CleanerGrid 2026

Background Reading & Topic Ideas

November 2025

This guide is designed to help students participating in CleanerGrid to understand the context of this year's topic and to help them narrow the focus of their projects. Use the table of contents to explore areas that match your interests or course. You don't need to solve everything—focus on one or two aspects that align with your skills or interests.

EirGrid

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Contents

Table 1 - Acronyms used throughout the document and definitions.

Acronym	Definition
AI	Artificial Intelligence
CRU	Commission for Regulation of Utilities
DC	Direct Current
DCEE	Department of Climate, Energy and the Environment
DLR	Dynamic Line Rating
DPFC	Dynamic Power Flow Controller
ESBN	Electricity Supply Board Networks
EMF	Electromagnetic Fields
EU	European Union
GIS	Geographic Information Systems
GW	Gigawatt
HV	High Voltage
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
LCC	Line Commuted Converter
ML	Machine Learning
MPA	Marine Protection Area
MW	Megawatt
NGO	Non-Governmental Organisation
NID	Nature Inclusive Design
OARP	Offshore Asset Readiness Plan
ORE	Offshore Renewable Energy
ORESS	Offshore Renewable Energy Support Scheme
PR6	Price Review 6
SAC	Special Area of Conservation
SPA	Special Protection Area
SC-DMAP	South Coast Designated Marine Area Plan
TSO	Transmission System Operator
TUoS	Transmission Use of System charges
VSC	Voltage Source Converter

1 CleanerGrid 2026

'Opportunities and Challenges in accelerating Offshore Wind Potential'

1.1 Details

This year's CleanerGrid competition asks third-level students to respond to the prompt: '*Opportunities and Challenges in Accelerating Offshore Wind Potential*'.

Developing the offshore electricity grid is key to harnessing Ireland's offshore wind energy potential and providing greater security of electricity supply from a clean renewable source. EirGrid's role is to build, own, operate and maintain the essential grid infrastructure necessary to bring power generated by offshore windfarms into Ireland's national grid onshore.

Your challenge is to propose innovative, practical solutions that address both the opportunities and the obstacles ahead.

Whether working individually, in discipline-specific, or interdisciplinary teams - participants should familiarise themselves with:

- Relevant Domestic and EU policies and regulations.
- EirGrid's existing ongoing and planned offshore projects.

Submissions should build on existing research but focus on fresh innovations and actionable proposals rather than produce literature reviews.

Sponsorship of the project by a member of academic staff is a requirement and their participation must be indicated when submitting the application.

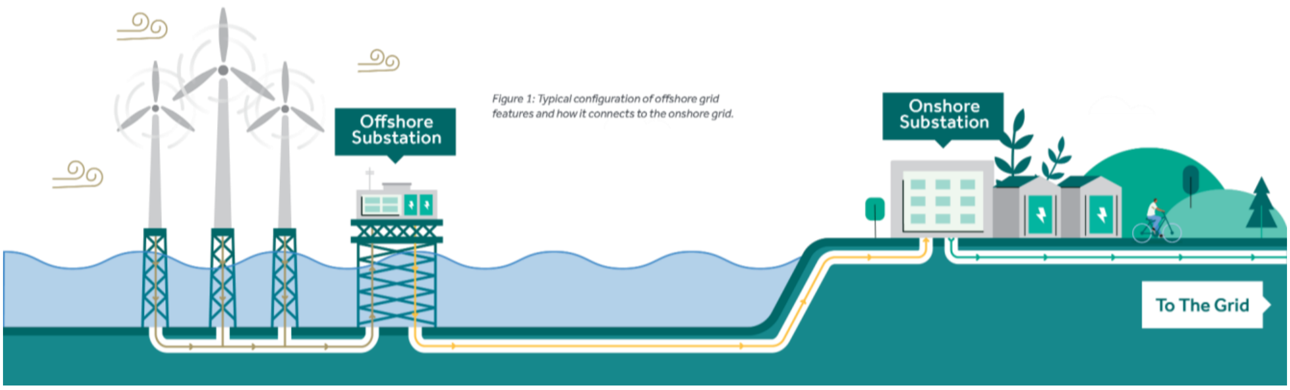

Figure 1: Typical configuration of offshore grid features and how it connects to the onshore grid.

1.2 Prizes

1.3 Frequently Asked Questions

What does EirGrid do?

EirGrid operate and develop the national high voltage electricity grid in Ireland. (Read more here)

Who can apply?

Any student enrolled in a 3rd level institute in the Republic of Ireland below PhD level.

When do applications close?

Applications will close at 23:59 on Wednesday the 19th of November 2025.

Why was this theme chosen?

Delivering on Ireland's policy and ambition for Offshore is a priority for EirGrid. While many of the offshore activities build on existing onshore expertise, offshore operations bring unique challenges which require new capabilities.

What needs to be submitted?

A report between 6000-7000 words and a presentation video of a maximum of 15 minutes.

What format does my submission need to be in?

Please submit your report in PDF format, and upload your video presentation, as an unlisted YouTube video and include a link to this in your email submission.

When is the submission deadline?

The report and video link are to be sent to research@eirgrid.com on or before 23:59 21st February 2026.

What are the key dates?

Applications open: 7 October 2025

Application deadline: 19 November 2025 at 23:59

Final submission deadline: 21 February 2026 at 23:59

After an internal review, shortlisted finalists will be invited to present their projects live at the CleanerGrid Finale & Awards Ceremony in EirGrid's offices at the end of March 2026

What is in it for students?

Real-World Challenge: Tackle a prompt related to Ireland's clean energy transition.

Long Project Timeline: With several months to develop your ideas, you can balance academic commitments while diving deep into energy innovation.

National Recognition: Finalists present their projects at a live event judged by experts from academia, media, and industry.

Build Your network: Engage with professionals, academics, and peers.

Boost Your CV: Showcase your innovation and presentation skills.

Not sure where to start?

Use the guide below to explore topic areas that align with your course or interests. You can focus on one area or combine ideas across disciplines. Each topic includes background information and optional prompts to help you develop a project that reflects your skills and academic focus.

