Preliminary possibilities to connect offshore wind power to Fingrid's main grid in the 2030s

FUTURE SCENARIO EMPHASISING OFFSHORE WIND POWER

INTERIM REPORT

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Future scenario emphasising offshore wind power

Electricity consumption is expected to begin rising sharply in the second half of the 2020s in line with Fingrid's prospects.

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Map view: Preliminary main grid reinforcement required to enable offshore wind power connections.

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01

Introduction

This report presents preliminary possibilities for connecting offshore wind power to the main grid of mainland Finland in the 2030s. The plans contain certain assumptions that differ from Fingrid's baseline scenario in terms of electricity production and consumption trends. For this reason, Fingrid's main grid development plan published in 2023, which foresees approximately EUR 4 billion of investment over the next ten years, does not include all the system reinforcement investments required to implement the plans. Fingrid will consider the results of this report, the stakeholder feedback received on the report, and the progress of offshore wind power project development when it updates its development plan.

The preliminary possibilities to connect offshore wind power presented in this report were technically specified from the main grid perspective, taking into consideration the offshore wind power projects that Fingrid is aware of, as well as other electricity production and consumption projects. The report does not present connection solutions for individual customer projects. Connection points and capacities are reserved for projects by concluding connection agreements once said after projects have obtained the necessary permits. In the 2030s, it may also be possible to implement more offshore wind power connections than indicated in this report and in areas other than those specified in the report if the growth in electricity consumption is greater than assumed in this report or new consumption facilities are located closer to offshore wind power connections.

Finland has significant potential as an offshore wind power producer. However, it is uncertain when offshore wind power will become financially viable in Finland. Finland also has enormous potential to increase the amount of onshore wind and solar power in addition to offshore wind power. The competition between onshore and offshore wind power will be decisive. The background scenario for this report assumes that wind power investments in Finland will be weighted towards offshore wind power from the end of the 2020s and the start of the 2030s onwards due to either financial viability or acceptability. This assumption differs from Fingrid's baseline scenario, and in practice, the rate of onshore wind power construction remains lower than in Fingrid's baseline scenario. If wind power construction becomes possible in Eastern Finland, onshore wind power could be assumed to have a stronger competitive position as new production areas and a different production profile become available.

In the 2030s, it may also be possible to implement more offshore wind power connections than indicated in this report and in areas other than those specified in the report if the growth in electricity consumption is greater than assumed in this report or new consumption facilities are located closer to offshore wind power connections.

02

Offshore wind power project development in Finland

By the end of April 2024, Fingrid had received preliminary electricity production connection enquiries for more than 370 GW of capacity, with offshore wind power accounting for 95 GW. About one-third of the offshore wind power projects are in Finland's territorial waters, more than half are in Finland's exclusive economic zone, and the remainder are in Åland's territorial waters. Some projects have overlapping offshore wind power areas, these overlapping projects can be found in the exclusive economic zone and Åland's territorial waters.

According to the Electricity Market Act, Fingrid is the transmission system operator in Finland, except in the self-governing province of Åland, which also includes the Åland territorial waters. The transmission system operator responsible for the Åland province is Kraftnät Åland. Fingrid is not responsible for connecting offshore wind power projects in Åland unless it is legally stipulated otherwise. Fingrid's responsibility for connecting projects in Finland's exclusive economic zone is also unclear from a legal perspective.

Metsähallitus, the state-owned enterprise that manages Finland's territorial waters, allocates the rights to offshore wind power projects using a commercial competitive tendering procedure. Vattenfall won a competitive tendering procedure held by Metsähallitus in late 2022, entitling it to an offshore wind power project area off the coast of Korsnäs, where Vattenfall plans to build an offshore wind farm with a capacity of 1.3–2.5 GW. Currently, Metsähallitus has two competitive tendering procedures underway: Ebba (1.5 GW) off the coast of Pyhäjoki–Raahe and Edith (1.6 GW) off the coast of Närpiö. These procedures should be complete by the end of 2024. Metsähallitus is also preparing competitive tendering procedures for three project areas in the waters near Kristinestad, Hailuoto, Siikajoki and Raahe. Metsähallitus also has a valid right-of-use agreement with Suomen Hyötytuuli for the Tahkoluoto offshore wind farm and extension, as well as reservation agreements with Skyborn Renewables Offshore Finland Ltd for the Suurhiekka area (known as the Pooki Project) and Rajakiiri Oy for the Maanahkiainen Project off the coast of Raahe.

