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

FUTURE SCENARIO EMPHASISING OFFSHORE WIND POWER

FINAL REPORT

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

Preliminary possibilities for connecting offshore wind power in the 2030s, specified at the substation level.

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Implementing new connection points and providing their timetables depend on rising electricity consumption, especially on the coast of the Bay of Bothnia.

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01

Summary

This report is a followup to the report published in May 2024 on the preliminary possibilities to connect offshore wind power to the main grid in mainland Finland. The report has been updated based on a stakeholder consultation held in the early summer and revised to present the preliminary connection points for offshore wind power at the substation level.

The connection possibilities are still preliminary. Fingrid has not decided on investments in the system reinforcements required to implement the offshore wind power connections described in this report. We will maintain the capability to connect offshore wind power to the main grid via designated substations and going forward, evaluate the necessary network investments as part of the main grid development plan, which is published every two years.

Seven potential connection points in mainland Finland have been identified for offshore wind power in the 2030s.

1. Inkoo substation
2. Lieto / Raisio / Uusikaupunki substation
3. Ulvila substation
4. Åback substation in Kristinestad
5. Tuovila substation in Mustasaari
6. Hirvisuo substation in Kokkola
7. Hanhela substation in Pyhäjoki

Figure 1 shows these.

The most significant changes since the May publication are that a new potential connection point for offshore wind power has been added in the Kokkola area, and alternative connection points and schedules have been provided in Southwest Finland. Of these, Lieto or Raisio could be implemented more quickly than the Uusikaupunki connection point, which would demand larger investments to reinforce the power system. Hirvisuo and Hanhela, the northernmost connection points, will become possible in the 2030s if electricity consumption in the area increases substantially from the current level before the offshore wind power connections are realised.

According to the modelling conducted for this report, implementing these seven offshore wind power connections will require EUR 0.7 billion to be invested in main grid reinforcements on top of Fingrid's ongoing investment programme of approximately EUR 4 billion. The majority of the reinforcements necessitated for offshore wind power consist of new and reinforced 400 kV transmission lines. The modelling indicates a need for 1,000–1,100 km of such lines. Some uncertainty exists regarding the necessary system reinforcements, especially due to the assumptions of electricity production and consumption trends in Finland and its neighbouring countries. The system reinforcements required could be very different if, for example, more wind power is built onshore than anticipated instead of offshore.

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

	Area	Preliminary connection point
1	Inkoo area	Inkoo
2	Raisio area	Lieto/Raisio/Uusikaupunki*
3	Ulvila area	Ulvila
4	Närpiö area	Åback
5	Vaasa area	Tuovila
6	Kokkola area**	Hirvisuo
7	Raahe area**	Hanhela

*Alternative connection points, schedule depends on the connection’s location and flexibility
**Schedule and feasibility depends on consumption growth in the area