2 Offshore Policy and Regulation

2.1 Background Reading

The Government has appointed EirGrid as owner of Ireland's offshore electricity transmission network. This decision follows the development of the '*Framework for Ireland's Offshore Electricity Transmission System'*[1] by the **Department of Climate, Energy and the Environment (DCEE)**, as outlined in the 2019 Climate Action Plan. The framework and associated policy were approved by Government on 14 April 2021. The framework provides clarity for all stakeholders regarding the future development, operation and ownership of Ireland's offshore electricity grid, ahead of the first of three scheduled **offshore wind-specific Renewable Energy Support Scheme[2] (ORESS)** auctions. The framework provides for a phased transition from a decentralised offshore transmission system model to a centralised model, with ownership of offshore transmission system assets to be assigned to EirGrid, Ireland's existing electricity **Transmission System Operator (TSO)**.

While EirGrid is not responsible for generating electricity or building windfarms, we are responsible for connecting electricity generation infrastructure, such as offshore and onshore windfarms, into the national electricity grid.

Phase One and *Phase Two* aim to address the decarbonisation of domestic energy supply as quickly as possible. *Phase One* will consist of developer led projects. Several **Offshore Renewable Energy (ORE)** projects are already being progressed by private developers in *Phase One*. On completion, the offshore assets connecting these offshore generation projects to the transmission system will be taken over by EirGrid. More detail on this is outlined in Section 3: Financing Offshore Transmission.

Ensuring EirGrid is fully prepared to own, operate and maintain offshore transmission assets is being managed through the '*Offshore Asset Readiness Plan'*[3](OARP). The OARP is made up of 30 individual programmes of work designed to ensure EirGrid is fully prepared to own, operate and maintain offshore transmission assets. Offshore operations bring unique challenges which require new capabilities. As part of EirGrid's readiness programme, we are engaging with experts in our supply chain to further grow our capabilities across our organisation to ensure we can continue to support the Ireland's climate objectives.

The '*Policy Statement on the Framework for Phase Two Offshore Wind'*[4] adopted by Government in March 2023 provides for a plan-led, centralised approach to future ORE delivery in Ireland, previously indicated in the 2021 Policy Statement on the Framework for Ireland's Offshore Electricity System. The move to a plan-led approach for ORE development in Ireland has taken place within the overarching frameworks of EU and national Marine Spatial Planning policy and legislation.

Phase Two involves EirGrid developing offshore transmission assets, rather than private developers. Once the new offshore wind farms are connected, EirGrid will also assume responsibility for the operations and maintenance of the offshore substations, cables and associated grid infrastructure as Ireland realises its ORE targets. EirGrid's readiness activities are planned to align with the delivery and asset transfer of the earliest offshore wind farm development.

[1] See Policy Statement on the Framework for Ireland's Offshore Electricity Transmission System here: https://www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/policy-statement-on-the-framework-for-irelands-offshore-electricity-transmission-system

[2] See Offshore Renewable Electricity Support Scheme (ORESS) here: https://www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/offshore-renewable-electricity-support-scheme-oress/.

[3] See the Offshore Asset Readiness Plan Guidance Document - September 2025 here: https://cms.eirgrid.ie/sites/default/files/publications/OARP-Guidance-Document-Rev-1.pdf

[4] See Policy Statement on the Framework for Phase Two Offshore Wind here: https://www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/policy-statement-on-the-framework-for-phase-two-offshore-wind/

The first project of *Phase Two* will see an additional 900 MW of generation capacity from wind farms off Ireland’s south coast, ‘*Powering Up Offshore - South Coast’*[5]shown in the ‘*South Coast Designated Marine Area Plan*’ (SC-DMAP). The SC-DMAP represents a spatial government-led approach for the development of offshore wind farms. The substantial marine space and sea depths off the South Coast of Ireland are suitable for both immediate and future developments of offshore wind. With the significant and growing population and industrial base along the South Coast the region is well placed to benefit from the long-term secure supply of green energy that will be provided by implementation of the SC-DMAP. The SC-DMAP includes four proposed areas for future offshore wind development. The SC-DMAP includes four proposed areas for future offshore wind development.

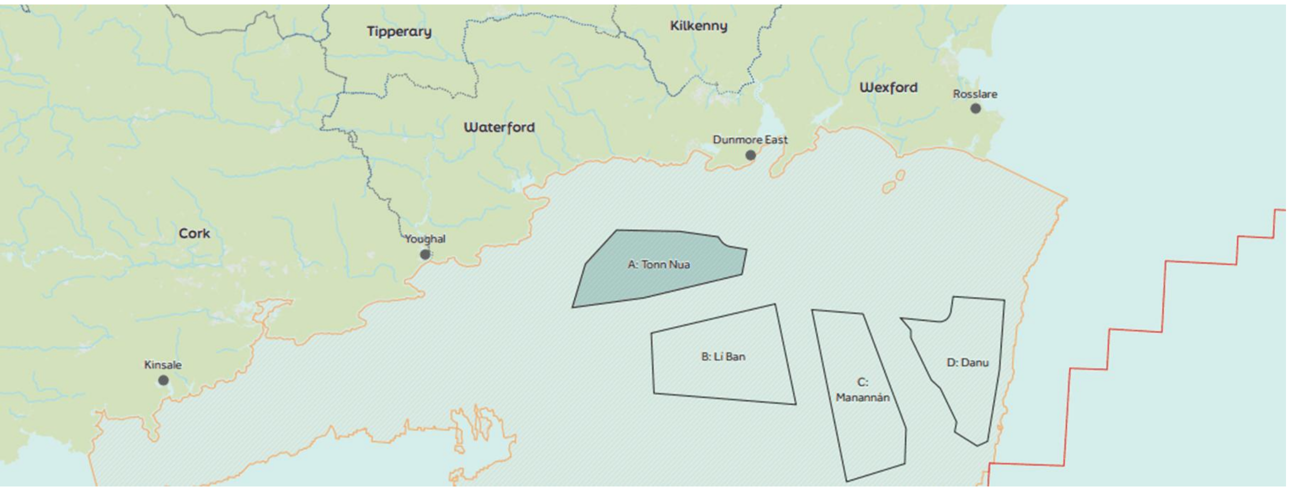

Figure 1 - South Coast Designated Maritime Area Plan (SC-DMAP) (Powering Up Offshore South Coast, 2025)

Area A, Tonn Nua off the south coast will hold two offshore substation platforms. This will help deliver approximately 900 MW of additional electricity - enough to power almost one million homes with clean energy. Private developers will then connect to the offshore station locations. The following supporting infrastructure will be required in Co Cork and in Co Waterford/Wexford:

- Offshore transmission cables connecting the offshore substations to landfall locations.
- New onshore substations.
- Connections between landfalls and new onshore substations by underground cables.
- Loop-in connections to the existing electricity transmission network from the new substations by either underground cables or overhead lines.

