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Electricity distribution network development plan 2024

Pursuant to the Energy Authority's regulation 3167/000002/2023

29.4.2024

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1. Strategic forecast for electricity distribution network regarding changes in the operating environment

1.1. Introduction

Electricity network companies have the responsibility to transmit electricity and connect customers to the distribution network in their responsibility areas. Helen Electricity Network Ltd's responsibility area is geographically limited to Helsinki (Figure 1). The area boundaries are rather stable, but as society and technologies evolve, the operating environment is changing significantly. Identifying these change factors is important to enable the company to develop its distribution network in a reasonable way. This section reviews the most significant changes influencing the operating environment as well as related forecasts.

In Helsinki, population increase, busy construction activity and energy efficiency improvements have had a significant impact on the development of electricity consumption. The green transition introduces a number of new electricity consumption-related factors to the operating environment. The electricity system (Figure 2) is one of the most important enablers of the green transition. The electrification of society with regard to both production and consumption, such as heating and traffic, is a key means to achieving the carbon neutrality goal. Finland's goal is to be carbon neutral by 2035. It means that Finland's carbon sinks will exceed its greenhouse gas emissions in 2035. This requires that emissions are reduced from the current level.

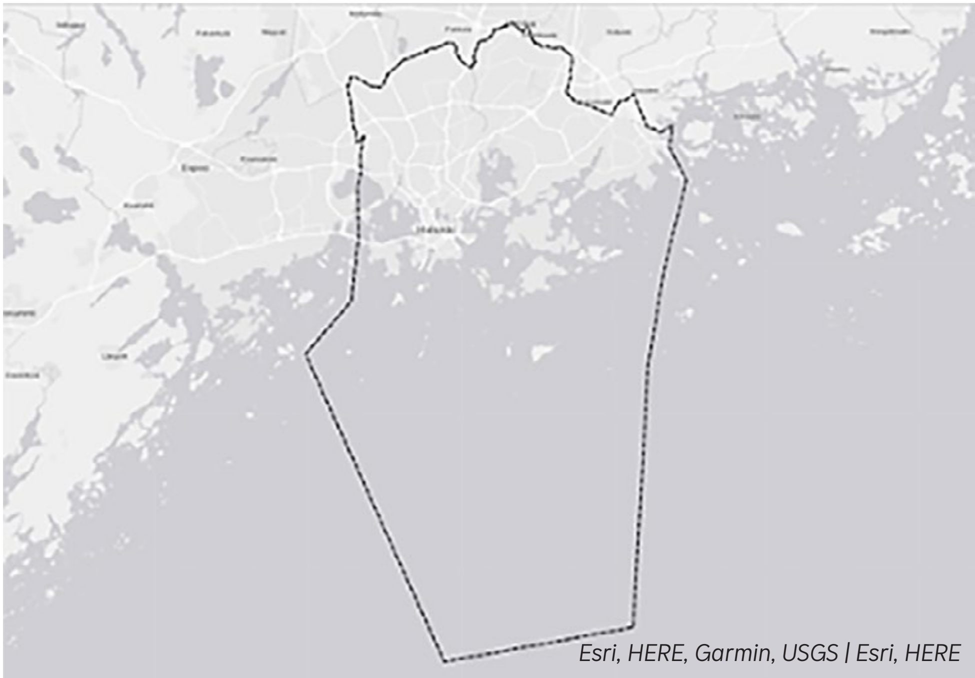

Figure 1. Helen Electricity Network Ltd's responsibility area.