So far, the activities in Finland's exclusive economic zone have been driven by project developers, and several such project developers have applied for exclusive rights to offshore wind power areas. Since autumn 2023, the Ministry of Economic Affairs and Employment has been preparing a legislative reform that proposes the adoption of competitive tendering in the exclusive economic zone. The new Act on Offshore Wind Power in the Exclusive Economic Zone is intended to take effect in 2025, enabling the first competitive tendering procedures in the zone. Furthermore, the Government of Åland is preparing a competitive tendering procedure for the water areas north of Åland in 2025.

The Maritime Spatial Plan for Finland currently in force also identifies areas suitable for offshore wind power in the waters south of Åland. Project developers are very interested in the area, but national defence requirements conflict with offshore wind power development there. This report separately examines a scenario in which offshore wind power construction is also allowed in Finland's southern sea areas. This would be desirable for the power system, as 80% of Finland's electricity consumption currently occurs south of the Vaasa–Kuopio line, and production is increasingly located to the north of this line. The polarisation of consumption and production is predicted to grow further in Finland. Building offshore wind power in Finland's southern water areas would benefit electricity consumers by allowing for more geographically dispersed wind power production and a more even electricity price.

03

Prospects for future electricity consumption and production in a scenario emphasising offshore wind power

This report on the possibilities for connecting offshore wind power is based on Fingrid's prospects for future electricity consumption and production and electricity market modelling published in early 2024. This report deviates from the baseline scenario for the future presented in Fingrid's prospects by assuming that wind investments will be weighted towards offshore wind power from the end of the 2020s and the start of the 2030s onwards as offshore wind power becomes more economically viable than onshore wind power or the acceptability of onshore wind power declines. The time horizon of the forecast was also extended to 2035. The report's results contain some uncertainties, especially

around the assumptions of growth in electricity production and consumption. Many of the production and consumption projects included in the forecasts are so large that they will substantially affect the need for main grid investments and connection capacity if they come to fruition.

Electricity consumption

Electricity consumption is expected to begin rising sharply in the second half of the 2020s in line with *Fingrid's prospects*. Growth is expected to continue into the 2030s, driven especially by the production of hydrogen and products derived from hydrogen. Finland's total consumption is estimated at 166 TWh in 2035, which is approximately double today's level. Peak consumption is expected to increase to 31 GW and to occur on a windy winter's day when electricity prices are low. The focal point of electricity consumption is expected to remain in Southern Finland. However, in the late 2020s, an additional focus will emerge on the west coast, especially because planned hydrogen projects tend to be in coastal areas.

The increase in electricity consumption depends on several drivers, particularly hydrogen and electric fuel production, data centres, and the metal industry. Figure 1 shows the assumed growth in consumption by sector.

