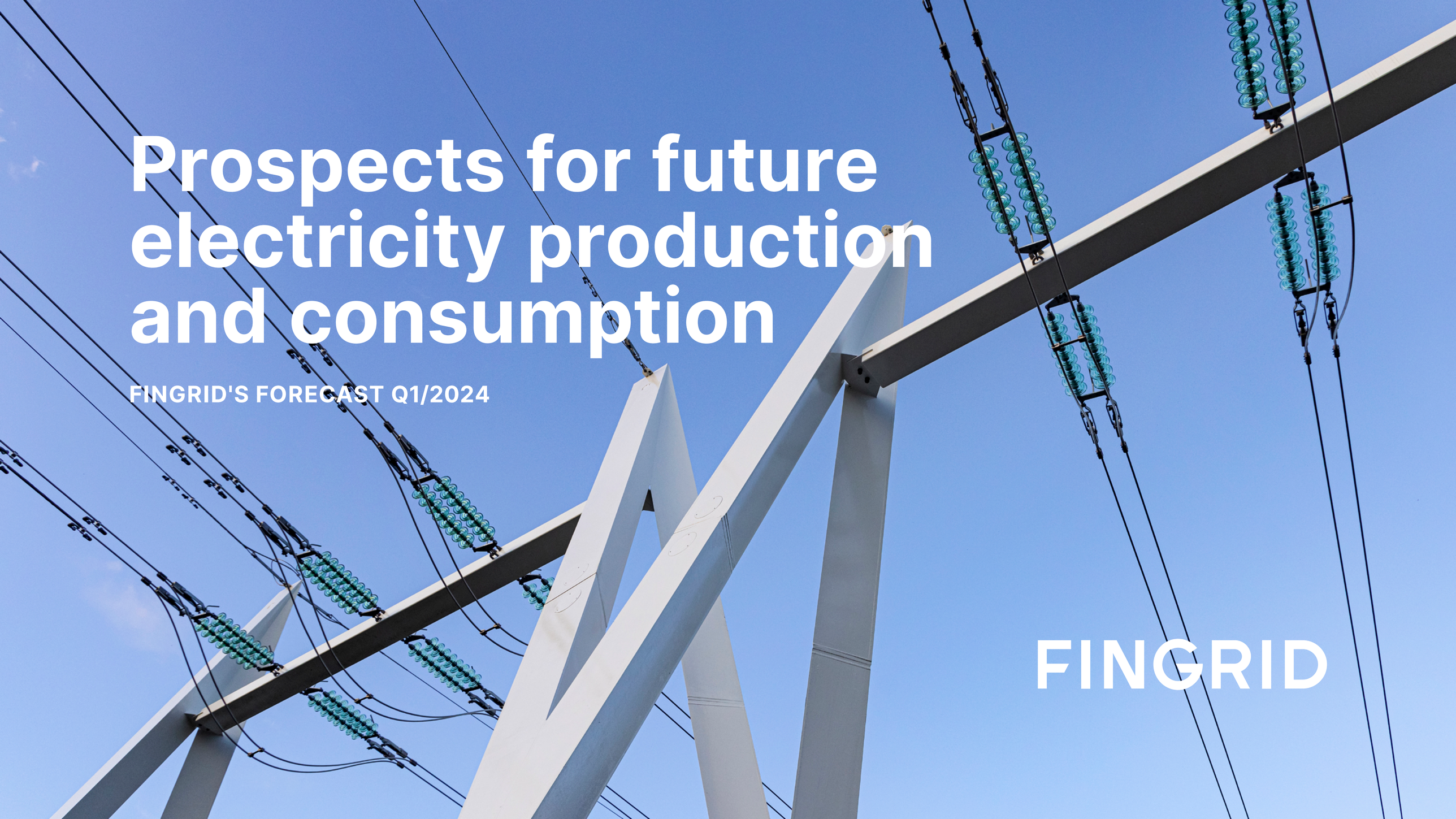

Prospects for future electricity production and consumption

FINGRID'S FORECAST Q1/2024

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Q1/2024

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Prospects for future electricity production and consumption

Reliable electricity grids are among the most important national competitiveness factors. **3**

Finland's large and competitive renewable electricity production potential offers excellent opportunities to succeed in the energy transition. **11**