Phase Three will be the enduring regime for offshore as outlined in the ‘*Future Framework for Offshore Renewable Energy*’[6]. The Future Framework Policy Statement outlines the Department's ambitions for long term ORE delivery for Ireland, the key processes needed for successful deployment, and a pathway to maximise economic benefits to the State. The key reasons for sustainably developing Ireland’s considerable offshore resources are threefold:

1. Decarbonising the Irish economy in line with legally binding national and international climate ambitions;
2. Ensuring long-term energy security; and
3. Developing green industrial opportunities for energy utilisation such as export markets.

The ‘*Future Framework for Offshore Renewable Energy*’ is aligned with and complementary to, Ireland’s existing climate, renewable energy and ORE policy and legislative frameworks. It further complements Government objectives contained within the pending National Industrial Strategy and the Offshore Transmission Strategy. As this is an overarching Framework for long-term delivery of ORE, the intention is

[5] For more information on the Powering Up Offshore – South Coast, go to: https://www.eirgrid.ie/offshore#project-documents
[6]For the Future Framework for Offshore Renewable Energy see here: https://www.gov.ie/en/department-of-climate-energy-and-the-environment/publications/future-framework-for-offshore-renewable-energy/

not to encapsulate the intricacies of the energy landscape in Ireland and beyond. As such, the Future Framework sets out several key actions, future directions and intergovernmental dependencies that will be addressed through subsequent policy to develop and initiate the long-term, plan-led approach to Ireland's ORE future.

- Plan-led 2 GW of floating offshore wind;
- The potential for ORE generation capacity;
- Long-term energy demand scenarios; and
- Interconnection with other energy markets and working to develop a pan-European electricity grid.

2.2 Prompts for Offshore Policy and Regulation

Optional Policy and Regulatory Framework Considerations for CleanerGrid
• Examine offshore policy challenges and/or opportunities.
• Explore the impact of offshore wind energy on Ireland's balancing of the Energy Trilemma.[7]
• Analyse EU regulatory frameworks for cross-border offshore grid cooperation.
• Investigate legal issues around offshore ownership, licensing, and liability.
• Recommend legal frameworks to streamline planning and environmental protection.
• Provide recommendations for regulated revenue recovery.
• Or any other idea you have…

Multidisciplinary potential!

Understand the capabilities and dependencies to delivering a multi-purpose, multi-terminal, multivendor high voltage direct current (HVDC) grid for Offshore.

[7]Energy security, energy equity and environmental sustainability.

3 Financing Offshore Transmission

3.1 Background Reading

A substantial and sustained investment in Ireland's electricity network is required in delivering the Government's policy and ambition for Offshore. As part of this work, we are preparing for the acquisition of transmission infrastructure from private developers, in the case of the East coast *Phase One* projects, as well as the design and construction of offshore transmission assets on the south coast of Ireland under *Phase Two*.

EirGrid's costs are approved and overseen in 5-year periods through the Commission for Regulation of Utilities (CRU)'s Price Review process. As part of this process, EirGrid submitted the '*Price Review 6 (PR6) Business Plan 2026-2030*[8]'. EirGrid's PR6 Business Plan aims to meet a range of objectives with emphasis placed on key programmes of work, including, EirGrid's new role owning and being responsible for offshore transmission assets.

Operation of the transmission system and all transmission work carried out by EirGrid and ESB Networks are funded over time through the **Transmission Use of System charges (TUoS)**. TUoS are paid by all users (generators, industry, businesses and households). For households, these charges are paid in the first instance by suppliers, who in turn charge end users through their regular bills.

As we continue to support Ireland's climate objectives, EirGrid is mindful of the potential impact on all users. As such, our PR6 Business Plan looks to deliver on what the grid needs to facilitate Government and regulatory targets in an efficient manner. We have provided a high-level summary of the costs below, for both onshore and offshore (See Table 1 - PR6 Cost Summary).

Description (2024 Monies**)	Offshore Total Forecast (€'bn) *
Transmission Capital **(Phase One and Two combined)**	€0.7 to €4.2
Non- Network Capital Expenditure	€0.08
Operational Expenditure: ***- Controllable***	€0.47 to €0.52
Total Costs	**€1.25 to €4.8**

Table 1: PR6 Cost Summary

* All Numbers are subject to rounding

** All costs were set in 2024 monies which exclude any forecast inflation

The Offshore Transmission investment requirement reflects a high-level estimate based on three different scenarios of *Phase One* delivery. The actual investment required will depend on the number of offshore windfarms that are transferred to EirGrid by 2030. To manage this uncertainty, an agile investment framework will be required over PR6. The Non-Network Capital Expenditure reflects EirGrid's required investment in the development of our core IT systems, to support onshore and offshore activities, critical all-island programmes and PR6 Delivery Roadmap programmes. Operational expenditure costs relate to EirGrid's day-to-day and recurring costs such as resource costs, facilities, IT licencing and service costs, and general business expenses.

To support our expanded role in offshore transmission development, our Shareholder (which is the Government) has indicated it will provide an equity injection to support EirGrid in raising funds to develop and acquire offshore transmission assets.