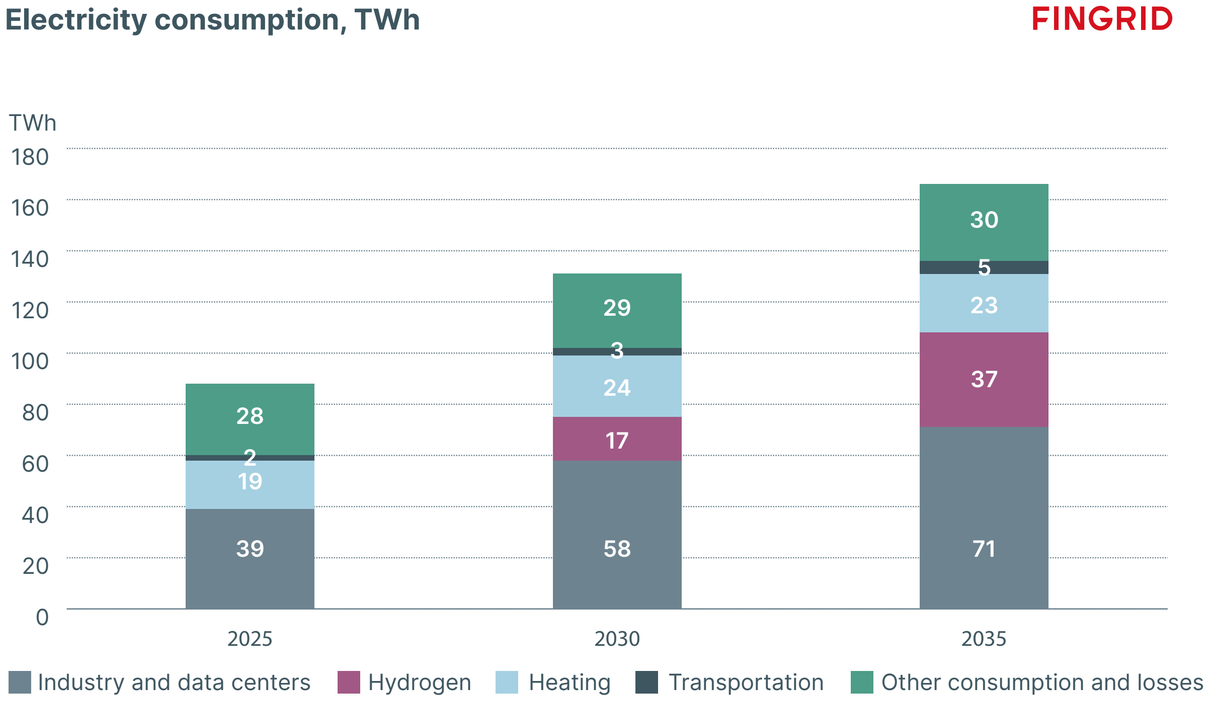

FIGURE 1 The electricity consumption forecasts used in this report.

Electricity production

The electricity production capacity in Finland has increased sharply in recent years, driven by clean, renewable electricity production. Our self-sufficiency in electricity production has increased in parallel with this. The report assumes that electricity production will continue to grow strongly as consumption increases. The estimated total production in 2035 will be 175 TWh, and the estimated installed production capacity will be 56 GW. Figures 2 and 3 show the electricity production trends

According to Fingrid's prospects, onshore wind power is expected to dominate the growth in electricity production in the 2020s, with the onshore wind power capacity increasing to 21 GW by 2030. This report assumes that the growth in wind power will be weighted towards offshore wind power in the 2030s, resulting in the construction of 6.5 GW of offshore wind power in the 2030s, equivalent to just over 30 TWh of annual production.

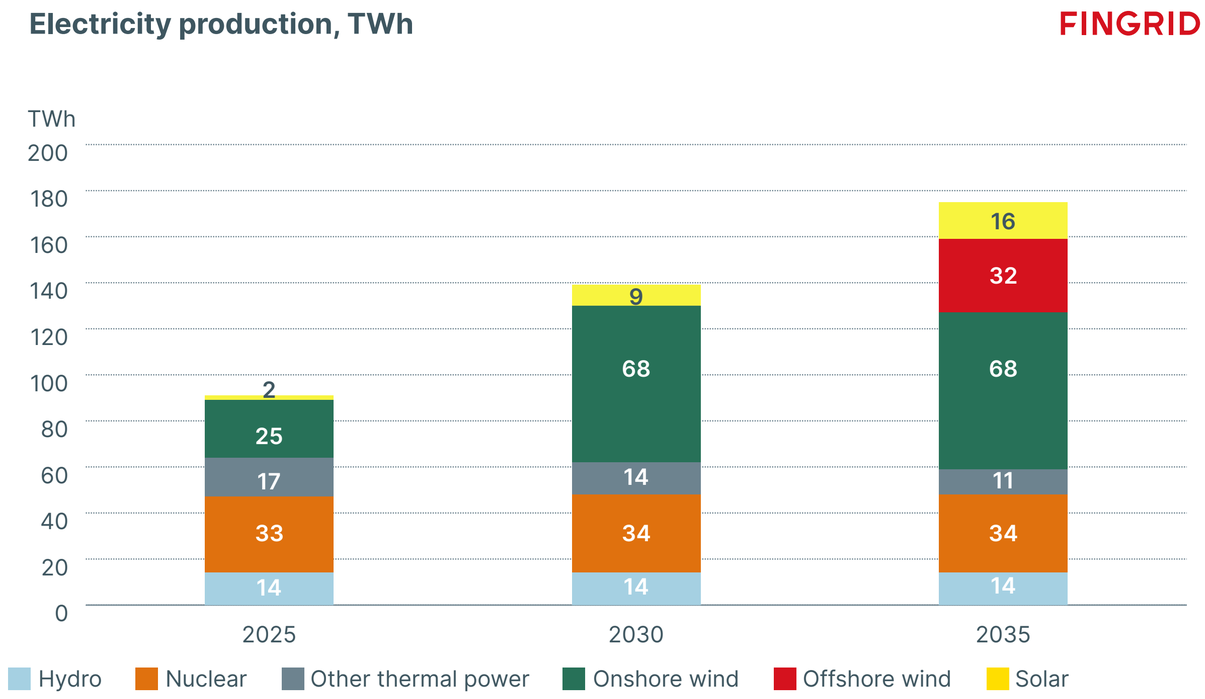

FIGURE 2 The electricity production forecasts used in this report.