01

Background

Energy production and consumption are undergoing a transition from conventional, mainly combustion-based energy to the increasing use of emission-free electricity. The need for clean electricity is forecasted to grow rapidly across Europe. Finland's large and competitive renewable electricity production potential provides excellent conditions for success in this transition. This can be seen in Fingrid: connection enquiries for renewable electricity production have been growing rapidly for several years, and Fingrid is already aware of 350 gigawatts of wind and solar power production projects. Currently, enquiries related to new power-intensive industrial projects[1] have also started to grow strongly, exceeding 25 gigawatts. In 2022–2023, more than 4 gigawatts worth of new power-intensive industry projects have progressed to the EIA or permit process, with a planned total electricity consumption of more than 30 terawatt hours. Projects have also progressed to investment decision and construction phases. For example, the total number of electric boilers used for heat and steam production in district heating and industry will grow to at least 1.5 gigawatts in the next few years due to investment decisions already made.

Reliable electricity networks are one of the most important national competitiveness factors for industrial projects requiring clean energy. Therefore, the long-term planning of the main grid must be prepared for the realisation of even high electricity consumption and production potentials. The forecasts presented in this document reflect the baseline scenario used in main grid planning, and their realisation involves several uncertainties. Uncertainties may affect the implementation schedules of production and consumption projects and, in general, the speed and direction of change. Such uncertainties include energy policy, regulation, permitting, availability and cost of financing, as well as the cost development of electricity and hydrogen production and storage technologies. The impact of various factors on the growth potential and price competitiveness of Finnish wind power relative to European and global competitors is particularly significant, as a considerable part of the projected growth in electricity consumption in Finland relies on refining electricity produced with wind power into export products.

[1] The figure includes electric boilers used in district heat production.

Achieving Finland's climate goals and enabling clean transition investment projects that create economic prosperity in Finland require significant main grid construction and development. According to our preliminary estimate, Fingrid's current main grid investment programme of approximately four billion euros will, if realized, enable the kind of development described in the forecast, though especially the geographical location of production and consumption projects creates some uncertainty in this regard. It is also important that opportunities to develop the main grid are maintained in the future. Smooth permitting and predictable regulation that enables grid investments play a key role in this.

Fingrid has previously presented forecasts and scenarios for the development of electricity consumption and production as part of the Main Grid Development Plan and the Network Vision and Electricity System Vision projects. The stakeholder feedback received from these projects has been valuable for the development of the main grid. Our goal is to continue communicating our views in order to increase transparency and enable even better dialogue between Fingrid and stakeholders. In this way, we ensure that the main grid and electricity system are planned on the basis of the best available information.

We welcome free-form feedback on this report by email at strateginen.verkkosuunnittelu@fingrid.fi. In the next update of the forecast, we will take into account the feedback received on this report.

02

Prospects for future electricity consumption

Figure 1 shows the development of electricity consumption in Finland by 2030 according to Fingrid's forecast. Electricity consumption is expected to increase in industry, heating and transport. Most of the growth included in the forecast will come from the electrification of industrial processes, data centres and the production of hydrogen and hydrogen derivatives. Connection enquiries for electricity consumption have increased significantly, and if all connection enquiries received by the end of 2023 were implemented in full, Finland's electricity consumption would rise to more than 200 terawatt hours. The forecast assumes a much more moderate development, with electricity consumption rising to around 130 terawatt hours by 2030, but still a significant increase of around 50 terawatt hours compared to current levels.

In addition to hydrogen production, the growth in industrial electricity consumption has several drivers, such as electricity for metals processing (in addition to hydrogen reduction), data centres, battery manufacturing, and the replacement