[8] Available at: EirGrid's PR6 Business Plan outlines its ambition to transform the electricity grid

In summary, EirGrid's expenditure proposals have been carefully considered and designed to support the delivery of Ireland's targets in a cost effective, efficient, safe, reliable and secure manner. And although we expect there to be an impact on household bills, this should be viewed as a long-term investment that supports a cleaner, more sustainable future for Ireland.

A new financing approach, separate from EirGrid's existing operational processes, will be adopted for offshore projects. EirGrid will receive an equity injection from the state to connect offshore wind projects. This will be the first time EirGrid will raise bonds and need to apply for a credit rating. A tariff-based approach will be implemented in place of the traditional offer process used to finance EirGrid's other assets.

3.2 Prompts for Financing Offshore Transmission

Optional Financing Considerations for CleanerGrid
• Estimate capital costs required in offshore wind construction and the following operational expenses, revenue streams, and returns with consideration given to asset life.
• Conduct risk assessments and develop investment strategies ensuring financial viability.
• Analyse market incentives and pricing models to support offshore grid investments.
• Propose financial mechanisms to encourage community participation and reduce costs.
• Develop financing strategies for EirGrid considering the uncertainty in development timelines for offshore wind farms.
• Comparative analysis of funding models
• Exploring trade-offs in investment strategies
• Community benefit schemes
• Any other idea you have…

Multidisciplinary potential!

Support EirGrid to develop scalable processes and solutions to manage the development of an offshore network.

4 Engineering Infrastructure

4.1 Background Reading

EirGrid has a multidisciplinary workforce made up of staff with a diverse range of perspectives. While many of the teams at EirGrid have some engineers, there are also some more engineering focused teams which are responsible for the design, development, and maintenance of the national electricity grid infrastructure. These teams ensure the safe and efficient transmission of electricity, overseeing projects related to interconnections and future power systems. Their work encompasses system integrity, operational compliance, and innovative solutions to support a reliable electricity supply for all users across the island.

Offshore wind farms differ from other generating stations in that they are, in almost all cases, located a significant distance from their onshore connection point. This introduces unique engineering challenges. The following sections outline the key technical considerations and opportunities for innovation.

4.1.1 Cable Capacitance and Reactive Power Compensation

These long distances are covered predominantly by subsea high-voltage cables, with a minor section of land cables. Compared to onshore wind farms, which typically use short underground cables or overhead lines with low capacitance, offshore cables have much higher capacitance. This leads to the generation of reactive power, which affects voltage levels and must be carefully managed to maximise the transfer of active power (usable electricity). Devices such as shunt reactors are used to absorb excess reactive power generated by long offshore cables, helping to maintain voltage stability and ensure efficient transfer of active power.

As the wind farm’s output increases, the amount of reactive power generated by the cable decreases. To maintain voltage stability, compensation devices like shunt reactors need to be adjusted gradually—either reduced or switched off in stages—to match the changing power levels. This flexible approach helps ensure the system remains balanced under varying operating conditions.

Voltage control is also critical across the cable length. When voltage is actively regulated at both ends of the cable, the voltage profile remains desirable for varied operating conditions. If only one end controls the power factor, undesirable voltage profile/reactive power flows may occur. Technologies such as Shunt Reactors, STATCOMs, or synchronous condensers can be deployed to support desirable voltage control and improve overall system performance. Beyond steady-state voltage considerations, there may be other transient and temporary phenomena, particularly during switching operations, that must be considered.

In addition to managing voltage and reactive power under normal conditions, offshore wind farms must also be capable of supporting the grid during disturbances for fault tolerance. During short-term faults, they are required to remain connected and inject reactive power rapidly within 10 to 100s of milliseconds. This capability, known as **Fault Ride-Through**, is essential for maintaining system stability and ensuring a resilient electricity supply.

4.1.1.1 Offshore Interconnection

Interconnection connects Ireland’s electricity grid to neighbouring systems, enhancing energy security, flexibility, and market integration. EirGrid is preparing for a **multi-purpose, multi-terminal, multi-vendor High Voltage Direct Current (HVDC) grid**, which will support future offshore developments. This transition highlights the importance of understanding how HVDC technologies are evaluated, operated, and maintained throughout their lifecycle. EirGrid’s active participation in international working groups is helping shape the development of technical standards, financial models, and policy frameworks to support this evolving infrastructure.

As part of this future vision, hybrid connections are also being explored. These combine offshore wind farm connections with interconnector functionality in a single infrastructure, enabling renewable energy export and cross-border electricity trading using shared assets. This approach can reduce costs, optimise seabed use, and improve system flexibility compared to building separate assets.

To prepare for future offshore HVDC links such as *Greenlink* and the *Celtic Interconnector*, EirGrid trialled increased interconnector ramp rates—up to 15 MW/min—on the *East West* and *Moyle* Interconnectors. Ramp rate refers to how quickly power output from a generator or interconnector can increase or decrease. The successful trial led to a permanent increase, approved under the Load Frequency Control Block Operational Agreement.

With offshore wind developments transmitting power through long-distance submarine cables, harmonic distortion mitigation becomes critical. EirGrid launched the Offshore Wind Development Harmonic Distortion Mitigation Co-ordination project to address power quality challenges associated with connecting five phase-one offshore wind farms to the transmission system via long cables.

These cables require:

- **Reactive power compensation**, typically using shunt reactors to offset capacitive effects.
- **Harmonic filtering** to meet power quality standards.

Because all connections were located in close electrical proximity, filters installed at one node had the potential to influence others. To prevent negative interactions between mitigation solutions, the project investigated how these systems interacted and explored opportunities to optimise the overall approach by identifying any excessive mitigation measures. Initiated in 2024, the project aimed to ensure that all mitigation solutions operated harmoniously, reducing unnecessary infrastructure and improving efficiency in terms of **reactive power (MVAr)** and supporting systems.

Additional technical challenges include:

- **Resonance**: Long subsea cables can resonate with the grid's inductance, potentially amplifying background harmonics and causing equipment stress.
- **Harmonic emissions**: Offshore converters introduce harmonics that must be managed through coordinated filtering strategies—both onshore and offshore.

