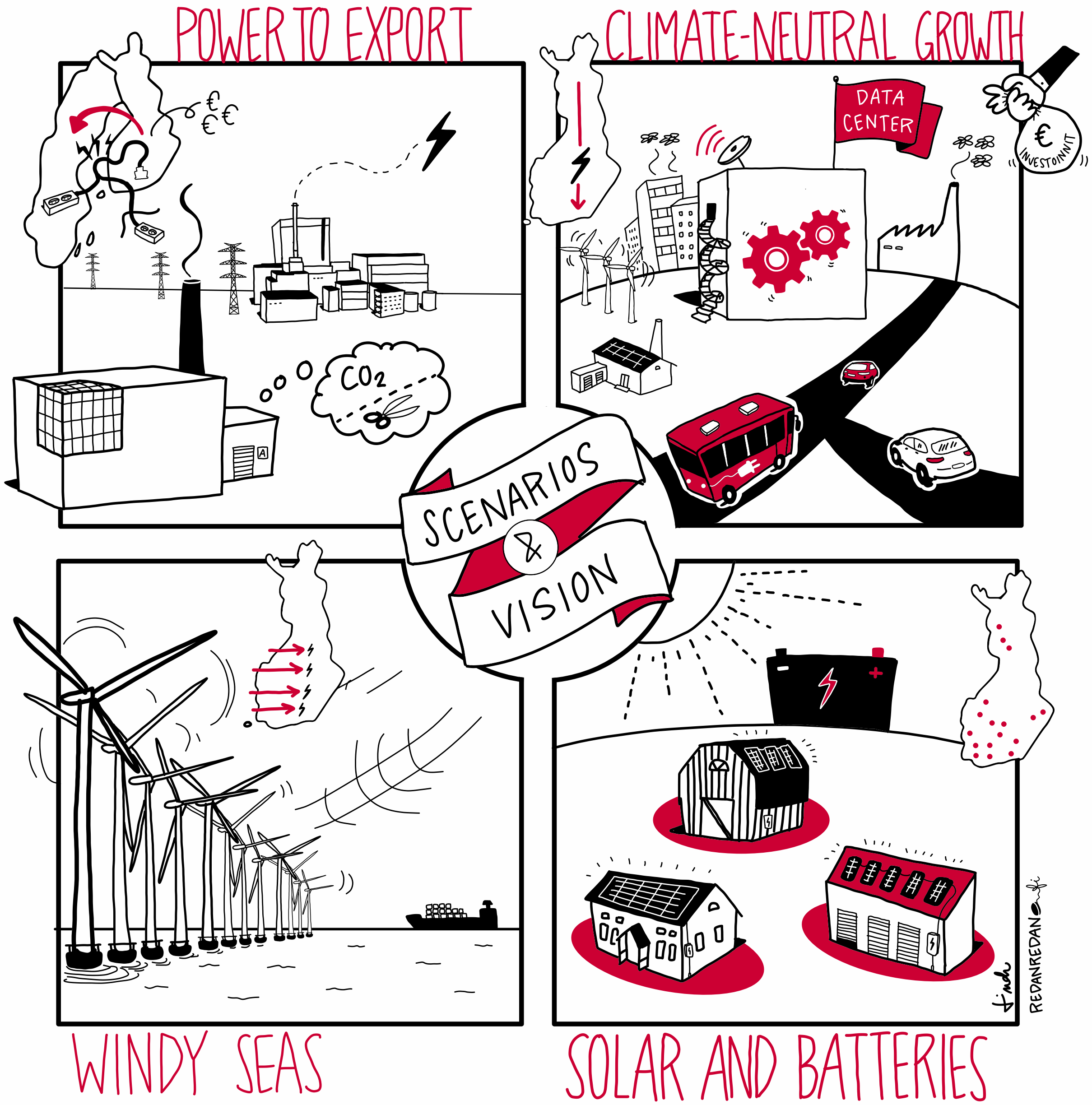


Network vision draft scenarios

FINGRID

Table of contents

Introduction

Work on Fingrid's network vision

Fingrid has begun working on its network vision with the aims of gaining insight into the development needs on the main power transmission grid (400 kV and 220 kV) and creating proposals for long-term solutions. Fingrid has chosen to examine the target years 2035 and 2045 for its network vision to ensure that the vision extends far enough into the future with respect to the planning of the main grid. It is particularly interesting to include year 2035 in the analysis, as this is the year in which Finland aims to become carbon neutral.

Fingrid's network vision work takes place in three phases: creating scenarios, identifying future challenges for the main grid, and planning network solutions to address these challenges. The first phase involves examining possible development pathways in the future and seeking to create sufficiently different scenarios. Once the scenarios and associated starting points are in order, Fingrid's network planners will identify the main grid's transmission needs based on each scenario and consider any necessary solutions to address these. This document focuses on the first phase of the work: building scenarios. When the network vision work is complete, Fingrid will publish a final report describing the possible solutions to strengthen the grid along with any other long-term network development solutions. This particular document is a translation from original Finnish document "Verkkovision skenaarioluonnokset" published on 28th of August 2020. In cases of ambiguities, the original Finnish document shall prevail.

Starting points for the scenario work

The network vision work involves assessing the need to strengthen the main grid under different scenarios. The scenarios represent the potential trends in electricity consumption and generation for which contingencies must be made in the main grid planning. The most significant variables in the scenarios are the electricity consumption of industry, heating and transport and the regional distribution of this consumption, the amount and location of onshore and offshore wind power generators, the amount of decentralised solar power, the amount of flexibility available in generation and consumption, and various potential combinations of new nuclear power construction and the continued operation of existing nuclear power plants. Four different scenarios have been created by consistently combining these and other variables, and each scenario is intended to give rise to distinct development needs for the main grid.

