it allows for optimised planning and roll-out of offshore wind farm transmission assets and onshore grid reinforcements.

[100] Renewable UK, 2018. Offshore wind projects timelines. https://cdn.ymaws.com/www.renewableuk.com/resource/resmgr/luke/RUK18_Offshore_Timeline.pdf

[101] Tennet, 2015. NL Offshore wind: stakeholder interaction. https://www.tennet.eu/fileadmin/user_upload/Our_Grid/Offshore_Netherlands/Consultatie_proces_net_op_zee/Planning/1_P1_Enclosure_nr.4_-_ONL_15-064_-Planning.pdf

<table>
<tr><td colspan="4">Technical</td></tr>
<tr><td>4</td><td colspan="3">Compatibility of multiple project developments</td></tr>
<tr><td colspan="4">Benefits of projects and different ORE technologies under different grid delivery models.</td></tr>
<tr><td>Information</td><td colspan="3">Combining multiple projects and ORE technologies on a single transmission asset hub (offshore substation, export cables, onshore substation) could benefit from synergies on multiple levels, including:
• reallocation of available transmission capacity (e.g. in case of partial connection failure);
• shared investment cost to benefit from economies of scale (offshore/onshore substation);
• shared operation and maintenance;
• shared planning overhead and project realisation;
• the combined power output of many ORE generators with different characteristics and at different locations reduces fluctuations; and
• shared marine infrastructure and trained personal.
Using hub connections for offshore wind farms, connecting wind farms that are close to one another to a single transmission asset hub, forming only one transmission corridor to shore, is often found to be beneficial for the advantages mentioned above.[102] Collaboration on a case-by-case basis could also achieve many of these advantages. However, in a plan-led approach it is easier to put structures and mechanisms in place that support such a collaboration.
Considering the potential pipeline of projects in Ireland, many are on the East Coast[103] and for geographical reasons are relatively close to each other and close to the shore. Therefore, opportunities to leverage the advantages of combining projects on a single hub are likely limited.</td></tr>
<tr><td rowspan="2">Grid delivery model</td><td colspan="2">Developer-led</td><td>Plan-led</td></tr>
<tr><td colspan="2">Project developers make the technological choices required to optimise the cost and usage of their own offshore ORE transmission assets. They may collaborate with each other (on a case-by-case) on technical solutions, but only if this is financially beneficial or is required by the regulator.</td><td>Shared infrastructure may be more cost-effective, overall. Connections can be bundled through hubs, and multiple dune crossings and landfalls can be avoided. Bundling of multiple cables into a single connection requires a relatively concentrated development area.</td></tr>
<tr><td>Assessment summary</td><td>○</td><td>Developers are not incentivised to optimise over multiple projects (of multiple developers). Suitable for the Relevant Projects as they are probably in areas with multiple disjointed individual projects and likely close to the coast</td><td>● Compatibility can be increased by governmental coordination and sharing of transmission assets amongst projects. In Ireland probably more suitable for longer-term projects with larger target areas jointly developed through multiple parties and projects, likely at some distance offshore.</td></tr>
</table>

[102] OffshoreGrid, 2011. Offshore Electricity Grid Infrastructure in Europe, https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/offshoregrid_offshore_electricity_grid_infrastructure_in_europe_en.pdf

[103] IWEA, 2019. IWEA Wind Energy Pipeline – Oct 2019. https://www.iwea.com/images/files/20191001-iwea-pipeline-survey-version-2-results-public-summary.pdf

Technical

5 Maximising offshore resources – technical aspects

Maximising the significant potential for ORE and the use of marine infrastructure in Ireland.

Information

Ireland has a significant ORE potential due to its vast exclusive economic zone (EEZ) as indicated under technical criterion 2. Maximising these resources could be a specific contributor towards meeting the ambitious climate targets such as laid out in the Climate Action Plan. Several infrastructure plans could support maximising this potential and usage of the marine infrastructure.

Transmission assets - The first development phase of at least 3.5 GW offshore wind capacity is likely to be accommodated by radial connections. This offshore transmission asset infrastructure could potentially also be used post 2030, e.g. for expanding, adding and connecting further projects in the Irish Sea through hub and hybrid solutions (see section 4.2). Pre-investments in such assets could be considered now for use post 2030, but actual developments mainly depend on certainty of longer-term developments (risk of stranded assets and sunken costs) and the economics of the anticipatory investments. A pre-investment approach would be easier to accommodate in a plan-led model than in a developer-led model where developers are typically incentivised to develop the current project at minimum costs. Appropriate regulatory controls would need to be in place to manage coordination and ensure that only efficient anticipatory investments are made under the plan-led models. The Climate Action Plan framework and NECP as well as ORE development plan should provide significant certainty in this regard.

Interconnections - Connecting projects with interconnectors requires involvement and planning from a State body as well as wider cross-border cooperation. It could be used in conjunction with far-offshore wind farms, depending on the priority given to renewable electricity and the demand for green power in connected countries.

Marine infrastructure - Existing offshore oil and gas platforms could be considered for the use and support of offshore wind transmission (e.g. O&M or hosting transmission assets). These platforms also consume electricity (and gas that could partly be substituted by electricity) and could benefit from a direct wind farm connection.[104] ORE systems can supply offshore facilities with electricity produced in-situ. These options are not likely to be developed before 2030.

Sector coupling - The existing gas network could be used to transport the output of ORE from far offshore projects via Power-to-X conversion to hydrogen, or powering carbon capture offshore. This would require detailed pro-active investigation and regulation by a State Body.[105] The advantage is that the existing pipeline network can be used, but this is not likely to be developed at scale before 2030.

Substantial investment in infrastructure is required to develop further offshore areas with a water depth between 50 and 100m (see section 2.4). The synergies and opportunities described above assist in unlocking far-offshore regions in the south and west of Ireland to maximise ORE development areas. However, due to the volume of infrastructural investment, planning, novel technologies and international agreements required, a private entity is not likely to be able to maximise the usage of the offshore potential in Ireland.

	Developer-led	Plan-led
Grid delivery model	There are historic examples of major strategic infrastructure projects being carried out without governmental support, but such an approach would not be likely to deliver results within the anticipated timeframe.	Strategic projects, of the type and dimensions mentioned here, are typically the exclusive domain of State bodies. They require legal and regulatory adjustments, and international coordination. Central planning could lead to maximising ORE use.
Assessment summary	Maximising offshore resources is possible for commercial developers. However, developers are incentivised in a developer-led model to use the most cost-effective ORE technology and will therefore not necessarily optimise the use of offshore resources	In a plan-led model a State body could choose to maximise the use of offshore resources.

[104] Rahul Chokhawala, 2008. Connecting oil and gas platforms to mainland power grids. https://library.e.abb.com/public/aab4c01eb564adf3c1257427002e53a5/52-56%201M811_ENG72dpi.pdf

[105] Gas Network Ireland, 2019. Vision 2050 - A Net Zero Gas Network for Ireland. https://www.gasnetworks.ie/vision-2050/future-of-gas/GNI_Vision_2050_Report_Final.pdf

Technical

6 Technical challenges

Technical challenges for ORE development in Ireland.

Information

Challenges in the marine environment - All ORE developments are susceptible to challenging conditions in the marine environment. These provide an opportunity for energy generation, but also affect construction, operation and decommissioning of the ORE devices. The conditions vary between the different coastal areas considered (see section 2.4).

Impact	Eastern coast	Southern coast	Western coast
Winds	Medium	Medium	Strong
Waves	Moderate	Strong	Strong
Tides & currents	Strong	Strong	Moderate
Water depth	Moderate	Medium	Medium

Opportunities to develop ORE

Opportunities	Eastern Coast	Southern coast	Western coast
Fixed bottom offshore wind	+++	++	+
Floating wind	+	+++	++
Tidal power	+++	++	+
Wave power	+	++	+++

(+ few projects on exceptional sites, ++ suitable conditions and sites, +++ best conditions and sites)

The eastern coast and Irish Sea are promising development areas for tidal power and offshore wind. The deeper waters of the southern coast and economic exclusion zone in the south would be well suited for floating wind. The most promising sites for wave power (considering in addition to the factors mentioned above the low visual impact) are along the western coast[106].

The choice of grid connection models could be impacted by the combination of offshore wind and tidal power for the eastern coast and the Irish Sea, floating wind and offshore wind for the southern coast and the economic exclusion zone in the south and wave power off the western coast.

Deployment at scale of any other technologies than fixed bottom offshore wind is not expected before 2030. The additional technical challenges in the Irish context do not result in a clear preference with regards to the developer-led or plan-led grid connection model.

	Developer-led	Plan-led
Grid delivery model	The more severe wave heights on the west coast are a major factor in construction, operation and maintenance of all ORE. This does not impact on the choice of grid delivery model.	The more severe wave heights on the west coast are a major factor in construction, operation and maintenance of all ORE. This does not impact on the choice of grid delivery model.
Assessment summary	(green) No significant challenges expected on the east coast, more severe challenges expected in other offshore areas, but these do not directly impact grid delivery model selection.	(green) No significant challenges expected on the east coast, more severe challenges expected in other offshore areas, but these do not directly impact grid delivery model selection.

[106] DCENR, 2014. Offshore Renewable Energy Development Plan, A Framework for the Sustainable Development of Ireland's Offshore Renewable Energy Resource. http://oceanenergyireland.com/Content/Files/20140204DCENROffshoreRenewableEnergyDevelopmentPlan.pdf

Technical

7 Technical complexity of the interface

The complexity of the interface between the developer and TSO/TAO.

Information

The complexity of the interface between the developer and TSO/TAO depends on the size and location of the offshore wind farm, and the governing grid delivery model.

For smaller sized wind farms relatively close to shore, connecting the array cables directly to onshore substations could be more cost effective than exporting power through an offshore substation. However, when the wind farm size and distance to the onshore connection increases, a tipping point arises where having an offshore substation becomes more beneficial (see also section 4.2.1).

When an offshore substation is employed, the grid delivery model will define the interface between the developer and TSO. In developer-led models, the interface typically resides at the onshore grid connection point, while in a plan-led grid model the interface lies at the offshore substation[12]. Having an interface at an offshore location increases complexity between the parties involved in terms of safety management, access to the platform, work permits etc. The onshore interface, in contrast, is easier to manage and more in line (physically) with the current "onshore" grid delivery (with developer delivered transmission assets).

In case of a plan-led model where a single offshore wind transmission asset connects multiple offshore wind farms, the offshore interface can become increasingly complex as the TSO/TAO has to coordinate responsibilities at the interface with multiple wind farm developers.

	Developer-led	Plan-led
Grid delivery model	A technical interface between the TSO/TAO and developer onshore is easier to manage, more in line (physically) with the current "onshore" grid delivery model and is made up out of standard components operating in a benign environment with a known set of requirements for all parties.	A technical interface between the TSO/TAO and developer offshore is more complex and requires a higher degree of management and coordination in terms of safety and work coordination between the parties.
Assessment summary	Onshore interface, which is relatively easier to manage as it is located in an onshore environment in line physically with the "onshore" grid delivery model.	Offshore interface, which requires more coordination between parties as it is located in an offshore environment (marine coordination, health and safety, weather etc.). Further increased complexity at multi-project interfaces.

Technical

8 Ease of enforcing maximum infeed requirements

Maximum single infeed requirements for generators in the Irish grid might limit the size of wind farm per single connection.

Information

The Irish and Northern Irish power systems together form a synchronous area and are jointly responsible for system stability including maintaining frequency containment reserves (FCR). The amount of FCR should minimally be equal to a reference incident within a synchronous area. This reference incident relates for upward reserves to the loss of the largest single infeed (LSI) in the grid (MW). The guidelines for system operation in the synchronous area IE/NI are jointly developed by EirGrid and the System Operator Northern Ireland (SONI) in the “Synchronous Area Operational Agreement.”[107]

For the all-island system, the FCR requirement relates to 75% of the largest single infeed. These FCR requirements for largest single infeed (LSI) could limit the size of wind farms per single connection or per connection point. Looking into the 2020s, the LSI is expected to be 700 MW (based on the Celtic Interconnector projected capacity.

With AC connections, a wind farm with a capacity exceeding the LSI limit (>700 MW), will be connected with multiple cables to shore (each ~350/400 MW). Due to the LSI limit for substations, no more than two times 700 MW capacity (i.e. approximately two 220 kV cables) of a single wind farm should be connected to a single onshore substation[108].

In case of a DC connection, a single cable could be used to connect a wind farm >700 MW to shore, which might need to be reconsidered to ensure the LSI requirements. The LSI limits in the system could thus impact design considerations and costs to ensure a wind farm larger than 700 MW would not be lost due to a single event.

In Great Britain all offshore wind farms with a capacity above 120MW must have two export cables, this is an SQSS (Security and Quality of Supply Standard) requirement where the loss of one circuit must not result in a loss of more than 50% of the generation[109].

	Developer-led	Plan-led
Grid delivery model	In the UK, the developer-led grid delivery model has seen a trend towards larger wind farms (~1 GW).[12] The system operation requirements in Ireland are reflected in grid connection standards for generation units. The single largest infeed and FCR requirements could limit the capacity of this wind farm per single connection, possibly increasing costs to developers by requiring more single lines.	The system operation requirements in Ireland are reflected in grid connection standards for generation units. In a plan-led grid delivery model, single largest infeed can be foreseen in the site pre-development and offshore wind transmission asset development phases in a pro-active manner. If there was a desire to increase the largest single infeed, a plan-led model would allow for an assessment between the cost of procuring additional reserves and the cost of specifying multiple grid connections.
Assessment summary	(green) Maximum infeed limits per single connection could be enforced in connection requirements for offshore wind.	(green) Maximum infeed limits per single connection could be enforced for offshore wind through site selection and throughout coordination and planning phases.

[107] EirGrid/SONI, 2019. Synchronous Area Operational Agreement (SAOA) for Synchronous area IE/NI. http://www.eirgridgroup.com/site-files/library/EirGrid/SAOA-for-the-Ireland-and-Northern-Ireland-Synchronous-area-V2.0-(for-consultation-post-RfA).pdf

[108] EirGrid, 2016. Transmission System Security and Planning Standards. http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Transmission-System-Security-and-Planning-Standards-TSSPS-Final-May-2016-APPROVED.pdf

[109] Ofgem, 2006. Offshore Transmission Expert Group. https://www.iwea.com/images/files/20191001-iwea-pipeline-survey-version-2-results-public-summary.pdf

4.5 Regulatory and policy assessment

Regulatory and Policy	
1	**Compatibility with RESS auction design**

Compatibility of grid delivery model for offshore wind with the RESS auction design for renewable energy in Ireland.

Information

The objective of the Renewable Electricity Support Scheme (RESS) is to help deliver Ireland's contribution to the EU-wide binding renewable energy target of 32% in 2030 (partly through 70% renewable electricity generation by 2030, see section 2.2). The draft terms and conditions of the first RESS 1 scheme were published in December 2019 for consultation.[24] The RESS 1 auction round is now foreseen to take place in 2020 with an auction volume of up to 3000 GWh, subject to a regulatory determined competition ratio. Further planning is still to be finalised.

The RESS 1 auction design presents an inclusive (technology neutral with the exception of Solar Preference Category) auction scheme, covering both onshore and offshore renewable activities. Under this scheme the (number of) interested parties and the characteristics and technologies of the winning bids will become clear only after the auction has taken place. A technology-specific or site-specific auction scheme, in contrast, increases the competitiveness of offshore wind in the auctions. Technology-specific auctions, such as offshore wind specific auctions, are foreseen to be included in later RESS rounds regardless of selected offshore grid delivery model for Ireland (see Section 4.2.4) as specific support for offshore wind in the RESS design has been included in the Climate Action Plan.[17] In addition, the MPDM Bill specifies for its centralised approach that sites are pre-developed by a State Body prior to a competitive auction.[30]

In Ireland, developers of onshore renewable energy projects (including onshore wind and solar-PV) have currently the right to construct all or part of their connection to the transmission or distribution network. A distinction is made between contestable activities and non-contestable activities. Non-contestable activities include the choice of connection method, supervision of contested assets and delivery of non-contestable and non-contested assets. Contestable activities include the actual construction of the contestable grid connection which is executed by the developers.

Upon completion, the transmission assets of these units are sold to ESB Networks for a nominal fee and the developer may be charged with a periodic fee for operation and maintenance by ESB Networks.[110] If offshore wind needs to fully account for the grid connection cost, their competitiveness with other technologies decreases, since the grid connection cost offshore accounts for a larger share of the total investment costs than for onshore wind farms.[111]

The Terms and Conditions of future RESS auctions for offshore renewables will need to set out specific eligibility and delivery requirements that reflect the specific grid connection framework including the various pathways identified in this paper. Similar to the onshore auctions, the balance of risk between developers and the State in terms of connection longstop dates and incentives and penalties for early/late delivery will need to be considered.

Separate consenting processes, differing grid connection arrangements and costs as well as generally longer delivery dates and the lumpiness of offshore projects require specific offshore RESS auctions. The RESS High Level Design has been developed to allow flexibility between RESS auctions and bespoke Terms and conditions, tailored to policy needs.

[110] EirGrid, 2007. Contestability and Connection Assets. http://www.eirgridgroup.com/site-files/library/EirGrid/Contestability-paper-Oct-2007.pdf; SB Networks, 2010. Contestability on the Distribution System – ESB Networks Key Principles and Processes Paper. https://www.esbnetworks.ie/docs/default-source/publications/contestability-on-the-distribution-system-esb-networks-key-principles-and-processes-paper.pdf?sfvrsn=9a5c33f0_4

[111] IRENA, 2012. Renewable Energy Technologies: Cost Analysis Series. https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-wind_power.pdf

Grid delivery model	Developer-led		Plan-led	
	Under a developer-led model, the size, timing and location of the wind farm and subsequently required onshore grid reinforcements are only known after the successful bids have been awarded. The TSO/TAO will then start developing required onshore grid reinforcements in a reactive manner and the developer will develop the offshore wind transmission assets. Hence there is no risk of stranded grid assets or sunken costs (for site planning and preparation) for the TSO/TAO or the Department. In an inclusive (technology neutral) auction scheme, there is a risk of reduced competitiveness of offshore wind compared to onshore technologies due to the relative higher cost of offshore wind. But future RESS rounds foresee the inclusion of offshore wind specific support as per the CAP.		Under a plan-led model, a State Body and the TSO/TAO are responsible for the pre-development and planning of the wind farm sites together with the required offshore wind transmission assets and onshore grid reinforcements ahead of the auction. This implies a risk for the TSO/TAO and the Department for sunken costs for site pre-development and grid planning, and potentially stranded onshore assets if no bids are made in a technology neutral - or even in an offshore wind specific - auction. Site-specific auctions are not yet included in the RESS but described in the MPDM Bill for the centralised approach. To ensure compatibility with the RESS, regulatory measures will have to be put into place to mitigate stranded assets and sunken costs. This could also be mitigated with a site-specific auction scheme (e.g. following the example in the Netherlands)[112].	
Assessment summary	● (full)	Compatible with currently proposed inclusive RESS 1 auction and potential future offshore-specific RESS scheme rounds, due to no risk of stranded assets or sunken cost.	◑ (half)	Not compatible with currently proposed inclusive RESS 1 auction scheme but compatible with future offshore-specific or site-specific RESS rounds. Uncertainty still exists around site-specific auctions as they are not yet foreseen under the RESS although described in the MPDM Bill for the centralised approach.