Project activities included:

- System modelling
- Harmonic compliance checks at onshore and offshore substations
- Filter design and adjustments
- Incremental limit compliance analysis

The overarching goal was to enable coordinated, efficient harmonic mitigation across all offshore wind farms.

EirGrid is coordinating filtering strategies to ensure:

- Coherent operation across nodes
- Efficient use of MVAr levels
- Avoidance of negative interactions between shunt filters

4.1.1.2 Reinforcement to the Onshore Grid

The integration of new renewable energy generation from offshore sources, along with new interconnectors, is driving the need for reinforcement of Ireland's onshore transmission grid. To meet this challenge, EirGrid is deploying flexible network technologies that maximise the use of existing infrastructure while minimising the need for extensive new builds.

As outlined in the '*Annual Innovation Report 2024*[9]', this approach helps to:

- Reduce network congestion

[9] https://cms.eirgrid.ie/sites/default/files/publications/2024-Annual-Innovation-Report.pdf

- Provide system services and operational flexibility
- Act as an alternative to large-scale infrastructure projects
- Maximise utilisation of existing transmission assets

To support Ireland's carbon emission and renewable energy targets, EirGrid is implementing technologies such as:

- **Dynamic Line Rating (DLR)**
  DLR uses weather sensors to measure ambient conditions (e.g. temperature, wind speed, line sag) at overhead electricity lines. These real-time measurements allow for more accurate calculation of the current-carrying capacity of lines compared to static or seasonal ratings, enabling safer and more efficient use of the grid.
- **Dynamic Power Flow Controller (DPFC)**
  DPFCs are devices installed on transmission circuits to control how power flows along a specific line and its neighbouring circuits. These systems improve system stability, increase transfer capacity, and reduce reliance on costly new builds. In 2024, the tendering process was completed for a DPFC device at Binbane 110 kV Station.

As more **Inverter-Based Resources (IBRs)**—such as offshore wind farms—connect to the grid, system strength and inertia can decrease. This raises the risk of control system interactions and oscillations. To address these challenges, EirGrid is exploring emerging technologies including:

- **Grid-Forming Inverters**, which can establish and regulate grid voltage and frequency
- **Oscillation Dampers**, which help mitigate dynamic instabilities caused by low-inertia conditions

4.1.2 Offshore wind supplemental programme

EirGrid has launched an Offshore Wind Supplemental Programme to address a critical knowledge gap in offshore wind development. This initiative provides a collaborative, cross-cutting research platform focused on offshore wind-specific challenges throughout the entire project lifecycle.

As Ireland moves toward large-scale offshore integration, EirGrid must prepare for the development, operation, and management of High voltage Alternating Current (HVAC) and HVDC transmission assets, considering the full asset lifecycle—from technology qualification to long-term asset management.

Offshore transmission assets must be designed to withstand both short-term and long-term electrical stresses. This includes ensuring:

- Adequate insulation coordination
- Adequate thermal ratings
- Fault tolerance under various operating conditions

Design studies also address complex phenomena such as **Zero-Miss**, which can affect circuit breaker performance and compromise asset reliability. Identifying and mitigating such risks at the design stage is essential to ensure safe and secure operation across all conditions.

4.2 Mini Engineering Glossary

HVDC

- High Voltage Direct Current is used as a way to transmit electricty over long distances using Direct Current (DC).

VSC

- Voltage source converters use insulated gate bipolar transistors (IGBTs) to control both active and reactive power independently, enabling black start capability and AC voltage generation without relying an an AC grid.
- They maintain constant DC polarity and control current flow, allowing the use of XLPE cables for efficent HVDC transmission.

LCC

- Line commutated converters convert AC to DC or vice versa, relying on the AC's systems's voltage zero crossings to switch current flow.
- They operate as current source converters (CSCs), maintaing constant DC current and controlling power flow via DC voltage polarity.

Grid-Forming Inverters

- Grid-forming inverters are advanced inverters used in Inverter-Based Resources (IBRs) like solar, wind and batteries. Unlike grid following inverteres they can establish and regulate grid voltage and frequency.

Inertia

- Energy system inertia is the aggregrate kinetic energy stored in the rotating masses of synchronous generators and motors directly connected to the grid.

Harmoinc Distortion

- Harmonic distortion refers to the presence of unwanted frequency components in an electrical signal which deviate from the fundamnetal frequency.

Dynamic Line Ratings

- DLR is a technology that measures real time capacity of power transmission lines based on atual enviromental conditions like temperature, wind and line sag.
- DLR helps utilities maximize transmission efficency and safety, enabling better use of existing infrastructure.

Ramping

- Ramping is the ability of a power source to adjust its output up or down, helping balance supply and demand on the grid.

Hybrid Connections

- A transmission solution that combines offshore wind farm connections with interconnector functionality, enabling both renewable energy export and cross-border electricty trading using shared infrastructure.

4.3 Prompts for Engineering Infrastructure

The following section explores technical and engineering challenges in offshore transmission. These prompts may suit students with backgrounds in mechanical, electrical, or energy systems but are not limited to these disciplines or essential requirements.

4.3.1 Mechanical Engineering

Optional Mechanical Engineering Considerations for CleanerGrid
• Propose design and location of converter stations, substations, and interconnection hubs to minimise maintenance and maximise lifespan in marine environments.
• Design with corrosion resistance and environmental load considerations (e.g., hydrodynamic loading, wave fatigue).
• Outline the design of remote deployment or inspection and maintenance systems, such as drones or underwater robotics, to lower long-term operational risk and improve safety.
• Develop or identify cooling solutions for offshore HVDC converters exposed to saltwater, wind, and fluctuating temperatures.
• Integrate condition monitoring sensors to enable predictive maintenance across the asset lifecycle.
• Test existing modelling techniques to evaluate deployment and assembly strategies, while accounting for vessel logistics, port constraints, and weather windows.
• **Or any other idea you have…**

Multidisciplinary potential!

- Cost benefit analysis of hybrid connections.

Multidisciplinary potential!

- Compare and rank floating vs fixed infrastructure options when deployed in different seabed types.

