Turning the Tide: Optimising Europe's Offshore Energy Future with Holistic Planning and Engagement

Modeller's Exchange Workshop, in collaboration with ENTSO-E and JustWind4All

DISCLAIMER

All statements in this document have been summarised by Renewables Grid Initiative based on the common understanding of the discussions carried out at the workshop. The opinions expressed in this document shall not be used to reflect the views of specific participants. You can access the expert presentations here.

1. Context

To meet decarbonisation targets, Europe needs to greatly accelerate renewable energy sources (RES), which will be sited and implemented on land and European seas, which provide a substantial potential for offshore RES development. The cumulative offshore targets based on the non-binding agreements per sea basin, shared by the EU Member States amount to 354 GW installed offshore capacities by 2050. This massive scale of offshore renewables deployment requires an understanding of the infrastructure needs and how the system shall be designed to use available resources in an optimised way.

In January 2024, ENTSO-E published the Offshore Network Development Plans (ONDP), which is the first assessment of what is needed to integrate such vast amounts of offshore RES by 2040 and 2050. The ONDP delivers important insights into the offshore infrastructure needs and related costs, which should be further explored in relation to increasing scarcities across the energy value chain and the evolving energy landscape. While attempts have been made to address these issues, such as alignment with Maritime Spatial Plans (MSP) and cross-sectoral integration options, more effort is needed to accommodate social and environmental aspects and sectoral groups, which should contribute to techno-economic considerations, when planning the offshore energy infrastructure.

Engaging stakeholders from academia, policymaking, civil society and industry is crucial for planning and ensuring sustainability across environmental, economic, and social dimensions. The Modellers' Exchange Workshop, entitled "Turning the Tide: Optimising Europe's Offshore Energy Future with Holistic Planning and Engagement", organised by RGI in collaboration with ENTSO-E and the JustWind4All project, involved experts focused on aspects of holistic modelling and planning for an optimised offshore energy system that contributes to realising the EU's climate, nature and energy targets.

Within three sessions, the workshop dived deeper into the following topics:

- **Enhancing modelling optimisation potentials for future offshore network planning**, including tools and techniques used to model offshore energy systems. Advanced modelling can help in understanding the dynamics of energy production, transmission, and consumption, facilitating better decision-making in planning future offshore networks.
- **Utilising tools to help stakeholders visualise** potential locations for offshore infrastructure projects. Open-source modelling combined with visualisation tools such as Geographic Information Systems (GIS) or interactive maps can aid in identifying suitable sites, assessing environmental impacts, and better integrate stakeholder needs with stronger collaborations with MSP.
- **Promoting cross-sectoral integration for optimisation**. Coordinating activities across different sectors such as energy, transportation, and environment can maximise synergies and minimise conflicts[1].

2. Session 1: Approaches to model offshore energy

As a part of the 2024 Ten-Year Network Development Plan (TYNDP) process, for the first time, the ONDP[2] was performed to better assess the needs of accelerated offshore wind installations and grid infrastructure, as currently there is only 7% of the offshore wind energy infrastructure needed in 2050 to realise the EU climate and energy targets. This significant scale of ambition for offshore in Europe (including Norway and the UK) will cost a minimum of 403 billion euros, requiring grid routes totalling up to 54,000 km, offshore and onshore stations and significant supply chain scale-up and capabilities.

Developing offshore transmission corridors to connect offshore RES is a complex task that demands close coordination across multiple actors. Implementing this infrastructure also requires a holistic approach to ensure that techno-economic and socio-environmental aspects are balanced to preserve and restore the marine environment to reduce conflict and support nature.

From the wind industry perspective, there are myriad challenges to accelerating offshore production, including delays in permitting and auctioning, issues relating to financing and infrastructure frameworks and grid planning. As of April 2024, Europe has 135 wind farms connected to the grid, accounting for 34,166 MW. The development time for offshore wind farms vary from 3-9 years, depending on the member state, and grid costs contribute to about 14% of the total cost of offshore wind farm[3].