[112] RVO, 2019. Offshore Wind Energy. https://english.rvo.nl/subsidies-programmes/offshore-wind-energy

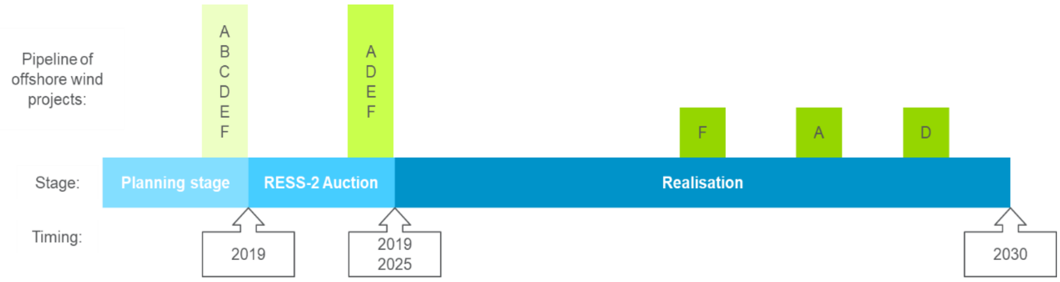
Regulatory and Policy

2a-c Impact on State - meeting RE targets through offshore wind projects

Certainty of reaching renewable energy generation/emission reduction targets by mobilising enough offshore wind projects in the planning, auction and realisation stages of the development process.

Information

At least 3.5 GW of offshore wind capacity development is targeted by 2030 in Ireland (see section 2.1).[17] Wind energy is the renewable energy technology expected to provide the largest contribution to the EU renewable energy targets for 2030 and beyond.[113] Risks within the planning process could lead to projects not progressing past different stages in the development process. It is therefore important to assure a sufficient pipeline of offshore wind projects in all development phases. The offshore grid delivery model may impact the planning of offshore sites, the competitiveness of planned projects in auctions, and timely project realisation.



Source: Navigant

[113] European Commission, 2019. Renewable Energy – Wind Energy. https://ec.europa.eu/research/energy/index.cfm?pg=area&areaname=renewable_wind

	Developer-led	Plan-led
Grid delivery model	**Planning phase:** Project developers are responsible for planning projects at sites that they consider suitable and potentially competitive within assigned offshore zones. The current Irish pipeline of offshore wind projects consists of approximately 15 projects in different stages of the planning phase.[35] **Auction phase:** Given sufficient offshore wind bids and timely planning and coordination of the auction design, high probability of meeting renewable energy targets by offshore wind or other technologies. However, projects need to be timely planned and pre-developed to participate in an auction. Developer-led auctions mostly target an energy output in MWh to support and achieve a general RES target. In reality, there will still be uncertainty on how much electricity will actually be generated due to externalities (e.g. RES resource variability and network availability). In developer-led auctions there is a higher degree of freedom when it comes to the timing of projects, i.e. some projects can be delayed or accelerated by project developers. **Realisation phase:** To ensure timely realisation of winning projects, an appropriate penalty structure as well as non-compliance rules are required.	**Planning phase:** a State Body and EirGrid are responsible for the planning of offshore wind in a coordinated roll-out. Ireland has a high potential for offshore wind development (see section 2.4), and if the State Body/TSO is able to timely coordinate and plan, sufficient offshore wind sites and required assets can be pre-developed. As there are a number of 'Relevant Projects' with some planning status this could complicate a move to fully plan led. **Auction phase:** Given sufficient offshore wind bids and timely planning and coordination of the auction design and site pre-development, high probability of meeting renewable energy targets by offshore wind or other technologies. Plan-led auctions mostly target MW capacity per envisioned site. This provides less control on actual generation (MWh). However, offshore wind has a higher capacity factor than onshore renewables,[114] and will therefore actively contribute to meeting MW and MWh targets. Higher likelihood of meeting MWhs can be achieved by conservatively estimating capacity factors. In addition, uncertainty exists on the actual electricity generation due to resource variability and network availability. **Realisation phase:** As bidders are incentivised to bid at the lowest development price, strict penalties and non-compliance rules need to be in place.[115]
Assessment summary	**Planning stage:** probably more than enough projects already proposed than required to achieve targets due to more degrees of freedom for developers and large project pipeline (10 GW) in Ireland. For Relevant Projects the work that has already been completed and the expertise of developers can be leveraged.	**Planning stage:** probably enough project sites can be identified and pre-developed to achieve targets with timely planning and pre-development by Department/TSO given favourable wind conditions in Ireland. Transition to a plan-led model would need careful consideration with respect to Relevant Projects.
	Auction stage: given enough bids, likely that sufficient projects are participating in the auction to ensure meeting targets, especially if auction scheme targets MWh but less certainty in capacity numbers and timing of projects.	**Auction stage:** given enough bids per site, high certainty that enough projects will be accepted to achieve targets due to site specifications. High capacity factors increase likelihood of sufficient MWh generated and capacity numbers achieved.
	Realisation: a correct penalty structure for untimely delivery of winning projects incentivises that the winning projects are timely realised.	**Realisation:** a correct penalty structure for untimely delivery of winning projects incentivises that the winning projects are timely realised.

[114] IRENA, 2018. Renewable power generation costs in 2018. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf

[115] IRENA, 2015. Renewable Energy Auctions: A Guide to Design. https://www.irena.org/publications/2015/Jun/Renewable-Energy-Auctions-A-Guide-to-Design

Regulatory and Policy

2d Impact on State - scalability of grid capacity to achieve higher targets

The potential to accelerate and scale-up the construction of grid connections to offshore wind farms and offshore wind transmission assets to exceed the renewable energy targets for Ireland.

Information

Due to its high capacity factors and high potential in Ireland, offshore wind projects can potentially contribute to meeting the renewable energy targets ahead of time or exceeding Ireland's ambitious targets (see section 2.1). The EU-wide binding renewable *energy* target for 2030 is 32%, and the new Directive includes a review clause by 2023 for an upward revision of the EU-wide target.[21]

Ireland is currently behind schedule regarding reaching their EU renewable energy targets. Ireland could buy renewable energy credits from other countries to comply with EU targets if the targets cannot be met within Ireland.[116] However, this will incur a significant additional cost. In addition, the current share of renewables is mostly accounted for by onshore wind. However, there is a large potential for offshore wind development as indicated by the ~10 GW pipeline of projects (see section 2.4).

The ability to meet the targets, and the capability to adjust to an upward revision of the EU-wide target depends on the ability to accelerate planning and development of the required transmission assets and onshore grid reinforcements. The lead times for the development of offshore wind transmission assets is generally 2 to 5 years.[117] An accelerated achievement of renewable energy targets through offshore wind is therefore highly dependent on the coordination and timely planning of offshore developments.

	Developer-led	Plan-led
Grid delivery model	The responsibility of developing offshore wind transmission assets lies with multiple commercial developers, therefore a potentially quicker roll-out and scale up could be realised due to a shared effort, but only with enough interested developers. However, coordination with onshore grid reinforcements may prove to be more challenging in the developer-led model due to the TSO/TAO having to coordinate action with multiple developers of which the size, timing and location of developments is only know after the auction. In addition, developers have no incentive to pro-actively design their assets to cater for uncertain future developments. This means that an upward adjustment of the renewable energy targets will require additional efforts for onshore grid reinforcements.	A State Body for ORE development and the TSO should ensure a timely planning of the offshore pre-development and roll-out process as this central entity should not be the bottleneck in the offshore wind development process. The central entity would be able to accelerate deployment but only if timely planned. This scalability is dependent on the capacity to timely build up required capabilities for a State Body for ORE development. A planned offshore wind roll-out timeline includes the size, location and timing of all offshore wind farm sites. The TSO can foresee onshore grid reinforcements in a timely manner and might build combined offshore connections for multiple future projects. The plan-led model also has the potential for future proof development by its potential to internationally coordinate developments in the offshore area. This could help to increase the share of offshore wind farms contributing to the acceleration of national and European renewable energy targets.
Assessment summary	Increase in offshore wind farm transmission capacity can more easily be achieved through a shared burden between developers. However, onshore grid reinforcements follow offshore wind transmission asset developments in an uncoordinated and reactive manner.	Increased coordination by the TSO/State Body can lead to timely planning for the scale up of offshore wind developments. However, the burden falls on a single State Body for ORE development to plan and pre-develop sites and (TSO/TAO) to plan and develop the grid.

[116] The Institute for International & European Affairs, 2018, Behind renewable energy fines. https://www.iiea.com/energy/behind-renewable-energy-fines/

[117] ECN, 2013. 16% Hernieuwbare Energie in 2020, Wanneer Aanbesteden?, https://publicaties.ecn.nl/ECN-E--13-006

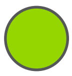
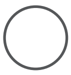
Regulatory and Policy		
3	**Capacity (of the party) to deliver offshore wind transmission assets and site (pre-)development**	
Capacity (experience level) of the responsible party to timely perform site (pre-)development and deliver the grid connection with quality. Risk of delay and non-realisation due to a lack of capacity (experience) to timely deliver.		
Information	Capacity to deliver relates to delivery risk (non-/delayed delivery) of site (pre-)development and offshore wind transmission assets based on the capacity/experience of the responsible party. To ensure timely delivery of at least 3.5 GW of offshore wind in Ireland to achieve 2030 targets, the capacity to deliver is an important requirement. Next to this, the capacity to deliver relates to the availability of skilled personnel.	

	Developer-led	Plan-led
Grid delivery model	International experience with developer-led grid delivery models (e.g. in the UK)[12] has shown that some developers have the necessary experience and capability to develop offshore wind transmission assets. In the Irish context, the pipeline of offshore wind projects shows a high interest of more mature developers as well as less experienced players who under the developer-led grid delivery model would also be responsible for building the offshore wind transmission assets (see section 2.4 and Figure 2-2). In a fully developer-led model where the wind farm developer would be responsible for the development of the offshore wind transmission assets, the risk of delayed delivery lies within the developer's control. It could therefore be argued that there is a reduced probability this risk will materialise since the developer is incentivised to ensure timely delivery of the grid, and developers have gained experience in other markets. However, no developer has experience to date with the realisation of offshore wind projects in Ireland.	International experience with plan-led grid delivery models (e.g. in NL, BE, DE) has shown that although TSOs/TAOs and State Bodies had limited previous experience with developing offshore wind transmission assets (TenneT became the official system operator on the Dutch North Sea in 2016[118]), they are able to learn fast and can benefit from their experience with onshore grid development as well as the ability to coordinate and share assets in the offshore area. In a plan-led model, new governmental capabilities and the capacity to manage ORE developments need to be developed in a timely manner, which poses a risk in capacity to deliver pre-development activities. A new state body or an expansion of an existing body would need to be established, resourced and mobilised in a plan-led model to carry out the pre-development and consenting works associated with the offshore wind farm sites. This includes site selection, site surveys, environmental studies and assessments, wind farm functional design and the preparation and submission of planning applications for the wind farm. The offshore wind industry may perceive the delayed delivery of transmission assets as a greater risk in a plan-led grid delivery model. Nonetheless, EirGrid has successfully delivered the East-West interconnector project to the UK on time and within budget.[92] The Celtic Interconnector is also under way, in early development and is running according to schedule with no delays to the original programme.[119] ESB Networks has extensive experience in developing onshore transmission assets as well as international experience with offshore transmission assets and wind farm development through their subsidiary ESB International.[91] In addition, delays in onshore grid reinforcement are not necessarily representative for offshore wind transmission assets development as the onshore environment is more challenging in terms of consenting issues and landowners. However, there is a significant risk associated with a discrete number of state bodies developing multiple major projects simultaneously both onshore and offshore.
Assessment summary	Although experience levels from developers can vary, many of the developers currently active in the Irish offshore wind farm sector have a track record of delivery of projects and offshore wind transmission assets in multiple jurisdictions (including (pre-)development of wind farm sites). This is offset somewhat by the fact that no developer has experience with large scale offshore wind farm realisation in Ireland to date. Experience with offshore wind transmission asset development is therefore not a differentiator between models.	Both EirGrid and ESB Networks have experience with development of offshore infrastructure. Experience with offshore wind transmission asset development is therefore not a differentiator between models. However, the plan-led model requires a single State Body for ORE development to be built up to ensure timely delivery of site pre-development and there are challenges and risks associated with state bodies simultaneously developing multiple projects (onshore reinforcements and offshore wind transmission projects).

118 ACM, 2016. 'Decision on certifying TenneT as the system operator of the offshore grid' (Besluit certificering TenneT als netbeheerder van het net op zee),

Regulatory and Policy		
4a-c	Complexity of grid planning procedure	
The responsibility of the planning and design of the offshore wind transmission assets lies with the constructing party (developer in developer-led model, TSO/TAO in plan-led model). The stakeholders in this process are the offshore wind farm developer, a State Body and the TSO/TAO. Consents are granted by the DHPLG, representing the national government.		
Information	Table 2-1 detailed the ORE consent sequence as stipulated under the MPDM Bill for both decentralised and centralised grid delivery models. The MPDM Bill updates the Foreshore Act 1933 and addresses the absence of a regulatory framework for offshore renewable energy developments beyond the limits of the foreshore (12 nautical miles), including for the first time, a comprehensive regime for the regulation of Offshore Renewable Energy. The MPDM Bill streamlines procedures by a single consent principle: one state consent (Maritime Area Consent: MAC) to enable occupation of the Maritime Area, and one development consent (planning permission), with a single environmental assessment. MACs for offshore renewable energy developments are awarded by the Minister of Communications, Climate Action and Environment (MCCAE). At this moment, both a decentralised and centralised grid delivery model are accommodated for under the MPDM.[30] The competitive process to obtain support for projects under both the developer- and plan-led approaches will include specific arrangements for access to and the charging mechanism for connection to and use of the electricity transmission/distribution system as set out under section 35 of the Electricity Regulation Act 1999.	

[119] DCCAE, 2019. Minister Canney bears witness to historic grant agreement signing ceremony in Brussels – Celtic Interconnector to proceed with €530m grant secured and signed. https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Minister-Canney-bears-witness-to-historic-grant-agreement-signing-ceremony-in-Brussels---Celtic-Interconnector-to-proceed-w.aspx

	Developer-led		Plan-led	
Grid delivery model	In the developer-led grid delivery model, the **developer** is responsible for submitting planning interest and development consent applications to the DHPLG and An Bord Pleanála, respectively. The interaction is one-on-one from a developer's point of view. The RESS will include the T&C's for the use and connection to the transmission system. The DHPLG as **consenting body** will have to deal with multiple commercial parties in the Planning Interest and Development Consent procedures, thereby increasing the complexity from their point of view. The DCCAE is responsible for assessing the bids and providing the Marine Area Consent. Coordination with EirGrid may be required to assess the developer applications on (onshore) grid compatibility. The RESS will include the T&C's for the use and connection to the transmission system. **EirGrid**, the **TSO,** does not have to manage the consent for the grid connection, as this is the responsibility of the developers. The RESS will include the T&C's for the use and connection to the transmission system. Onshore grid reinforcement becomes more complex due to the uncertainty in timing, location and size of the grid connections. EirGrid would need to coordinate developments with individual developers.		In the plan-led grid delivery model, the **developer** does not have to apply for a Planning Interest or Development Consent for the wind farm, as this is pre-consented by the DHPLG prior to the competitive auction. The RESS will include the T&C's for the use and connection to the transmission system. The DHPLG as **consenting body** does not have to interact with individual offshore wind farm developers regarding Planning interests and Development consents, as this is coordinated by a State Body for ORE development and executed by EirGrid/ESB Networks. The DCCAE is, however, responsible for assessing the bids and providing the Marine Area Consent. **EirGrid**, the **TSO**, is charged with the planning of the offshore wind transmission assets. EirGrid will interact with multiple developers at multiple wind farm sites, the planning and development of the onshore grid and offshore wind transmission assets is easier to coordinate.	
Assessment summary		**Developer perspective:** medium complexity in offshore wind transmission asset procedure as the full procedural responsibility lies with the developer who interacts one-on-one with the DHPLG and An Bord Pleanála.		**Developer perspective:** no complexity in grid connection procedure as offshore wind transmission assets are developed by TSO and consents are part of tender award.
		**Consenting body perspective:** medium complexity due to interactions with multiple individual developers for Planning interest and Development consent procedures.		**Consenting body perspective:** limited complexity in grid connection procedure as there is only the TSO/TAO to interact with regarding offshore grid development.
		**TSO perspective:** complex grid connection procedure as TSO faces more uncertainty in offshore wind project planning and the number of developers, resulting in increased complexity regarding onshore – offshore grid coordination and development.		**TSO perspective:** Medium complexity in grid connection procedure due to coordination between onshore and offshore developments as multiple developers are involved at different offshore sites but there is only a single consenting body.

<table>
<tr><th colspan="3">Regulatory and Policy</th></tr>
<tr><th>5</th><th colspan="2">Coordinated onshore integration of renewables</th></tr>
<tr><td colspan="3">Ability to coordinate the integration of offshore renewables in the onshore grid.</td></tr>
<tr><td>Information</td><td colspan="2">EirGrid conducted the “East Coast Generation Opportunity Assessment” in February 2019 to assess the integration potential of ORE capacity for the east coast power system (see section 2.5).[44] Although this study is not cumulative, a total of ~1.5 GW grid connection capacity for offshore wind is estimated to be available at several 220 kV substations along the east coast. To integrate the target of at least 3.5 GW of offshore wind and potential other ORE by 2030, significant onshore grid reinforcements - and potential expansions - will be required. This poses a risk of stranded assets when onshore grid development is not coordinated and aligned with offshore wind developments, and the auction design is unaligned with the grid delivery model. In addition, the connection of ORE capacity to the onshore grid needs to be coordinated operationally to maximise renewable energy generation. This coordination should consider minimisation of RES curtailment due to onshore congestion or re-dispatch with other potentially non-renewable generation units.</td></tr>
<tr><td rowspan="2">Grid delivery model</td><th>Developer-led</th><th>Plan-led</th></tr>
<tr><td>Individual developers propose onshore grid connection points to EirGrid that are most cost-efficient for individual projects with limited consideration for larger onshore congestion issues (grid “unfriendly” connection). The connection point may differ when trying to minimise congestion by also considering clustering of single projects and ongoing/planned onshore grid reinforcements.