This report assumes that offshore wind power will only be built in the Gulf of Bothnia. However, the report also examines a scenario in which the construction of offshore wind power is also allowed in Finland's southern sea areas. Most offshore wind power is expected to be located south of Vaasa. This results in smaller grid reinforcement needs and the possibility of more connections than if offshore wind parks were concentrated north of Vaasa because electricity consumption is weighted towards the southern parts of Finland. The offshore wind power production areas are expected to be distributed along the Gulf of Bothnia. This will lead to more even production of offshore wind power and make it easier to reconcile power production with other uses of the sea area, such as maritime transport, in contrast with a situation where offshore wind power production is concentrated in a small sea area.

Finland's offshore wind power in the 2030s is expected to consist of five offshore wind power parks with connection capacities of 1.3 GW. The capacity is based on the maximum size of an individual power plant and connection in Finland in accordance with Fingrid's General Connection Terms (YLE2021). Offshore wind projects with an overall production capacity of more than 1.3 GW are also planned for construction in Finland. These must be separated into independent power generating facilities according to Fingrid's instructions, Largest permitted stepwise power change in power plant connections in Finland.

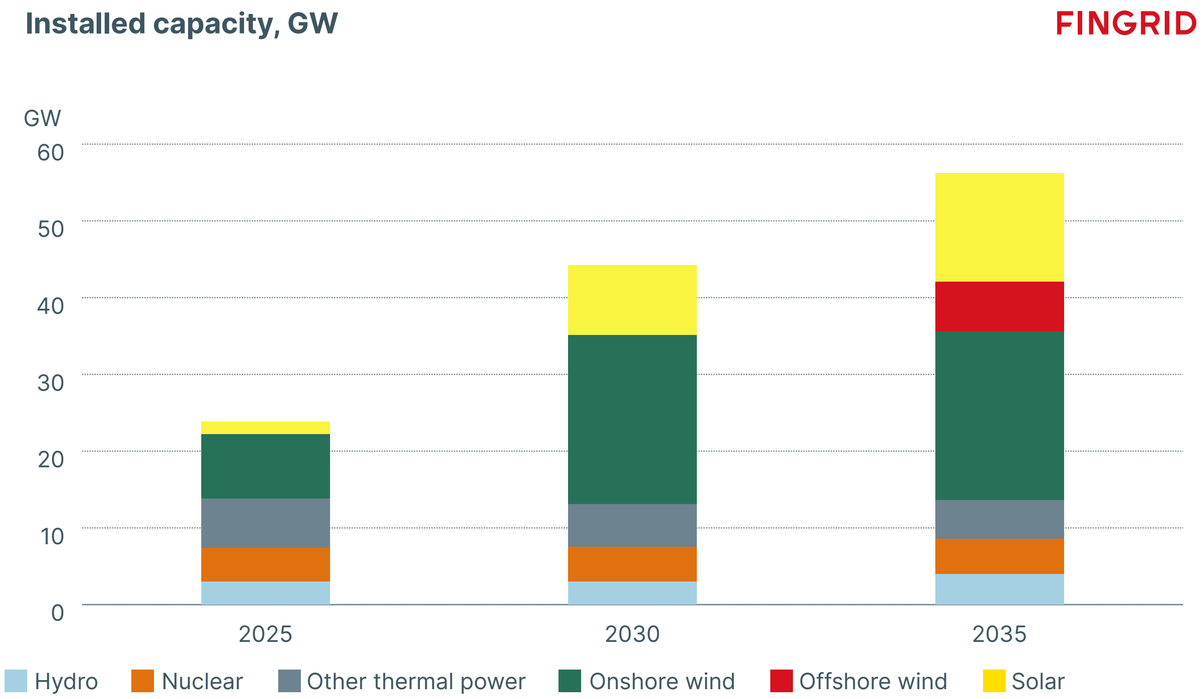

FIGURE 3 The forecasts of electricity production capacity used in this report.

In addition to wind power, solar power is expected to grow significantly in the coming years. The solar power capacity is assumed to be 14 GW in 2035, accounting for 5–10% of Finland's electricity production. Growth is expected in both rooftop installations and industrial-sized solar farms. Solar power production is assumed to be located predominantly in Southern and Central Finland.