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[1] All materials presented at the workshop have been circulated among the participants and are available at the dedicated page on RGI website.

[2] ENTSO-E released the Offshore Network Development Plans, "European offshore network transmission infrastructure needs" pan-European summary in January 2024, which details the scale and investment needs.

[3] WindEurope has developed an interactive tool of Offshore Wind Farms Map for public view.

To facilitate effective acceleration, offshore infrastructure planning needs to include port readiness at the local level, while also diversifying and preparing short and long-term supply chain readiness at both the regional and EU levels.

While modelling offshore grid infrastructure, grid configuration granularity (decoupling components and optimising locations of substations), system stability and additional coordination with MSP are necessary to better holistically consider political, technical and socio-environmental aspects. Model granularity and spatial resolution clustered in a simplistic scenario can provide a snapshot into capacity expansion and market models to ensure a holistic, system-wide optimisation.

Such an integrated approach can not only address the various technical and logistical challenges, but also foster greater collaboration among stakeholders by promoting a comprehensive understanding of the entire, interconnected system.

Challenges and Recommendations

Processual themes such as holistic planning, understood as not slowing down the process, but increasing awareness of environmental permitting and bureaucracy, and standardisation were questioned as potentially conflicting. These considerations led to an overarching question: how do we standardise modelling to accelerate processes related to offshore grid development?

ENTSO-E considers this by incorporating iterative planning steps through open exchanges and the alignment of modelling methodologies to meet specific needs and objectives expressed by various stakeholders. This process requires a high level of coordination, because offshore infrastructure planning is expanding into previously uncharted areas, including the unknown number of connections and technical configuration. Therefore, it is essential to holistically consider technical, political, and spatial factors, such as MSP, to ensure the successful development of offshore infrastructure.

3. Session 2: Addressing Spatial Challenges of Offshore Infrastructure

This session focused on how open-source modelling and visualisation tools, such as GIS and interactive maps, can help to address spatial challenges, while assessing environmental impacts, and enhance stakeholder collaboration with MSP in offshore infrastructure projects.

Investigating and developing more holistic approaches to wind energy acceleration and energy system modelling is also one of key objectives of the Horizon Europe JustWind4All project. The project upgraded their existing European open-source energy system optimisation model (Calliope) to include higher spatial and technological details for wind power. However, a challenge of large-scale energy system optimisation models is the lack of local details and underrepresentation of societal and environmental aspects. When considering societal factors such as justice, it is important to integrate local aspects into

energy system modelling. By resolving energy system design at the local scale, the model can reveal local impacts and benefit maximisation that are alternative to techno-economic optimisation. Due to the complex downscaling methods, the JustWind4All modeller presented open questions relating to local benefit assessment (such as assumptions) and how to address holistic spatial mapping that considers ecosystem impact and local population effects.

The second spatial modelling approach presented an innovative and important way to incorporate national MSPs into future offshore grid planning through a parametrised, bottom-up method of GIS analysis and open-source energy system modelling. Application of such method into modelling is important, because European seas are busy with many human-related activities, such as fishing, shipping, military and some of their parts are covered by marine-protected areas (MPA). By mapping the designation areas, which include renewable energy infrastructure zones as well as no-go zones such as military areas or Natura 2000, the analysis of future network infrastructure became more robust and realistic by providing a high resolution of spatial constraints for least cost pathways for offshore network infrastructure. The next step planned by the presenter in the modelling exercise is to take the GIS analysis of the sea basins into an open-source optimisation model.

The final presented modelling approach further examined the spatial scale of offshore expansion to determine how to increase the detail and resolution without losing the whole energy system picture. Low-resolution models have historically been used for planning, but these are inaccurate and infeasible. With higher spatial resolution, costs are more accurate and better consider grid bottlenecks, such as congestion.