4.3.2 Electrical/Energy Engineering

Optional Electrical and Energy Engineering Considerations for CleanerGrid
• Identify optimal offshore-to-onshore grid connection points to minimise losses and maximise reliability.
• Design an offshore grid layout that optimises reliability, scalability and supports future offshore wind development.
• Evaluate the technical and operational requirements for implanting meshed offshore HVDC grids.
• Propose the necessary transmission system upgrades to meet Ireland's offshore wind targets.
• Propose optimal use of HVAC and HVDC equipment in offshore transmission systems, exploring multi-vendor HVDC networks.
• Explore smart grid and control technologies to optimize offshore assets through modelling and simulation of offshore grid nodes and interconnection to integrate multiple offshore wind farms effectively.
• Compare Voltage Source Converter (VSC) and Line Commutated Converter (LCC) technologies for offshore applications.
• Propose new or improved protection coordination schemes to handle faults in complex offshore networks.
• Develop techniques to maintain grid frequency and voltage stability during high non-synchronous penetration.
• Assess grid-forming inverters or synthetic inertia from offshore sources.
• Evaluate data communication systems for reliable control of remote assets.
• **Or any other idea you have…**

Multidisciplinary potential!

- Prepare EirGrid to fulfil its role in the planning, development, operation, and maintenance of an offshore transmission system throughout the three phases of the network development model.

5 Data-Driven Solutions for Offshore Transmission

5.1 Background Reading

Artificial intelligence (AI) and **machine learning (ML)** are increasingly shaping the energy sector, and EirGrid is no exception. As outlined in EirGrid's '*Research and Innovation Strategy (2023)*'[10], one of our Strategic Innovation Programmes is to *"Enhance data-driven decision-making leveraging artificial intelligence capability."* Progress in this area is detailed in our '*Annual Innovation Reports*[11]'.

In Industry and Society, data-driven techniques are used in data governance, open data and to support decision making. EirGrid is exploring the use of data-driven AI/ML in network planning, forecasting within control centres, and predictive maintenance — the last being particularly valuable for offshore assets located in harsh and inaccessible environments.

Some recent data-driven solutions created at EirGrid include:

- **Look-Ahead Security Assessment Tool**: Helps Grid Controllers assess system stability in real time and forecast near-future conditions; thus, reducing curtailment of wind and solar generation.
- **Voltage Trajectory Tool:** Supports voltage management by modelling how different reactive power sources affect local voltage levels. The tool's importance increases as wind farms and underground cables increase.
- **Ramping Margin Tool**: Improves scheduling of reserve services to manage fluctuations in electricity demand and renewable generation.

Current ongoing work includes:

- Exploring how AI/ML can help determine strategic network reinforcement projects in the transmission system including the technology type, length of cable or overhead line and so on. This project aims to prioritise network reinforcement projects in order to efficiently achieve the targets outlined by the Climate Action Plan.
- Alleviating network congestion and improving grid efficiency by creating '**Virtual Dynamic Line Rating Sensors,**' from advanced weather forecasting and AI software, to predict dynamic line ratings. This software approach replaces hardware sensors which are more expensive.
- Exploring how AI/ML can help define strategic storage, demand, or generation projects in the transmission system, including the technology type, export and import capacities, duration of storage. The project aims to prioritise the integration of new transmission-system projects to efficiently achieve the targets in the Climate Action Plan.

In offshore transmission, digital twins can be used to simulate the performance and condition of subsea cables, substations, and other grid components under varying conditions. A **digital twin** is a dynamic, virtual representation of a physical asset, system, or process that is continuously updated with real-time data from sensors and operational systems. This enables predictive maintenance, scenario testing, and optimisation of asset performance without physical intervention — critical for assets in remote marine environments.

Data-driven approaches also support outage coordination by using predictive analytics to schedule maintenance windows that minimise downtime and avoid overload conditions. For clarity, ***overload*** is the condition where equipment or lines carry more current than their rated capacity, risking overheating or failure, while ***downtime*** is the period when a system or component is unavailable due to maintenance, faults, or outages.

[10] Available at https://www.eirgrid.ie/industry/innovation-and-research#Innovation%20and%20Research%20Strategy

[11] Available at https://www.eirgrid.ie/industry/innovation-and-research#Documents

Geographic Information Systems (GIS) and spatial datasets are increasingly used to optimise cable routing, substation siting, and environmental impact assessments. These tools, combined with AI-based forecasting, also inform pricing models by predicting congestion patterns and curtailment risks, ensuring fair and efficient market operation.

5.2 Prompts for Data-Driven Solutions for Offshore Transmission

Optional Data Considerations for CleanerGrid
• Design and build an outage co-ordination dashboard that integrates data from scheduled outages, maintenance windows, and dependencies to identify conflicts and overload risks.
• Design and build an outage co-ordination dashboard that integrates weather forecasts to consider the weather's impacts on 1) the available renewable generation such as wind and solar, or 2) the accessibility of sites due to weather.
• Develop an optimisation technique for outage sequencing that minimises downtime. The technique will account for maintenance windows, conflicts, dependencies and overload risks.
• Digital-Twin development: Create dynamic digital representations of offshore assets or grid nodes which can undergo simulation of stress testing and virtual commissioning.
• Predictive maintenance and management: apply anomaly detection and condition-based monitoring models to reduce downtime and extend offshore asset lifetime.
• Use GIS and spatial datasets to propose optimal locations for offshore substations, cable routes or landfall points.
• Using machine learning to optimise offshore grid reinforcement and asset placement.
• Develop a model of offshore wind effects on either electricity prices, curtailment or congestion.
• **Or any other idea you have…**

6 Environmental Protection

6.1 Background Reading

As Ireland accelerates the development of offshore wind energy, it is essential that this progress is achieved in harmony with the environment. Any new infrastructure will fully consider the natural and social environment and all the interactions between the two. Offshore grid infrastructure—such as subsea cables, substations, and landfall points— may affect hydrodynamics, sediment transport, fisheries, seabirds and marine mammals, communities, landowners, tourists, landscape/seascape and visual, cultural heritage, and more. These impacts must be carefully assessed and either avoided, reduced, or mitigated, where possible. Many other environmental topics should be considered, and these can be seen in the Environmental protection agency's Environmental impact assessment report[12].