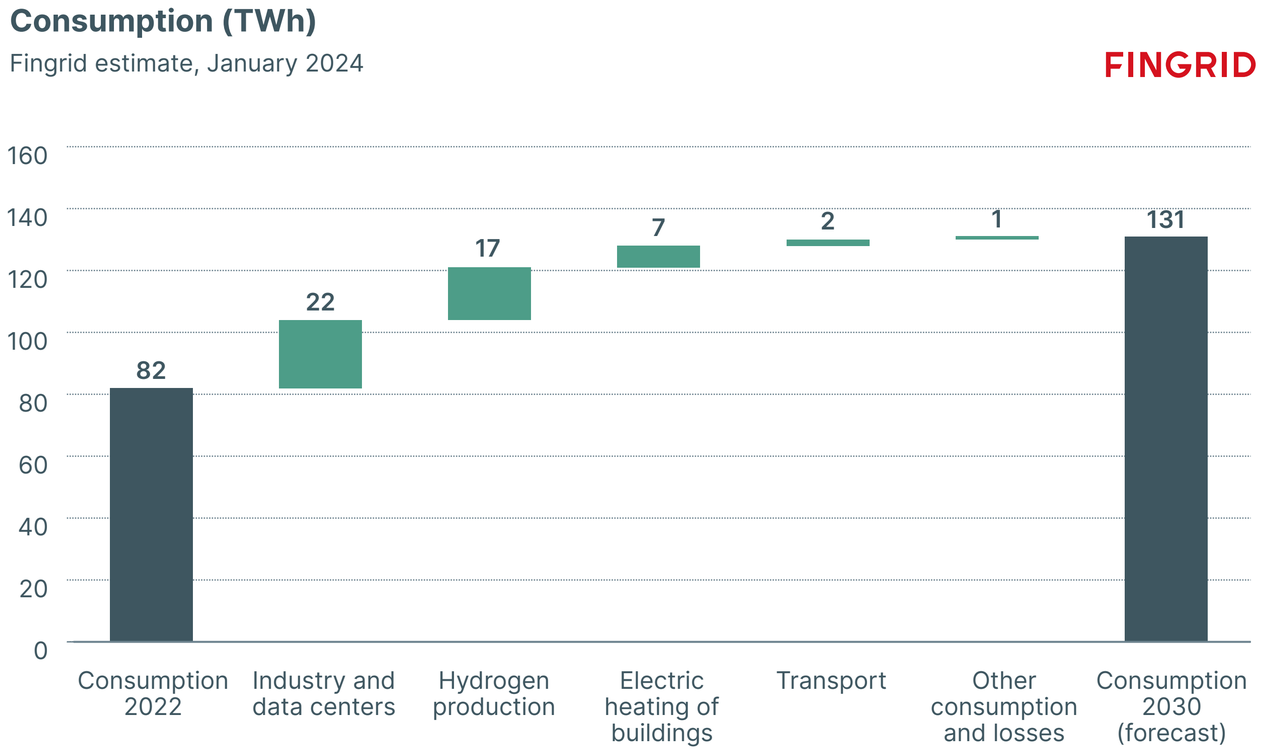

FIGURE 1 Growth drivers of electricity consumption in the 2020s.

of combustion with electricity in heat and steam production. As a whole, the projected growth in industrial electricity consumption is approximately 40 terawatt hours, of which about half will be directed at the production of hydrogen and electric fuels and the other half at other industrial activities. The growth in industrial electricity consumption will take place particularly in the second half of the 2020s and beyond.

Industrial electricity consumption is the biggest driver of growth in the forecast. It also involves the greatest uncertainty in terms of the forecast, as the growth rate depends on Finland's competitiveness in projects that require a lot of clean electricity. The competitiveness and growth potential of Finland's wind and solar power compared to European and non-European competitor countries play a key role in this. In addition, it is essential that Finnish industry is able to make efficient use of low-cost electricity production that varies according to the weather.

Electricity consumption for space heating is forecast to increase by about seven terawatt hours. This increase is boosted especially by electric district heating, where investment in electric boilers has grown sharply over the past year. As a result of the investment decisions, the electric boiler capacity utilised in district heat production is estimated to grow to more than one gigawatt over the next two years. Along with this, the number of electric boilers is growing in industry. In the report, the consumption of industrial electric boilers is presented in the category Industry and district heat production in the category Space Heating.