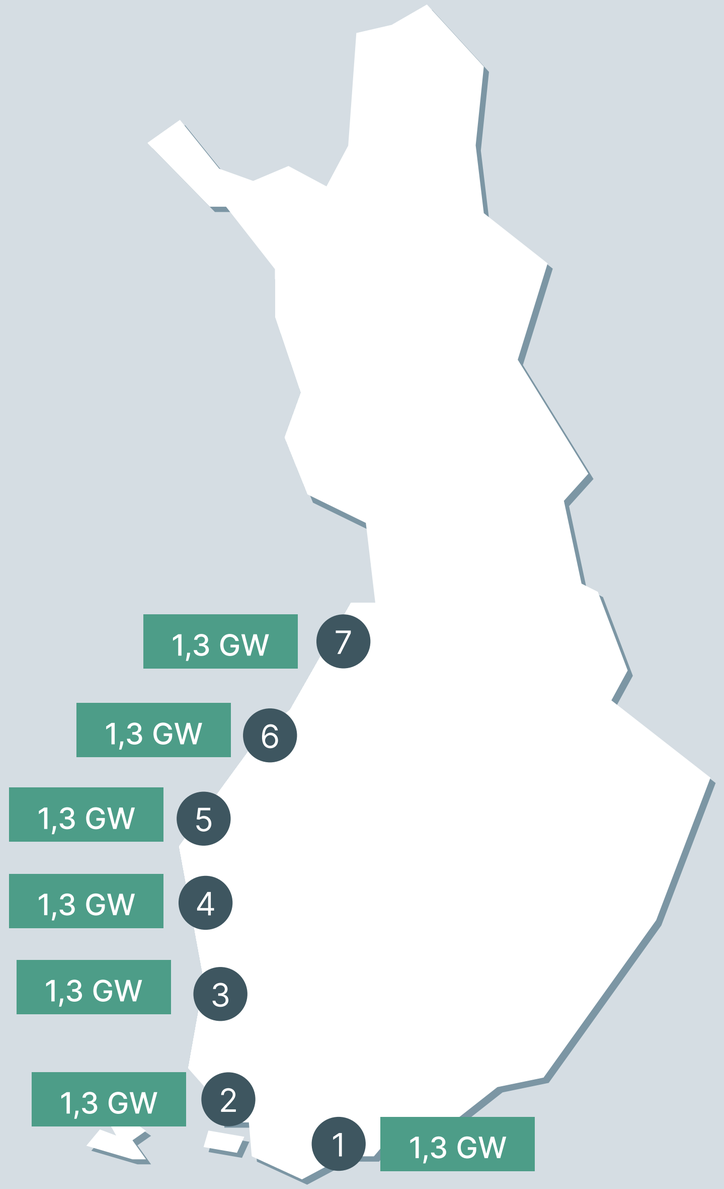

FIGURE 1 Preliminary possibilities to connect offshore wind power to Fingrid’s main grid in the 2030s.

02

Background of the study

Finland has significant potential as an offshore wind power producer. Interest in developing offshore wind power projects in Finland's sea areas grew sharply in 2022 and 2023. In autumn 2023, Fingrid launched a study on the possibilities for connecting offshore wind power to the main grid in mainland Finland. The preliminary areas where offshore wind power could connect to the main grid in the 2030s were published in May 2024. A public consultation was held on the results, and a summary was published in August. The May publication was updated based on feedback received during the consultation and additional studies by Fingrid. This final report presents preliminary possibilities for offshore wind power connections at the substation level.

The background scenario used for this report relies on assumptions about electricity production and consumption trends that differ from the baseline scenario used in Fingrid's main grid planning. Wind power investments are assumed to lean towards offshore wind power as the 2020s end and the 2030s begin, while Fingrid's baseline scenario remains weighted towards onshore wind power in the 2030s. Consequently, the system reinforcement investments required to realise the offshore wind power scenario in the report are not included in Fingrid's EUR 4 billion investment programme for the next ten years, as published in the main grid development plan for 2023. When updating the main grid development plan, Fingrid will consider the results of this report, the progress of offshore wind power projects, and the progress of other customer projects.

The preliminary possibilities to connect offshore wind power have been technically and economically determined from the standpoint of the power system, taking into account the existing main grid, the planned reinforcements of it, and the feasibility and costs of the new system reinforcement investments required. The development prospects for consumption projects were considered in addition to the development of offshore wind power projects. The goal was to maximise the possibility of connecting offshore wind power to the grid and implement grid connection solutions for these enormous production hubs as quickly as possible. The report does not present connection solutions for individual customer projects. Connection points and capacities are reserved for projects by concluding connection agreements once the permit application process of the projects proceeds.

The background scenario for the report has changed since the preliminary report was published. The changes were based on feedback received from the public consultation. The growth in electricity consumption remained the same as in the original scenario. In other words, it is expected to double by 2035. However, the locations of new consumption facilities were changed: consumption was increased on the coast of the Bay of Bothnia and reduced in Southern Finland. Based on feedback from project developers, the peak operating period of offshore wind power plants was reduced, too. Consequently, energy production from offshore wind power remained at the same level as in the original report, even though the offshore wind power production capacity was increased with the addition of one entirely new offshore wind power connection to the scenario. No changes were made to the cross-border transmission capacities.

It is possible that more offshore wind power connections could be implemented in the 2030s than proposed in this report, and they could be implemented in areas other than those specified in this report. This would require faster growth in electricity consumption than the rate assumed in the report or new consumption facilities closer to the offshore wind power connections. However, the results of the study include substantial uncertainty due to assumptions about the development of consumption and production. If consumption grows more slowly than projected, offshore wind power projects and connections would likely be delayed. Implementing hybrid connections would improve the connection possibilities. Chapter 7 covers hybrid connections in more detail.