EirGrid's Innovation and Research Strategy outlines a clear ambition:

"To accelerate and expand implementation of evidence-based environmental measures, and wherever possible, move beyond impact avoidance or reduction to actively enhance the environment in response to the biodiversity and climate emergency."

This means that offshore grid development must not only minimise harm but also contribute positively to marine biodiversity and ecosystem resilience. EirGrid evaluates its emissions using science-based targets and publishes results to support public trust and engagement.

EirGrid is working to standardise **Nature-Inclusive Design (NID)** across all offshore grid assets. This includes integrating biodiversity features into infrastructure design and advising developers on sustainable contestable designs. Where possible, EirGrid supports nature restoration projects—such as planting native coastal vegetation or retrofitting infrastructure with bird diverters—to enhance biodiversity. NID principles are being integrated into offshore and onshore grid assets, including eco-friendly substation foundations and cable protection systems[13].

Offshore projects must comply with EU environmental directives and national legislation to avoid or mitigate impacts on designated areas such as **Special Areas of Conservation (SACs)** and **Special Protection Areas (SPAs)**. These protections are part of broader frameworks like the Birds Directive, Habitats Directive, and Marine Strategy Framework Directive. **Marine Protected Areas (MPAs)** including Marine SACs and Marine SPAs are designated to improve and protect marine biodiversity. The implementation of the Birds, Habitats and Marine Strategy Framework Directives more broadly contribute to the protection of the Marine and Coastal Environment Considerations.

EirGrid's policy commitments to marine biodiversity (8 policies and 5 objectives) are specified in our adopted Grid Implementation Plan 2023-2028 (page 49-50). These include commitments around marine protected areas, fisheries, and nature restoration (including 'marine nature inclusive design' to integrate low carbon, habitat features into offshore infrastructure).Technical specifications for Marine NID developed by ARC Marine and WSP Consulting will be applied to future projects like Powering Up Offshore South Coast. This aligns with the EU Nature Restoration Law and Ireland's biodiversity emergency declaration. Subsea cable design must also consider **Electromagnetic Field (EMF)** impacts. The FlatEMF Research[14] Initiative investigated how EMFs may affect flatfish behaviour. The findings, reported in the peer-reviewed scientific

[12] Environmental Protection Agency. 2022. https://www.epa.ie/publications/monitoring--assessment/assessment/EIAR_Guidelines_2022_Web.pdf

[13] See examples of NID here: https://tethys.pnnl.gov/sites/default/files/publications/Executive-Summary_Options-for-Biodiversity-friendly-designs-and-approaches-for-offshore-wind-farms-in-Ireland.pdf.

[14] FlatEMF is a pan-European research project coordinated by the Offshore Coalition for Nature and Nature, and is part-funded by EirGrid https://offshore-coalition.eu/event/emf-and-the-flounder-webinar/

literature[15] concluded: "Flatfish showed no indication of attraction, avoidance, or erratic behaviour to EMF". The research included:

- Ecological research (field and lab studies).
- Technical modelling and monitoring.
- Stakeholder engagement with fisheries and **Non-Governmental Organisations (NGOs).**

The research is relevant in the context of 'co-existence' whereby offshore renewables and other sea users including fisheries will need to share marine use sustainably. The social/human environment is a key part of the consideration of EirGrid projects. As much as the natural environment considerations, the social environment must be fully assessed and considered in the siting or routing of the projects, and in the assessment of the potential impacts. Noise, air quality, climate, landscape/seascape, construction traffic, disruption due to construction, archaeology, agriculture/fisheries etc. are all topics that will be affected by onshore and offshore projects.

6.2 Prompts for Environmental Protection

Optional Environment Considerations for CleanerGrid
• Consider how the impacts of offshore infrastructure on the natural and social environment can be assessed and addressed.
• Assess impacts of offshore grid infrastructure on marine ecosystems.
• Propose mitigation and long-term environmental monitoring strategies.
• Study broader ecological impacts including coastal habitats and climate resilience.
• Propose sustainability practices for offshore grid development.
• Map optimal offshore and onshore grid routes considering environmental, technical, and social factors.
• Analyse spatial data and leverage new technologies to support planning and impact assessments.
• Design or compare Wildlife-friendly substation foundations.
• Design or compare scour[16] protection and cable burial enhancements.
• How to minimise impacts to local communities
• Or any other idea you have…

Multidisciplinary potential!

- Engineering offshore substations and cable protection with features that support marine biodiversity.

Multidisciplinary potential!

- Subsea Cable Design: Considerations for EMF mitigation, burial depth, and integration with marine habitats.

Multidisciplinary potential!

- Propose and evaluate challenges to traditional offshore infrastructure restrictions (e.g. planting over underground cables).

[15] Chapman, E.C., Rochas, C.M., Burns, Z., Harsányi, P., Hermans, A. and Scott, K., 2026. Effects of electromagnetic fields on flatfish activity levels. Marine Pollution Bulletin, 222, p.118652.

[16] Scour refers to the erosion of seabed material around structures like wind turbine foundations, offshore platforms, or subsea cables caused by water movement (waves, currents, tides). Scour protection involves placing materials around these structures to prevent erosion.

7 Stakeholder Engagement

7.1 Background Reading

Offshore wind development faces unique challenges beyond technical and environmental considerations, including workforce availability and stakeholder engagement. This level of ambition will require significant and sustained collaboration across industry, including supply chain partners, ORE developers, service providers and technology innovators. As part of our commitments under Ireland's Offshore Wind Industrial Strategy, Powering Prosperity, EirGrid will work with other state agencies, Enterprise Ireland and the IDA Ireland to ensure that the economic impact of offshore wind development is best harnessed for Irish businesses. EirGrid's offshore wind initiatives are shaped by collaboration with communities, fisheries, NGOs, regulators, and industry partners to ensure socially accepted and ecologically responsible development.