In 2035, the nuclear power production capacity is assumed to be similar to today's level. New flexible generation capacity is also needed to balance the forecasted electricity production and consumption at all times. Hydropower capacity is assumed to remain the same, except for the addition of 0.5 GW of pump power capacity to be built in Northern Finland. Combined heat and power production is expected to decrease significantly from the current situation. New thermal power capacity is assumed to take the form of engine power plants, with 1 GW built by 2035. Consequently, the forecast does not predict a significant decrease in thermal power capacity, but its share of energy production will decline. The engine power plants will provide additional flexibility to the power system, further assisted by new battery-based energy storage facilities. The forecast predicts 1.5 GW of battery storage capacity in 2035.

Cross-border connections

Based on the forecasts in this report, Finland will be a slight net exporter of electricity, but electricity exports will not be significant on a system-wide scale. The cross-border connections are expected to be substantially reinforced by 2035. In addition to the cross-border connections in operation today, the new alternating current (AC) connection between Finland and Northern Sweden, Aurora Line 1, is currently under construction, and another new AC connection between Finland and Northern Sweden (Aurora Line 2) is expected to be built along with a third direct current (DC) connection between Finland and Estonia (Estlink 3). In addition, the report considers the possibility of transmitting energy in the form of hydrogen between Northern Finland and Northern Sweden.

The FennoSkan 1 DC connection between Finland and Central Sweden will need to be replaced in the late 2030s. Fingrid and the Swedish transmission system operator will investigate this in the coming years. One option is a hybrid interconnector, which would provide a transmission connection between the two electricity market areas while also connecting offshore wind power in the Gulf of Bothnia to the two mainlands. This report does not consider the hybrid interconnector, and issues remain to be resolved concerning its technical implementation and operation in the electricity market.

04

Preliminary possibilities for connecting offshore wind power

This report presents the preliminary possibilities for connecting offshore wind power projects to the grid in the form of areas. The report will be updated in autumn 2024 to specify the possibilities at the substation level based on stakeholder feedback and additional studies in progress at Fingrid. The criteria for selecting areas and setting preliminary timetables were the feasibility and costs of system reinforcement investments, as well as the number, scale, and stage of development of production and consumption projects in the areas. This report takes into account the potential offshore wind power production areas and sea areas reserved for other activities identified in Finland's Maritime Spatial Plan for 2030. It is also noted that the maritime spatial plan is currently being updated, and a new plan is set to be published in 2026.

Table 1 shows the preliminary areas, timetables, and capacities of offshore wind power connections in the 2030s.

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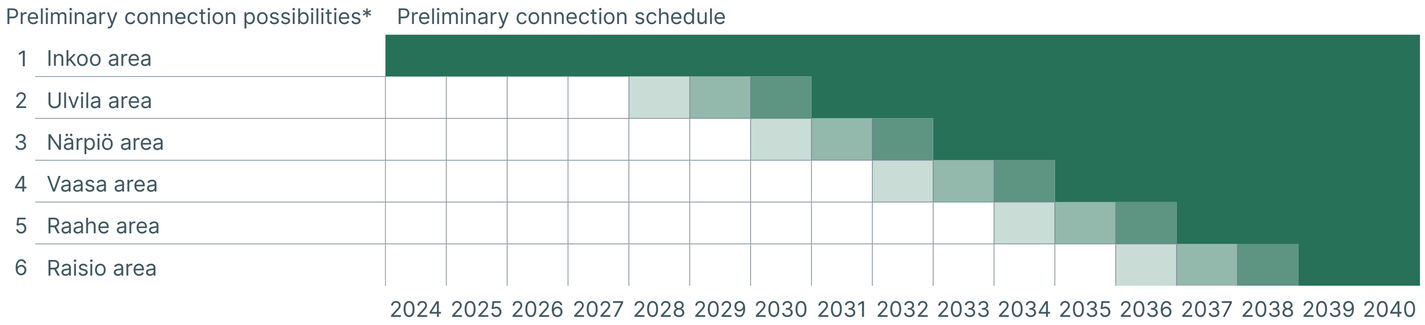

*Maximum size of an individual connection is 1,3 GW

TABLE 1 Preliminary possibilities for connecting offshore wind power in Finland in the 2030s

Preliminary possibilities to connect offshore wind power to the main grid have been identified in the **Ulvila**, **Närpiö**, **Vaasa**, **Raahe** and **Raisio regions**. In the Raisio, Ulvila and Närpiö regions, it would be possible to connect offshore wind power from the Sea of Bothnia, which includes project areas in Finland's sea areas and exclusive economic zone. In addition, it could also be possible to connect projects in the southernmost areas of Raisio and Ulvila from the waters of Åland if Fingrid is deemed responsible for connecting such projects.