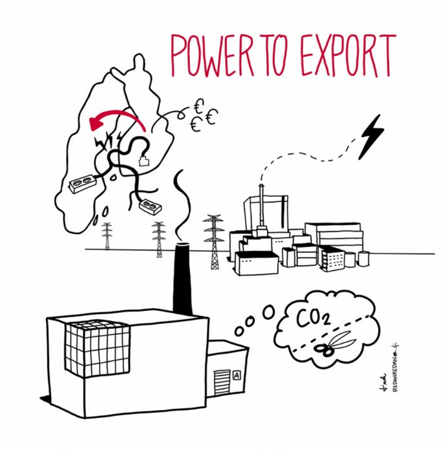
The network vision work aims to identify the main grid solutions that will be required in the future. The most suitable solutions will serve many or all of the four scenarios. The development pathways have been incorporated into the scenarios in such a way that they do not counteract each other's effects from the perspective of network development. Instead, each scenario contains challenging elements with regard to network development, such as large net imports/exports of electricity or major needs for transmission within the country. The scenarios are not forecasts for the future, nor do they seek to describe how Fingrid would like the future to be. The analysis places equal value on each scenario.

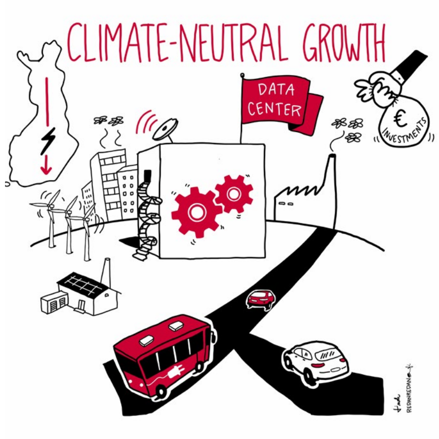
Fingrid has created its scenarios for Finland independently. The sectoral low-carbon roadmaps published in the spring of 2020 were a key source of data, especially in terms of electricity consumption trends. In addition to the electrification pathways described in the low-carbon roadmaps, some of the scenarios include other sources of growth in electricity consumption, such as Power-to-X generation located in Finland. In terms of electricity generation, the scenarios are based on varying assumptions of the potential for and profitability of building different forms of electricity generation, and these were used as the basis for preparing a suitable electricity generation structure for each scenario. The joint European scenarios prepared by ENTSO-E and ENTSOG under the Ten-Year Network Development Plan (TYNDP)[1] were used as sources of initial information for other countries, along with more detailed information obtained

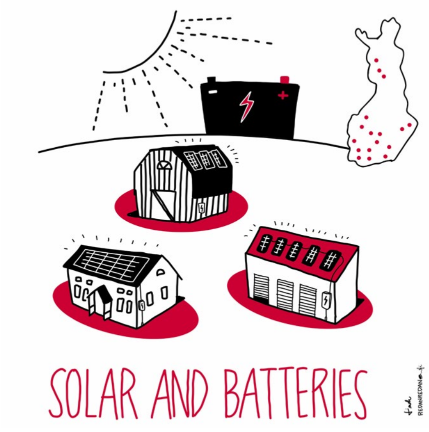
[1]Further information on the ENTSO-E and ENTSOG TYNDP process and scenarios: https://www.entsos-tyndp2020-scenarios.eu/

from transmission system operators in the Baltic Sea region. This information has been altered in the scenarios to ensure that the assumptions for other European countries are consistent with Fingrid's assumptions for Finland. In particular, the scenarios include specific variations in regional development pathways with the greatest relevance for and impact on Finland, such as nuclear power in Sweden.

The four scenarios examined here are called Power to Export, Climate-Neutral Growth, Windy Seas, and Solar and Batteries. The image and table below provide brief descriptions of each scenario and a comparison of the scenarios in terms of their most significant variables. The following chapter explains each scenario in more detail. The final section of this document is a summary that compares the scenarios.







Power to Export

- No significant electrification, consumption does not increase much
- Onshore wind power and nuclear power are the dominant forms of electricity generation, combined heat and power is mainly maintained.
- Electricity exports drive growth in electricity generation.

Climate-Neutral Growth

- Fossil-fuelled energy is replaced by electricity
- Significant new electricity-intensive industrial production in Finland
- High onshore wind power and maximum north-south electricity transmission

Windy Seas

- Fossil-fuelled energy is replaced by electriciy
- Some new electricity-intensive industrial production in Finland
- Lots of offshore wind power
- Electricity generation is increasingly focused on the west coast