As the designated Transmission Asset Owner for future offshore grid connections, EirGrid conducts structured public consultations at key project stages. These include early scoping sessions, environmental impact consultations, and technical workshops. Feedback is gathered through online platforms, community meetings, and targeted stakeholder forums, as outlined in EirGrid's '*Stakeholder Engagement Plan 2025*[17]'.

EirGrid must ensure necessary systems, processes and workforce capabilities to be fully prepared to operate and maintain offshore transmission assets safely, effectively, efficiently and in line with regulatory and environmental obligations from day one of asset transfer.

To support sustainable offshore development, EirGrid is updating its Evidence-Based Environmental Guidelines to reflect new legislation, technologies, and ecological priorities. These updates address gaps in survey methods, impact prediction, and mitigation strategies, particularly around cultural heritage, marine ecology, and **electromagnetic fields (EMFs)**. EirGrid is also involved in the FlatEMF Research Initiative, which investigates the effects of EMFs from subsea cables on flatfish species through ecological studies, technical modelling, and stakeholder engagement.

EirGrid's Offshore Wind Supplemental Programme supports research and development across the offshore wind lifecycle, addressing knowledge gaps in areas such as harmonic distortion mitigation, EMF monitoring, and biodiversity enhancement. Public consultations and stakeholder collaboration remain central to this programme, ensuring social acceptance and integration of offshore infrastructure with land-based systems.

[17] Available at https://consult.eirgrid.ie/en/system/files/reports/3277/EirGrid%20Final%202024%20Stakeholder%20Engagement%20Report.pdf

Planning and permitting challenges include navigating new maritime and environmental legislation, cultural heritage protections, and ecological impact assessments. These are being addressed through updated guidelines and collaborative research. EirGrid also considers broader economic and social impacts on coastal regions, including engagement with ports and supply chains. Through participation in EU working groups and national consultations, EirGrid helps shape policy instruments and technical standards to ensure offshore development aligns with community values and environmental priorities.

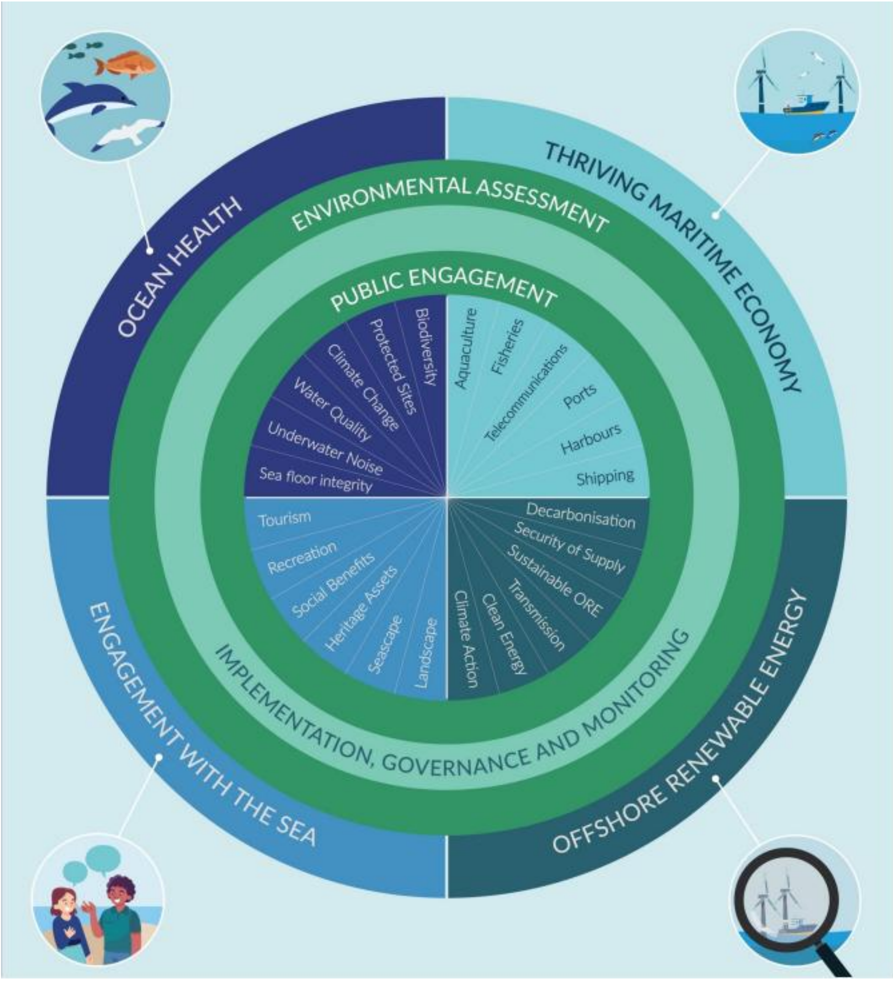

Figure 2 - National Marine Planning Framework (Department of the Environment, Climate and Communications, 2025)

7.2 Prompts for Stakeholder Engagement

Optional Stakeholder Engagement Considerations for CleanerGrid
• Design stakeholder engagement strategies including local communities, fisheries, developers, and policymakers.
• Proposing a mechanism or engagement plan for the development and training of a workforce to enable Eirgrid to connect, own and operate offshore assets.
• Measure the potential effects of engaging with ports, workforce and supply chain to boost economic impact on coastal areas.
• Propose business frameworks balancing profitability with environmental and social responsibility.
• Enhance ways of engaging with communities and developers through novel solutions, processes, and data.
• Identify the opportunities for Irish businesses and supply chain partners.
• How to promote successful planning applications in *Phase Two*, by anticipating public concerns, environmental constraints, and developer interests to avoid delays and reduce costs.
• Plan integration of offshore grid connections with land infrastructure and communities.
• Address land-use conflicts and development strategies supporting energy transition.
• Research social acceptance, community attitudes, and cultural impacts of offshore infrastructure.
• Design effective policy instruments and coordination strategies for offshore grid projects.
• Evaluate roles of public agencies in facilitating transition.
• **Or any other idea you have…**