Offshore wind power could connect to the Vaasa area from the northern parts of the Sea of Bothnia or the southern parts of the Bay of Bothnia. The Raahe area offers the only clear possibility for connecting projects in the Bay of Bothnia. From the perspective of the grid, the northern part of the Bay of Bothnia is the most difficult area to connect large new production hubs, as Northern Ostrobothnia is already a production-centric area, and it has the longest transmission distance to the consumption-centric south of Finland. If the balance between consumption and production changes substantially in this area, it would likely enable more than one offshore wind power project to be connected in the region.

In a scenario where offshore wind power construction is also allowed in Finland's southern sea areas, the report identifies the possibility of connections in the **Inkoo area**, closer to the consumption-centric area. In this scenario, more offshore wind power could be connected overall, and Fingrid could already provide offshore wind power connections to Southern Finland in the 2020s.

When specifying more precise connection points – in other words, the substations to which projects can be connected – it is necessary to examine the possibility of building a new substation, expanding existing substations, and building connecting lines. The security of the power system must also be considered. The first of these criteria are influenced by the locations of substations and the environmental constraints. The security of the power system is affected by the network topology and other electricity production and consumption facilities in the nearby area. In other words, it is affected by how the substation is connected to the rest of the grid and what types of production and consumption are in the area. Fingrid is currently preparing more detailed system security studies, which will affect the selection of precise substation locations. Fingrid intends to publish an update to this report, specifying its results at the substation level in autumn 2024 based on these additional reports and stakeholder feedback.

The timetable for the presented connection points largely depends on the potential implementation schedules for new 400 kV transmission lines. In Finland, reinforcement investments in the 400 kV transmission grid take, on average, seven to eight years from planning to implementation. For resourcing reasons, only a limited number can be ongoing at the same time. Fingrid is carrying out a historically large investment programme to enable the energy transition. Resource shortages are already foreseeable in every construction phase from grid design through environmental impact assessments, permit applications, and expropriation to construction. Moreover, the social acceptability of power transmission infrastructure can challenge schedules, especially if essential system reinforcements are concentrated in areas that already have several transmission lines or are near settlements. The regulation model for grid companies, which changed at the beginning of 2024, also weakens the financial conditions for the necessary investments. Although the modelling for this report focuses on 2035, it is unrealistic to expect all the necessary system reinforcement investments to be implemented by then. However, it is also unrealistic to assume that several gigawatt-scale offshore wind projects could be constructed simultaneously in the Gulf of Bothnia due to factors such as the availability of installation vessels and port capacity.

05

Preliminary power system reinforcements needs

This report identifies the preliminary need to boost the main grid's transmission capacity by more than stated in Fingrid's main grid development plan, published in 2023, in order to connect the five offshore wind power projects modelled in this report to the power system. The sixth offshore wind project, which would connect to the main grid in the Inkoo region, would not require reinforcement measures.

In order to connect the offshore wind power projects in the Gulf of Bothnia, the main grid must be reinforced from Central Ostrobothnia all the way to Uusimaa. This would enable the transmission of electricity from the west coast, where there is surplus, to major consumption hubs in Uusimaa and to the Helsinki metropolitan area to meet its demand for consumption. The grid must also be reinforced on the southwest coast and further inland. New transmission line routes, the possibility of expanding existing substations, and the precise locations of new substations have not yet been examined at this stage of the study. However, the need for system reinforcement has been identified. Some uncertainty surrounds the necessary system reinforcements, especially due to the assumptions of electricity production and consumption trends in Finland and its neighbouring countries. Figure 4 shows the preliminary system reinforcement needs.

In order to connect offshore wind power, the modelling for this report calls for approximately 1,000 kilometres of new 400 kV transmission lines and at least two entirely new substations. The cost estimate, indicating the scale of the preliminary system reinforcement needed for offshore wind power connections, is EUR 0.6 billion, most of which is for transmission lines. Based on the study, some transmission line reinforcements could be avoided using other technical and grid topology solutions. For example, series compensation could be replaced by shunt compensation. This would yield significant cost savings and benefits in terms of land use and scheduling.

Fingrid's current investment programme, presented in the 2023 development plan, was used as a basis for the system reinforcement needs modelled in this report. If this report is correct about the trend in wind power investments leaning toward offshore wind power at the start of the 2030s, the investments presented in the development plan will need to be reassessed. In particular, in a scenario where offshore wind power construction is allowed in Finland's southern sea areas, some of the north–south transmission system reinforcements could probably be avoided.

This report adheres to the current principle of the connecting party being liable for the construction and costs of the connecting line to the main grid connection point on the mainland. If this distribution of responsibilities changes, the need for and costs of system reinforcements and timetables for connections will need to be reassessed.