Certainty regarding the location, timing and size of the grid connection point only exists after a successful RESS auction. Hence long-term grid planning and coordination with onshore grid reinforcements is uncertain for the TSO/TAO. Onshore grid connection points and resulting onshore grid reinforcements are potentially more numerous and less certain. The TSO/TAO can only react to the plans of the developers. Although some coordination is possible through specifications of grid connection standards and a timely auction and realisation planning, this will be very challenging to realise.

Inability to guarantee firm capacity or compensation for curtailment to developers could result in reduced developer confidence to develop offshore wind farm projects.</td><td>The TSO/TAO is responsible for the development (planning and construction) of the offshore wind transmission assets and required onshore grid reinforcements. Onshore connection points will be planned ahead of time to optimise onshore grid reinforcement efforts and limit congestion issues (grid “friendly” connection).

Certainty regarding the location, timing and size of the sites and connection points exists before a successful RESS auction, where only a winning developer will be assigned to this site. The onshore grid reinforcements and the offshore wind transmission assets can thus pro-actively be optimised to roll-out transmission assets in line with onshore developments (e.g. upgrade onshore grid ahead of time for multiple transmission asset connections).</td></tr>
<tr><td>Assessment summary</td><td>Limited ability to coordinate the integration of renewables into the onshore grid due to uncertainty in location, timing and size of required grid connections (only known after auction) and resulting onshore grid reinforcements.</td><td>Full ability to coordinate the integration of renewables into the onshore grid due to extensive planning and pre-development phases with certainty regarding location, timing and size of required grid connections and required onshore reinforcements.</td></tr>
</table>

Regulatory and Policy

6 Compatibility with Relevant Projects

Compatibility of grid delivery model with Irish "Relevant Projects" - reliability of policies.

Information

The assumed pipeline of offshore wind projects in Ireland consists of over 10 GW (see section 2.4). Approximately half of this capacity has applied for a grid connection.[36] Although many of these projects are still in an early stage of development, some projects have developed further than others by e.g. obtaining a lease and/or grid connection offer. The DHPLG together with DCCAE has defined criteria to qualify some of these as "Relevant Projects", which can continue their development under a transitional protocol prior to enactment of the MPDM (see section 2.4).

The CRU has mandated EirGrid to develop a plan for assessing the onshore network reinforcements once the number, scale and status of Relevant Projects has been confirmed through engagement with the relevant government departments and developers (see section 2.4).[39]

	Developer-led	Plan-led
Grid delivery model	The developer-led model is compatible with Relevant Projects as the developer is still responsible for site selection and (pre-)development of the wind farm. Therefore, the competitiveness of Relevant Projects will not be further reduced. However, additional policy measures might be required to ensure a level playing field between Relevant Projects and new projects.	The plan-led model is not compatible with Relevant Projects as developers of new projects do not select and pre-develop wind farm sites. This would impact the perceived reliability of policies. Additional policy measures or compensation schemes would be required to reduce this disadvantage of Relevant Projects within a plan-led grid delivery model.
Assessment summary	Compatible with Relevant Projects as the wind farm site selection and (pre-)development is performed by the developer.	Not compatible with Relevant Projects as wind farm site selection and pre-development is performed by the state and not what has been chosen by a developer already.

Regulatory and Policy

7 Social acceptance

Social acceptance relates to the impact from offshore wind developments as perceived by the public including e.g. dune crossings, onshore substations and visual impact of offshore wind farms.[120, 121,122]

Information

Offshore wind farms could impact local and coastal communities through e.g. visual impact and landscape changes, despite overall public acceptance. Local opposition to wind developments may pose a risk to meeting renewable targets, as shown by e.g. onshore wind and grid developments in Denmark[123] and Germany[124]. Public acceptance will be important to facilitate and support the timely development of at least 3.5 GW of offshore wind in Ireland. For this reason, the RESS design strongly focuses on community participation in and ownership of renewable electricity projects to increase public acceptance of renewable developments.[24] Public involvement in renewable projects can happen at various stages: information, planning participation and financial participation.[125,126] Examples across Europe where public participation was part of renewable energy projects:

- **Denmark:** Denmark has placed great importance on public involvement in wind projects.[125] Changes in wind farm ownership patterns to community cooperative ownership models have been established over the last couple of decades allowing profits to be shared with or reinvested in local communities. The near-shore Middelgrunden[127] (~40 MW) park is, for example, partly community owned (cooperative and developer). Near-shore developments are required to open up 20% of shares to local communities.[125] Developers can take advantage of a higher feed-in tariff if community ownership is above 30%.
- **United Kingdom**: For project developments a "statement of community consultation" needs to be submitted that should be developed jointly between the developer and a local authority.[125] Various islands have community development of renewables increasing awareness and acceptance with local communities. The Tilley wind farm in Scotland is, for example, organised by a community trust and run through local participation.[128]
- **Belgium**: ParkWind, amongst others, launched an initiative in June 2019 to raise up to €20 million from private Belgian individuals to support its offshore projects (*North Sea Wind Burgerparticipatie)*. Investors can earn interest linked to the performance of the project.[129]

If community investment capability is small, community buy-in could also be improved by the developer through investing revenues partly back to benefit local communities or by the Government through prescribing this.

---

[120] Wind Europe, 2019. Environment & Planning. https://windeurope.org/policy/topics/environment-planning/

[121] Environmental Impact Statement (EIS) Orial Wind Ltd., 2003. http://www.orielwind.com/documents/Vol_II_Main_Text/Main%20Text.pdf

[122] PROMOTioN, 2018. CBA methodology for offshore grids. https://www.promotion-offshore.net/fileadmin/PDFs/Deliverable_7.11_-_CBA_methodology_for_offshore_grids_-_final_-_DNVGL20180817.pdf

[123] WWEA Policy Paper Series (PP-02-18-A), Denmark, 2018. https://www.wwindea.org/wp-content/uploads/2018/06/Denmark_full.pdf

[124] DW, 2019. German wind energy stalls amid public resistance and regulatory hurdles. https://www.dw.com/en/german-wind-energy-stalls-amid-public-resistance-and-regulatory-hurdles/a-50280676

[125] PROMOTioN, 2017. Intermediate Deliverable – Economic framework for offshore grid planning. https://www.promotion-offshore.net/fileadmin/PDFs/D7.3_-_Economic_framework_for_offshore_grid_planning.pdf

[126] Sorensen, H.C, et al. 2002. Experience with and strategies for public involvement in offshore wind projects. Int. J. Environ. Sustain. Dev. 1, 327. doi:10.1504/IJESD.2002.002353; Sorenson, H.C., et al., 2001. Social acceptance, environmental impact and politics. Final Rep. WP2. 5 Concert. Action Offshore Wind Energy Eur.

[127] Middelgrundens Vindmollelaug. http://www.middelgrunden.dk/middelgrunden/?q=en/node/35; Larsen J.H.M., et al. 2005. Experiences from Middelgrunden 40 MW offshore wind farm. Copenhagen Offshore Wind 26-28 October 2005.

[128] Tiree Community Development Trust. http://www.tireetrust.org.uk/tilley/

[129] Wind Power Monthly, 2019. Community investor schemes gaining ground in offshore. https://www.windpowermonthly.com/article/1594408/community-investor-schemes-gaining-ground-offshore; ParkWind, North Sea Wind Burgerparticipatie/Cooperative, 2019. https://press.parkwind.eu/north-sea-wind-burgerparticipatie--cooperative

Grid delivery model	Developer-led		Plan-led	
	Developer-led projects could result in wind farms closer to shore (< 20 km), increasing visual impact to coastal communities, as these locations are more competitive and cost efficient to developers since offshore wind transmission assets take up a significant part of the project development cost.[111] As a developer-led model will not typically lead to offshore hub connections, it could generally result in more individual connections to shore that could negatively impact public acceptance. Since a social acceptance process needs to be established for each individual project separately, this process is less standardised across developments and does not take into account future projects. However, minimal shares for community ownership of wind farms or requirements for developers to reinvest back into local communities could be prescribed by the Government.		Plan-led developments might improve social acceptance due to an overarching coordinated planning strategy across individual wind developments through clustering of projects and combining social acceptance processes. This approach increases coordination between projects, taking a holistic approach to multiple projects delivering to meet overall targets rather than focussing on a single project. In addition, locations further offshore could be selected for development - although not being the most cost-effective - to reduce visual impacts from wind farms for coastal communities. Minimal shares for community ownership of wind farms or requirements for developers to reinvest back into local communities could also be prescribed by the Government.	
Assessment summary	◑	Medium potential for improving social acceptance of offshore wind in Ireland beyond single projects as individual developers have no financial incentive to look for synergies beyond own project. The social acceptance process and stakeholder engagement is tailored to each project, is not standardised and will not account for future projects.	●	High potential for improving social acceptance of offshore wind in Ireland beyond single projects as high incentive for the government and TSO to standardise processes for offshore wind development and look for synergies between individual projects.

Regulatory and Policy

8 Environmental impact

Potential to minimise environmental impact from offshore wind and other offshore renewable energy sources beyond standard environmental assessment requirements.

Information

All offshore wind developments will impact the environment and under both grid delivery models an environmental assessment will be required. This assessment is therefore not a differentiator between grid delivery models. An environmental assessment evaluates the effects of a development on the environment. The SEA Directive will ensure an assessment of the effects of certain plans and programmes on the environment.[130] Environmental impact arises from both wind farms and transmission assets: [120,121,122,131]

- **Impact from wind farms** on marine fauna and flora, migration routes, seabed, marine activities (tourism, aviation, military, archaeological heritage). No differentiator between grid delivery models as under both models an environmental assessment is required to minimise the impact of the wind farm and mitigate any detrimental effects.
- **Impact from transmission assets** through overhead lines or seabed and underground cables might impact local fauna and flora if running through environmentally “sensitive” areas, such as dunes, and the location of substations and landfall points. This impact can potentially be minimised beyond prescribed requirements depending on grid delivery model.

Landing points - Using a single landing point and cable route reduces the potential impact on competing marine uses, construction cost and the impact onshore. A single landing point, however, could increase the length (and cost) of the transmission lines and could introduce a risk of simultaneous failure of all cables routed through the same route and landing point.

In the Netherlands, the number of landing points are reduced by using single 700 MW offshore hubs with two 350 MW export cables instead of separate 350 MW offshore substations and export cables (see section 4.2). Also, single cable corridors and landing points are used across projects (e.g. Borssele Alpha and Beta connections). This approach reduced the number of landing points and was a main benefit of adopting the plan-led grid model. However, given the 3.5 GW target level, geography of the East Coast, the relative proximity of deep waters to shore and proximity to Great Britain, in the period to 2030 offshore wind farms are likely to be relatively close to shore and offshore hubs are not likely to be adopted.

Along the eastern and southern coasts of Ireland, no contiguous protected area exists. Stretches of the immediate coastline are designated Special Protection Areas[132], and certain foreshore areas are designated as Special Areas of Conservation[133], but they do not form a wide or long barrier that would prevent the landing of cables altogether.

	Developer-led	Plan-led
Grid delivery model	Developers are incentivised to optimise development of grid connections points and offshore wind transmission assets of their own offshore wind farm(s) based on cost. They are therefore not likely to look for synergies with other projects through combining/sharing transmission assets with other wind farms and other developers, which could potentially have reduced the environmental impact.	The plan-led model has greater potential to take onshore-offshore transmission asset coordination into consideration due to the long-term planning horizon for the coordinated roll-out of offshore wind developments. This may result in the State Body and TSO minimising environmental impacts. More plan-led models could realise synergies between individual projects to limit required landfall points and dune crossings, thereby minimising the cumulative environmental impact of Irish offshore wind developments beyond the pre-set requirements.
Assessment summary	Limited potential to take onshore-offshore transmission asset coordination into consideration which may result in cumulative environmental impacts. However, all developers have to develop a comprehensive environmental assessment for their projects.	High potential to take onshore-offshore transmission asset coordination into consideration which may result in the State Body and TSO minimising cumulative environmental impacts.

[130] SEA Legislation – SEA Directive 2001/42/EC. https://www.epa.ie/monitoringassessment/assessment/sea/sea%20legislation/

4.6 International context assessment

International context	
1	**Consistency with future offshore grid technology**
Potential to be consistent with and connecting to future offshore developments in e.g. neighbouring countries or broader North Sea area (offshore hybrid assets, meshed grid, offshore wind power hubs).	
Information	**Offshore transmission asset connections: AC or DC -** Most currently implemented technologies across Northwest Europe are AC systems (NL, DE, DE, UK, FR). However, there is a trend towards HVDC technology (DE, NL), which allows offshore connections with longer distances from shore (> 100 km)[134] and higher capacities. This requires the generated electricity to be converted to DC at an offshore location and then back to AC at the onshore connection point. **Offshore transmission asset typologies: radial, hub or integrated[135] -** To connect larger shares of offshore wind, moving further offshore and increasing international collaboration, there is a trend of stepping away from radial offshore wind connections to combining multiple wind farms in offshore hubs before connecting to the onshore grid. This is, for example, currently being explored by the North Sea Wind Power Hub (NSWPH) consortium that is working on a modular Hub-and-Spoke infrastructural concept to connect offshore wind.[136] **Offshore hybrid assets and meshed offshore grids -** The PROMOTioN project presents another alternative typology where these trends are further integrated on a larger scale: offshore meshed HVDC grids.[137] Within PROMOTioN offshore hybrid assets are defined as "*cross border, between two or more states, offshore and with the aim of connecting offshore renewable electricity generators to the onshore transmission network/s and of hosting cross-border electricity flows*". Hybrid assets, such as WindConnectors, combining more than one function, are also in line with ENTSO-E's objectives of integrating a high degree of renewable energy in Europe's energy system.[138] A recent example of a hybrid connection is the AC grid system linking the Kriegers Flak (DK) wind farm, which is currently under construction,[139] and the Baltic 2 (DE) wind farm. In addition, the ISLES projected assessed the feasibility of a meshed offshore network between Ireland, Northern Ireland and Great Britain.[140] The North Sea region is considered to have strong potential for hybrid assets. In 2016, countries in the North Sea region, including Ireland, signed the North Seas Energy Cooperation declaration aiming to facilitate more cost-effective deployment of offshore renewables.[141] Eighteen potential hybrid projects were identified in the North Sea.[141] In the North Sea region there is also interest in joint development of hybrid projects allowing for instance a Dutch wind farm to connect to both the British and Dutch grids.[141]

131 European Commission, 2019. Environmental Assessment. https://ec.europa.eu/environment/eia/index_en.htm

132 National parks & wildlife service, 2020. Special Protection Areas. https://www.npws.ie/protected-sites/spa

133 National parks & wildlife service, 2020. Special Protection Areas. https://www.npws.ie/protected-sites/sac

134 Navigant Netherlands B.V, 2019, A Comparison of Offshore Electricity Grid Development Models in Northwest Europe. https://www.navigant.com/-/media/www/site/downloads/energy/2019/2019-navigant-comparison-offshore-grid-development.pdf

135 Gorenstein Dedecca, J., Hakvoort, R.A., 2016, A review of the North Seas offshore grid modelling: Current and future research. Renewable and Sustainable Energy Reviews 60(2016)129-143.

136 North Sea Wind Power Hub, 2019, The Vision; The Hub-and-Spoke concept as modular infrastructure block to scale up fast. https://northseawindpowerhub.eu/wp-content/uploads/2019/07/Concept_Paper_2_The-Vision.pdf. Navigant has performed multiple studies for the NSWPH Consortium over the last few years: Navigant, Supporting the North Sea Wind Power Hub, 2019. https://www.navigant.com/experience/energy/2019/supporting-the-north-sea-wind-power-hub

137 PROMOTioN, 2016, Deliverable 1.1, Detailed description of the requirements that can be expected per Work Package. https://www.promotion-offshore.net/fileadmin/PDFs/160415_PROMOtioN_WP1_D_1.1_V1.0.pdf

138 ENTSO-E, 2019. ENTSO-E objectives. https://www.entsoe.eu/about/inside-entsoe/objectives/.

139 Vattenfall, 2019. News: construction of Kriegers Flak Offshore Wind Farm has started. https://group.vattenfall.com/press-and-media/news--press-releases/newsroom/2019/construction-of-kriegers-flak-offshore-wind-farm-has-started

140 http://www.islesproject.eu/

141 Roland Berger, 2018. Hybrid Projects: How to reduce costs and space of offshore developments; North Seas Offshore Energy clusters study. https://op.europa.eu/en/publication-detail/-/publication/59165f6d-802e-11e9-9f05-01aa75ed71a1

	Developer-led		Plan-led	
Grid delivery model	A developer-led grid model allows for industry-led research and development and the application of innovative technology but only when technology has become cost-effective. Developers are incentivised to optimise for their own project to maximise revenues. A developer-led approach can thus limit the possibilities of shared connections and linking interconnectors, especially hybrid systems linking an offshore wind farm to multiple countries. International coordination can under this model also be less efficient as more complex coordination amongst different (potentially international) stakeholders is required. To date, no concrete plans for hybrid projects have been developed in Ireland. In addition, in the period to 2030 offshore wind farms are likely to be relatively close to shore and offshore hubs are not likely to be adopted.		A plan-led grid model allows for Government- and TSO-led research and development and the application of innovative technology on a longer time frame. It allows the progression of innovations even if they are not yet cost-effective. TSOs and Governments are incentivised to optimise the offshore area to achieve climate targets on a longer time frame. A central approach can thus increase standardisation, the possibilities of shared connections and linking interconnectors, especially hybrid systems linking an offshore wind farm to multiple countries. It reduces the risk of conflict in international coordination as fewer parties are involved in the coordination effort and those parties (ministries/TSOs) have similar incentives. To date, no concrete plans for hybrid projects have been developed in Ireland. In addition, in the period to 2030 offshore wind farms are likely to be relatively close to shore and offshore hubs are not likely to be adopted.	
Assessment summary	◐	Uncertainty regarding consistency with future technology developments in the offshore area since international coordination might work but with a higher degree of complexity as more different parties are involved. This requires more standardisation across projects and developers, limiting developer flexibility.	●	High consistency with future technology developments in the offshore area since the Government and TSO plan longer term and can foresee technically future-proof developments and standards as less parties are involved with cross-TSO/Government coordination of infrastructure developments in an international context.

International context

2 Consistency with future policy of offshore renewable energy

Potential to adapt and develop policy to be in line with neighbouring countries and future regulatory developments.