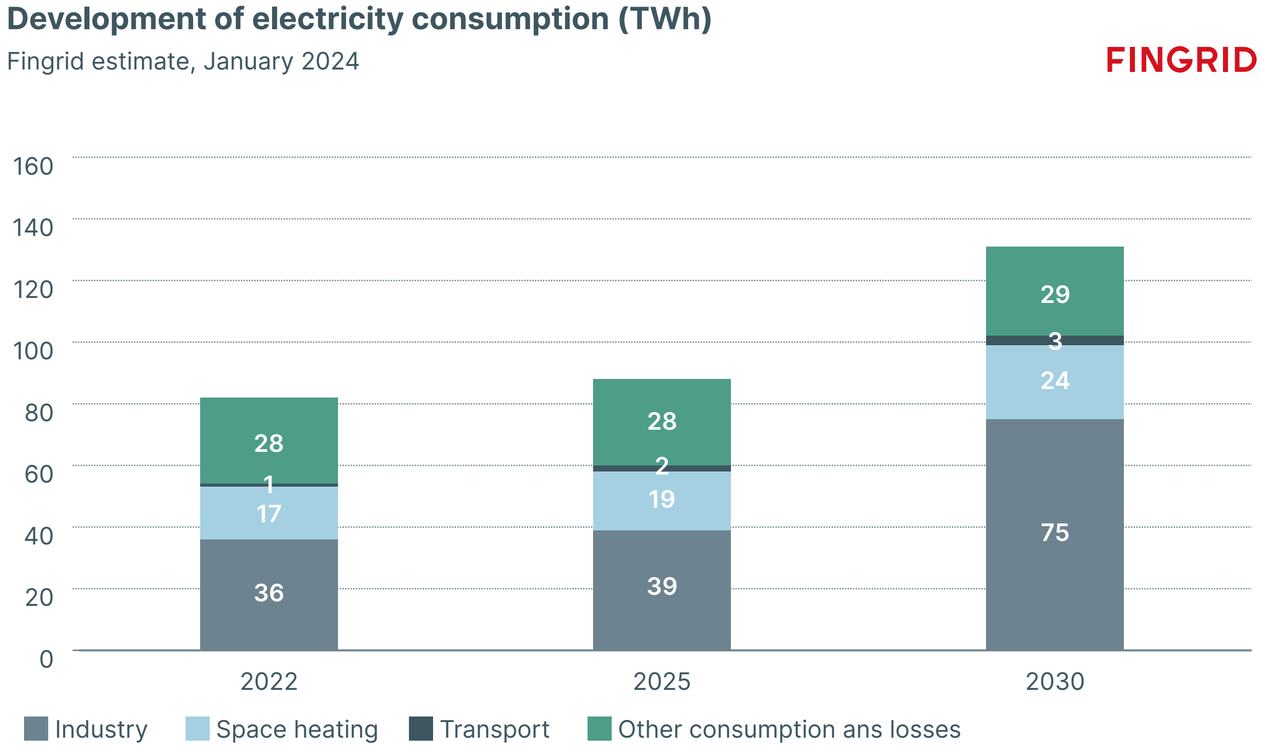

FIGURE 2 Development of electricity consumption in different sectors in 2025 and 2030 compared to 2022.

According to the forecast, electricity consumption in transport[2] will increase to more than three terawatt hours from the current one terawatt hour. Depending on mileage and specific consumption, the increase corresponds to the electricity consumption of approximately 800,000–900,000 electric and plug-in hybrid passenger cars in 2030. Despite the forecasted rapid growth in the number of electric cars, the total annual electricity consumption of electric transport is very small compared to industrial electricity consumption. However, the impact of charging electric cars on the need for electric power is large, and thus optimising the charging time has significant effects on the electricity system.

Fingrid is preparing for strong consumption growth in the sectors presented above. Compared to the forecasts presented in the 2023 Main Grid Development Plan, the growth in industrial electricity consumption has remained more or less the same. For hydrogen production, the growth forecast has been slightly delayed compared to the previous forecast due to the slower-than-expected progress of some projects. We continue to estimate that Finland will be an attractive destination for hydrogen investments, as long as the European hydrogen value chain as a whole gets the investment wheels turning. For electric district heating, forecasts have risen due to the investment boom in electric boilers. For electric transport, the forecasts remain unchanged.

[2] Excludes electricity used in the production of electric fuels used in transport. In the forecast, electricity used in the production of electric fuels is included in the categories Industry and Hydrogen Production.

03

Prospects for future electricity generation

Electricity production in Finland has grown rapidly. In 2012–2022, electricity production varied between 65 and 70 terawatt hours. In 2023, production was approximately 78 terawatt hours, and in 2025, production is forecasted to exceed 90 terawatt hours. In 2026, production would approach one hundred terawatt hours, and by 2030 production is forecasted to rise to almost 140 terawatt hours. Such a large increase in production requires strong growth in domestic consumption in order to enable market-based production growth. The development of electricity production is shown in Figure 3.