It should be noted that the system reinforcements presented in this report do not guarantee the 100% availability of gigawatt-scale customer connections. Under some grid maintenance and fault conditions, it may be necessary to limit the production of offshore wind farms.

Grid reinforcements

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- Grid reinforcements that are included in the Main grid development plan
- Grid reinforcements needed to connect offshore wind
- Offshore wind connection areas

- Existing 400 kV transmission lines
- Existing 220 kV transmission lines
- Existing 110 kV transmission lines

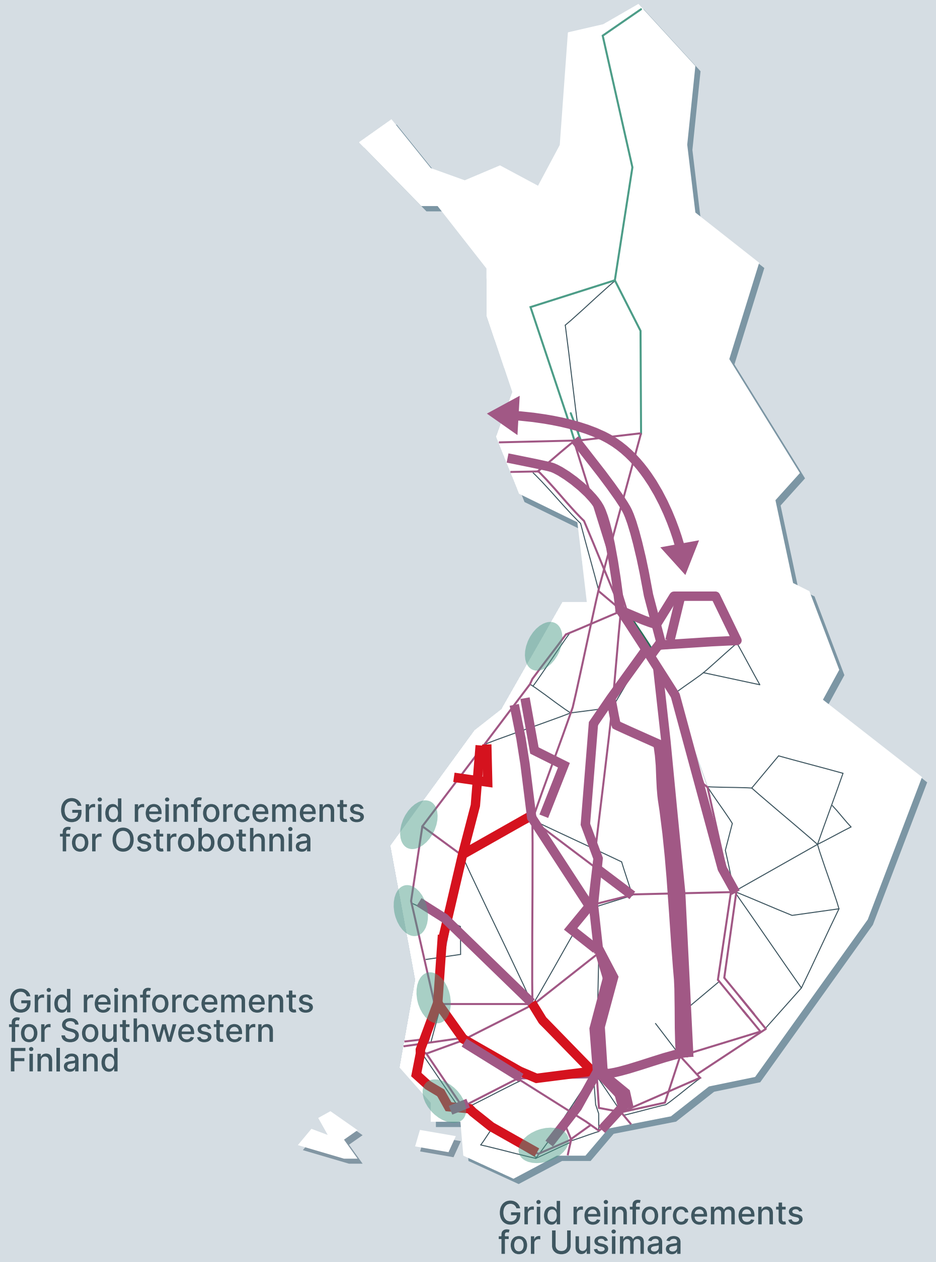

FIGURE 4 Preliminary main grid reinforcement required to enable offshore wind power connections in the 2030s.