Solar and Batteries

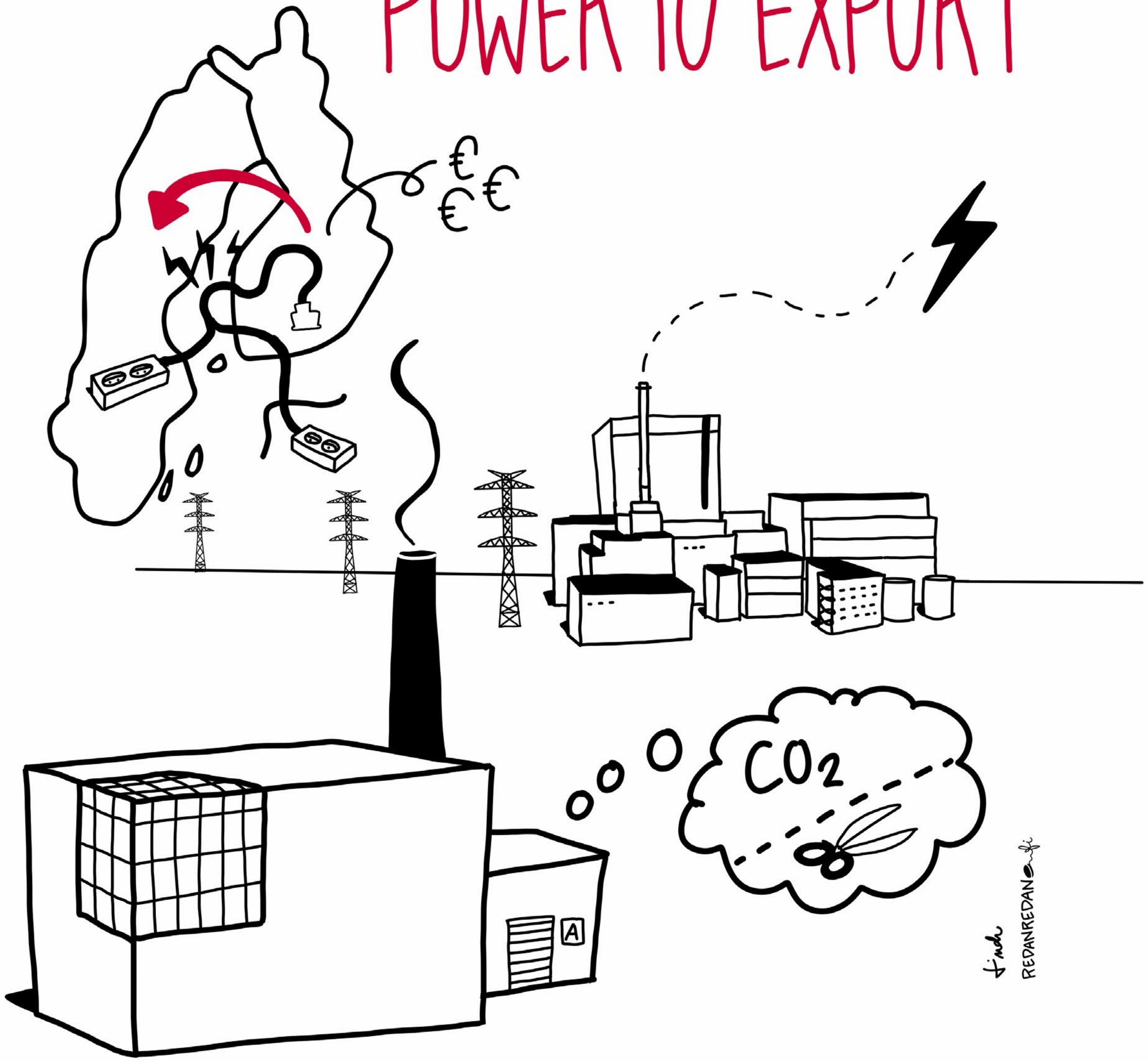
- Fossil-fuelled energy is replaced by electricity
- Lots of decentralised solar power and battery storage connected to distribution networks
- Small amounts of conventional power generation, low inertia
- On an annual basis, Finland will remain a net importer of electricity

Most significant variables in the scenarios	Power to Export	Climate-Neutral Growth	Windy Seas	Solar and Batteries
Hydroelectric power	≈	≈	≈	≈
Onshore wind power	++	+++	+	+
Offshore wind power	≈	+	+++	≈
Solar power and energy storage	+	+	+	+++
Nuclear power	+	≈	+	-
Other thermal power	-	--	--	-
Electricity consumption	≈	+++	++	+
Available demand-side response	+	+++	++	++
Finland's annual balance of electricity exports and imports	Exports	Balanced	Balanced	Imports

The table shows how the most significant variables differ between the scenarios. The variables in the table are not comparable with each other. More precise figures on the differences between the variables from one scenario to the next are presented in the section entitled "Summary of the scenarios". Meanings of the symbols used in the table: ≈ no significant change, + increase, - decrease.

Scenarios

POWER TO EXPORT



Under the Power to Export scenario, Finland will not reach its target of becoming carbon-neutral by 2035, and energy derived from fossil fuels will not be replaced by electricity on any significant scale. Other European countries will comply with the EU's climate targets (known as the 40–32–32.5 targets), which were updated in 2018[2]. The tools and solutions related to implementing energy generation and the EU's climate policy will be primarily national in scope.

[2]https://ec.europa.eu/clima/policies/strategies/2030_en

In terms of the network structure, this scenario describes a future in which Finland is a net exporter of electricity. Power to Export is the scenario in which Finland's consumption does not appreciably increase. Although Finland's electricity consumption will not significantly increase, a substantial amount of onshore wind power will be constructed in Finland because it will be competitive in the joint European electricity market and Finland offers good wind and construction conditions.

Electricity consumption

Electricity consumption under the Power to Export scenario (TWh)	2018	Change 2018-2035	2035	Change 2035-2045	2045
Industry	42	+4	45	+0	45
Heating	17	+2	19	+0	19
Transport	1	+2	3	+2	5
Other consumption and losses	28	-1	27	-1	26
Total	87	+7	95	+0	95

Under the Power to Export scenario, consumption will increase only by a small amount. Stand-alone fossil-fuelled heating plants will largely be replaced by electricity, and the use of electricity in passenger transport will increase moderately. The growth in electricity consumption envisaged in the sectoral low-carbon roadmaps will not materialise, and no other significant investments will be made in electricity-intensive sectors in Finland. Demand-side response will increase somewhat, mainly thanks to the flexibility provided by smart charging systems for electric vehicles.

Electricity generation

Electricity generation capacities under the Power to Export scenario (GW)	2018	2035	2045
Hydroelectric power	3	3	3
Onshore wind power	2	14	17
Offshore wind power	0	0	0
Solar power	0	3	5
Nuclear power	2.8	5.6	5.6
Other thermal power	8	5	5

Electricity generation under the Power to Export scenario (TWh)	2018	2035	2045
Hydroelectric power	13	14	14
Onshore wind power	6	48	56
Offshore wind power	0	0	0
Solar power	0	2	4
Nuclear power	22	41	39
Other thermal power	27	14	12
Total generation	67	118	124
Consumption	87	95	95
Finland's power balance	-20	+24	+29

Combined heat and power plants will replace fossil fuels with biofuels, so the amount of electricity generated by large combined heat and power plants will decrease more slowly than in the other scenarios. Nuclear power generation will increase with the commissioning of the Olkiluoto 3 and Hanhikivi 1 units. It is also assumed that the service lives of the old units in Loviisa and Olkiluoto will be extended so that they are still in operation in 2045. Hydroelectric power output is assumed to remain at the present level.