Information

The regulatory framework plays a large role in the development of offshore wind in Europe. Across the EU, Member States have adopted various approaches that are evolving based on developing insights and EU policy priorities. This influences the compatibility of policy schemes between countries.

Offshore renewable energy support schemes - Offshore wind developments in a specific exclusive economic zone (EEZ) nearly always only receive support from the country they are located in.[142] In Europe, support schemes are moving away from a market feed-in tariff to a premium system that is implemented differently per country. This trend is a first step towards harmonisation of support schemes and follows the recommendations of the European Commission for more market exposure for renewables. In addition, the package "Clean Energy for all Europeans" has opened the door for renewable support schemes for generators that are based in the EEZ of other Member States.[143]

Coordination and cooperation mechanisms - With the growing interest in hybrid assets and offshore international developments there is also a growing need to internationally cooperate in the development of offshore wind. For this, the EU has defined statistical transfers, joint projects and joint support schemes (Directive 2019/28/EC), although they have only occasionally been used to date, for example in the German-Danish joint auction scheme for PV and the Swedish-Norwegian joint support scheme.[125] In the EU, onshore grid development as well as interconnector developments fall mostly under the responsibility of TSOs. For joint international developments, coordination and standardisation of planning and consent procedures, grid connection standards and chargers, as well as grid codes would be required.

Auction schemes - Competitive auctions specific to offshore wind are most commonly used in Europe.[125] To facilitate international developments of renewables also cross border auctions are being investigated.[115]

Grid delivery models - The competitiveness of offshore wind projects in the international context could be impacted by the in- or exclusion of offshore wind transmission assets in bids. Aligned grid delivery models could therefore facilitate joint offshore wind developments between countries. A direct neighbour for Ireland is the UK (developer-led grid delivery model) or France (plan-led grid delivery model).[12]

Grid delivery model

Developer-led	Plan-led
Most policy developments are not a differentiator between grid delivery models. However, international coordination of grid connection processes and standards for offshore developments would be more complex as this requires the interaction with more individual parties including individual developers, TSOs and governments. International cooperation in the offshore area is likely to first emerge with closest neighbouring countries. For Ireland, this is the UK. A developer-led grid delivery model would be fully aligned with the current UK model, potentially facilitating further process alignment and standardisation towards cooperation. However, Ofgem, the electricity regulator in Great Britain has stated in February 2020 that it will explore whether a more coordinated offshore transmission system planning approach to connect offshore wind generation in the future could reduce both financial and environmental costs.[71]	Most policy developments are not a differentiator between grid delivery models. The responsibility of the TSO and Government in grid coordination, planning and site pre-development could facilitate more internationally aligned grid connection standards and site development processes as TSOs and governments are incentivised to look for synergies beyond local developments as long as they do not conflict with national policies. This coordination effort would involve fewer individual parties at the TSO and Government levels. A plan-led model is currently not adopted in the closest neighbouring country to Ireland (UK), potentially forming a barrier for direct project cooperation. The UK is however starting to explore a potential move toward a more coordinated offshore transmission system planning approach in the future.[71] However, France is also a potential candidate for joint project undertakings - although over longer distances. France adopted a plan-led model for its latest tender round.[12]

[142] PROMOTioN, 2019. WP 7.1: Final deliverable (D7.2) Designing the target legal framework for a meshed offshore grid. https://www.promotion-offshore.net/fileadmin/PDFs/D7.2_Designing_the_Target_Legal_Framework_for_a_Meshed_Offshore_Grid.pdf

Assessment summary	◑	Full compatibility with current grid delivery model of main neighbouring country (UK) but no central body to coordinate and align policy developments internationally.	◑	A central body could coordinate and align policy developments internationally and is aligned with the grid delivery model in France but currently less compatible with current grid delivery model of main neighbouring country (UK).

4.7 Summary

The results of the assessment of the developer-led and plan-led grid delivery models in the Irish context are summarised below through a summary of the criteria per topic: financial/economic, technical, regulation/policy and international context. This report does not apply any weighting to the various drivers – weighting would be key to any policy decision on the choice of model.

Table 4-3 represents the financial and economic summary. The assessment of the financial and economic criteria indicates a nuanced result for the suitability of the two grid delivery models, with pros and cons for each grid delivery model for each criterion. A main differentiator for the plan-led model is the ability to coordinate and optimise onshore and offshore grid developments thereby reducing the risk for delayed and stranded onshore grid reinforcements (and corresponding costs).

Table 4-3. Financial/economic summary of grid delivery models in the Irish context.

	Criteria	Developer-led score	Plan-led score
Financial/economic criteria	Impact on cost level - offshore transmission assets	◑	◑
	Impact on cost level - onshore grid reinforcements	○	●
	Impact on consumer electricity prices - PSO levy	○	◑
	Impact on consumer electricity prices - network tariffs	◑	○
	Impact on consumer electricity prices - energy tariffs	●	●
	Impact on state support scheme income/expenditure - offshore wind assets	◑	◑
	Impact on state support scheme income/expenditure - transmission assets scope	◑	N/A
	Impact on financeability of transmission assets	◑	◑
	Impact on financeability of offshore wind assets	◑	●
	Impact on level of risk of lost revenue for the wind farm developer	◑	○

Source: Navigant.

The technical summary is depicted in Table 4-4. The assessment of the technical criteria indicates a slightly higher overall appraisal of a plan-led grid delivery model. The plan-led model would provide more opportunities for coordination across technologies and projects, and compatibility with multiple project developments and maximising offshore resources. These advantages are likely more relevant post 2030. On other criteria, there is a limited difference in performance between the models for the Irish context. The developer-led model creates a less complex interface onshore, instead of the offshore interface for plan-led models.

[143] European Commission, Clean energy for all Europeans package, 2016. https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

The regulatory and policy summary is depicted in Table 4-5. The plan-led model performs overall better than the developer-led model for the regulatory and policy criteria and is more suited than the developer-led model for coordinated integration of renewables, grid planning procedures as well as the potential to take a multi-project public acceptance approach and reduce total environmental impact of offshore wind developments. The developer-led grid delivery model, in contrast, is more suited for compatibility with the RESS design and Relevant Projects.

Table 4-4. Technical summary of grid delivery models in the Irish context.

		Developer-led score	Plan-led score
Technical criteria	Technological advancement of offshore wind technology (2020-2030)	◐	◐
	Technological advancement of other ORE technologies (2020-2030)	◐	●
	Speed of delivery – offshore wind farm transmission asset development	◐	◐
	Compatibility of multiple project developments	○	●
	Maximising offshore resources - technical aspects	◐	●
	Technical challenges	●	●
	Technical complexity of the interface	●	○
	Ease of enforcing maximum infeed requirements	●	●

Source: Navigant.

Table 4-5. Regulatory and policy summary of grid delivery models in the Irish context.

	Criteria	Developer-led score	Plan-led score
Regulatory/policy criteria	Compatibility with RESS auction design	●	◐
	Impact on state: meeting RE targets through offshore wind projects – planning stage	●	◐
	Impact on state: meeting RE targets through offshore wind projects – auction stage	◐	●
	Impact on state: meeting RE targets through offshore wind projects – realisation stage	●	●
	Impact on state – scalability of grid capacity to achieve higher targets	◐	◐
	Capacity to deliver offshore wind farm transmission assets and site pre-development	●	◐
	Complexity of grid planning procedure – developer perspective	◐	●
	Complexity of grid planning procedure – consenting body perspective	◐	●
	Complexity of grid planning procedure – TSO/TAO perspective	○	◐
	Coordinated onshore integration of renewables	○	●
	Compatibility with Relevant Projects	●	○
	Social acceptance	◐	●
	Environmental impact	◐	●

Source: Navigant.

The international context summary is depicted in Table 4-6. The international criteria are relatively balanced between the plan-led and the developer-led grid delivery models. Within the plan-led model, however, there is more opportunity to coordinate current grid planning with future technology developments in the European international context.

Table 4-6. International context summary of grid delivery models in the Irish context.

	Criteria	Developer-led score	Plan-led score
International context	Consistency with future offshore grid technology	◐	●
	Consistency with future policy of offshore renewable energy	◐	◐

Source: Navigant.

5. GRID DELIVERY MODEL OPTIONS FOR IRELAND

5.1 Overview

Chapter 4 presented the results of the assessment of the developer-led and plan-led grid delivery models in the Irish context based on a set of criteria. This chapter summarises and analyses the outcomes of the assessment based on an overview of the key drivers in the Irish context (section 5.2).

Following the results of the analysis, four grid delivery model options for Ireland are presented in section 5.3 followed by a comparison of the advantages and disadvantages of each model in section 5.4 and a risk analysis in section 5.5. This chapter concludes with a proposed roadmap with key actions and milestones for Ireland to facilitate the roll-out of at least 3.5 GW of offshore wind by transitioning to one of the enduring model options assessed (see section 5.6). Section 5.7 concludes this chapter.

5.2 Assessment of key drivers

Cost

From a **cost** perspective, the difference between developer-led and plan-led grid delivery models in the Irish context is rather nuanced as both the developer-led and plan-led models have their own benefits and drawbacks. The main contributing factors to the total cost for the offshore grid delivery model are the offshore wind transmission asset costs and the costs for onshore grid reinforcements.

For the **offshore wind transmission assets,** a plan-led model allows for a more standardised design, which could benefit from scalability and shared O&M, which could reduce the costs of transmission assets. However, the recent offshore wind tender results in the round 3 CfD auction in the UK (including the Doggerbank Creyke Beck A P1 project of 1.2 GW tendered at 39.6 $£_{2012}$/MWh)[74] have demonstrated that competitive pressure can bring down cost levels of offshore wind farm projects (including transmission assets), also in a developer-led model. Therefore, at this point it is not possible to clearly define which model would deliver the lowest cost level for the transmission assets. The investment costs required for developing the transmission assets for 3.5 GW of offshore wind capacity are estimated to be approximately 1.5-2.0 billion euro, as described in Appendix A.

In addition, the **onshore grid reinforcements** that are required to increase onshore capacity beyond the currently estimated available capacity of ~1.5 GW will also require investments. These costs will be dependent on the adopted offshore grid delivery model. Further assessment is still required to define the necessary level of onshore grid reinforcements required in Ireland to accommodate at least 3.5 GW of offshore wind. In a plan-led grid delivery model, it is easier to dictate, coordinate and plan the roll-out and connection of offshore wind farms, which makes it easier to optimise offshore and onshore grid developments in a holistic manner and prevent e.g. stranded assets. In a developer-led model, the roll-out planning is less predictable, which could result in a sub-optimal, delayed and more costly grid integration. At this point it is not possible to assess the cost difference for onshore grid reinforcement costs under the developer-led or plan-led model as further analysis is required.

In terms of **cost impact to consumers** and the **Irish State**, developing at least 3.5 GW of offshore wind will inevitably lead to costs and will impact the Irish consumers. Depending on the grid delivery model, these costs will be paid for by consumers and the State in different ways. In a developer-led model, the costs for the offshore wind transmission assets are primarily recovered through the PSO levy (as the offshore wind transmission assets are part of the developer scope) while in a plan-led model these costs are recovered through network tariffs. Under both models the costs for the onshore grid reinforcements will be recovered through the network tariffs.

Environment

Limiting the cumulative environmental impact of Irish offshore wind developments is an important consideration. Regardless of grid delivery model, any wind farm or ORE project will have to perform an environmental assessment and limit environmental impact following the guidelines specified in the National Marine Planning Framework (NMPF) currently under development.

A developer has limited financial incentive for onshore-offshore transmission asset coordination which may result in environmental impact due to increased need for onshore and offshore transmission infrastructure.

The plan-led model has greater potential to take onshore-offshore transmission asset coordination into consideration due to the long-term planning horizon for the coordinated roll-out of offshore wind developments. This may result in the State Body and TSO minimising infrastructure and associated environmental impacts. More plan-led models could realise synergies between individual projects to limit required landfall points and dune crossings thereby minimising the cumulative environmental impact of Irish offshore wind developments.

Future proofing

Initiating the development of at least 3.5 GW of offshore wind capacity in Ireland requires many short- and medium-term decisions to be made regarding grid planning, subsidy schemes, auction design, policy changes, grid delivery models, etc. An important risk is that a decision made today could pose issues beyond 2030. This risk is particularly relevant when looking at innovations in the offshore area that might emerge over the coming decade, or at offshore technological and policy developments in the international European context.

Future proofing policies and technologies that will be adopted in Ireland over the next decade is important to prevent lock-in, investment regrets and to safeguard post-2030 offshore developments. Currently, there is significant international interest in hybrid assets and meshed offshore projects in the North and Baltic Seas (sections 4.2 and 4.6) to increase interconnection and offshore wind integration. Examples of these initiatives include the North Sea Wind Power Hub consortium and the Kriegers Flak Combined Grid solution.

Adopting a developer-led model might pose a risk to future proofing. Developers are incentivised to minimise costs and mitigate risks for their single projects. In addition, developers are generally reluctant to take on high upfront costs (e.g. to over-dimension offshore substations or adopt innovative technologies) for assets that might only deliver their full potential and revenue post-2030 when operating in a larger offshore grid system. However, there is potential for the TSO to specify the use of certain connection approaches and/or technologies and for the developer to be compensated accordingly. In addition, the developer-led model is directly aligned with the model currently adopted in Ireland's closest neighbouring country, the UK, which could facilitate shared projects on a shorter time frame. Note, however, that in February 2020, Ofgem, the electricity regulator, has stated that Great Britain will look toward developing a more coordinated offshore transmission system planning approach to connect offshore wind generation in the future.[71]

Conversely, the plan-led grid delivery model allows the State Body and TSO to plan over a longer time horizon to minimise total societal cost, also in an international context. Longer-term planning can foresee technical future proofing of developments - despite technologies not yet being cost-effective - in today's planning phases. This foresight could facilitate scaling up offshore RES deployment within Ireland and Europe. Note that shared projects between two countries with different grid delivery models is not uncommon as, for example, TenneT and Vattenfall are investigating the feasibility of an interconnector between a TenneT offshore substation in the Netherlands and a Vattenfall offshore substation in the UK.[144]

To date, no concrete plans for hybrid projects have been developed in Ireland. In addition, in the period to 2030 offshore wind farms are likely to be close to shore and offshore hubs are not likely to be adopted.

Infrastructure

Developing at least 3.5 GW of offshore wind in Ireland requires significant infrastructure to be built, including onshore grid reinforcements and offshore wind transmission assets. As indicated in section 2.5, the currently available onshore grid capacity is estimated to approximately 1.5 GW and is therefore insufficient to fully integrate the 2030 target of at least 3.5 GW of offshore wind capacity. A more detailed assessment is required to fully map the necessary grid reinforcements that are required to facilitate the offshore wind roll-out, and to enable timely reinforcement of the onshore grid. Lead times for these types of projects can easily reach up to ten years[145] (depending on the type of project: upgrades of existing substations or transmission lines are generally faster than construction of new substations and lines), making it urgent to start the grid reinforcement process as soon as possible to prevent delays and onshore grid bottlenecks.

As indicated in the cost driver, a plan-led model would allow for a holistic and optimised planning of the offshore wind transmission assets and required onshore grid reinforcements, while a developer-led model makes the offshore wind farm planning less predictable, which could result in sub-optimal onshore and offshore grid development.

One main risk involves the interface of the onshore grid and offshore wind transmission assets, which in case of a plan-led model would be more technically complex due to its offshore location, although procedurally less complex due to only the TSO/TAO being involved in the consenting process. A developer-led model allows for more development flexibility for the developer. However, due to the infrastructural developments required in the Irish power system - in particular in the medium term when onshore grid connections beyond ~1.5 GW will be required - this poses a risk of stranded offshore assets when onshore grid expansion is uncoordinated and unaligned with offshore wind developments.

The plan-led model would be more suited for longer-term planning of the transmission infrastructure, taking into account coordination of on- and offshore developments to minimise onshore grid reinforcement needs. Furthermore, standardisation of processes and connections, and coordination between single offshore projects and different ORE technologies in the (pre-)development phase by e.g. dimensioning offshore substations for future developments beyond a single site, would be easier to obtain in a plan-led model. However, in a fully plan-led model the responsibility of delivering both the onshore deep reinforcements as well as the offshore assets will be with the TSO/TAO. Multiple major projects would be simultaneously delivered by a small number of parties compared to a spread of responsibility in a developer-led model.

Relevant Projects

A large pipeline of offshore wind projects exists in Ireland. Although many of these projects are still in an early stage of development, some projects have progressed further than others in terms of development by e.g. acquiring a lease and/or grid connection offer. Therefore, the DHPLG together

[144] TenneT, 2018. TenneT and Vattenfall to study potential Dutch and UK offshore wind farm connections https://www.tennet.eu/news/detail/tennet-and-vattenfall-to-study-potential-dutch-and-uk-offshore-wind-farm-connections/
[145] Interview with EirGrid grid planning on 22 October 2019.

with DCCAE has defined criteria to qualify some of these as Relevant Projects, which can continue their development under a transitional protocol, prior to the enactment of the MPDM Bill[146]

A developer-led grid delivery model would be most consistent with Relevant Projects since the developer is responsible under both models for site selection and (pre-)development and construction of both the wind farm and transmission assets. The “onshore” model is a variation on the developer-led model.

A plan-led grid delivery model poses significant difficulties for Relevant Projects developing as they intended, due to the shift in responsibilities related to site selection and (pre-)development and construction of offshore wind transmission assets from the developer to a State Body. A transitional scheme towards an enduring model could provide additional benefits here, but the timing of the transition (particularly in relation to auctions) would need to be carefully considered. This is further elaborated on in section 5.3.

Timing

Achieving the climate ambitions as stated in the Climate Action Plan and the timely realisation of at least 3.5 GW of offshore wind capacity by 2030 requires a swift deployment of offshore wind in the short-term, and further scale-up and integration in the medium term towards 2030. Meeting the short-term need will be realised by supporting the development of Relevant Projects under the transitional protocol to ensure they can be developed as soon as possible.

For the medium term, it is important that sufficient onshore grid connection capacity is available, beyond the currently estimated ~1.5 GW. Therefore, a more plan-led grid delivery model for the medium term could be more suited as it allows for greater onshore-offshore coordination. A more plan-led model would require time to develop new governmental capabilities, and policy, regulatory, licence and legislative frameworks. A single State Body for ORE development requires establishment with the capabilities to manage the planning and pre-development processes. This could pose a potential risk. Risks associated with the establishment of a plan-led model and the mobilisation of a new ORE body could be addressed by starting the planning process in parallel with the development of Relevant Projects. This transitional approach could ensure that offshore wind deployment targets are met on time (see also section 5.3).