03

Preliminary connection points for offshore wind power and estimated timetables

The report published in spring 2024 identified preliminary possibilities to connect offshore wind power to the main grid in the Inkoo, Raisio, Ulvila, Närpiö, Vaasa, and Raahe regions. This report presents the preliminary connection possibilities as connection points specified at the substation level. In addition, the selected regions and estimated timetables were updated based on stakeholder feedback and additional studies by Fingrid. An entirely new connection possibility was added in the Kokkola region, and alternative connection points were examined in Southwest Finland. Table 1 shows the preliminary possibilities for connecting offshore wind power to the main grid and the estimated timetables.

The preliminary connection points are the Inkoo, Uusikaupunki/Raisio/Lieto, Ulvila, Åback, Tuovila, Hirvisuo, and Hanhela substations. Inkoo, Lieto, Ulvila, Tuovila, and Hirvisuo are existing main grid substations. Åback in Kristinestad and Hanhela in Pyhäjoki are new substations planned for construction under Fingrid's investment programme. Åback is due for completion in 2028, but large offshore wind power connections will only be possible once system reinforcements are built. Hanhela substation is planned for construction when the consumption projects in the Raahe region progress. The implementation of offshore wind power connections in the northernmost regions of Raahe and Kokkola (Hanhela and Hirvisuo) depends on electricity consumption increasing in the regions.

Preliminary connection possibility*		Preliminary connection point
1	Inkoo area	Inkoo
2	Raisio area	Lieto/Raisio/Uusikaupunki**
3	Ulvila area	Ulvila
4	Närpiö area	Åback
5	Vaasa area	Tuovila
6	Kokkola area***	Hirvisuo
7	Raahe area***	Hanhela

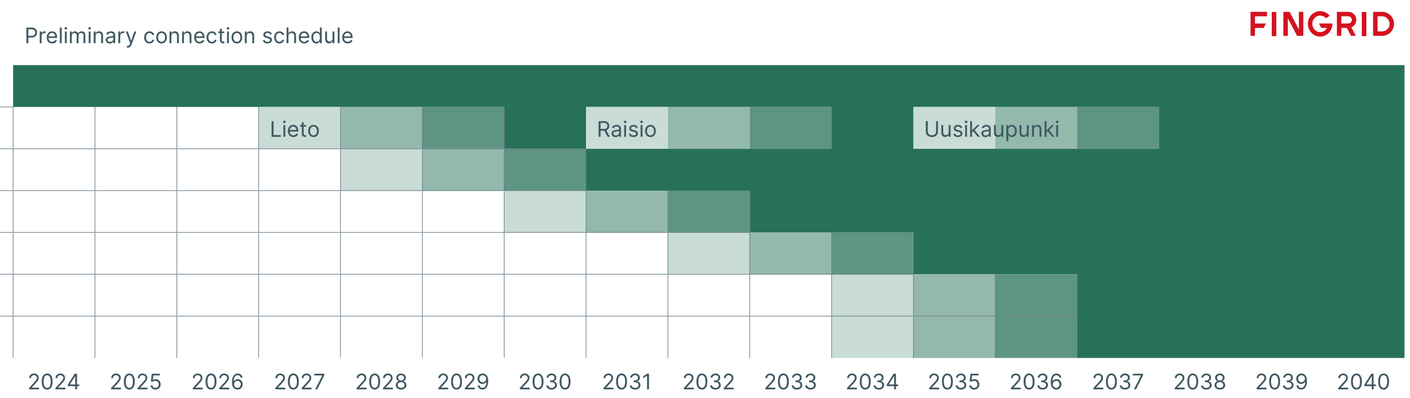

TABLE 1 Preliminary possibilities for connecting offshore wind power in the 2030s, specified at the substation level.

*Maximum size of an individual connection is 1,3 GW
**Alternative connection points, schedule depends on the connection's location and flexibility
***Schedule and feasibility depends on consumption growth in the area

The Lieto, Raisio, and Uusikaupunki substations are alternative locations for the Southwest Finland connection point and have different timetables. Connections to the existing Lieto substation would be the quickest to facilitate. A new substation is planned in Raisio in the early 2030s. This report also examines the option of building a new 400 kV substation in the Uusikaupunki region.

Technical rationale for selecting the connection points

The following were examined when determining the precise connection points (i.e., substations) to which projects could connect:

- The need to reinforce the main grid
- Customer projects under development
- The potential to construct new substations
- The potential to expand existing substations
- The feasibility of connection lines
- The security of the power system

Connection possibilities are quicker to implement when less main grid reinforcement is required. Connections are also faster if the necessary system reinforcements are planned and a substation already exists or is planned. Efforts were made to consider the environmental constraints when examining potential substations and transmission lines, but no exact routes were planned at this stage.