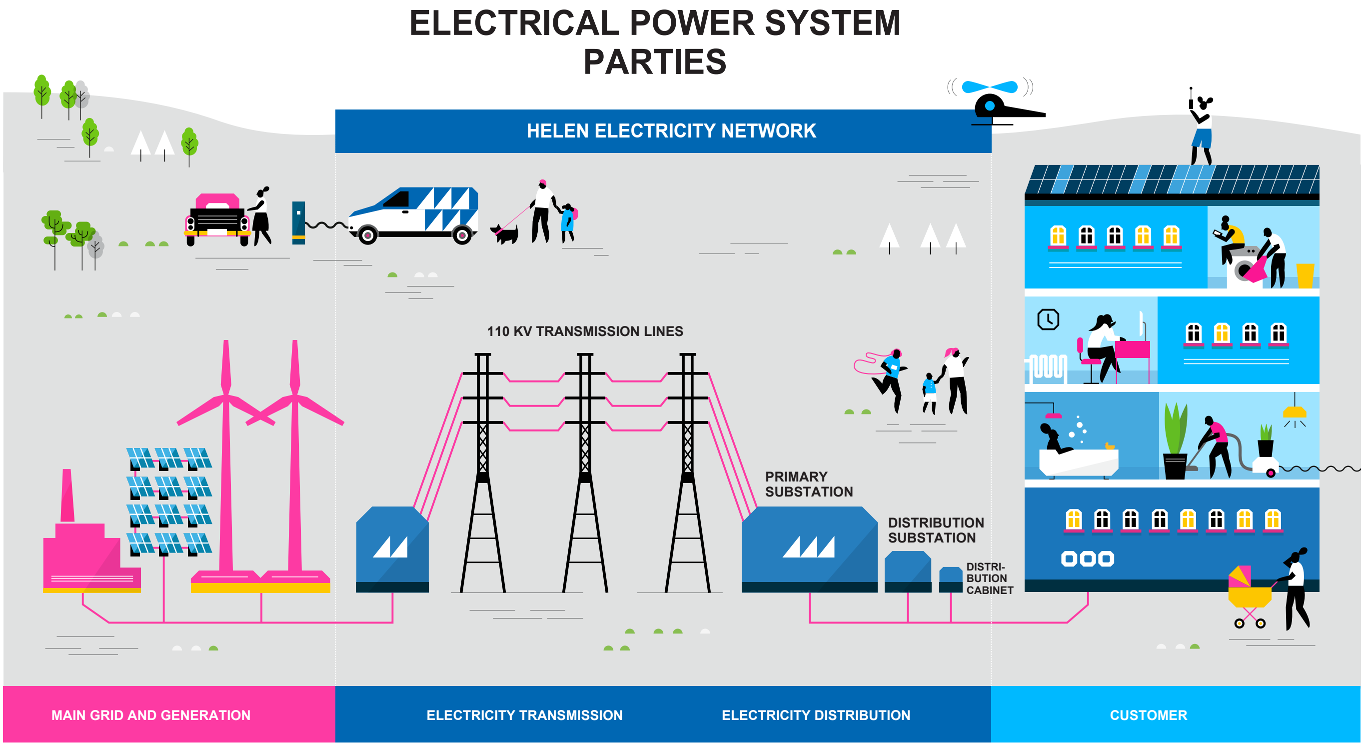

Figure 2. Electric power system parties and interfaces.

Municipalities and companies contribute to the achievement of Finland's climate goal. Helsinki's goal is to be carbon neutral by 2030. In Helsinki, the most significant sources of carbon dioxide emissions are the heating of buildings (more than 50%) and transport (approximately 25%). Emissions from industry and work machines account for less than 1%. To contribute to the achievement of the goal, Helen, owned by the City of Helsinki, has decided to phase out coal combustion in Helsinki by 2025, among other actions. This influences both heat and electricity production. In heat production, alternative solutions must be sought locally because heat cannot be transmitted over long distances as economically as electricity. In the future, the electricity system will play a considerably larger role in heat production. One of the benefits of the electricity system is that electrical energy can be produced further away and converted into heat energy closer to the location where it is needed. As a result, electrical energy can be produced where this can be done as cleanly and cost-efficiently as possible.

Helen Electricity Network has approximately 430,000 customer measurement points and 36,000 connection points. There are 25 primary substations, 1,900 own distribution (secondary) substations and 750 customer transformer substations. The total length of the electricity network is about 6,500 km. In Helsinki, there are a high number of significant, highly critical sites where electricity supply reliability is crucial. These include, for instance, the state's central government, the central hospital of Finland's largest hospital district and altogether five other hospitals, numerous key locations of Finland's business life, concentrations of energy production, the main hubs of railway and metro traffic in the Helsinki metropolitan area, a military area, approximately 60 embassies, data centres, one of the busiest international passenger ports in Europe and a significant freight port.

1.2. City's growth and demographic development in the network area

The population of Helsinki has been increasing for a long time and this trend is expected to continue. At the moment, Helsinki's population is approximately 670,000. The latest population forecast of the City of Helsinki has three scenarios: slow, basic and fast. In each scenario, the population increases. In ten years (2034), the population is expected to be about 750,000.