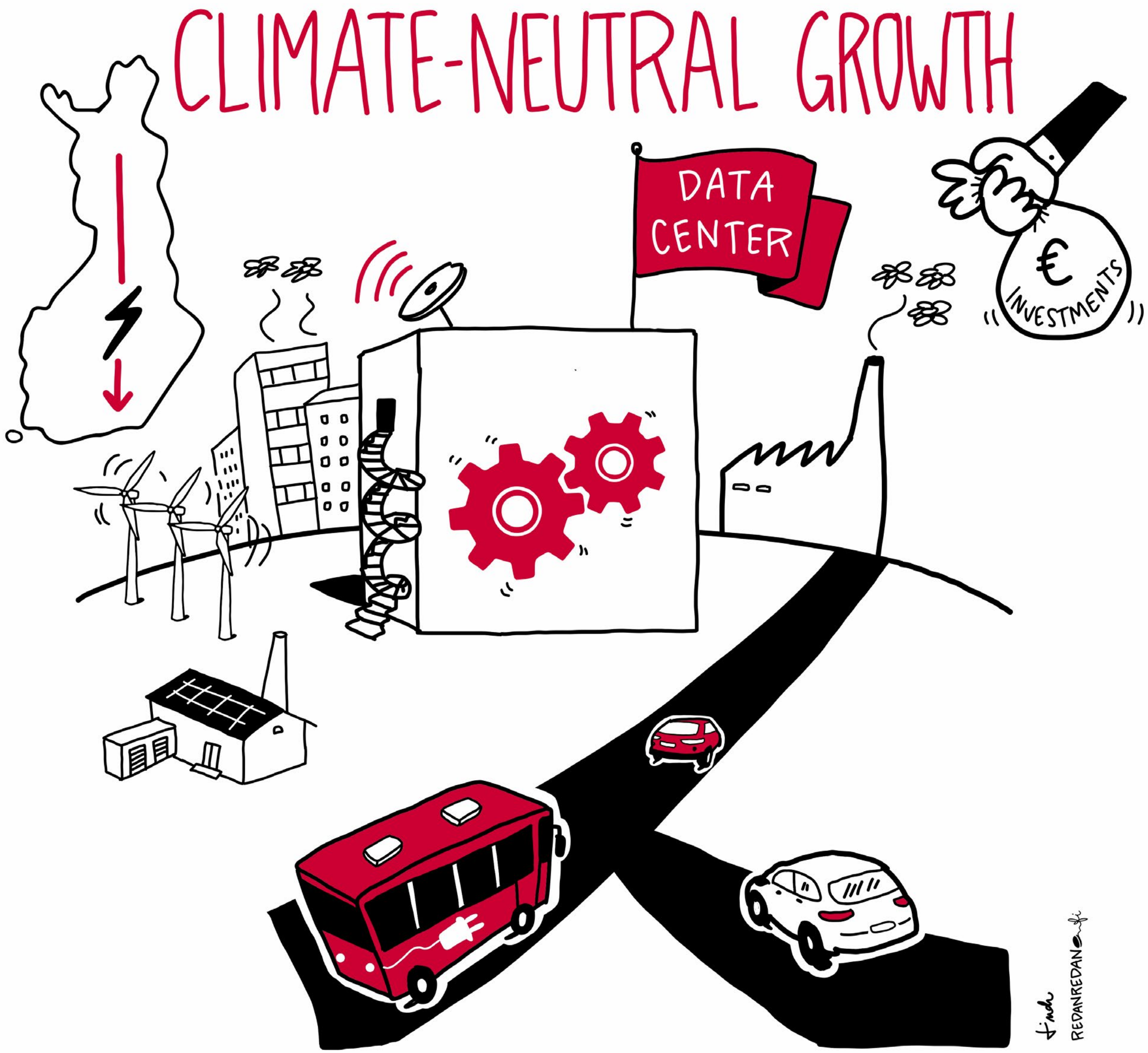
In this scenario, onshore wind power capacity will increase by about 1,000 megawatts per year until 2030, after which growth will slow somewhat. Offshore wind power will not make a substantial breakthrough in Finnish conditions.

The surrounding world

This scenario assumes that the climate targets set by the EU in 2018 will be reached but each country takes separate national measures to reach the targets. The climate targets will lead to the closure of fossil-fuelled electricity generation facilities in the surrounding world, enabling Finland to export clean electricity. Sweden will stop using nuclear power by 2045. The Vyborg direct current link between Finland and Russia will be replaced by a new link, which will be available during the years under examination. The applicable sections of the “National Trends” scenario in the TYNDP were used as the source data on other countries in this scenario.

Which challenges does this scenario pose for network development?

The scenario foresees Finland becoming an electricity exporter, so the investments required to enable exports are taken into consideration in this scenario. In addition, electricity consumption in this scenario will not significantly increase in comparison with the other scenarios, so this scenario includes investments that are not dependent on an increase in electricity consumption.



Under the Climate-Neutral Growth scenario, Finland will reach its target of becoming carbon-neutral, thanks in large part to the electrification of industrial processes, heating and transport, as well as an increase in clean electricity generation. Finland will be a highly attractive location for new investments in industries that require electricity, and this will lead to greater increases in electricity consumption than in the other scenarios.

From the perspective of the main grid, this scenario envisages more north-to-south transmission than any of the other scenarios. Most of the wind power will be located to the north of Cross-section Central Finland[3], while the majority of consumption will be on the south side of the cross-section. However, some wind power is also constructed in Eastern Finland.

Electricity consumption

Electricity consumption under the Climate-Neutral Growth scenario (TWh)	2018	Change 2018-2035	2035	Change 2035-2045	2045
Industry	42	+43	84	+59	143
Heating	17	+10	27	-1	26
Transport	1	+4	5	+6	11
Other consumption and losses	28	+1	29	+1	30
Total	87	+57	145	+65	210

In this scenario, electricity consumption will increase substantially due to the electrification of industrial processes, transport and heating, as well as growths in the production of climate-neutral fuels and materials. Most of the targets described in the sectoral low-carbon roadmaps for the electrification of processes will be reached. Finland will also be attractive for new investments in electricity-intensive industries, which increases the electricity consumption of data centres and Power-to-X industries. In this scenario, the electricity consumption required for Power-to-X generation in the EU will exceed 1,000 TWh in 2045, offering significant growth potential. The low-carbon roadmaps for the chemical industry foresee changes in electricity consumption related to the substitution of fossil raw materials, and this will also provide substantial potential for growth in electricity consumption.