The number of meshed connections at connection point substations, the topology of the surrounding network, and the number and type of other electricity production and consumption facilities in the region affect the security of the power system. Substations already connected to significant electricity production facilities or cross-border connections were excluded from the potential connection points. This is to avoid a single substation becoming critical to the security of the power system.

Replacing the Raisio region with alternative connection points in Uusikaupunki, Raisio, and Lieto

In their feedback during the consultation, several project developers expressed a wish for the connection possibility in Raisio to be moved closer to the Sea of Bothnia coast. Their rationale was that building submarine connecting lines to the Raisio region would be difficult. In practice, the cable landing would need to be closer to Uusikaupunki. Parties also wanted connections sooner.

The connection possibilities and timetables for Southwest Finland depend on the readiness of project developers to build connecting lines to land and the level of availability that project developers expect from the connection. The connection point options are Lieto, Raisio, and Uusikaupunki. The possibilities are staggered: connections can be facilitated more quickly when less system reinforcement is required. Lieto would enable the earliest connection, which could happen in the late 2020s.

A new substation is planned in the Raisio area. If a temporarily or permanently flexible connection model were used, it would enable the second fastest connection (early 2030s). The Raisio–Lieto line is a radial 400 kV transmission line, so the customer would need to commit to disconnecting their electricity production facility connected to the Raisio substation in the event of a fault on the Raisio–Lieto line until a meshed 400 kV network is built in the region later in the 2030s. For more information on the flexible connection model, see Fingrid's June 2024 paper, "Proposed changes to the structure of main grid fees – addressing challenges with the grid capacity".

Connecting to Uusikaupunki, which is nearest the coast of the Sea of Bothnia, would necessitate a new substation in the Uusikaupunki region. Facilitating connections to Uusikaupunki would require approximately 80 km of new 400 kV transmission lines to the coast. A connection to Uusikaupunki could not be implemented before the late 2030s because planning the necessary transmission lines has not even begun.

Connection possibilities in the Bay of Bothnia

During the consultation, more connection points in the Bay of Bothnia, especially in the Kokkola region, were requested. The rationale is the region's consumption potential and active development of offshore wind power projects. In the background scenario for this final report, more growth in electricity consumption was assumed to occur in the Kokkola region instead of Southern Finland. This change would enable a 1.3 GW offshore wind power connection to the Kokkola region. Hirvisuo substation was selected as the connection point in the Kokkola region. Consumption would need to increase substantially in the coastal areas of the Bay of Bothnia to enable connection points in both the Raahe and Kokkola regions in the 2030s because the region is currently very production-dominated.

04

System reinforcements required

This report identifies the preliminary need to reinforce the main grid by more than stated in Fingrid's main grid development plan, published in 2023, to enable the seven offshore wind connections of up to 1.3 GW modelled in this report. The southernmost connection possibilities to Inkoo and Lieto could be realised without significant reinforcement investments in the main grid. Figure 2 shows the preliminary system reinforcement needs.

Approximately 1,000 km of new and reinforced 400 kV transmission lines were identified in the May report. They are shown in red in Figure 2. When the report was updated, approximately 100 km of new main grid reinforcement needs were identified in Ostrobothnia and Southwest Finland. They are shown in black in Figure 2. The new reinforcement needs in Southwest Finland depend on the location of the connection point. Of the three options, Uusikaupunki, which is closest to the Sea of Bothnia coast, would require the construction of an entirely new substation in the Uusikaupunki area and a new 400 kV transmission line connection to the shore.

The modelling used for this report indicate a need for 1,000–1,100 km of new and reinforced 400 kV transmission lines and three to five entirely new substations to connect offshore wind power to the grid. The estimated cost of these is EUR 0.7 billion, most of which is the cost of transmission lines. This is EUR 0.1 billion more than the cost estimate in the spring report. The prices were calculated at current prices without inflation adjustments. It is important to note that these system reinforcement needs would be in addition to Fingrid's current investment programme of approximately EUR 4 billion.

Implementing a new offshore wind connection in the Kokkola region did not lead to significant new reinforcement requirements for the main grid because the background scenario foresees a substantial increase in consumption in the Kokkola region. This updated report highlights that implementing new connection points and providing their timetables depend on rising electricity consumption, especially on the coast of the Bay of Bothnia.