The growth in electricity production is strongest in wind power. The growth forecast for wind power until 2030 is shown in Figure 4. If realised, the projects under construction and those that have already signed a connection agreement to the main grid will increase wind power capacity to approximately 11 gigawatts by the end of 2026. This corresponds to an annual production of approximately 30–35 terawatt hours, i.e. about a third of Finland's electricity consumption. Wind

Projected development of electricity generation (TWh)

Fingrid estimate, January 2024

FINGRID

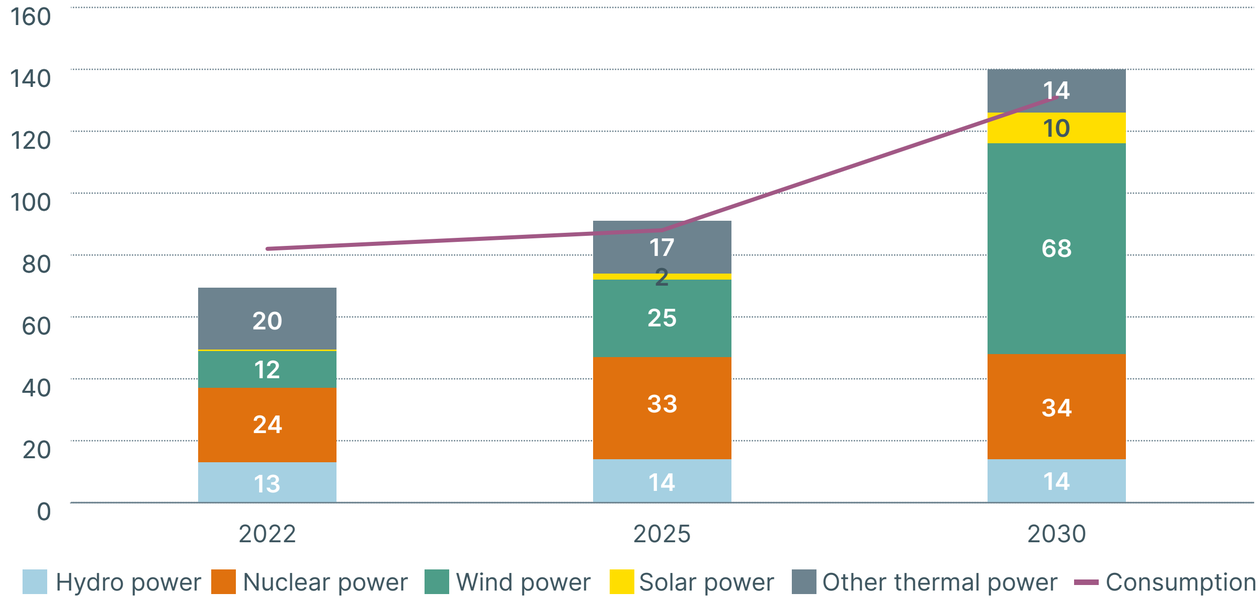

FIGURE 3 Projected development of electricity generation.

power production capacity is projected to continue to grow as electricity consumption increases, reaching 21 gigawatts in 2030. This means that wind power would produce 65–70 terawatt hours of electricity per year, which corresponds to about half of Finland's projected electricity consumption. Wind power is projected to be built onshore until 2030, and the first large offshore wind projects are expected to be completed in the early 2030s.

In addition to wind power, significant growth drivers of electricity production include the Olkiluoto 3 nuclear power plant and the growing production of solar power. Solar power production capacity has grown strongly in 2022–2023, mainly due to rooftop solar panels. According to the Energy Authority[3], solar power capacity was already well over 600 megawatts at the beginning of 2023, and by the end of the year the capacity grew to about a gigawatt level. From 2024 onwards, solar power production is also expected to grow significantly in large ground-mounted solar farms, and in the long term, the majority of solar power would be located in such farms. The growth forecast for solar power is shown in Figure 5.

For other forms of production, Finland's nuclear electricity production will rise to slightly under 35 terawatt hours with Olkiluoto 3 in 2024. In addition, the forecast takes into account the planned power upgrades of the Olkiluoto 1 and 2 power plant units.[4] Net hydro power production[5] is expected to remain at around 14 terawatt hours. The production of thermal power is expected to decline moderately. The production decline caused by the closure of fossil thermal power production is partly offset by the Kemi bioproduct mill power plant (250 MW), which was completed in autumn 2023.

Compared to the forecasts presented in the 2023 Main Grid Development Plan, the growth forecast for wind power production has been slightly reduced for the next few years. In terms of solar power, the forecast for the next few years in particular has risen. In the longer term, the growth trends of wind and solar power are largely unchanged and wind power will become by far the largest form of production in Finland, whilst the share of solar power is estimated to be between 5–10 per cent of Finland's electricity production. For other forms of production, there are no significant changes in the forecast.