There is a perception amongst the offshore wind industry that EirGrid and ESB Networks have limited experience in the development of transmission assets for offshore wind farms. This concern could be addressed by involving stakeholders early on in the process and through knowledge sharing between European TSOs. An alternative setup could be to allow developers to build the assets that are planned by EirGrid (see also section 5.3).

It should be noted that challenges experienced with onshore grid reinforcement are not necessarily representative for the development of offshore wind transmission assets, as the onshore environment is more challenging in terms of consenting issues and landowners.[91] In addition, EirGrid has successfully delivered the East-West interconnector project to the UK on time and within budget.[92] The Celtic Interconnector is also under way, in early development and is running according to schedule with no delays to the original programme.[147] ESB Networks has extensive experience in developing onshore transmission assets as well as international experience with offshore transmission assets and wind farm development through their subsidiary ESB International.91

[146] DHPLG, 2019. The Marine Planning and Development Management Bill. https://www.housing.gov.ie/planning/marine-spatial-planning/foreshore/marine-planning-and-development-management-bill

[147] DCCAE, 2019. Minister Canney bears witness to historic grant agreement signing ceremony in Brussels – Celtic Interconnector to proceed with €530m grant secured and signed. https://www.dccae.gov.ie/en-ie/news-and-media/press-releases/Pages/Minister-Canney-bears-witness-to-historic-grant-agreement-signing-ceremony-in-Brussels---Celtic-Interconnector-to-proceed-w.aspx

Social acceptance

Experience with international developments has shown that public acceptance is a major factor for the timely realisation of renewable projects. With the ambitious targets in Ireland of delivering at least 3.5 GW of offshore wind capacity by 2030, public acceptance will be crucial to prevent major development delays. Public participation in the various development stages is often cited to be important to create buy-in for projects by local communities through information provision, joint planning and financial participation (see section 4.5). For this reason, the Irish RESS design focuses strongly on community participation in and ownership of renewable electricity projects to increase public acceptance of renewable developments (Community Preference Category). These can be prescribed for any potential offshore wind development.

A plan-led grid delivery model could mitigate the risks related to public acceptance by its ability to streamline and group social acceptance processes across multiple (future) projects and providing a coordinated social acceptance campaign emphasising the importance of offshore wind to meeting Ireland's renewable energy targets. A more developer-led model would require a public acceptance process on a project-by-project basis with cost effectiveness as major driver. This approach does not consider future offshore wind developments and increases risks of untimely realisation of Ireland's 2030 targets through project-specific delays.

5.3 Grid delivery options for Ireland

Currently the "onshore" grid delivery model provides the framework for offshore wind project and offshore wind transmission asset development in Ireland. Based on the outcomes of the analysis in Chapter 4, four enduring options for offshore grid delivery models for Ireland are assessed.

5.3.1 Definition of model options

The four models that were assessed are compatible with the key drivers in the Irish context (section 5.2), whilst still providing developer responsibility in various project phases. The models represent a set of options, each with their advantages and disadvantages, to indicate a spectrum of options fit for the Irish context. The constituent elements of the four models presented could be combined in a variety of ways to form a wide range of additional model options. It follows that the model option or options ultimately chosen will not necessarily be set out in the report and could contain elements of two or more options.

The following four enduring model options are assessed, see Figure 5-1:

- **Option 1:** developer-led delivery model;
- **Option 2:** plan-defined, developer consents and builds grid delivery model - where the State defines a minimum distance from shore for wind farms, as well as onshore grid connection points and available onshore grid capacity for RESS auctions; EirGrid pro-actively plans and coordinates onshore grid reinforcements;
- **Option 3:** plan-led, developer builds grid delivery model - where the developers are responsible for offshore transmission asset construction, ownership, operation and maintenance in plan-led model;
- **Option 4:** plan-led grid delivery model.

An overview of relation between the models for the specific project phases is presented in Figure 5-1. A detailed overview of the key responsibilities for each option is given in Table 5-1.

Option 1, developer-led, presents the full developer-led model, as described in section 4.2.3, as a variation on the current "onshore" grid delivery model. After the identification of designated zones by a State Body, developers have the responsibility for offshore wind farm site selection and pre-development, and – following successful participation in an auction – development of the wind farm and offshore wind transmission assets. Developers are responsible for securing the required consents, financing, construction and operation and maintenance of both wind farm and transmission assets. The grid connection point lies onshore. Required onshore grid reinforcements are undertaken by EirGrid and ESB Networks in a reactive manner based on the announcement of the successful projects.

Option 2, plan-defined, developer consents and builds, the State defines a minimum distance from the wind farm to shore to enhance public support for offshore wind developments. In addition, EirGrid pro-actively plans and coordinates onshore grid reinforcements and for each RESS auction identifies the locations, capacities and timelines for the onshore connection points. In this way EirGrid can optimise the upgrades of the onshore grid such that the connection capacity to meet the CAP targets is made available in a timely manner. The developer remains responsible for wind farm site selection and pre-development, and the consenting and construction of the offshore wind farm transmission assets. Option 2 also requires engagements with developers to understand which projects are most likely to be developed towards 2030, to take into account in the onshore grid development planning. Developing shared transmission assets across wind farm sites would be possible under this model. After the RESS auction, if there is more than one winner of capacity at one location, shared assets[148] could be defined by EirGrid as part of the connection method similar to the onshore sub-group model. Alternatively, a developer could be requested by EirGrid to e.g. increase its transmission asset connection capacity to also account for nearby wind farm sites to be developed in that area (and would be compensated for the additional costs). However, there remains a risk that the nearby sites will not be successful in future tenders as there is no coordination between onshore and offshore developments, thereby risking sunken costs.

Options 3 and 4 adopt a more central offshore planning and coordination approach by shifting responsibilities from the developers to a State Body and EirGrid / ESB Networks.[149] A single State Body for ORE development will manage the planning and the site pre-development processes for offshore wind farms. Planning of onshore grid reinforcements and offshore developments could be optimised, and shared asset development[148] could be prescribed for relevant offshore wind farm sites, where appropriate.

Option 3, plan-led, developer builds, combines strong developer and State Body responsibilities where sites are selected and (pre-)developed by the State Body and the offshore wind transmission assets are defined and (pre-)developed by EirGrid (see Table 5-1 for more details on exact responsibilities). The developer winning the auction for a pre-developed site receives the responsibility for construction, financing, operation and maintenance of both the wind farm and transmission assets. Since only these specifically planned and pre-developed sites will be tendered, there is a lower risk for sunken costs compared to option 2 (related to onshore grid reinforcements and shared offshore assets) as a result of a wind farm site not successfully progressing through auctions.

Option 4 follows the fully plan-led model as described and assessed in section 4.2.3, shifting even more responsibilities to EirGrid and ESB Networks compared to option 3. Alongside site (pre-) development also the construction, ownership and operation and maintenance of the offshore wind transmission assets are now centrally planned by EirGrid and ESB Networks.

Figure 5-1 details the grid delivery model options assessed for Ireland following the phases of a project timeline

[148] If shared assets are adopted under this model, issues might arise due to unbundling requirements (Directive on common rules for the internal market for electricity (EU) 2019/944) that restrict generation and operation by a single party, in this case the developers. The ownership and operation of shared assets may then have to fall under the responsibility of the TAO/TSO.

[149] IEA Offshore Wind Report 2019 also articulates the need for market transparency and long term planning, irrespective of the model chosen[77].

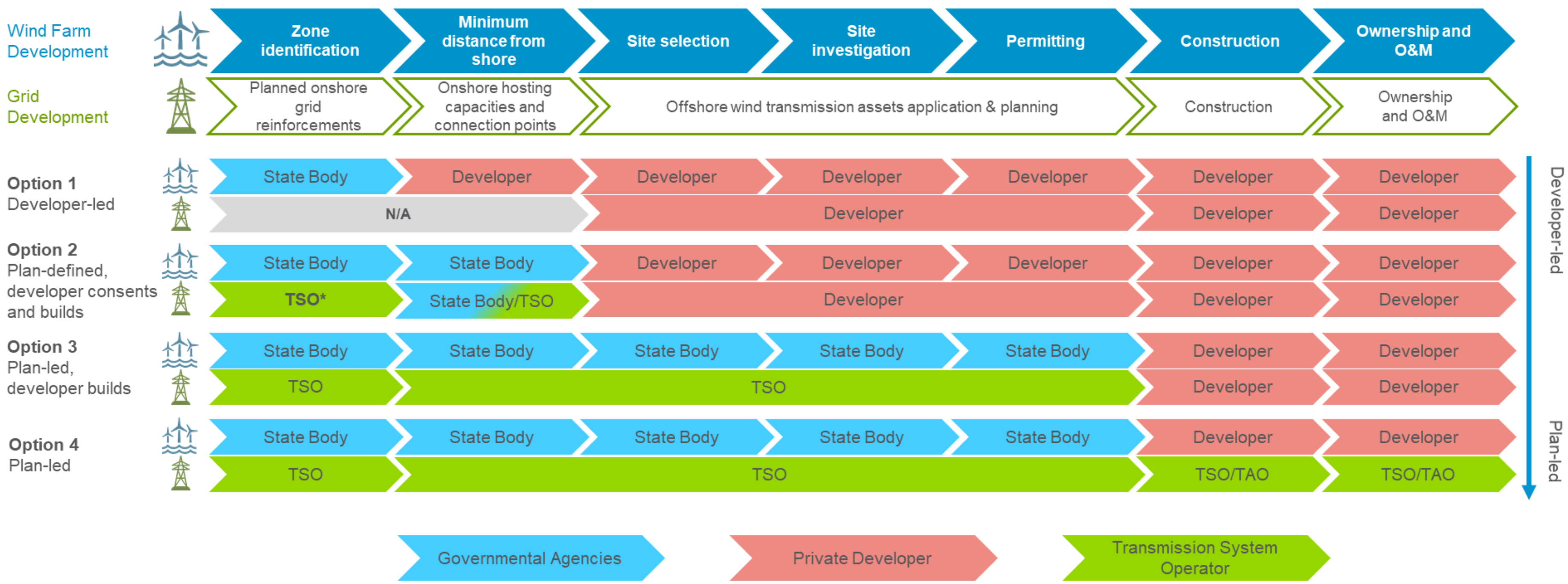


Figure 5-1. Grid delivery model options assessed for Ireland following the phases of a project timeline. *In option 2 the TSO will more pro-actively plan and communicate the timeline for onshore grid reinforcements early in the development process. *Source: Navigant.*

5.3.2 Responsibilities in model options

Table 5-1 presents the responsible parties for each project phase per model option. The different options are further detailed below the table. In addition to the key responsibilities for each option, a common set of assumptions underpins all four options:

- A Government auction scheme is in place specific to offshore wind but with a different auction design depending on the grid delivery model; an auction amongst wind farm sites that are pre-developed by developers for options 1 and 2, and a site-specific auction for sites pre-developed by a State Body for options 3 and 4;
- EirGrid chooses the onshore connection point and defines the connection method (note that the extent of connection method specification (e.g. the cable route) differs between the model options);
- EirGrid and ESB Networks design and build onshore grid reinforcements and costs are recovered through network tariffs;
- Zones are large areas, and typically include several sites (e.g. the Irish East Coast area could be one zone);
- All offshore assets are built to TSO transmission standards and compliant with Grid Codes (i.e. minimal standards must be met) with appropriate oversight by TSO/TAO;
- Whoever builds the transmission assets organises financing;
- Connection charging policy will follow the onshore model;
- EirGrid can seek to transfer grid connection ownership to the TAO in any option where the developer builds the asset; This would need to appropriately balance ownership of risk and cost of risk;
- Under option 4, current outturn availability rules are assumed to apply for offshore wind transmission assets where the developer bears the responsibility for a defined period in case the offshore wind transmission assets owned by ESB Networks and operated by EirGrid experience an outage.[150] Under options 1, 2 and 3 the offshore wind transmission assets are owned and operated by the developer[148], who manages and bears the risk of outages to its transmission assets;
- Currently no compensation from EirGrid or ESB Networks to developers is defined under the first competition of the RESS scheme (RESS 1) for delayed delivery of either onshore or offshore grid connections. Because this is out of the control of the developers for options 1, 2 and 3 (onshore grid reinforcements) and option 4 (onshore grid reinforcements and offshore grid connection), this poses a risk from the developer's perspective. To address this risk of delayed delivery, developer compensation arrangements could be included in offshore RESS competitions, similar to e.g. the Netherlands.[151]

[150] EirGrid, 2017. The EirGrid and SONI Implementation Approach to the SEM Committee Decision Paper SEM-15-071. http://www.eirgridgroup.com/site-files/library/EirGrid/The-EirGrid-and-SONI-Implementation-Approach-to-the-SEM-Committee-Decision-Paper-SEM-15-071-Version-2.pdf

[151] TenneT, 2020. Compensatieregeling. https://www.netopzee.eu/borssele/zo-werkt-de-netaansluiting-borssele/compensatieregeling

Table 5-1. Overview of responsibilities for the model options assessed for Ireland.

Project phase	Responsibility	Description	Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Pre-development	**Zone selection**	Selection of location of offshore zone wherein wind farm sites (including transmission assets) could be developed as well as identification and appointment of exclusion zones (e.g. military, shipping, fishing etc.)	DHPLG/ DCCAE	DHPLG/ DCCAE	DHPLG/ DCCAE	DHPLG/ DCCAE
Pre-development	**Site selection**	Selection of location of offshore wind farm site (including transmission assets) within the selected offshore zone	Developer	Developer	State Body	State Body
Pre-development	**Timing wind farm roll-out**	Timing of wind farm site development (roll-out plan)	Developer	Developer	State Body	State Body
Pre-development	**Offshore wind farm transmission asset planning**	Timing of offshore wind transmission asset development	Developer	Developer	EirGrid	EirGrid
Development	**Wind farm consents – application**	Consents for the offshore wind farm site (including surveys, wind resource and environmental assessments, and any required leases or licences)	Developer	Developer	State Body	State Body
Development	**Offshore wind farm transmission asset consents – application**	Consents for the offshore wind transmission assets (including environmental assessment and any required leases or licences)	Developer	Developer	EirGrid	EirGrid
Development	**Financing**	Financing of offshore wind transmission assets	Developer	Developer	Developer	ESB Networks
Development	**Final selection of onshore grid connection point**	Final decision on onshore grid connection point	EirGrid	EirGrid	EirGrid	EirGrid
Development	**Functional design offshore wind farm transmission assets**	High-level design of the functional requirements and specs of transmission assets beyond grid codes and applicable standards (e.g. voltage level, capacity, cable corridor, offshore substation location, landing points, shared assets if applicable[148]…)	Developer	EirGrid and Developer	EirGrid and ESB Networks	EirGrid and ESB Networks

Project phase	Responsibility	Description	Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Construction	**Detailed design offshore wind farm trans-mission assets**	Detailed design of offshore wind transmission assets (e.g. full technical definition of transmission assets, installation methodology, construction timeline etc.)	Developer	Developer	Developer	EirGrid and ESB Networks
	Offshore wind farm transmission asset construction	Construction and commissioning of transmission assets	Developer	Developer	Developer	ESB Networks
O&M	**Ownership and maintenance**	Ownership and maintenance of offshore wind transmission assets (including decommissioning)	Developer[148]	Developer[148]	Developer[148]	ESB Networks
	Operation	Operation of offshore wind transmission assets	Developer[148]	Developer[148]	Developer[148]	EirGrid
Onshore grid reinforcements	**Responsibility onshore grid reinforcement**	Planning, specification, consenting (EirGrid) and construction (ESB Networks) of required reinforcements in the onshore grid to facilitate the infeed of offshore wind energy	ESB Networks/ EirGrid Reactive	ESB Networks/ EirGrid Pro-Active	ESB Networks/ EirGrid Pro-Active	ESB Networks/ EirGrid Pro-Active
Auction design	**Auction type**		Amongst sites	Amongst sites	Site-specific	Site-specific
	Definition of offshore capacity in RESS auctions		DCCAE	DCCAE	DCCAE	DCCAE
	Selection and definitions of onshore connection points (stations, capacity, timing) for RESS auctions		N/A	EirGrid and DCCAE	EirGrid and DCCAE	EirGrid and DCCAE
Ownership boundary	Ownership boundary assuming assets do not transfer to TAO in options 1, 2 and 3		Onshore	Onshore	Onshore	Offshore

Note that offshore wind farm transmission assets include the offshore substation, export cables and onshore connection assets.
Source: Navigant.

The below questions provide more context regarding the responsibilities of the different stakeholders for each option.

- **Who plans the location of the offshore wind farms including the location of offshore substations and the requisite offshore and onshore transmission assets?**

These responsibilities are covered in the *pre-development* phase in Table 5-1 and summarised below.

Option 1: Developer-led	• Zone selection by State Body but wind farm site selection and pre-development by developer; • Offshore wind transmission asset development (functional and detailed design beyond grid codes and applicable standards) by developer; • Onshore grid reinforcements and developments by EirGrid and ESB Networks in a reactive manner.
Option 2: Plan-defined, developer consents and builds	• Zone selection by State Body but wind farm site selection (outside minimum distance to shore) and pre-development by developer; • Offshore wind transmission asset functional design (beyond grid codes and applicable standards) by developer and EirGrid and detailed design by developer; • Onshore grid reinforcements and developments by EirGrid and ESB Networks in pro-active manner (onshore grid capacity and reinforcement planning is taken into account in RESS design).
Option 3: Plan-led, developer builds	• Zone and wind farm site selection and pre-development by State Body for ORE development; • Offshore wind transmission asset development (detailed design) by developer based on functional design by EirGrid; • Onshore grid reinforcements and developments by EirGrid and ESB Networks in pro-active manner.
Option 4: Plan-led	• Zone and wind farm site selection and pre-development by State Body for ORE development; • Offshore wind transmission asset development (functional and detailed design) by EirGrid and ESB Networks; • Onshore grid reinforcements and developments by EirGrid and ESB Networks in pro-active manner.

- **Who funds the offshore wind transmission assets?**

These responsibilities are covered in the *development phase* in Table 5-1 and summarised below. The common assumption for all grid delivery model options is that the party building the offshore wind transmission assets is responsible for funding them.

Option 1: Developer-led	• Developer fully responsible for financing and construction of the offshore wind transmission assets; • Cost of offshore wind transmission assets recovered through PSO levy.
Option 2: Plan-defined, developer consents and builds	• Developer fully responsible for financing and construction of the offshore wind transmission assets; • Cost of offshore wind transmission assets recovered through PSO levy.
Option 3: Plan-led, developer builds	• Developer responsible for the construction and funding of the offshore wind transmission assets. • Cost of offshore wind transmission assets recovered through PSO levy.
Option 4: Plan-led	• EirGrid and ESB Networks responsible for the design, construction and funding of the offshore wind transmission assets; • Cost of offshore wind transmission assets recovered through network tariffs.