The system reinforcement needs are indicative of the necessary connections between various substations and regions, modelled based on this report. They do not describe the exact line routes. In reality, the reinforcement needs could change significantly, depending on the realised electricity consumption, production and cross-border transmission

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

Fingrid's investment programme will next be updated when the main grid development plan is published in 2025, taking into account the development of electricity consumption and production projects at that time. The results of this report on offshore wind power connection possibilities will not directly lead to investments. However, they will be considered in the future when Fingrid updates its main grid development plan. Fingrid maintains the readiness to connect offshore wind power to the main grid at designated substations and, if necessary, updates the timetables for connection points as offshore wind projects progress.

Main grid reinforcements

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- Grid reinforcements that are included in the main grid development plan
- Grid reinforcements needed to connect offshore wind
- Additional 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

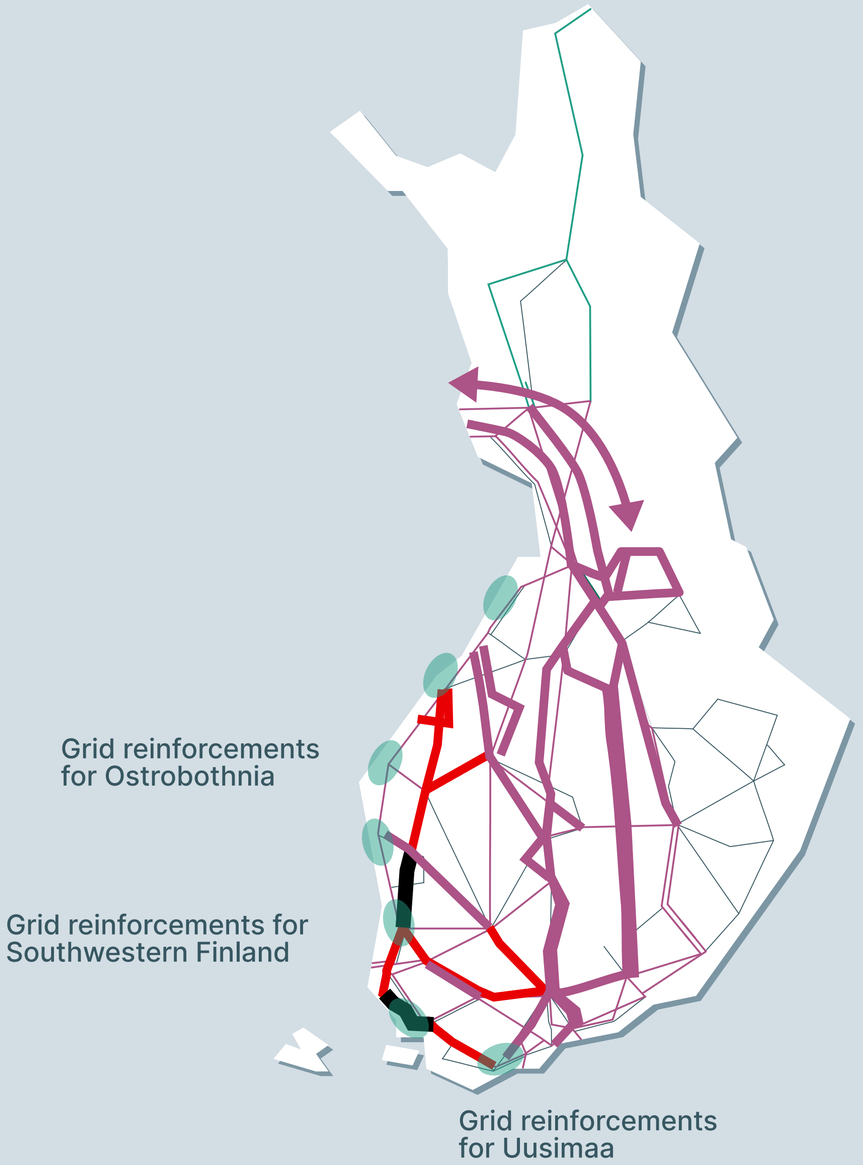

FIGURE 2 Preliminary main grid reinforcement required to enable offshore wind power connections. The system reinforcements shown in the figure describe the connection needs between different substations and regions; they do not describe the exact cable routes.

05

Agreeing on a connection

Fingrid's current practice is to reserve connection capacity for customer projects once the projects are assured of receiving permits. Fingrid has identified the need to update its connection agreement practices, especially for large customer projects, to ensure fair processing of different types of projects. For large projects, the permit application process typically takes a long time, and the customer must make significant financial commitments before the permits are assured.