Most of the fossil fuel used for heating will be replaced by technologies based on electricity. Electricity will replace the majority of the combustion processes in district heating, as well as oil- and gas-fired heating in individual buildings. The electricity consumed by transport will increase when passenger transport is almost entirely electrified by 2045, and cargo traffic will also begin using electronic solutions in significant amounts.

The scenario envisages a dramatic increase in demand-side response. The majority of new industrial processes will be designed to work with demand-side response by default.[4] As district heating is electrified, heat storage facilities and demand-side response for heating can be utilised to optimise the use of electricity in the district heating system. Electric cars are expected to use smart charging. Most of the flexibility that this provides is assumed to be available on an hourly and daily level.

Electricity generation

Electricity generation under the Climate-Neutral Growth scenario (GW)	2018	2035	2045
Hydroelectric power	3	3	3
Onshore wind power	2	22	43
Offshore wind power	0	1	3
Solar power	0	3	5
Nuclear power	2.8	4.6	2.8
Other thermal power	8	4	3

[3] Cross-section Central Finland (also known as Cross-section P1) is theborder between the transmission lines of Northern and Southern Finland defined in electrical engineering terms. In the future, the precise location of Cross-section P1 will be affected by matters such as the connection of new generating capacity along transmission lines between the north and south. The main grid must be capable of transmitting the output of these facilities from the north to the south over Cross-section P1. There must be sufficient capacity in the cross-section to prevent Finland from being divided into different price areas.

[4] Flexible industrial electricity usage is assumed to account for an average of about one-third of the maximum capacity, so the flexibility will better enable fluctuating wind and solar power output to be harnessed by processes (such as electrolysis equipment).

Electricity generation under the Climate-Neutral Growth scenario (TWh)	2018	2035	2045
Hydroelectric power	13	14	14
Onshore wind power	6	79	155
Offshore wind power	0	3	13
Solar power	0	2	4
Nuclear power	22	32	18
Other thermal power	27	11	9
Total generation	67	141	213
Consumption	87	145	210
Finland's power balance	-20	-4	+3

Significant growth in electricity consumption will create a good investment environment for clean electricity generation. The costs of wind power generation will have continued to fall, and administrative obstacles will have been successfully overcome, resulting in growth of more than 1,000 megawatts of onshore wind power capacity per year, surpassing 15,000 megawatts in the early 2030s, before reaching 40,000 megawatts in 2045.

Most of the wind power investments made up to the end of the 2020s will have been in Western Finland (Ostrobothnia and Sea Lapland). After 2030, more investments will be made in Central and Northern Lapland, and there will also be significant investments in Eastern Finland, where the problems posed by radars have been overcome. Onshore wind power will remain much more competitive than offshore wind power in Finland. The amount of decentralised solar power will increase slightly, mainly as a consequence of the interest and activity of households.

As combined heat and power plants begin to age, replacement investments will mainly be made in technologies and boilers based on electricity, no new combined heat and power plants will be built, and a substantial proportion of the existing combined heat and power plants used for district heating will have been shut down by 2035. Industries will continue to use combined heat and power if they are fuelled by side streams that cannot be used for any other purpose. Hydroelectric power output is assumed to remain at the present level.

As regards nuclear power, the scenario assumes that the nuclear power units currently operating in Loviisa and Olkiluoto will be decommissioned when their existing operating permits expire. Olkiluoto 3 is assumed to be in operation, and the Hanhikivi nuclear power plant is expected to be completed before 2035.

This scenario seeks to challenge the grid's transmission capacity from north to south. The location of Hanhikivi in a more northern area of Finland combined with the removal of the Loviisa plant from the 2035 scenario and Olkiluoto units 1 and 2 from the 2045 scenario will increase the need for transmission from north to south.

The surrounding world

In this scenario, the EU will be carbon-neutral by 2050. Replacing imported fossil fuels with electricity generated in Europe and synthetic fuels made using electricity will increase electricity consumption significantly, thereby improving Europe's energy self-sufficiency. Sweden's nuclear power is assumed to have been decommissioned by 2045. The scenario assumes that the Vyborg direct current link between Finland and Russia is replaced by a new link, which is available during the period under examination. The Climate-Neutral Growth scenario is not a direct consequence of any of the TYNDP scenarios, but the initial information has been integrated where appropriate.

Which challenges does this scenario pose for network development?

In this scenario, most of Finland's rapid increase in electricity consumption is assumed to be concentrated to the south of Cross-section Central Finland, while generation investments – especially wind power – will mainly occur to the north of Cross-section Central Finland. The scenario challenges the transmission capacity between Northern and Southern Finland as the output must be transmitted from the north of the cross-section to the south. This scenario also envisages a dramatic increase in electricity transmission to urban areas as heating and transport are electrified and the combined heat and power capacity decreases.

WINDY SEAS

The key factor in the Windy Seas scenario is a sharp increase in offshore wind power generation. Under this scenario, Finland will reach its target of becoming carbon-neutral, thanks in large part to the electrification of industrial processes, heating and transport, as well as an increase in clean electricity generation. Finland will be an attractive location for new investments in industries that require clean electricity, but the rise in electricity consumption will be less pronounced than in the Climate-Neutral Growth scenario. Finland will reach its target of becoming carbon-neutral mainly through centralised energy solutions, such as large wind farms and nuclear power.

Offshore wind power is assumed to be concentrated on the west coast, which will pose challenges for the main grid's transmission capacity. The main grid must be capable of transmitting the substantial wind power output onwards to consumption sites. In this scenario, the amount of electricity transmitted from the main grid to urban areas will increase.

Electricity consumption

Electricity consumption under the Windy Seas scenario (TWh)	2018	Change 2018-2035	2035	Change 2035-2045	2045
Industry	42	+31	72	+24	96
Heating	17	+4	21	-2	19
Electric vehicles	1	+4	5	+6	11
Other consumption and losses	28	-2	26	-2	24
Total	87	+37	125	+25	150

Industrial operators will achieve their goal of becoming carbon-neutral by electrifying processes. In particular, the chemical and steel industries will be able to substitute processes based on fossil energy sources with electricity. Finland will be a competitive place for industries that require clean electricity, but the competitive advantage and the consequent overall electricity consumption by industries will be smaller than in the Climate-Neutral Growth scenario. Investments in energy efficiency will decrease electricity consumption in building heating systems, the service sector and households, but this will be of little overall consequence in comparison with the increase in industrial electricity consumption.