- **Who is responsible for securing consents and building the offshore wind transmission assets?**

These responsibilities are covered in the *development and construction* phases in Table 5-1 and are summarised below.

Option 1: **Developer-led**	• Developer responsible for securing required consents and permits (including environmental assessment and any required licences or leases) and building wind farm sites and offshore wind transmission assets;
Option 2: **Plan-defined, developer consents and builds**	• Developer responsible for securing required consents and permits (including environmental assessment and any required licences or leases) and building wind farm sites and offshore wind transmission assets. In case transmission assets should be shared amongst different developers (in case of a hub concept) a lead developer could be nominated, in line with current onshore connection grouping methods[148].
Option 3: **Plan-led, developer builds**	• State body for ORE development and EirGrid/ESB Networks responsible for securing required consents and permits (including environmental assessment, and any required licences or leases) for each wind farm site and respective offshore wind transmission assets; • Developer receives permit for a site which integrates the permit to develop the wind farm at the designated site and the permit to develop the corresponding offshore wind transmission assets. In case transmission assets should be shared amongst different developers (in case of a hub concept) a lead developer could be nominated, in line with current onshore connection grouping methods[148].
Option 4: **Plan-led**	• State body for ORE development and EirGrid/ESB Networks responsible for securing required consents and permits (including environmental assessment, and any required licences or leases) for each wind farm site and building respective offshore wind transmission assets;

- **Who owns, operates and maintains the offshore wind transmission assets?**

These responsibilities are covered in the *O&M phase* in Table 5-1 and summarised below.

Option 1: **Developer-led**	• Developer is responsible for construction, ownership, operation and maintenance of offshore wind transmission assets.[148]
Option 2: **Plan-defined, developer consents and builds**	• Developer is responsible for construction, ownership, operation and maintenance of offshore wind transmission assets.[148]
Option 3: **Plan-led, developer builds**	• Developer is responsible for construction, ownership, operation and maintenance of offshore wind transmission assets.[148]
Option 4: **Plan-led**	• ESB Networks is responsible for construction, ownership and maintenance of offshore wind transmission assets; • EirGrid is responsible for operation of offshore wind transmission assets.

5.4 Advantages and disadvantages of model options for Ireland

Figure 5-2 gives an overview of the advantages and disadvantages of the four grid delivery model options assessed for Ireland based on the results of the assessment, summary tables and the key drivers in the Irish context.

Mapping the advantages and disadvantages of each model option for Ireland shows that in the longer term, options 3 and 4 have specific advantages and a lower risk profile compared to options 1 and 2. **It should be noted that these advantages/disadvantages and risks have not been weighted in this report – clearly this would be key to any policy decision on the optimum model for Ireland.**

The advantages of the developer-led model include compatibility with the Relevant Projects that can be developed quickly and that are more likely to be compatible with existing legislative and policy frameworks and leveraging existing developer experience in the delivery of offshore wind farms. The disadvantages include minimal onshore-offshore transmission asset coordination, the likelihood that any public acceptance campaign will be focused on a single project rather than multiple projects, greater risk of additional infrastructure with associated environmental impact and more complexity involved in future proofing of offshore transmission assets. Option 2 provides mitigation to some of these disadvantages compared to option 1.

The advantages of the plan-led model include long-term onshore-offshore transmission coordination with the potential for reduced infrastructure, the ability to craft a coordinated public acceptance process covering multiple projects and ease of future proofing of technology. The disadvantages include the time needed to develop new governmental capabilities, policy, regulatory, licence and legislative frameworks which are likely required, challenges with state bodies simultaneously developing multiple offshore and onshore renewable energy and transmission projects and incompatibility with Relevant Projects. Option 3 gives developers control of the construction of both the offshore wind farm and transmission assets, reducing potential risks as perceived by the offshore wind industry.

Key drivers		Option 1 Developer-led	Option 2 Plan-defined, developer consents and builds	Option 3 Plan-defined, developer builds	Option 4 Plan-led
Cost	+	Competitive pressure can reduce cost levels transmission assets No sunken costs associated with Relevant Projects		Optimised transmission asset costs through standardised and holistic planning, and synergies Optimised cost for onshore grid reinforcements through effective coordination of on- and offshore asset developments Central pre-development and de-risking of offshore wind sites	
	+		Potential cost upside due to pro-active onshore grid reinforcement		Further optimisation of transmission costs through economies of scale on programme level
	+		Potential upside from economies of scale on a project level through hubs and shared infrastructure		
	-	Suboptimal costs onshore grid reinforcements through misalignment on- and offshore developments	Less optimal onshore grid co-ordination with offshore wind capacity compared to options 3 and 4		State exposed to compensating developers for lost revenue in event of fault on offshore transmission connection
	-	Sunken costs for pre-development of sites unsuccessful in auction			
Environ-ment	+		More optimal onshore-offshore grid coordination compared to option 1 by definition of grid connection point with potential to reduce environmental impact	Lower cumulative environmental impact by coordinating onshore-offshore transmission works, minimising the need for new transmission infrastructure	
	-	Limited potential to take onshore-offshore transmission asset coordination into consideration resulting in greater environmental impact due to potential need for more transmission infrastructure			
Future proofing	+		Potential upside as EirGrid can specify technologies and connection methods including shared assets	High potential for future-proofing of technology and shared assets due to long planning horizon and societal incentives of State Body Potential to adopt innovative technologies if not yet cost-effective	
	-	Limited developer incentive for future-proofing of technology Only cost-effective technologies and incremental innovations			
Infra-struc-ture	+	Leverages developer experience and expertise in delivery of offshore infrastructure Less complex onshore interface One party (developer) for development, construction and O&M windfarm and transmission assets			Leverages experience of EirGrid and ESB Networks with delivery of offshore infrastructure
	+		Increased on- and offshore grid coordination compared to option 1 through pro-active planning and communication of onshore development timeline and alignment with RESS auctions	Long-term planning horizon allows to coordinate and optimise on- and offshore developments and between ORE projects Reduced procedural complexity with limited stakeholders in consenting process	
	-	No coordination and optimisation on- and offshore grid and across ORE projects	Less coordination potential and optimisation of on- and offshore grid and across ORE projects compared to options 3 and 4	Planning phase by new State Body for ORE development could introduce bottleneck since multiple large-scale projects with similar timelines being developed by a small number of bodies	
	-	Procedural complexity with more stakeholders and potentially more projects in consenting process grid and across ORE projects			Developers perceive a risk as they do not have control of site pre-development and offshore wind transmission infrastructure development More complex offshore interface
Relevant projects	+	Compatible with Relevant Projects, and leverages work already completed by developers on Relevant Projects			
	-			Incompatible with Relevant Projects	
Social accep-tance	+		Prescription of minimal distances from shore		
	+	Targeted and specific campaigns have the potential to improve social acceptance of some projects		Central public acceptance campaign Coordination of sites and minimisation of landing points and visibility to increase public acceptance	
	-	Social acceptance campaign on project-by-project basis		Offshore wind farm developers less likely to be supportive of plan-led model	
Timing	+	Relevant Projects can be developed quickly to commence offshore wind developments in the short-term, leveraging work already completed by developers providing a programme advantage		Controlled and coordinated onshore-offshore transmission asset roll-out plan to timely achieve targets	
	-	No control and coordination of onshore-offshore transmission assets roll-out to achieve targets	Proactive planning of programme for onshore capacity and auctions but less coordination of offshore wind roll-out compared to options 3 and 4		Capacity needs to be built up in EirGrid and ESB Networks
	-			Transitioning to a plan-led model takes time to develop new governmental capabilities, and policy, regulatory, licence and legislative frameworks, which are likely required Challenges with state bodies simultaneously developing multiple ORE projects	

Figure 5-2. Pros and cons of grid delivery model options assessed for key drivers in Ireland. The pros and cons have not been weighted – clearly this would be key to any policy decision.

Source: Navigant.

5.5 Risk analysis

The most important risks related to grid delivery models are evaluated for the four options assessed in Table 5-2. For each option, the probability of the risks occurring is indicated. The risk probabilities for the different options are stated relatively to each other. The parties responsible for managing the risks are given in Table 5-1, for the respective project phases.

Option 1: A key risk area for option 1 relates to the coordination of onshore grid reinforcements to keep in step with connections of offshore wind capacity due to a limited relation between the timing and planning of wind farm sites, capacities and landing points and the required onshore grid reinforcements to accommodate these. Also, a lack of coherent and efficient social acceptance process is an important risk in option 1.

Option 2: When compared to option 1, this option mitigates certain risks such as onshore-offshore grid coordination by pro-actively planning and managing the onshore reinforcements. In addition, existing onshore grid capacity and the timing of future reinforcements are included in RESS tender specifications. Option 2 also enhances social acceptance by specifying a minimum distance from shore for offshore wind farm projects.

Options 3 and 4: The risk analysis shows that the more plan-led options have a lower probability of risks to occur. There is a higher likelihood of a timely integration in the onshore grid due to a more coordinated and holistic grid and wind farm planning approach. Option 3 reduces the probability of construction risks as perceived by the offshore wind industry by assigning the developer this task. The most important risks lie with the timely establishment, resourcing and mobilisation of a new state body for ORE development and the challenges associated with a small number of state bodies simultaneously developing multiple offshore grid projects along with the onshore grid reinforcement projects.

The risks have not been weighted in this report – this would be key to any policy decision on the optimum model for Ireland.

Table 5-2. Risk matrix of grid delivery model options assessed for Ireland including impact and relative risk probability. Relative risk probabilities are presented.

Project phase	Risk	Impact	Risk probability for options: Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Pre-development	No control over timeline of offshore wind capacity roll-out	High uncertainty in achieving 2030 targets	Higher	Medium	Lower	Lower
Pre-development	Incompatibility with future grid developments	Lock-in with current technologies and reduced advantages of participating in meshed and hybrid assets	Higher	Medium	Lower	Lower
Pre-development	Sunken costs related to site pre-development	No wind farms will be developed at pre-developed sites	Medium	Medium	Lower	Lower
Pre-development	Social acceptance issues associated with offshore wind projects and related offshore wind transmission assets	Delays or cancellations of offshore wind projects	Higher	Medium	Lower	Lower
Pre-development	Delay in establishing, resourcing and mobilising a new State Body for ORE development and/or making necessary legislative/TSO or TAO licence changes	Delays in offshore wind roll-out	Lower / N/A	Lower / N/A	Higher	Higher
Development	No wind farm consents granted	Wind farm will not be developed resulting in possibly sunken costs, stranded assets, not meeting 2030 targets and reduced developer confidence	Medium	Medium	Medium	Medium
Development	No offshore wind transmission asset consents granted	Wind farm cannot connect to onshore grid resulting in sunken costs to developer and damaged developer confidence	Medium	Medium	Medium	Medium
Development	No financing secured for wind farm and/or transmission assets	Wind farm and/or transmission assets cannot be developed resulting in reduced developer confidence, possible sunken costs and uncertainty in reaching 2030 targets	Low	Low	Low	Low

Project phase	Risk	Impact	Risk probability for options			
			Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Construction	Delay in offshore wind farm project development	Possible temporary sunken costs and stranded (onshore/offshore) transmission assets and delay in reaching targets	**Low**	**Low**	**Low**	**Low**
Construction	Delayed delivery of offshore wind transmission assets	Possible temporary sunken costs and stranded (onshore) transmission assets, delay in reaching 2030 targets and reduced developer confidence *Developer is impacted under all options under current RESS design (no compensation foreseen)*	**Low** *Managed by developer*	**Low** *Managed by developer*	**Low** *Managed by developer*	**Low** – likely perceived **Medium** by industry *Managed by ESB Networks*
O&M	Insufficient reliability and availability of offshore wind transmission assets (export cable and offshore substation)	High levels of curtailment of onshore wind and very low developer confidence. Not reaching renewable energy generation targets *Developer is impacted under all options. Current outturn availability rules limit impact under option 4*	**Low** *Managed by developer*	**Low** *Managed by developer*	**Low** *Managed by developer*	**Low**[152] *Managed by EirGrid/ESB Networks*
Onshore grid reinforcements	Delayed onshore grid reinforcements	Possible temporary sunken costs and stranded wind farm and offshore transmission assets, delay in reaching 2030 targets and reduced developer confidence	**Higher**	**Lower**	**Lower**	**Lower**
Onshore grid reinforcements	Stranded onshore grid assets	Onshore grid reinforcements made to accommodate offshore wind capacity but hosting capacity not (fully) used. High unnecessary cost to consumers	**Higher**	**Lower**	**Lower**	**Lower**
Onshore grid reinforcements	No firm capacity of onshore grid	High levels of constraint of offshore wind capacity resulting in not reaching renewable energy generation targets and low developer confidence	**Higher**	**Medium**	**Lower**	**Lower**

Source: Navigant.

[152] Outturn availability rules apply, see section 5.3.

5.6 Roadmap and key milestones for Ireland towards 2030

A transition towards an enduring grid delivery model would be required to leverage the development of the Relevant Projects in the short term and to implement any required regulatory, policy and legislative changes. A transition towards option 1 would require limited actions but has a higher risk of misalignment between onshore and offshore developments. A transition to option 2 increases the onshore and offshore coordination and requires action by EirGrid to assess in detail the availability of onshore capacity and align this with auctions. A transition to options 3 and 4 would require significant changes and actions that would need to be implemented as soon as possible but ensures onshore and offshore developments are fully aligned. The overall suitability of each model option in the Irish context highly depends on the emphasis and relative weighting of certain criteria to reflect key stakeholder perspectives.

Option 1 presents the variation on the current "onshore model" where the developer would contest the development of the offshore wind transmission assets. **Option 2** presents a variation on the "onshore model" where the State defines minimum distance from shore for wind farms, as well as onshore grid connection points and available offshore wind capacity for RESS tenders. EirGrid pro-actively plans and coordinates onshore grid reinforcements under option 2. The offshore development responsibilities remain largely the same. The pro-active approach to onshore grid reinforcements under option 2 provides the opportunity for developers to develop their offshore wind farms in line with available onshore capacity or the onshore grid reinforcement timeline.

Options 1 and 2 share a start-up phase with **options 3** and **4**, which presents common no-regret actions that should start as soon as possible in line with the planning and development of required onshore grid reinforcements, namely:

- Offshore zone selection;
- Decision model option for Relevant Projects and enduring model option;
- Assessments on current hosting capacity onshore grid.

In 2020, these common no-regret actions should start as soon as possible. Following publication of the Transition Protocol, those projects which will be classified as 'Relevant Projects' need to be identified quickly in order to increase the likelihood of meeting the 2030 targets. In addition, building on the results of the existing East Coast study, the hosting capacity of the current onshore grid should be assessed as soon as possible.

The CRU has already directed EirGrid to process any grid applications from Relevant Projects. EirGrid will now be developing a plan for assessing the onshore network reinforcements once the number, scale and status of the Relevant Projects have been confirmed through engagement with the relevant government departments.[153]

A possible high-level roadmap with key actions and milestones towards 2030 for **options 1 and 2** is given in Figure 5-3. Significant uncertainty remains regarding the timing and duration of the actions as some are sequentially dependent (e.g. assessment, planning and construction onshore grid reinforcements). The actions to transition from the current "onshore" model to options 1 and 2 are limited. Under option 1, the construction of onshore grid reinforcements will start once the outcome of the auctions is known.

Option 2 includes more actions prior to the auction rounds, which reduces this risk by pro-actively managing and developing onshore grid reinforcements and including the onshore grid reinforcement planning in RESS tender specifications. The RESS auction specifications will include which onshore connection points are available for offshore wind connection, together with their capacities and timelines. Onshore grid reinforcements will start prior to the auction rounds.

[153] CRU, 2020. Offshore grid connection. https://www.cru.ie/document_group/offshore-grid-connection/

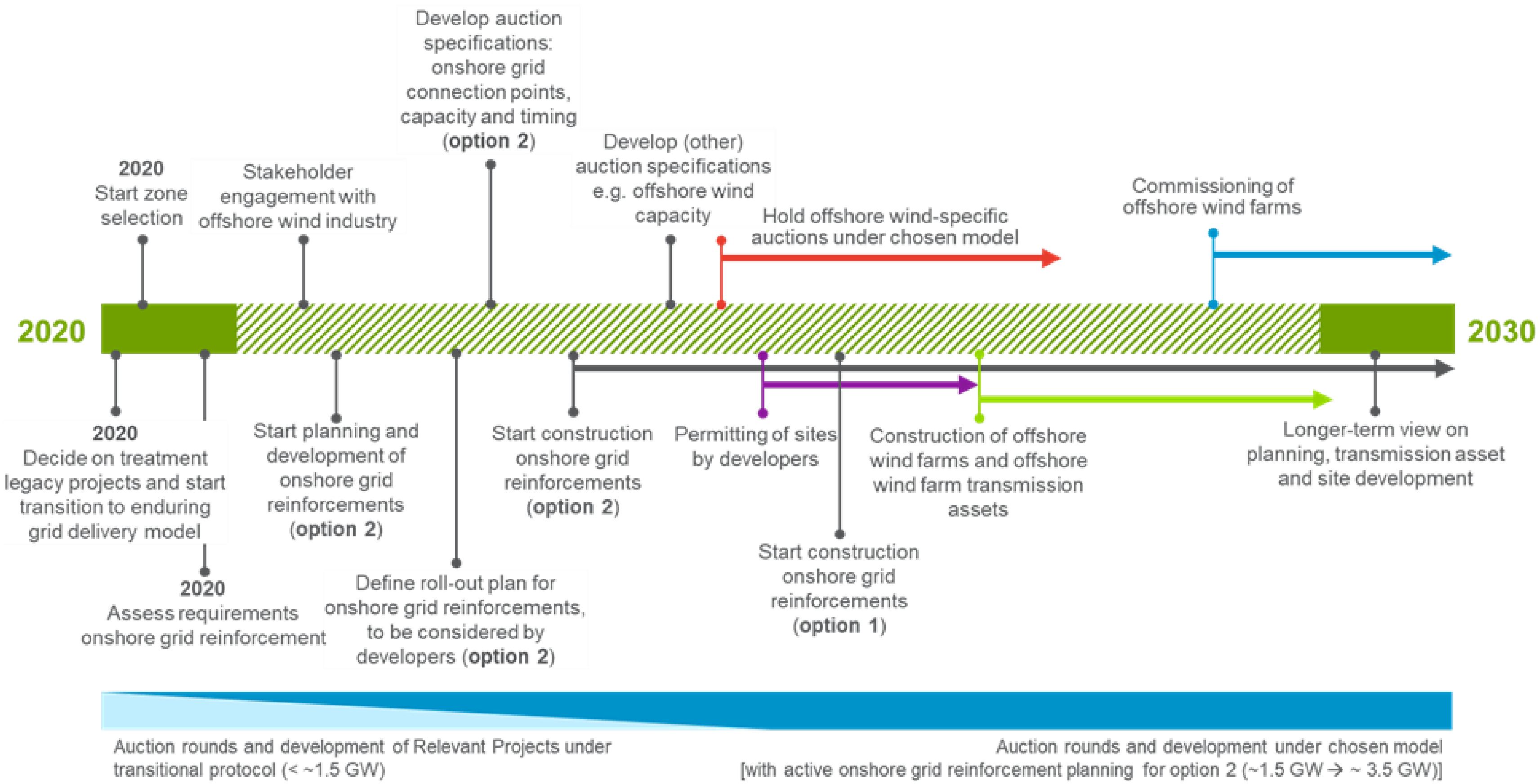


Figure 5-3. Possible high-level roadmap with key actions and milestones towards 2030 for option 1 and 2. Significantly more uncertainty remains regarding the timing and duration of the actions since they fall out of the control of the State Body and EirGrid. *Source: Navigant.*

Options 3 and **4** do not seem to be compatible with Relevant Projects as such, but Relevant Projects can be developed in the shorter term while a smooth transition to the chosen enduring model option can ensure 2030 targets are met. A possible high-level roadmap for options 3 and 4 with key actions and milestones towards 2030 is given in Figure 5-4. Some milestones (*) have a different interpretation depending on the option. The exact timing and duration of the actions depends on the time required by the involved stakeholders to perform the required actions.