The realisation of the production forecast requires a significant increase in consumption, and correspondingly, the realisation of the consumption forecast requires that a sufficient amount of affordable and clean electricity is available. The majority of new electricity production is based on wind and solar power, and especially onshore wind power, where Finland's competitive advantage is strongest. However, industrial energy demand has traditionally been stable, and this development will require a significant increase in demand-side response and energy storage capacity in Finland. New storage capacity can be obtained, for example, from pumped storage power plants, battery power plants, growing electric transport, heat storage, and the storage of hydrogen and synthetic fuels.

[3] energiavirasto.fi/-/aurinkosahkon-pientuotanto-kasvoi-voimakkaasti-vuonna-2022
[4] tvo.fi/ajankohtaista/tiedotteetporssitiedotteet/2024/olkiluoto1-jaolkiluoto2-laitosyksikoidenkayttoianpidennystajatehonkorotustakoskevayva-ohjelmaonvalmistunut.html
[5] Production of hydro power without electricity produced or consumed by pumped storage power plants.

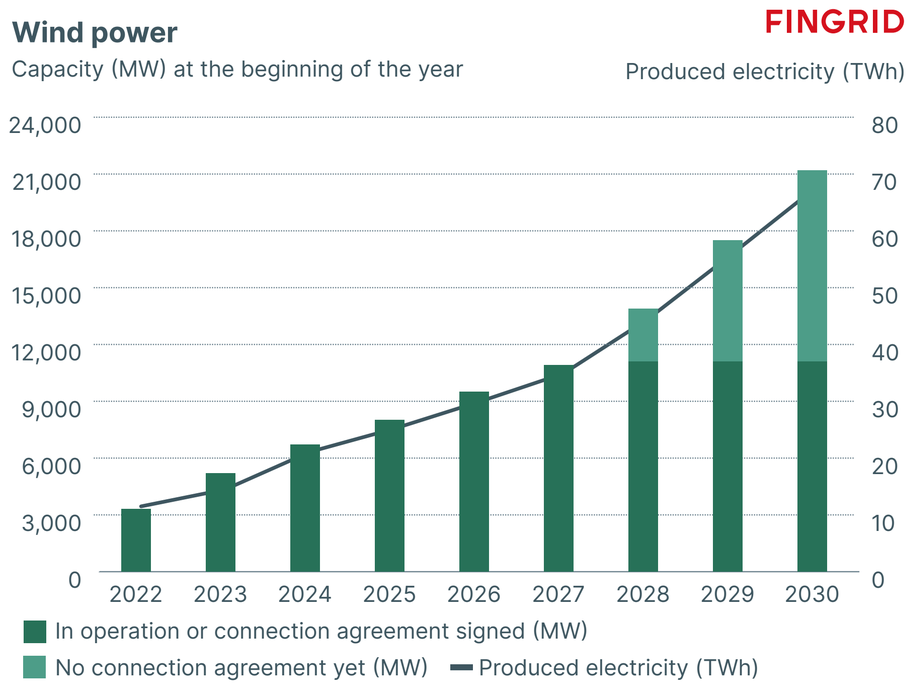

FIGURE 4 Projected development of wind power.