Most of the fossil fuel used for heating will be replaced by technologies based on electricity. Electricity will replace the majority of the combustion processes in district heating, as well as oil- and gas-fired heating in individual buildings. With regard to heating solutions, it is assumed that the energy efficiency of buildings will increase, which will curb the growth in electricity consumption. The electricity consumed by transport will increase when passenger transport is almost entirely electrified by 2045, and cargo traffic will also begin using electronic solutions in significant amounts.

Demand-side response will increase significantly. Some new industrial processes will be designed to work with demand-side responset by default. As district heating is electrified, heat storage facilities and demand-side response for heating can be partially utilised to optimise the use of electricity in the district heating system. Most electric cars are expected to use smart charging. Most of the flexibility that this provides is assumed to be available on an hourly and daily level.

Electricity generation

Electricity generation under the Windy Seas scenario (GW)	2018	2035	2045
Hydroelectric power	3	3	3
Onshore wind power	2	11	11
Offshore wind power	0	4	12
Solar power	0	3	5
Nuclear power	2.8	4.4	4.6
Other thermal power	8	4	3

Electricity generation under the Windy Seas scenario (TWh)	2035	2035	2045
Hydroelectric power	13	14	14
Onshore wind power	6	35	33
Offshore wind power	0	22	60
Solar power	0	2	4
Nuclear power	22	33	31
Other thermal power	27	11	9
Total generation	67	117	151
Consumption	87	124	150
Finland's power balance	-20	-7	+1

Significant growth in electricity consumption will create a good investment environment for clean electricity generation. Wind power capacity will increase at a steady rate of about 1,000 megawatts annually, reaching approximately 10,000 megawatts by 2030 and surpassing 20,000 megawatts in the 2040s. Until the end of the 2020s, wind power will be built mainly on land, but the construction of offshore wind power will gradually become more profitable than onshore wind power. By 2045, the amount of offshore wind power will have surpassed the amount of onshore wind power. In order for offshore wind power to be built on this scale, the technology will need to become less expensive, and the costs of connecting offshore wind power to the grid must either come down or be subsidised by society.

The amount of decentralised solar power will increase slighly, mainly as a consequence of the interest and activity of households. As combined heat and power plants begin to age, replacement investments will mainly be made in electric heating and boilers, no new combined heat and power plants will be built, and a substantial proportion of the existing combined heat and power plants used for district heating will have been shut down by 2035. Most of the combined heat and power capacity used by industry will remain. Hydroelectric power output is assumed to remain at the present level. As regards nuclear power, the operation of the old nuclear power units in Loviisa is assumed to be extended by 10 years until 2037 and 2040 respectively. The commissioning of the Hanhikivi plant is expected to be delayed until around the same time that the Loviisa units are decommissioned. The service lives of the old units in Olkiluoto will be extended until the end of the 2040s.

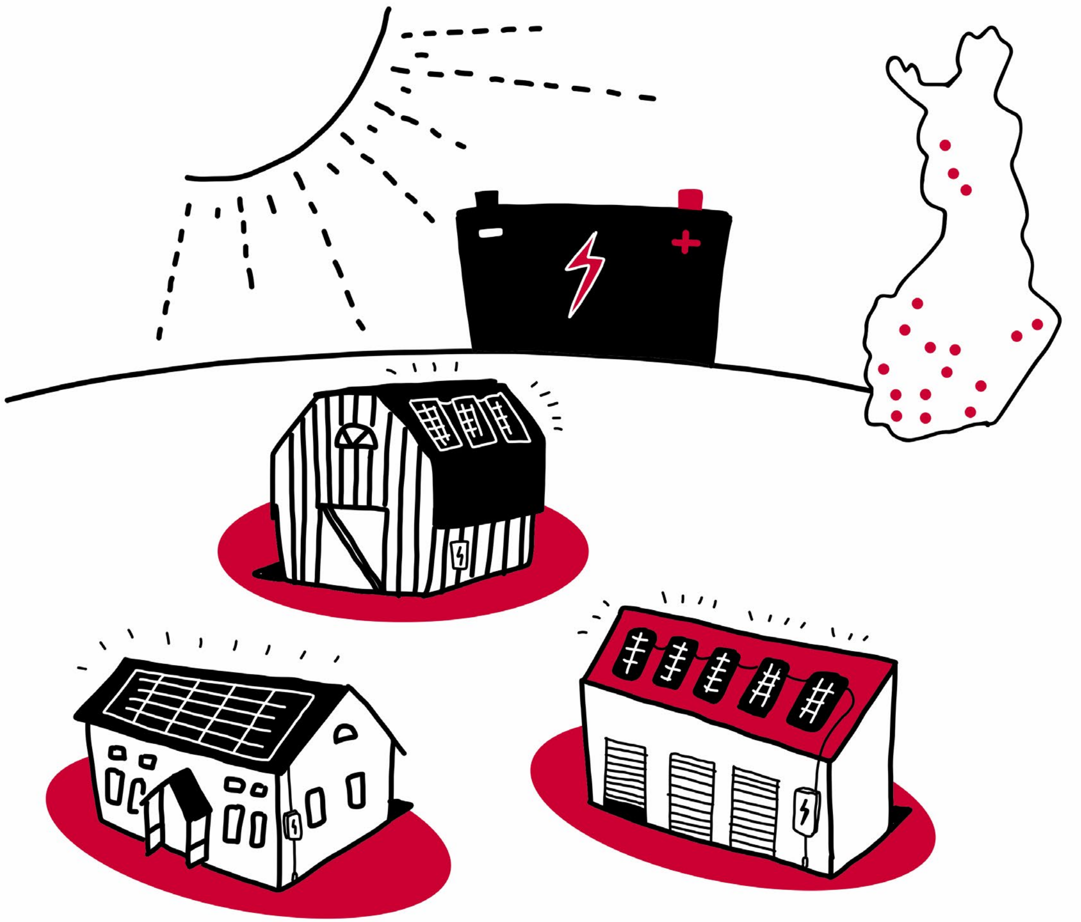
The surrounding world

Offshore wind power will become one of the most competitive forms of electricity generation in Europe thanks to a decrease in generation costs, while opposition to onshore wind power will prevent the largest and most efficient turbines from being used on land. The scenario makes use of the TYNDP "Global Ambition" scenario in the sections that apply to other European countries.