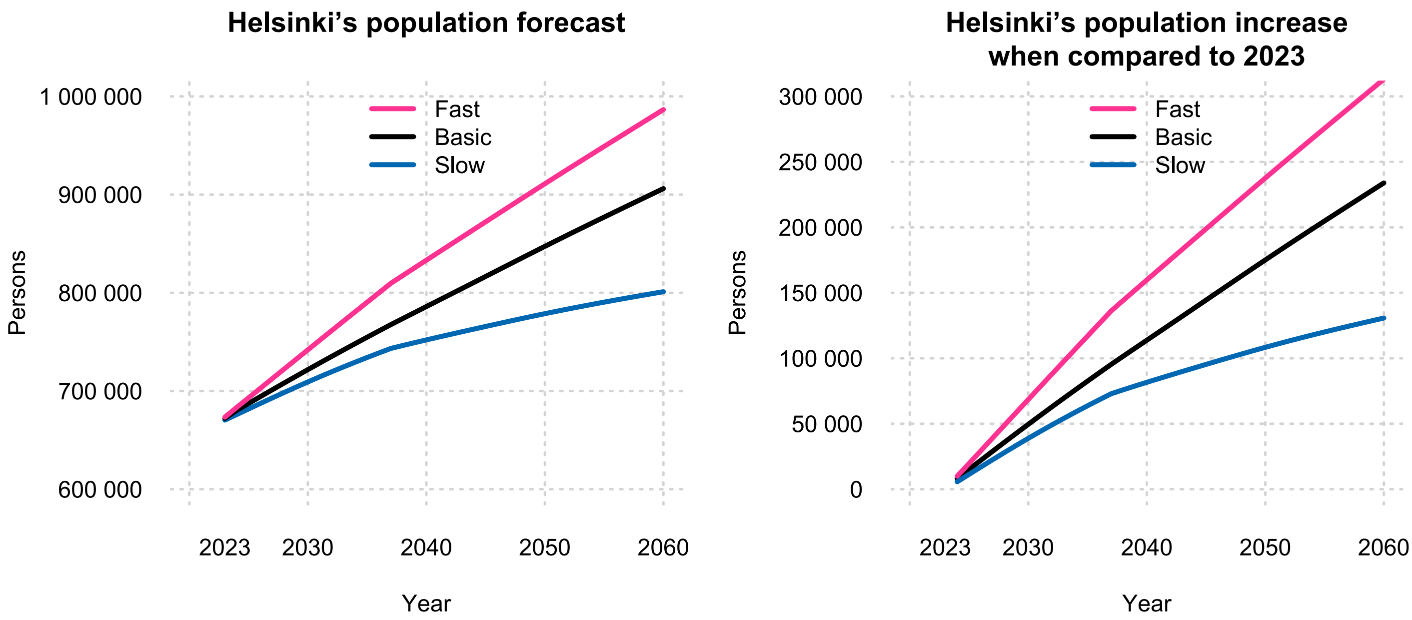

Figure 3. Helsinki's population forecast. Data: City of Helsinki, City Executive Office, Urban Research and Statistics Unit.

A population increase implies abundant additional construction. The City of Helsinki has created a forecast for housing floor area. In 2020, the total housing-related floor area was 31 million square metres. The housing floor area is expected to total 35 million square metres (+13%) in 2028 and 39 million square metres (+26%) in 2036.

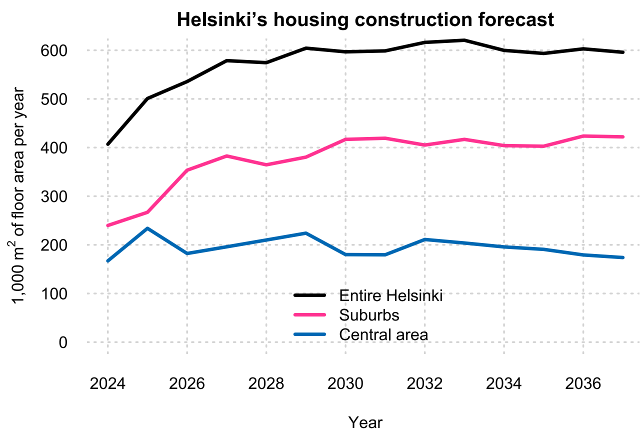

Figure 4. Annual housing construction forecast for the whole of Helsinki, the suburbs and the central area of the city. Data: City of Helsinki, City Executive Office, Urban Research and Statistics Unit.

In Helsinki, the volume of construction varies by area. In some city districts, no new construction is planned, and in some areas, the population may even decrease slightly. Especially in the central area of the city, the possibilities of new construction, generating an increase in the population, are slim. In the suburbs, population-increasing housing construction is expected to rise from the current rate of construction.

In late 2022, housing construction dipped. Factors contributing to this included economic uncertainty and rising interest rates. The impact of these factors can also be seen in the commercial property market. In the number of apartments completed annually, the dip appears with a delay. In the long run, there will be abundant construction activity in Helsinki and its population will continue to increase.