Challenges and Recommendations

ENTSO-E expressed interest in the integration of MSP, GIS and modelling into future offshore energy infrastructure scenarios. While optimising distances first and transmission smart is a promising solution to include within the next ONDPs, the time constraints related to development of the methodology may remain challenging. In that manner, ENTSO-E faced some difficulties during the preparation of the first edition of the ONDP, due to changing definitions of designation zones by authorities and difficulty in finding consistent and available MSP data, as national formats delivered by member states varied. The modeller, who integrated the GIS method in their work, also encountered difficulties with data availability, requiring them to manually download and consolidate each member states' MSP data for the GIS analysis. This led to future recommendations, emphasising the critical need for **EU-standardised definitions** for national MSPs, e.g., for nature protection areas (e.g., Natura 2000 vs. MPA). For future offshore infrastructure planning, including the 2026 ONDP, clearer guidance and improved coordination is needed by the EU and the member states to ensure that the MSPs have consistent formats, resolution and denominations across national and regional levels.

From a process perspective, each of the different spatial optimisation assessments require time resources to run calculations, which increase with the more detailed resolution. This time constraint forces compromises on prioritisation within the model. This may have implications for the 2026 ONDP, as it is essential to find a balance between both: the accuracy of infrastructure needs in terms of network distances and the impact of space granularity into accurate cost figures.

4. Session 3: Enhancing optimisation via cross-sectoral integration

This session explored approaches to modelling on how to integrate hydrogen production into offshore development. The modelling results reached contrasting conclusions regarding whether hydrogen production is more viable onshore or offshore. As electrolysis-based hydrogen production is still at the exploratory stage and there are many uncertainties related to hydrogen infrastructure, the differing conclusions provided food for thought on modelling long-term infrastructure planning.

The first study investigated how to make use of wind resources in the North Sea to locate hydrogen production offshore in a beneficial and cost-effective manner. Using an open-source, sector-coupled model, the optimisation carried out in this analysis considered operation and investment of generation, grids and storage, and demand. Limiting the onshore wind potential to 25% and considering the transmission capacity as optimal, the four scenarios considered Point-to-point (P2P) and meshed offshore networks and the availability of offshore hydrogen or not. When considering hydrogen production, with updated higher transmission costs, the model prefers offshore hydrogen production, resulting in no onshore electrolysis from North Sea offshore wind production. The total cost of the P2P network without hydrogen is 800 billion euros annually. The meshed power network has a benefit of 4 billion euros annually, while hydrogen production provides an additional benefit of 11 billion euros annually.

The second analysis examined the integration of hydrogen into energy systems in the Baltic Sea, how offshore energy hubs connect and whether it is more beneficial to have hydrogen production onshore or offshore. On the one hand, offshore hubs can positively improve economies of scale. On the other hand, offshore hubs may increase large-scale wake losses, which is a negative effect from an optimisation point of view. Using open-source modelling, this study found that hydrogen production is more optimal onshore, due to lower CAPEX of at least 30% and closer vicinities to demand centres. Within the most "pro-offshore H2" scenario, only 20% of hydrogen production is projected offshore, due to the high CAPEX.

Finally, the TSO implementation perspective on cross-sectoral integration highlighted the North Sea Wind Power Hub (NSWPH), a key initiative selected by the EU as a Project of Common Interest (PCI). The NSWPH project utilised a decentralised and modular hubs-and-spoke concept that is able to link the

North-West European energy system in one well-planned, hybrid network. The NSWPH also integrated a system integration toolbox that models TYNDP scenarios, enabling transnational cooperation between multiple energy carriers across sectors throughout the North Sea basin.

Challenges and Recommendations

As the impact of renewables and cross-sectoral expansion is not only between onshore and offshore wind but also different technologies such as solar, a discussion question was raised about how these various technologies are represented in the subsequent cross-sectoral integration analyses. A participant pointed out that if onshore wind and other technologies' potential are limited to 25%, then it forces the model to build offshore and increase the transmission grid expansion, which may also encounter public acceptance challenges. However, because the modelling resolutions were low, the representation of transmission system bottlenecks were not adequately represented.