06

Technical system studies

Offshore wind farms are enormous electricity production hubs, so system reinforcement investments and technical system and security investigations are required before they can be connected to the power system. Detailed technical system engineering is carried out in collaboration with customers as the technical data, implementation schedules and connection methods of their projects become more specific.

In recent years, stability challenges have arisen on the west coast, as converter-connected production is concentrated in a limited geographic area. This report assumes there will be no significant stability challenges in the 2030s, as converters are required to be capable of operating stably without the stabi-lising properties of synchronous machines (known as grid forming in the European Union Require-ments for Generation). The required capability can be realised in wind farms or with separate compensation equipment.

Fingrid's grid code specifications (VJV) set the requirements for electricity production in Finland. Fingrid is currently updating the VJV requirements, with the new requirements expected to take effect in 2025. The updated document will contain no specific requirements for offshore wind power. However, additional requirements may be imposed on offshore wind power projects due to their large size on a case-by-case basis through the specific study requirements, which Fingrid assesses during the project's preliminary planning phase. Detailed interpretations of how the VJV requirements apply to offshore wind power projects can only be made as project development progresses.

Fingrid is currently examining the possibility of a hybrid connection as an alternative to a traditional connection. A hybrid connection allows electricity production and consumption at the same main grid connection point or in the same section of the grid. This would reduce the need for system reinforcements. It would also enable a larger number or size of customer projects to be connected more quickly. The concept entails technical and system-security challenges due to the interdependence of produc-tion and consumption in this connection method. Furthermore, legislation currently limits the use of such a connection. A reform of the Electricity Market Act, beginning in spring 2024, will examine whether to enable the concept in legislation.

07

Summary

This report assumes that Finland’s electricity consumption will approximately double from its current level by 2035, driven especially by industry. In addition, this report assumes that offshore wind power will become a more competitive or acceptable form of production than onshore wind power in the late 2020s, with wind investments leaning toward offshore wind power in the 2030s. Consequently, the amount of offshore wind power will increase to approximately 6.5 GW in the 2030s, equivalent to just over 30 TWh of annual production. The assumptions differ from the baseline scenario in Fingrid’s main grid planning, which foresees wind investments focusing on onshore wind power in Finland in the 2030s.

Fingrid has, through preliminarily study, identified five areas where large offshore wind farms could be connected to the main grid in mainland Finland: Ulvila, Närpiö, Vaasa, Raahe and Raisio. In addition, the Inkoo region has been defined as a potential connection area if offshore wind power is allowed in Finland’s southern sea areas. More precise preliminary connection points will be defined in autumn 2024 based on stakeholder feedback and Fingrid's more detailed internal studies. Connection points will be reserved for individual projects as project development progresses.

This report indicates that around EUR 0.6 billion will need to be invested to implement offshore wind power connections in the 2030s in addition to the EUR 4 billion investment programme described in Fingrid’s main grid development plan in 2023. Additional investments will be needed in Central Ostro-bothnia, Southwest Finland, and Uusimaa, including approximately 1,000 km of new and reinforced 400 kV transmission lines. However, some uncertainty surrounds the need for investments, especially with regard to the implementation, locations and schedules of large electricity consumption and produc-tion projects. If offshore wind power construction also becomes possible in Finland’s southern sea areas, there would be less need for main grid reinforcements to connect offshore wind power.

This report explains the preliminary grid connection possibilities for offshore wind power, but Fingrid has yet to decide on the implementation of the grid reinforcement investments. Fingrid will revisit its investment programme for the next ten years when it publishes the main grid development plan in 2025, taking into account the outlook for the development of electricity consumption and production projects at that time. However, the potential for investing in the grid is limited. It is limited not only by the time required for investments and the financial constraints, but also by the social acceptability of electricity transmission infrastructure and the resources available for planning, permit applications, and construction. Investments must be prioritised, so there may be delays in implementing connections for customer projects in certain areas.

In addition to deciding which system reinforcement investments to implement, the principles for allocating newly constructed connection capacity to customer projects must be reviewed. In accordance with Fingrid’s current practices, connection capacity is only reserved for an individual project when the permits for the project take legal effect. In addition, an expropriation permit for the connecting line must be applied for from the Ministry of Economic Affairs and Employment. Fingrid has identified the need to update its connection agreement practices, especially for large customer projects where the permit application process takes a long time, and the customer must make a significant financial commitment before securing a permit. This would ensure that different types of customer projects are treated fairly.

Fingrid delivers.
Responsibly.

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