Figure 3 shows Fingrid's planned three-step connection agreement process for 400 kV connections, consisting of the following phases: letter of intent, preliminary agreement on grid connection, and the actual connection agreement.

Of the process phases, Fingrid currently uses the letter of intent (only for 400 kV connections) and the actual connection agreement. In other words, the preliminary agreement on grid connection is planned to be a new agreement model.

A letter of intent is prepared at the project developer's request and is not an essential step in the connection process.

The letter of intent describes the process leading to a main grid connection and a connection agreement. The parties to a letter of intent undertake to communicate the progress of the project and connection to each other and work together to enable the connection. A letter of intent requires that the customer is entitled to use the project area (for offshore wind power, an exclusive right to the sea area is required) and that the project's EIA programme has been published. In areas requiring town planning (for offshore wind power in the territorial waters, planning of the sea area is required), a planning initiative must also be made. The letter of intent neither guarantees a connection nor reserves the connection capacity.

The purpose of introducing a preliminary agreement on grid connection is to assure the customer that the required connection capacity is available in the main grid for a fixed period. The agreement will be valid for a limited time, and its validity will depend on the customer's project proceeding as planned. Fingrid has yet to determine which phase of an offshore wind power project would be required for a preliminary agreement on grid connection and what progress would be required of the project during the term of the agreement. A procedure must also be in place in case several projects in the same development phase compete for a connection. Moreover, it should be noted that only a limited number of connections may be available for reservation under a preliminary agreement, in order to make connections available also for smaller projects.

A connection agreement represents the final agreement on a connection. Fingrid plans no changes to the prerequisites for connection agreements. In other words, the town plan enabling the project must be legally valid, the project must have a building permit, and an application for an expropriation permit for the connecting line must be submitted to the Ministry of Economic Affairs and Employment. The project must be executed in compliance with the grid code specifications and general connection terms applying when the connection agreement is signed. The connection fees will also be determined according to the procedures applying when the connection agreement is signed.

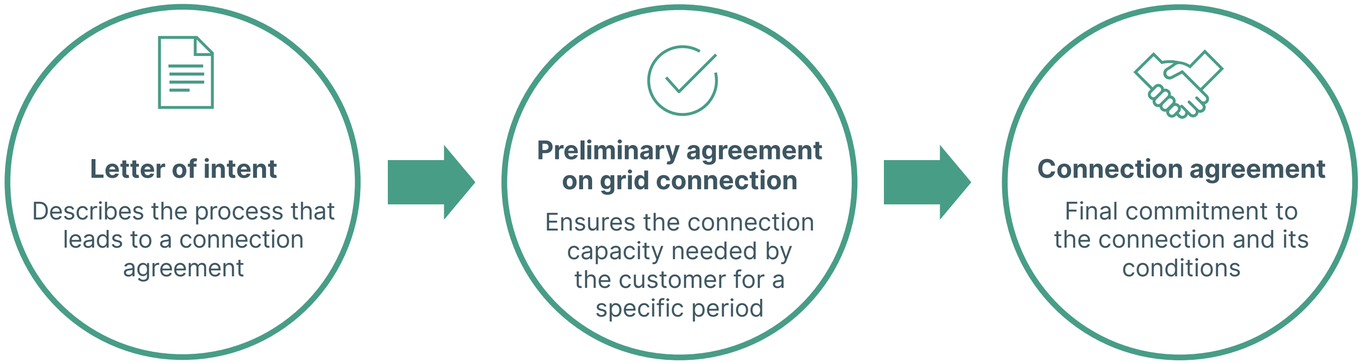

FIGURE 3 The planned three-step connection agreement process for large customer projects.

06

Grid code specifications for offshore wind power

Fingrid's grid code specifications (VJV) set out the requirements for electricity production at power-generating facilities in Finland. They are based on the European Requirements for Generators (RfG). Fingrid is currently updating the grid code specification, with the new specification expected to take effect in early 2025.

The updated specification will not contain specific requirements for offshore wind power. However, additional plant-specific requirements, known as specific study requirements, may be imposed on offshore wind power projects due to their large size. Potential specific study requirements for offshore wind power projects include the following:

- Stability analyses (operation of inverters at low short-circuit powers)
- Need for special protection solutions (such as disconnecting production in the event of a fault in the main grid)
- Power oscillation damping (POD)
- Geomagnetically induced currents (GICs)
- Operating principles for hybrid connections with both production and consumption
- Electricity quality analyses

Figure 4 shows an example timeline of the grid code specification process for an offshore wind power project.