While the technical potential for onshore wind and hydrogen production exists, it's not always realistic due to regulatory and political hurdles. The challenge then becomes how to mathematically quantify these obstacles within the modelling process. Additionally, there is the question of how to effectively communicate these modelling results to policymakers. Although many results can be shared with decision-makers, it is generally not advisable to make direct policy recommendations from modelling results. Offshore hydrogen production and social cost assessments are relevant, but differing assumptions can lead to varying conclusions.

5. Takeaways & Next steps

These workshop takeaways aim to summarise relevant points mentioned at the workshop and relevant for the holistic, accelerated expansion of offshore energy infrastructure in Europe:

1. **Enhanced Coordination**: Foster stronger collaboration throughout the offshore infrastructure planning for the 2026 ONDP and TYNDP. The levels of coordination include further collaboration with bodies responsible for the MSPs' preparation and the other stakeholders within the sea basin, the energy system modelling community, environmental experts and civil society.
2. **A Need for Standardised Data and Processes**: Develop standard definitions and methodologies to improve data consistency and model accuracy across Europe.
3. **Integration of Local Benefits**: Ensure local socio-economic and environmental benefits are maximised through detailed, bottom-up spatial planning that integrates processes like MSP.
4. **Implementation of Cross-Sectoral Approaches**: Use sector-coupled models to optimise investment and operation costs across multiple sectors in offshore and onshore integration.

The discussions and insights gathered during the workshop emphasised the relevance of holistic offshore infrastructure modelling and planning. In July 2024, the TYNDP 2026 cycle officially kicked off, highlighting the growing complexity and a stronger coordination need between the ONDP and TYNDP modelling exercises. This expanding assessment of targets on the European energy system is a critical tool to communicate and collaborate by utilising integrated and holistic approaches.

In addition to this summary report shared with the workshop's participants, RGI is developing a factsheet that can share and visualise the main takeaways of this workshop with a broader audience. Moving forward, RGI will continue organising expert exchanges to foster collaboration and knowledge sharing within the offshore energy modelling community.

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6. Appendix I – Workshop agenda

9:30	30’	Registration
10:00	10’	Welcome, agenda, objectives, setting scene *Renewables Grid Initiative*
		Session 1: Approaches to model the offshore energy
10:10	20’	**Keynote: European offshore network transmission infrastructure needs – the ONDP results** *Francesco Celozzi, ENTSO-E*
10:30	40’	**Modelling offshore grid systems** *Sebastian Porras Aparicio, Hitachi Energy* **Modelling offshore wind systems** *Riccardo Longo, WindEurope*
11:10	30’	Discussion
11:40	15’	Coffee break
		Session 2: Addressing spatial challenges of the offshore infrastructure
11:55	50’	**Planning the offshore energy infrastructure that supports the decarbonization of the European energy system. How can technologically and spatially explicit energy modelling contribute?** *Jann Launer, TU Delft* **Form follows function? Dualism between maritime spatial planning and the future offshore grid** *Felix Jakob Fliegner, 50Hertz & TU Dresden* **The impact of spatial scale on offshore expansion in electricity system optimisation models** *Dr. Martha Frysztacki, Open Energy Transition*
12:45	30’	Discussion
13:15	60’	Lunch break
		Session 3: Enhancing optimisation via cross-sectoral integration
14:15	50’	**Offshore power and hydrogen networks for Europe’s North Sea** *Philipp Glaum, TU Berlin* **Going offshore or not: Where to generate hydrogen?** *Matti Koivisto, Technical University of Denmark (DTU)* **TSO perspective on offshore cross-sectoral integration** *Tobias Frohmajer, TenneT*
15:05	25’	Discussion
15:30		Wrap up and outlook