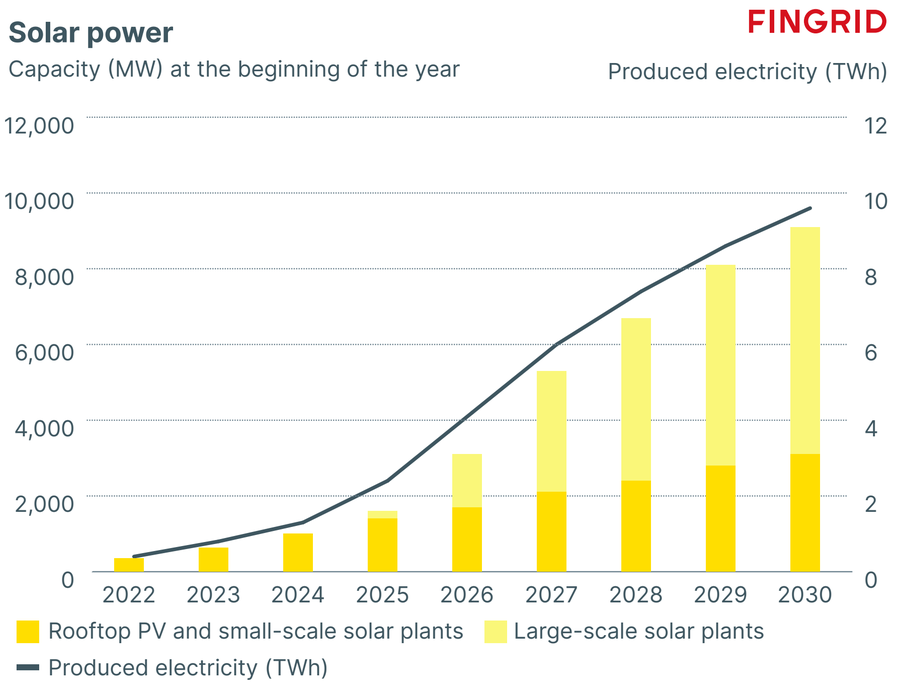

FIGURE 5 Projected development of solar power.

04

Prospects for future electricity imports and exports

Finland almost reached annual self-sufficiency in electricity in 2023, i.e. the amount of electricity produced (78 terawatt hours) and consumed (80 terawatt hours) in Finland during the year was approximately at the same level. This is a significant change, as in 2012–2021, net imports of electricity to Finland amounted to around 15–20 terawatt hours per year, or 20–25 per cent of consumption. The growth in self-sufficiency enabled by wind power and Olkiluoto 3 has been remarkably fast. The development forecast for Finland's electricity balance is shown in Figure 6.

Finland is not expected to become self-sufficient in terms of electrical power within the horizon of the forecast, which means that Finland will still need imported electricity in low-wind peak consumption situations, for example. The development of power self-sufficiency is affected by the extent to which the fossil capacity being phased out is replaced by, for example, energy storage facilities or new flexible production capacity. In addition, power self-sufficiency is significantly affected by how flexible Finland's future electricity consumption investments will be. On the other hand, even if Finland were self-sufficient in power, there would still be situations where electricity is cheaper in neighbouring countries and importing electricity would be profitable. The export-import balance for an individual year is significantly influenced by the weather conditions (rainfall, wind, sunshine, temperature) in Finland and surrounding areas.

Net exports of electricity are forecast to be around 5–10 terawatt hours per year in the second half of the 2020s, which corresponds to approximately seven per cent of electricity consumption. Finland is not expected to develop into a significant net exporter of electricity, but the majority of the growth in electricity production will correspond to the growth in electricity consumption in Finland. Instead of exporting electricity, Finland will produce products with higher added value from electricity for the domestic market and export.

Changes in the production and consumption balance of electricity in Finland and neighbouring areas will change transmissions on cross-border connections between Finland and neighbouring countries. In recent years, electricity has mainly been imported from Sweden to Finland and exported from Finland to Estonia. Transmission between Finland and Sweden is becoming more balanced. This is due not only to the increasing production of electricity in Finland, but also to the considerable increase in electricity consumption in northern Sweden.

Transmission from Finland to Estonia will remain very export-oriented in the next few years. The electricity production potential in the Baltic region is good, and if wind and solar power capacity increases as anticipated, electricity imports from Estonia to Finland will gradually increase in the second half of the 2020s. This will balance the transmissions on the EstLink connections between Finland and Estonia. Electricity consumption is not expected to grow significantly in the Baltic countries.