Significant amounts of wind power will be built in the North Sea as well as in the Baltic Sea. In Europe, no new decisions will be made to prematurely decommission nuclear power plants, but the decisions that have already been made will not be reversed. Sweden will still have a substantial amount of nuclear power in operation in 2045. Under this scenario, the Vyborg direct current link will not be replaced, and the old link will be decommissioned after 2030.

Which challenges does this scenario pose for network development?

This scenario calls for a large amount of new generation on the west coast of Finland. In this scenario, Finland's electricity consumption will increase, and electricity must be transmitted from the west coast to the points of consumption. This scenario also envisages a dramatic increase in electricity transmission to urban areas as heating and transport are electrified and the combined heat and power capacity decreases.



SOLAR AND BATTERIES

The significant variables in the Solar and Batteries scenario are the growth in the amount of decentralised solar power and the reduction in the amount of nuclear power. Finland will reach its target of becoming carbon-neutral, thanks in large part to the electrification of industrial processes, heating and transport, as well as an increase in clean electricity generation. The electrification of Finnish industry will follow the route laid out in the low-carbon roadmaps, but Finland will not attract any new industrial production.

From the perspective of the main grid, decentralised generation and the transformation of households and other electricity consumers into producer-consumers will give rise to new challenges. The scenario assumes that distribution networks will enable households to dramatically increase their solar power output and that batteries will be connected to the grid in growing numbers. In addition, the reduction in the amount of electricity generated by nuclear power and other conventional methods will pose the challenge of ensuring sufficient inertia in the power system.

Electricity consumption

Electricity consumption under the Solar and Batteries scenario (TWh)	2018	Change 2018-2035	2035	Change 2035-2045	2045
Industry	42	+25	67	+9	76
Heating	17	+1	18	+0	19
Electric vehicles	1	+4	5	+0	5
Other consumption and losses	28	+0	28	-1	27
Total	87	+30	118	+8	126

The targets described in the low-carbon roadmaps for industry will be reached by electrifying processes. In particular, it will be possible to replace the processes in the chemical and steel industries that were formerly based on fossil energy by using electricity. Electricity consumption will increase, but the growth will be more moderate than in the Windy Seas and Climate-Neutral Growth scenarios.

The electrification of heating will become more common, but fossil fuels will mainly be replaced by using geothermal energy, harnessing waste heat and using biofuels, so there will be no appreciable net growth in the amount of electricity consumed by heating as the energy efficiency of buildings will also improve.

Passenger and cargo transport will move away from fossil fuels. Hydrogen will become a major transport fuel alongside electricity, and this will reduce the direct consumption of electricity by electric cars, although the production of hydrogen will increase the industrial consumption of electricity.

Demand-side response will become more commonplace chiefly due to the growth in decentralised energy storage, smart charging of electric vehicles and the use of vehicle-to-grid technology.

Electricity generation

Electricity generation under the Solar and Batteries scenario (GW)	2018	2035	2045
Hydroelectric power	3	3	3
Onshore wind power	2	11	12
Offshore wind power	0	0	0
Solar power	0	6	16
Nuclear power	2.8	3.4	1.9
Other thermal power	8	4	4

Electricity generation under the Solar and Batteries scenario (TWh)	2035	2035	2045
Hydroelectric power	13	14	14
Onshore wind power	6	39	45
Offshore wind power	0	0	0
Solar power	0	5	14
Nuclear power	22	25	13
Other thermal power	27	11	11
Total generation	67	94	97
Consumption	87	118	126
Finland’s power balance	-20	-24	-29

Solar power decentralised into small units and batteries used by households and the service sector are the characteristics of this scenario. The amount of wind power will also increase, but the rate of growth will be slower than in the other scenarios. Local energy generation will be favoured, and investments will be made in wind power projects in rural parts of Southern Finland. As the costs of solar power will fall substantially, solar energy will also be used in large amounts elsewhere in Europe, which will play a part in Finland becoming a net importer of electricity on an annual scale.

In terms of the generation of district heating, large combined heat and power plants will be replaced by the use of waste heat, geothermal energy and micro CHP plants. Hydroelectric power output is assumed to remain at the present level.

As regards nuclear power, the scenario assumes that no more nuclear power plants based on conventional technology are built in Finland after Olkiluoto 3, and the old plants are decommissioned when their existing operating permits expire. Small, modular nuclear power plants are assumed to arise as an alternative for electricity and heat generation towards the end of the 2030s. By 2045, modular nuclear power plants will generate electricity in some quantity, mainly in large cities.

The surrounding world

Replacing fossil energy with renewable energy will improve Europe's energy self-sufficiency, and replacing imported energy with locally-generated energy will increase electricity consumption significantly. The costs of generating solar power will decrease dramatically, and solar power will become the cheapest way of generating electricity in most of Europe. The costs of energy storage technologies will also decrease substantially, so decentralised energy generation will become significantly more profitable. Sweden's nuclear power plants are assumed to have been closed by 2045. Under this scenario, the Vyborg direct current link will not be replaced, and the old link will be decommissioned after 2030. The scenario makes use of the TYNDP "Distributed Energy" scenario in the sections that apply to other countries around the world.

Which challenges does this scenario pose for network development?