Fingrid and the customer analyse the need for and scope of specific studies in the preliminary planning phase for the power plant before the connection agreement. At that point, Fingrid specifies which specific studies are required based on the preliminary planning information submitted by the customer. The customer is responsible for conducting the specific studies. If Fingrid's network models are required for a study, Fingrid and the customer conduct the study collaboratively. The ultimate interpretations of how the grid code specifications apply to offshore wind power projects arise when the connection agreement is made and the specific studies are conducted in the preliminary planning phase. Some of the specific studies are conducted before the connection agreement (VJV phase 0), and others are agreed to be conducted as part of the actual planning phase (VJV phase 1) once the project's technical design and equipment selections have been clarified. The specific studies must be completed and approved before an interim operational notification (ION) can be granted for the plant, authorising it to begin production.

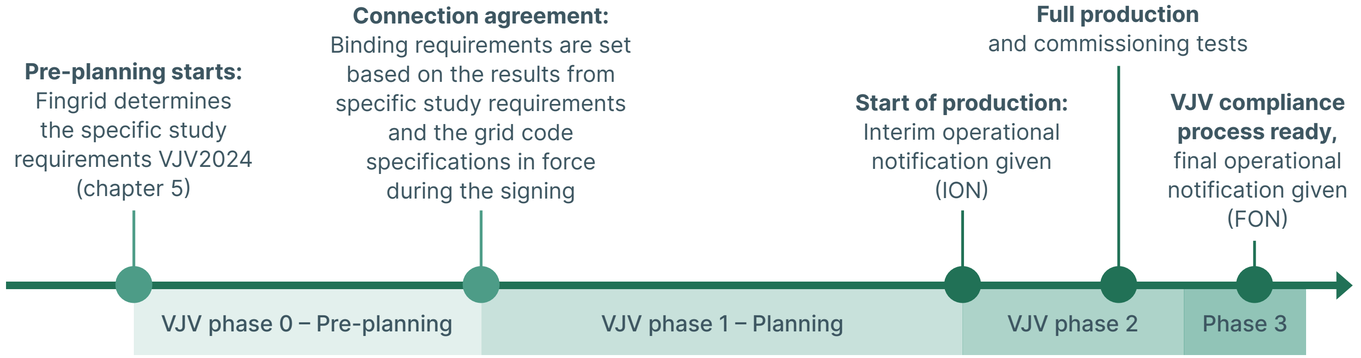

FIGURE 4 Timeline of the grid code specification process for an offshore wind power project.

07

Hybrid connections

A hybrid connection is a connection that includes electricity consumption and production managed by a shared top-level controller, known as a hybrid controller, which makes the operation of plant components interdependent. A hybrid connection may also include grid energy storage facilities in addition to consumption and production facilities. Figure 5 is a general principle diagram of a hybrid connection.