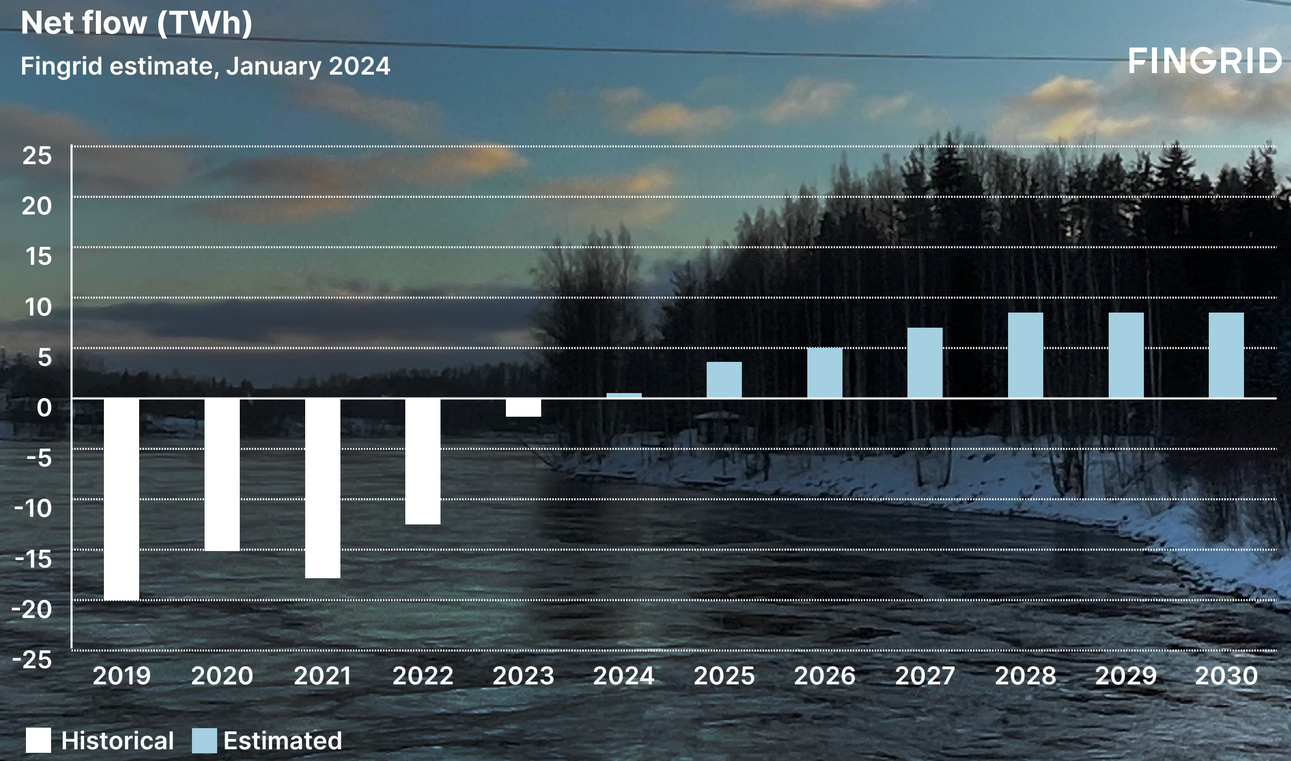

FIGURE 6 Finland's actual annual electricity balance in 2019–2023 and forecast for 2024–2030.

05

Preparing the forecast

The forecast is based on connection enquiries received by Fingrid for production and consumption and on the results of electricity market modelling. The forecast takes into account the growing need for clean electricity and products produced from electricity in Europe, as well as Finland's excellent potential to be a competitive producer of these products. The forecast has been created so that it is challenging in terms of main grid planning and the electricity system, but nevertheless realistic. The forecast guides Fingrid to proactively solve challenges related to the transition of the electricity system and to find solutions with which the company can contribute to enabling investments related to clean electricity located in Finland. The forecast takes into account Fingrid's connection agreements with production, consumption and storage projects, but the projected total growth also includes capacity for which a connection agreement has not yet been made. On the other hand, the forecast does not include nearly all projects for which Fingrid has received a connection enquiry.

Electricity market modelling models the operation of the electricity market and the resulting electricity transmission needs on an hourly basis. The modelling takes into account growing electricity consumption and growing electricity production that is becoming increasingly variable according to the weather. In addition to Finland, the entire Baltic Sea region and central and western Europe have been taken into account in electricity market modelling. For other countries, forecasts received from other transmission system operators and scenarios prepared by the European Network of Transmission System Operators for Electricity (ENTSO-E) have been utilised. The modelling assumes that the price formation of the electricity market in Finland will remain unchanged ("energy-only"), possibly supplemented by a capacity mechanism for new flexible capacity investments or investment aid with moderate annual costs (AFRY's[6] estimate: EUR 50 million per year) and thus the impact on the forecast would be limited. If a market-wide capacity mechanism were to be introduced in Finland, its impact on the forecast would have to be considered separately, considering the wider implications as well as the higher annual costs (Afry's[6] estimate: EUR 500–1,000 million per year.

[6] Afry: Assessment of capacity solutions to ensure sufficient electricity supply in Finland. fingrid.fi/contentassets/847fad4023ae42b2add99fffd0e81bab/fingrid--capacity-markets-high-resoultion_links.pdf

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