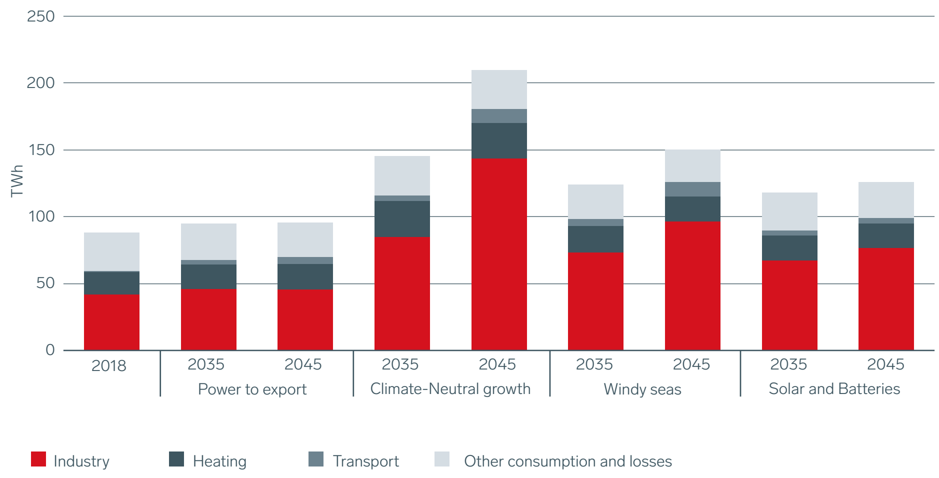
This scenario envisages a significant amount of new, decentralised generation and a reduction in the number of conventional power plants connected to the main grid. This will lead to a decrease in system inertia, which will pose challenges in terms of maintaining the frequency on the main grid. The same trend will also be accompanied by other technical challenges, such as the adequacy of fault currents and voltage support on the main grid. The scenario assumes that distribution networks will develop to meet the needs of decentralised generation and electricity storage.

Summary of the scenarios

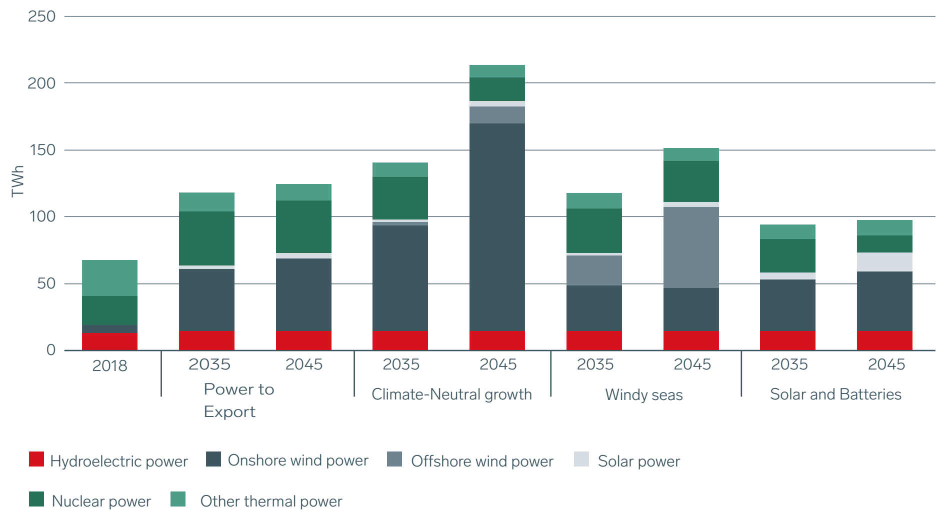
This section presents a summary and comparison of the scenarios. The industrial consumption of electricity will grow dramatically in the scenarios where Finland's goal of becoming carbon-neutral is reached by increasing the consumption of electricity. Electricity consumption will increase even further if products made using electricity (such as hydrogen) are also refined for export purposes, and cheap, clean electricity attracts new industrial investments to Finland (such as data centres). The consumption of electricity for heating will increase, particularly when the fossil fuels used to generate district heat are replaced by solutions that use electricity. The consumption of electricity for transport will increase under all the scenarios, but the scenarios envisage differing degrees of electrification. The illustration below presents the electricity consumption under different scenarios in comparison with the consumption in 2018.

The illustration below and the tables present the amount of electricity generation, Finland's power balance, and the electricity generation capacity under different scenarios in 2035 and 2045. The amount of onshore wind power will increase significantly under all the scenarios, although the growth will be most pronounced in the Climate-Neutral Growth scenario. The amount of offshore wind power will increase, especially under the Windy Seas scenario, while the amount of solar power will increase most rapidly under the Solar and Batteries scenario.

Electricity consumption under different scenarios



Electricity generation in different scenarios



Power balance under different scenarios in 2035

Power balance 2035 (TWh)	Power to Export	Climate-Neutral Growth	Windy Seas	Solar and Batteries
Hydroelectric power	14	14	14	14
Onshore wind power	47	79	35	39
Offshore wind power	0	3	22	0
Solar power	2	2	2	5
Nuclear power	41	32	33	25
Other thermal power	14	11	11	11
Total generation	118	141	117	94
Total consumption	95	145	124	118
Finland's power balance	24	-4	-7	-24

Power balance under different scenarios in 2045

Power balance 2045 (TWh)	Power to Export	Climate-Neutral Growth	Windy Seas	Solar and Batteries
Hydroelectric power	14	14	14	14
Onshore wind power	55	155	33	45
Offshore wind power	0	13	60	0
Solar power	4	4	4	14
Nuclear power	39	18	31	13
Other thermal power	12	9	9	11
Total generation	124	213	151	97
Total consumption	95	210	150	126
Finland's power balance	29	3	1	-29

Generation capacity under different scenarios in 2035

Capacity 2035 (MW)	Power to Export	Climate-Neutral Growth	Windy Seas	Solar and Batteries
Hydroelectric power	3	3	3	3
Onshore wind power	14	22	11	11
Offshore wind power	0	1	4	0
Solar power	3	3	3	6
Nuclear power	5.6	4.6	4.4	3.4
Other thermal power	5	4	4	4

Generation capacity under different scenarios in 2045

Capacity 2045 (MW)	Power to Export	Climate-Neutral Growth	Windy Seas	Solar and Batteries
Hydroelectric power	3	3	3	3
Onshore wind power	17	43	11	12
Offshore wind power	0	3	12	0
Solar power	5	5	5	16
Nuclear power	5.6	2.8	4.6	1.9
Other thermal power	5	3	3	4

Giving feedback about the scenarios

Fingrid will refine the scenarios on the basis of stakeholder feedback. Feedback can be provided by sending e-mail to strateginen.verkkosuunnittelu@fingrid.fi by 11 September. The final network vision report will be published once the work is complete in winter 2020/21.

FINGRID