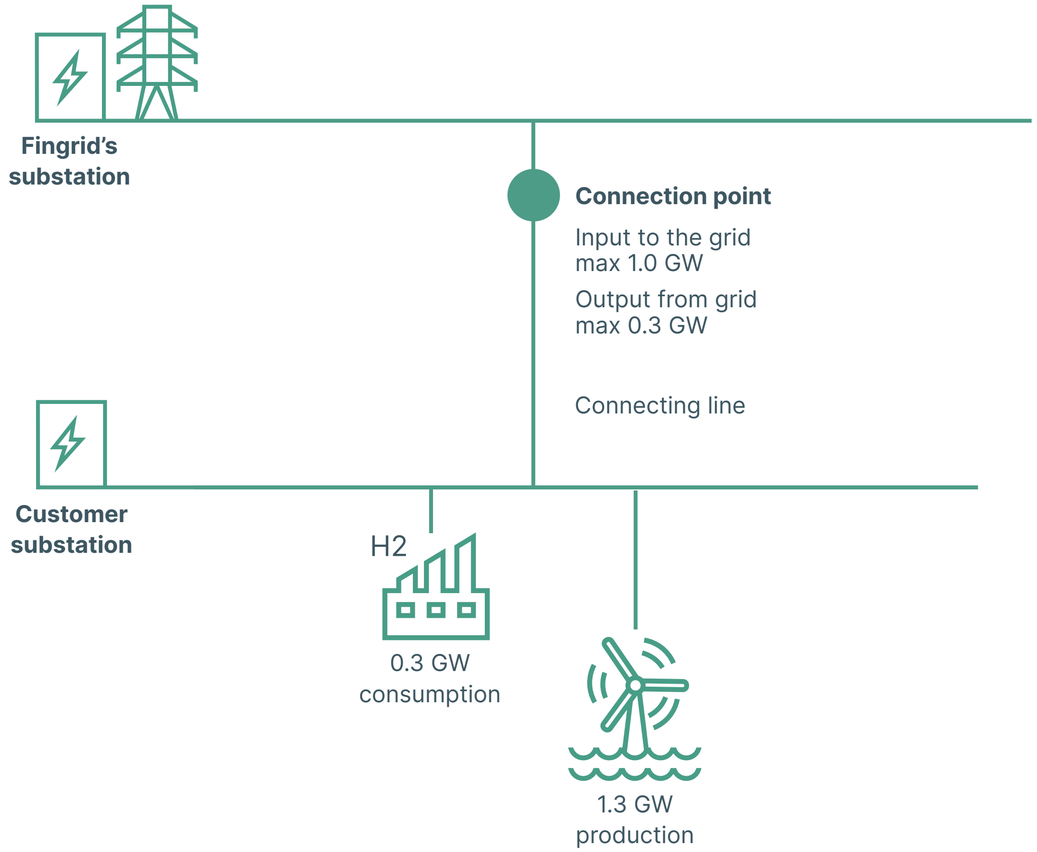

FIGURE 5 Principle diagram of a hybrid connection

Fingrid has examined the possibilities for facilitating hybrid connections to the main grid with the following conditions:

- The customer has one connection point to the main grid. In other words, the customer has one connecting line to one Fingrid substation.
- One party is responsible for the connection. In other words, one contracting party concludes the connection agreement and main grid service agreement with Fingrid for the entire life cycle of the connection. Amendments must be agreed upon separately.
- The hybrid connection agreement specifies separate transmission for production mode (maximum permitted input into the grid) and consumption mode (maximum permitted output from the grid). The party responsible for the connection must ensure these limits are not exceeded.
- The hybrid connection must comply with Fingrid's grid code specifications. If a hybrid connection is built in phases or the plant components are also operated independently (for example, when consumption facility is out of use due to maintenance break), the plant components must also meet the VJV/KJV/SJV specifications independently.
- The customer's hybrid controller must constantly ensure that the electricity production and consumption track each other to avoid exceeding the agreed transmission limits. In addition, the customer must equip the hybrid connection with protective devices in order to remain within the agreed transmission limits.
- Fingrid must be entitled to disconnect plant components in a hybrid connection, either partially or entirely, if the agreed transmission limits are exceeded.
- Fingrid must receive real-time status and power data on the plant components and hybrid controller.
- The customer must conduct a reliability study on the functionality of the systems essential for the main grid's system security and submit the study to Fingrid for approval. In addition, the functionality of these systems should be tested before commissioning and periodically thereafter.
- The telecom connections between the plant components must be reliably duplicated.

Furthermore, hybrid connections require an amendment to the Electricity Markets Act to enable connection lines capable of connecting electricity consumption facilities and power-generating facilities to the grid. The Ministry of Economic Affairs and Employment has indicated that the amendment will occur in spring 2025. If the amendment is enacted, Fingrid plans to enable hybrid connections with a production component of up to 1,300 MW. Fingrid is still examining the terms and conditions for hybrid connections with a power greater than 1,300 MW, as well as the power limits to impose on consumption. In addition, Fingrid will further investigate hybrid connections where the customer has several connection points at one Fingrid substation.

08

Next steps

Offshore wind power has the potential to become a key part of Finland's energy future in the coming decades. However, it remains to be seen 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. Offshore wind power can be expected to become profitable first in production areas where the wind production profile does not strongly correlate with existing onshore wind power production. Fingrid will continue to monitor the development of offshore wind power projects, work closely with project developers, and respond to the progress of customer projects.

This report focused on the grid connection possibilities for offshore wind power in the 2030s. If offshore wind power projects are realised then, growth can be assumed to continue in the subsequent decades. Fingrid will examine the longer-term outlook in its vision work, which will be carried out next year as a follow-up to the electricity system vision of 2023.

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Responsibly.

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