Options 3 and **4** share a plan-led pre-development phase, which presents common no-regret actions that should start as soon as possible in line with the planning and development of required onshore grid reinforcements:

- Offshore zone selection (common no-regret action with options 1 and 2);
- Assessments on hosting capacity current onshore grid (common no-regret action with options 1 and 2);
- Set-up of a new State Body for ORE development to manage pre-development actions;
- Selection, planning and sizing of offshore zones, sites and auctions;
- Pre-development for specific selected sites: surveys, permits, cable routing, wind resource assessment, etc.;
- Planning of onshore grid connection points and required technical and operational specifications of transmission assets;
- Planning and development of required onshore grid reinforcements beyond ~1.5 GW;
- Stakeholder engagement (interest of wind industry in model and sites);
- Public acceptance campaign.

The choice of enduring model option should be agreed upon in order to increase the likelihood of meeting the renewables targets. In addition, the hosting capacity of the current onshore grid should be assessed as soon as possible to determine the onshore grid reinforcement plan and development timeline in line with the planned offshore wind farm commissioning timeline.

Whilst the pre-development of the new enduring model is taking place, the assumed roll-out towards ~1.5 GW (based on expected currently available onshore grid capacity) is expected under the chosen model to allow some Relevant Projects to be developed. This model will be gradually phased out to be replaced with the chosen enduring model. Due to the tight timeline, the next couple of years should focus on the pre-development actions as shown above.

Once the enduring model is selected and the pre-development phase is well under way, the auction design and specifications for the selected sites can be developed around 2021-2024. To achieve the targeted capacity of at least 3.5 GW of offshore wind in 2030, a ramp-up of the capacity of tendered sites is likely to be best suited to achieve the development of ~2 GW of offshore wind within the 2028-2030 timeframe. The yearly capacity additions should be decided based on yearly targets, planned roll-out timeline, onshore grid developments and wind resource potential at the identified sites.

To achieve a ramped commissioning of offshore wind farms in within the 2028-2030 timeframe, the auctions should start no later than 2025, 2026 and 2027, respectively. This allows time for the construction of the offshore wind farms and offshore wind transmission assets.

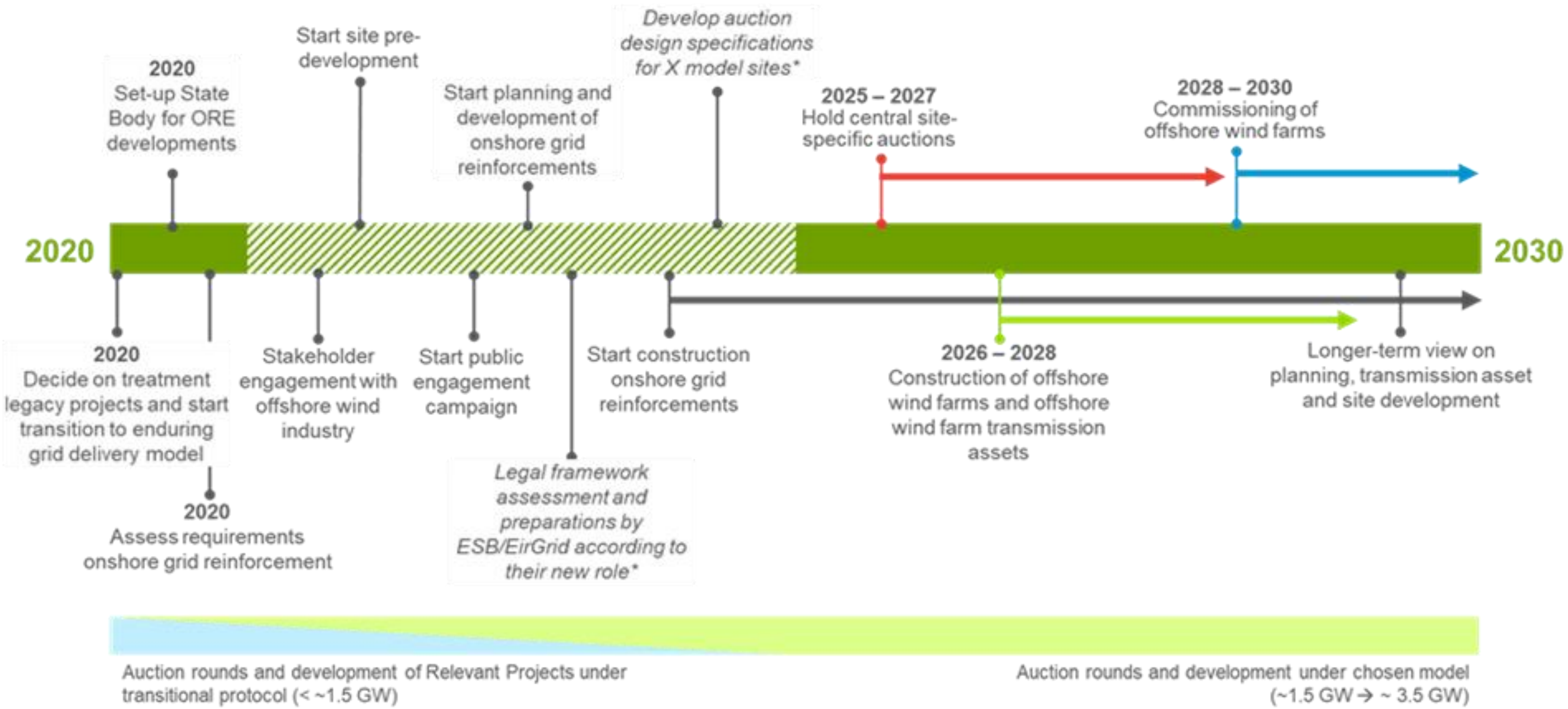


Figure 5-4 .Possible high-level roadmap with key actions and milestones for options 3 and 4 towards 2030. Note that the exact timing and duration depends on the time required by the involved stakeholders to perform the required actions. *Source: Navigant.*

*These milestones will have a different interpretation depending on the selected model option.

5.7 Summary

The results of the assessment of the developer-led and plan-led grid delivery models showed advantages and disadvantages for both models for the key drivers in Ireland. However, the overall suitability of each grid delivery model in the Irish context will depend on the emphasis and relative weight on certain criteria to reflect the main perspectives of the involved stakeholders.

Based on the assessment of the key drivers, four enduring grid delivery options were assessed to support the roll-out of at least 3.5 GW of offshore wind capacity in Ireland. The models assessed represent a set of options, with each their advantages and disadvantages, to indicate the spectrum of options fit for the Irish context. The constituent elements of the four models presented could be combined in a variety of ways to form a wide range of additional model options. It follows that the model option or options ultimately chosen will not necessarily be set out in the report and could contain elements of two or more options. A brief description of these grid delivery models is as follows:

- **Option 1:** developer-led delivery model;
- **Option 2:** plan-defined, developer consents and builds grid delivery model - where the State defines a minimum distance from shore for wind farms, as well as onshore grid connection points and available offshore wind capacity for RESS tenders; EirGrid pro-actively plans and coordinates onshore grid reinforcements;
- **Option 3:** plan-led, developer builds grid delivery model - where the developer is responsible for offshore transmission asset construction, ownership, operation and maintenance in plan-led model;
- **Option 4:** plan-led grid delivery model.

For each of these options, the advantages and disadvantages were mapped, and a risk analysis was conducted.

Finally, a roadmap with key milestones and actions for the transition towards 2030 in Ireland was presented for the different options. A transition towards an enduring grid delivery model would be required to leverage the development of the Relevant Projects in the short term and to implement any required regulatory, policy and legislative changes.

Adopting option 1 requires limited actions but has a higher risk of misalignment between onshore and offshore developments. Adopting option 2 increases the onshore and offshore coordination and requires significant immediate action by EirGrid to assess in detail availability of capacity and align this with auctions. A transition to options 3 and 4 requires significant changes and actions that should be implemented as soon as possible but ensures onshore and offshore developments are fully aligned. The overall suitability of each model option in the Irish context highly depends on the emphasis and relative weighting of certain criteria to reflect key stakeholder perspectives.

Note that this report was not intended to provide a decision on the best available option, but rather to present evidence that informs the decision for a grid delivery model suitable for offshore wind development in Ireland. All model options assessed in this report have their advantages and disadvantages from the various stakeholder perspectives and the decision for the chosen grid delivery model for Ireland will require careful consideration of the key drivers in the Irish context.

6. DISCUSSION AND CONCLUSION

6.1 Discussion

This options paper compared and assessed the main grid delivery models in the international context (developer-led and plan-led) and assessed specific grid delivery model options for Ireland based on identified key drivers in the Irish context. The focus of the assessment was defined by the targets as laid out in the Climate Action Plan (CAP) - at least 3.5 GW of offshore wind capacity by 2030 - and through interviews with working group members, which led to a primary focus of the analysis on the Irish East Coast and a timeline towards 2030.

One of the benefits of a more plan-led approach is the ability to coordinate onshore grid reinforcements and offshore wind farm and transmission asset developments in time, location and size. This benefit is especially important when onshore grid capacity is constrained, as is the case on the Irish East Coast as identified by EirGrid in the East Coast Study,[44] albeit EirGrid is still to assess the available grid connection capacity of the existing onshore grid in more detail. However, the transmission grid along the South and West Coasts currently mostly consists of single 220 kV lines, which limits the possibilities for tie-in of offshore wind capacity. Therefore, it is likely that the outcomes of this paper related to limited onshore grid capacity on the East Coast are also valid in general for other areas in Ireland, regardless of geography. The South and West Coasts also provide opportunities for other offshore renewable energy (ORE) technologies, such as floating offshore wind and wave energy. These developments could also benefit from a more plan-led approach as these ORE technologies are not likely to be cost-competitive in the short term and could benefit from multi-project developments.

The timeline of this options paper focusses primarily on meeting the 2030 targets as defined in the CAP. An outlook beyond this timeline could see the emergence of more internationally coordinated transmission asset developments, such as hybrid assets and meshed grids. In addition, sector coupling, e.g. through Power-to-X conversion, could start to play an increasing role in the transmission of ORE generation and balancing within the wider European energy system.

The model options 3 and 4 would be compatible with these longer-term developments; hybrid assets, meshed grids and sector coupling generally favour a plan-led component as they require anticipatory investments that may only pay off in the longer term across the full roll-out of offshore wind, and not necessarily for individual projects.

The enduring Irish grid delivery models as assessed in this options paper deviate to a certain extent from the current "onshore" grid delivery model. Options 3 and 4 require a significant restructuring of roles and responsibilities in the roll-out and development of offshore wind projects and transmission infrastructure. It is of utmost importance that key wind industry stakeholders, such as wind farm developers and equipment suppliers, are engaged in an early stage to ensure they are fully informed and engaged with the process and ready to deal with the chosen enduring model.

Apart from the grid delivery model, also technological decisions for the offshore wind transmission assets are to be consulted thoroughly at an early stage. An example of such an engagement is the stakeholder engagement process ran by TenneT in the Netherlands in 2015 to consult their standardised 700 MW offshore substation design with industry players, which included the connection of 66 kV cables array cables (instead of the conventional 33 kV cables), a new technology at the time.[154]

[154] TenneT, 2016. TenneT in Dialogue. https://www.tennet.eu/fileadmin/user_upload/Our_Grid/Offshore_Netherlands/Leaflet_Offshore_Consultation_ENG_SEPT2016_web.pdf

6.2 Conclusions

6.2.1 Ongoing developments Ireland

Ireland has ambitious climate targets towards 2030, including the addition of at least 3.5 GW of offshore wind capacity as stated in the Climate Action Plan (CAP) and supported by a Renewable Energy Support Scheme (RESS). Criteria for "Relevant Projects" have been defined to qualify some projects from the large pipeline of offshore wind projects in Ireland to be included in a transitional scheme to facilitate a fast build-out of offshore wind.

To support this roll-out of offshore wind capacity, various developments are ongoing in Ireland that are relevant for the choice of grid delivery model for offshore wind: an update in marine spatial planning with the development of the National Marine Planning Framework (NMPF) and the Marine Planning and Development Management (MPDM) Bill; the identification of Relevant Projects, which can continue their development under a transitional protocol prior to enactment of the MPDM Bill; and required onshore grid reinforcements with significant lead times to integrate the targeted 3.5 GW of offshore wind capacity.

6.2.2 Offshore wind grid delivery models

A suitable grid delivery model should be adopted to facilitate the build-out of offshore wind in Ireland in order to meet the target of at least 3.5 GW by 2030. Navigant carried out a comprehensive review of international approaches and developed four delivery model options that are tailored to the Irish context.

The two main classes of grid delivery models in the international context are plan-led and developer-led models[155], representing both ends of a spectrum of model options:

Developer-led model	Plan-led model
Developers prepare the requirements for consents, select and pre-develop wind farm sites and develop and build both offshore wind farm and transmission assets (offshore substation, export cables and onshore connection assets). This model is applied in e.g. the United Kingdom.	A State Body and/or the TSO is the responsible party for the complete process of wind farm site selection and pre-development and offshore grid connection development. This model is applied in e.g. the Netherlands.

Source: Navigant.

The Climate Action Plan specified that EirGrid leads the development of an Options Paper on Offshore Grid Models for the Working Group on Framework for Offshore Electricity Grid. The Working Group is chaired by the Department of Communications, Climate Action and Environment (DCCAE) with the Commission for Regulation of Utilities (CRU), ESB Networks and EirGrid identified as the other key stakeholders. The DCCAE will decide on the offshore grid framework.

6.2.3 Model options for Ireland

Based on the analysis, four grid delivery models for Ireland are assessed ranging from a fully developer-led model to a fully plan-led model. The models assessed represent a set of options, each with their advantages and disadvantages, to indicate a spectrum of options fit for the Irish context. The constituent elements of the four models presented could be combined in a variety of ways to form a wide range of additional model options. It follows that the model option or options ultimately chosen will not necessarily be set out in the report and could contain elements of two or more options. A brief description of these grid delivery models is as follows:

[155] Plan-led and developer-led can also be referred to as centralised and decentralised grid delivery models, respectively.

Option 1. Developer-led	Option 2. Plan-defined, developer consents and builds	Option 3. Plan-led, developer builds	Option 4. Plan-led
Fully developer-led grid delivery model	State defines minimum distance from shore for wind farms, as well as grid connection points and available onshore grid capacity for RESS auctions; EirGrid pro-actively plans and coordinates onshore grid reinforcements	Developers responsible for offshore wind farm transmission asset construction, ownership, operation and maintenance in plan-led model	Fully plan-led grid delivery model

Source: Navigant.

Figure 6-1 details the model options assessed following a project timeline:

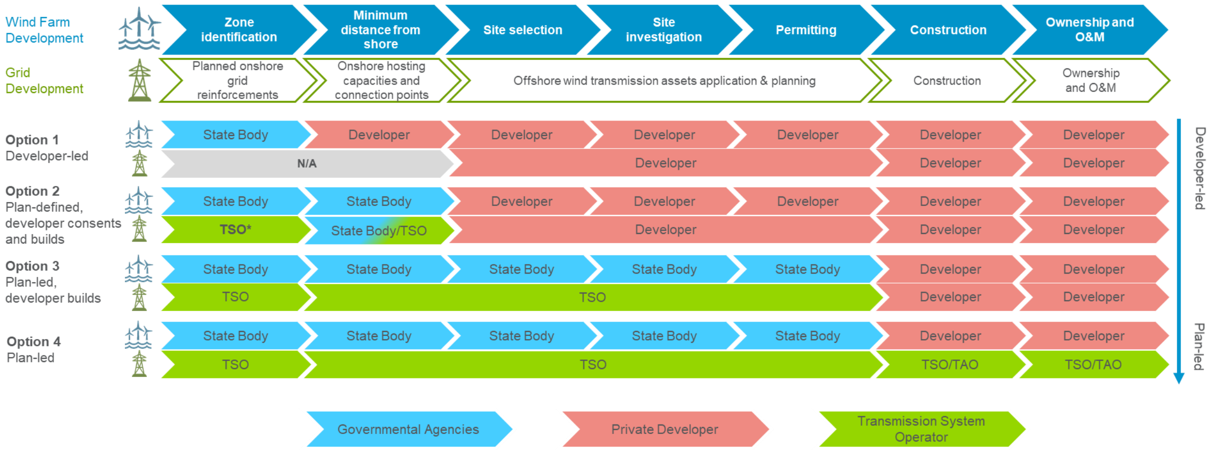


Figure 6-1. Grid delivery model options for Ireland following the phases of a project timeline.
*In option 2 the TSO will more pro-actively plan and communicate the timeline for onshore grid reinforcements early in the development process. *Source: Navigant.*

Option 1, developer-led, presents the full developer-led model as a variation on the current “onshore” grid delivery model. Developers have the responsibility for offshore wind farm site selection and pre-development, and – following successful participation in an auction – development of the wind farm and offshore wind farm transmission assets. Developers are responsible for securing the required consents, financing, construction and operation and maintenance of both wind farm and transmission assets. The grid connection point lies onshore. Required onshore grid reinforcements are undertaken by EirGrid and ESB Networks in a reactive manner based on the announcement of the successful projects.

Option 2, plan-defined, developer consents and builds, the State defines a minimum distance from the wind farm to shore to enhance public support for offshore wind developments. In addition, EirGrid pro-actively plans and coordinates onshore grid reinforcements and for each RESS auction, identifies the locations, capacities and timelines for the onshore connection points. In this way EirGrid can optimise the upgrades of the onshore grid such that the connection capacity to meet the CAP targets is made available in a timely manner. The developer remains responsible for site selection and pre-development, and the consenting and construction of the offshore wind farm transmission assets.

Options 3 and 4 adopt a more central offshore planning and coordination approach by shifting responsibilities from the developers to a State Body and EirGrid / ESB Networks. A single State Body for ORE developments will manage the planning and the site pre-development processes for offshore wind farms. Planning of onshore grid reinforcements and offshore developments could be optimised, and shared asset[156] development could be prescribed for offshore wind farm sites, where appropriate.

Under **Option 3, plan-led, developer builds,** the developer winning the auction for a pre-developed site receives the responsibility for construction, financing and operation and maintenance of both the wind farm and offshore wind transmission assets.

Option 4, plan-led, follows the fully plan-led model, shifting even more responsibilities to EirGrid and ESB Networks compared to option 3. Alongside site (pre-)development, the construction, ownership, operation and maintenance of the offshore wind transmission assets are now centrally planned by EirGrid and ESB Networks.

A common set of assumptions underpins all four options.

6.2.4 Pros and cons of grid delivery models assessed

Mapping the advantages and disadvantages of each model option assessed shows that in the longer term, options 3 and 4 have specific advantages and a lower risk profile compared to options 1 and 2. It should be noted that these advantages, disadvantages and risks have not been weighted in this report – clearly this would be key to any policy decision on the optimum model for Ireland.

The advantages of the **developer-led model** include compatibility with the Relevant Projects that can be developed quickly and that are more likely to be compatible with existing legislative and policy frameworks, and leveraging existing developer experience in the delivery of offshore wind farms. The disadvantages include minimal onshore-offshore transmission asset coordination, the likelihood that any public acceptance campaign will be focused on a single project rather than multiple projects, greater risk of additional infrastructure with associated environmental impact and more complexity involved in future proofing of offshore transmission assets. Option 2 provides mitigation to some of these disadvantages compared to option 1.

The advantages of the **plan-led model** include long-term onshore-offshore transmission coordination with the potential for reduced infrastructure, the ability to craft a coordinated public acceptance process covering multiple projects and ease of future proofing of technology. The disadvantages include the time needed to develop new governmental capabilities, policy, regulatory, licence and legislative frameworks which are likely required, challenges with state bodies simultaneously developing multiple offshore and onshore renewable energy and transmission projects and incompatibility with Relevant Projects. Option 3 gives developers control of the construction of both the offshore wind farm and transmission assets, reducing potential risks as perceived by the offshore wind industry.

Figure 6-2 summarises the advantages and disadvantages of the grid delivery model options assessed in this report.

[156] If shared assets are adopted under this model, issues might arise due to unbundling requirements (Directive on common rules for the internal market for electricity (EU) 2019/944) that restrict generation and operation by a single party, in this case the developers. The ownership and operation of shared assets may then have to fall under the responsibility of the TAO/TSO.

<table>
<tr><th>Key drivers</th><th></th><th>Option 1
Developer-led</th><th>Option 2
Plan-defined, developer consents and builds</th><th>Option 3
Plan-defined, developer builds</th><th>Option 4
Plan-led</th></tr>
<tr><td>Cost</td><td>+</td><td colspan="2">Competitive pressure can reduce cost levels transmission assets
No sunken costs associated with Relevant Projects</td><td colspan="2">Optimised transmission asset costs through standardised and holistic planning, and synergies
Optimised cost for onshore grid reinforcements through effective coordination of on- and offshore asset developments
Central pre-development and de-risking of offshore wind sites</td></tr>
<tr><td></td><td>+</td><td></td><td>Potential cost upside due to pro-active onshore grid reinforcement</td><td></td><td>Further optimisation of transmission costs through economies of scale on programme level</td></tr>
<tr><td></td><td>+</td><td></td><td colspan="3">Potential upside from economies of scale on a project level through hubs and shared infrastructure</td></tr>
<tr><td></td><td>-</td><td>Suboptimal costs onshore grid reinforcements through misalignment on- and offshore developments</td><td>Less optimal onshore grid co-ordination with offshore wind capacity compared to options 3 and 4</td><td></td><td>State exposed to compensating developers for lost revenue in event of fault on offshore transmission connection</td></tr>
<tr><td></td><td>-</td><td colspan="2">Sunken costs for pre-development of sites unsuccessful in auction</td><td></td><td></td></tr>
<tr><td>Environ-ment</td><td>+</td><td></td><td>More optimal onshore-offshore grid coordination compared to option 1 by definition of grid connection point with potential to reduce environmental impact</td><td colspan="2">Lower cumulative environmental impact by coordinating onshore-offshore transmission works, minimising the need for new transmission infrastructure</td></tr>
<tr><td></td><td>-</td><td colspan="2">Limited potential to take onshore-offshore transmission asset coordination into consideration resulting in greater environmental impact due to potential need for more transmission infrastructure</td><td colspan="2"></td></tr>
<tr><td>Future proofing</td><td>+</td><td></td><td>Potential upside as EirGrid can specify technologies and connection methods including shared assets</td><td colspan="2">High potential for future-proofing of technology and shared assets due to long planning horizon and societal incentives of State Body
Potential to adopt innovative technologies if not yet cost-effective</td></tr>
<tr><td></td><td>-</td><td colspan="2">Limited developer incentive for future-proofing of technology
Only cost-effective technologies and incremental innovations</td><td colspan="2"></td></tr>
<tr><td>Infra-struc-ture</td><td>+</td><td colspan="3">Leverages developer experience and expertise in delivery of offshore infrastructure
Less complex onshore interface
One party (developer) for development, construction and O&M windfarm and transmission assets</td><td>Leverages experience of EirGrid and ESB Networks with delivery of offshore infrastructure</td></tr>
<tr><td></td><td>+</td><td></td><td>Increased on- and offshore grid coordination compared to option 1 through pro-active planning and communication of onshore development timeline and alignment with RESS auctions</td><td colspan="2">Long-term planning horizon allows to coordinate and optimise on- and offshore developments and between ORE projects
Reduced procedural complexity with limited stakeholders in consenting process</td></tr>
<tr><td></td><td>-</td><td>No coordination and optimisation on- and offshore grid and across ORE projects</td><td>Less coordination potential and optimisation of on- and offshore grid and across ORE projects compared to options 3 and 4</td><td colspan="2">Planning phase by new State Body for ORE development could introduce bottleneck since multiple large-scale projects with similar timelines being developed by a small number of bodies</td></tr>
<tr><td></td><td>-</td><td colspan="2">Procedural complexity with more stakeholders and potentially more projects in consenting process grid and across ORE projects</td><td></td><td>Developers perceive a risk as they do not have control of site pre-development and offshore wind transmission infrastructure development
More complex offshore interface</td></tr>
<tr><td>Relevant projects</td><td>+</td><td colspan="2">Compatible with Relevant Projects, and leverages work already completed by developers on Relevant Projects</td><td colspan="2"></td></tr>
<tr><td></td><td>-</td><td colspan="2"></td><td colspan="2">Incompatible with Relevant Projects</td></tr>
<tr><td>Social accep-tance</td><td>+</td><td></td><td colspan="3">Prescription of minimal distances from shore</td></tr>
<tr><td></td><td>+</td><td colspan="2">Targeted and specific campaigns have the potential to improve social acceptance of some projects</td><td colspan="2">Central public acceptance campaign
Coordination of sites and minimisation of landing points and visibility to increase public acceptance</td></tr>
<tr><td></td><td>-</td><td colspan="2">Social acceptance campaign on project-by-project basis</td><td colspan="2">Offshore wind farm developers less likely to be supportive of plan-led model</td></tr>
<tr><td>Timing</td><td>+</td><td colspan="2">Relevant Projects can be developed quickly to commence offshore wind developments in the short-term, leveraging work already completed by developers providing a programme advantage</td><td colspan="2">Controlled and coordinated onshore-offshore transmission asset roll-out plan to timely achieve targets</td></tr>
<tr><td></td><td>-</td><td rowspan="2">No control and coordination of onshore-offshore transmission assets roll-out to achieve targets</td><td rowspan="2">Proactive planning of programme for onshore capacity and auctions but less coordination of offshore wind roll-out compared to options 3 and 4</td><td></td><td>Capacity needs to be built up in EirGrid and ESB Networks</td></tr>
<tr><td></td><td>-</td><td colspan="2">Transitioning to a plan-led model takes time to develop new governmental capabilities, and policy, regulatory, licence and legislative frameworks, which are likely required
Challenges with state bodies simultaneously developing multiple ORE projects</td></tr>
</table>

Figure 6-2. Pros and cons of grid delivery model options assessed for key drivers in Ireland. The pros and cons have not been weighted – clearly this would be key to any policy decision.

Source: Navigant.

6.2.5 Developing an offshore grid delivery model for Ireland

A transition towards an enduring grid delivery model would be required to leverage the development of the Relevant Projects in the short term and to implement any required regulatory, policy and legislative changes.

A transition towards option 1 would require limited actions but has a higher risk of misalignment between onshore and offshore developments. A transition to option 2 increases the onshore and offshore coordination and requires action by EirGrid to assess in detail the availability of onshore capacity and align this with auctions. A transition to options 3 and 4 would require significant changes and actions that would need to be implemented as soon as possible but ensures onshore and offshore developments are fully aligned. The overall suitability of each model option in the Irish context highly depends on the emphasis and relative weighting of certain criteria to reflect key stakeholder perspectives.

A possible high-level roadmap with key actions and milestones towards 2030 for options 1 and 2 is given in Figure 6-3. Significant uncertainty remains regarding the timing and duration of the actions as some are sequentially dependent (e.g. assessment, planning and construction of onshore grid reinforcements). The actions to transition from the current "onshore" model to options 1 and 2 are limited.

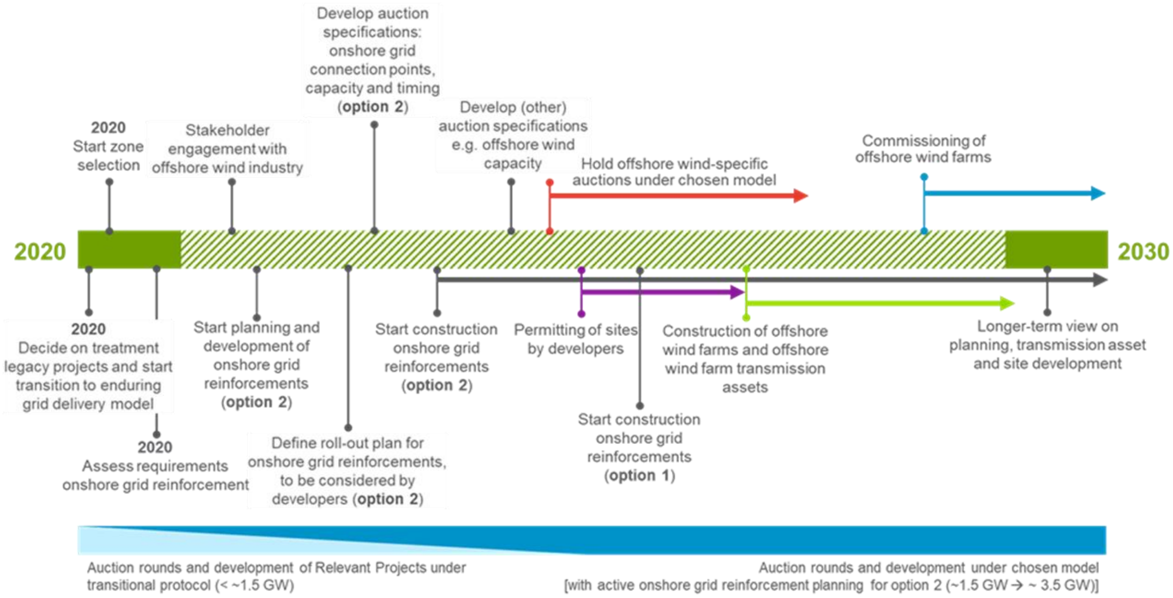


Figure 6-3. Possible high-level roadmap towards 2030 for options 1 and 2. *Source: Navigant.*

A possible high-level roadmap for options 3 and 4 with key actions and milestones towards 2030 is given in Figure 6-4. Some milestones (*) have a different interpretation depending on the option. The exact timing and duration of the actions depends on the time required by the involved stakeholders to perform the required actions.

Whilst the pre-development of the new enduring model is taking place, the assumed roll-out towards ~1.5 GW (based on expected current available onshore grid capacity) is expected under an interim model to allow some Relevant Projects to be developed. If a different enduring option is chosen, this model could be gradually phased out to be replaced with the chosen enduring model. Due to the tight timeline, the next couple of years should focus on the pre-development actions as shown above.

The yearly capacity additions should be decided based on yearly targets, planned roll-out timeline, onshore grid developments and wind resource potential at the identified sites.

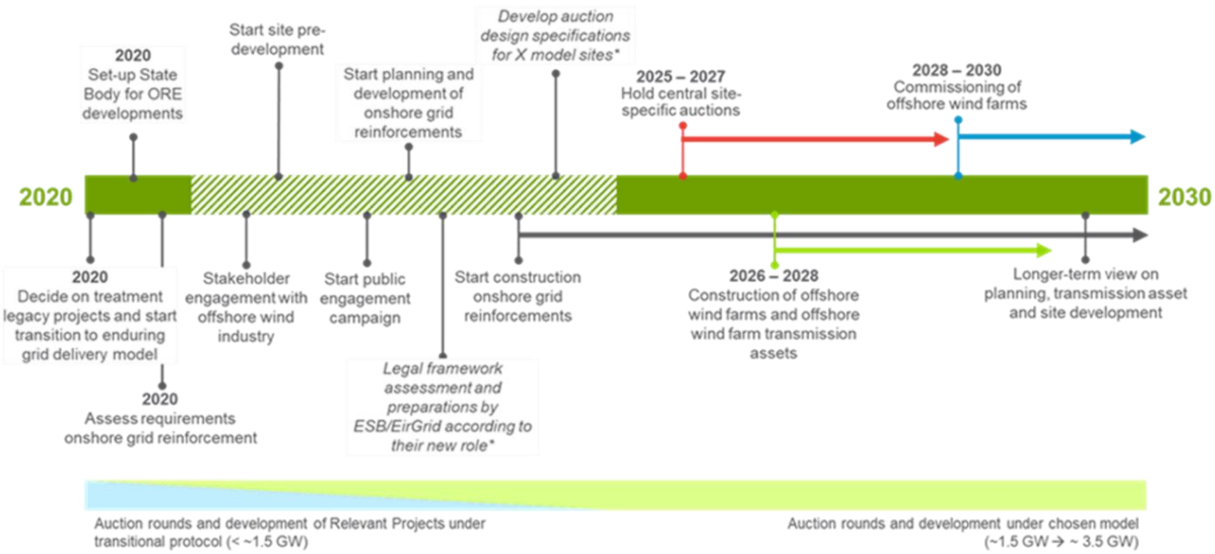


Figure 6-4. Possible high-level roadmap for options 3 and 4 towards 2030.
*These milestones will have a different interpretation depending on the selected model option. *Source: Navigant.*

It is important that a grid delivery model decision is made to determine which grid model will be adopted in Ireland to ensure preparations for the enduring model can commence in time such that the 2030 RES-E targets are achievable.

Note that this report was not intended to provide a decision on the best available option, but rather to present evidence that informs the decision for a grid delivery model suitable for offshore wind development in Ireland. All models assessed have their advantages and disadvantages from the various stakeholder perspectives and the decision for the grid delivery model for Ireland will require careful consideration of the key drivers in the Irish context.

APPENDIX A. ECONOMIC FINANCIAL ASSESSMENT

Ireland requires an additional 3.5 GW of offshore transmission assets to be built in order to integrate the required offshore wind capacity into the onshore grid. In 2019, Navigant assessed the cost levels for a selection of OFTO connections in the UK, and TSO-led connections in mainland Europe as indicated in Figure A-1.[12]

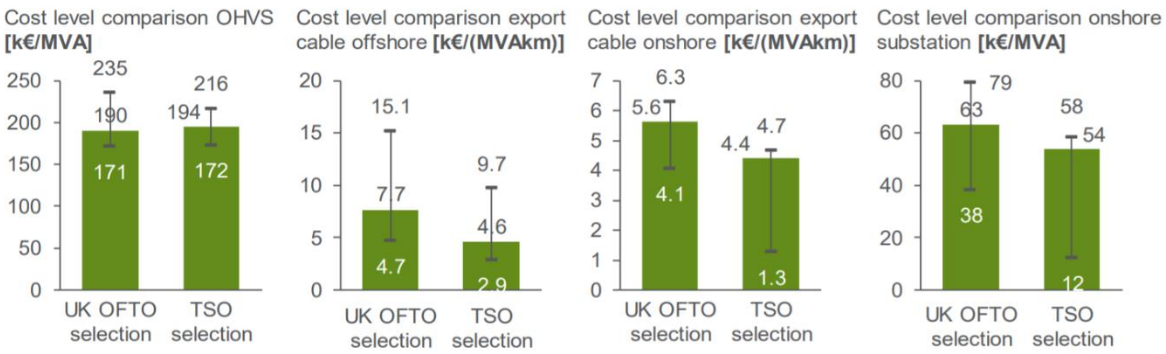


Figure A-1. Cost level comparison (CAPEX) only. *Source: Navigant, 2019.*[12]

Assuming an offshore cable length of 20 km, an onshore cable length of 10 km and an apparent power rating of 4 GVA (3.5 GW), the total investment cost would be between 1.5 and 2 billion Euros, as detailed in the table below. Note that this is an estimation based on a selection of UK OFTO connections (which excludes the most recent CFD round 3 auction).

Table A-1. Indicative cost range for 3.5 GW of offshore wind transmission assets.

Component	Unit	Upper range	Lower range
Offshore substation	M€/GVA	190	194
Export cable offshore	M€/GVAkm	7.7	4.6
Export cable onshore	M€/GVAkm	5.6	4.4
Onshore substation	M€/GVA	63	54
Offshore substations	M€	760	776
Export cables offshore	M€	616	368
Export cables onshore	M€	224	176
Onshore substations	M€	252	216
Total	**B€**	**1.9**	**1.5**

Source: Navigant, 2019.[12]

For the onshore grid reinforcements, it is currently not possible to provide an accurate estimation of the required investment, as the exact need for grid reinforcements is still subject to further investigation by EirGrid (and is also dependent on the offshore grid delivery model adopted).