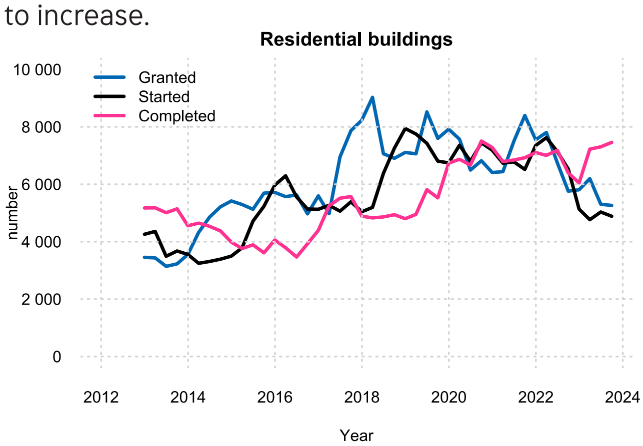

Figure 5. Rolling annual number of residential buildings that have been granted permits, started and completed in Helsinki. Data: City of Helsinki, City Executive Office, Urban Research and Statistics Unit.

1.3. Electricity consumption changes in housing, services and heating methods

When it comes to the annual consumption of electrical energy in the Helsinki region, housing accounts for approximately one third of it and the service sector for half. It is predicted that the population, and thus the consumption of electrical energy, will increase. The electrification of heating and traffic result means that electricity consumption will increase. As electric vehicles are mainly charged at home, the specific consumption from housing increases most significantly in this respect. In the service sector's electricity consumption, the specific consumption rates have decreased probably due to energy efficiency especially as property utilisation rates increased before the COVID-19 pandemic. Remote work has increased and remained at a higher level compared to the pre-pandemic period. The influence of remote work has been seen as a decrease in the specific consumption in office buildings, for instance. The fact that solar energy production in buildings is becoming more common is expected to reduce the amount of energy transmitted in the network in the spring, summer and autumn months. In the winter, solar energy production does not yet have a major impact. As a whole, electricity consumption in Helsinki is at its highest in the winter. Thus far, solar energy production has not reduced network dimensioning criteria, although, from the annual total energy point of view, distributed generation usually means less transmission of electrical energy from the distribution network to the customer.

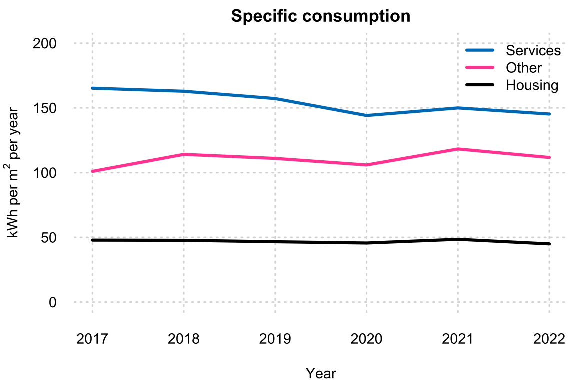

Figure 6. Development of the specific consumption of housing, services and other sources of electricity consumption. Data: Helsinki's Aluesarjat statistical database and Finnish Energy.

In residential buildings, ground source heating as the heating method has become more and more common also in apartment buildings and terraced houses. In detached houses, ground source heating has been a popular heating method for a longer time. Heat pumps are expected to increase the customer's electricity consumption as they are used to replace district or oil heating. On the other hand, air source heat pumps are also used for cooling. This may be one reason for the fact that the specific consumption of electrical energy in housing has hardly decreased in recent years. Most apartment buildings and terraced houses are connected to the district heating network and the share of oil heating is still a few per cent. Oil heating is more common in detached houses than in apartment buildings and terraced houses.

1.3.1. Electrification of industry and data centres

In Helsinki, certain areas in Vuosaari, Pitäjänmäki and Herttoniemi can be categorised as industrial areas. The share of industry in Helsinki's electricity consumption is rather small: approximately 5% in 2023. Industry produces less than 1% of the city's carbon dioxide emissions. As carbon dioxide emissions from industry are very small, no significant increase in electricity consumption is expected to take place in Helsinki due to the green transition of the existing industrial facilities. Instead, Helsinki may offer opportunities for producing hydrogen on an industrial scale.

In the future, there may be a significant amount of electricity consumption associated with hydrogen production. In the EU-funded hydrogen valley project, Helen is developing a pilot plant in Vuosaari, which integrates hydrogen production with electricity, heating, transport and energy storage systems. The project introduces essential infrastructure to the Baltic Sea Region, enabling various industries to move away from carbon-intensive processes and enhancing energy supply security in Finland and other European countries. Finland and Estonia are the project's core countries.

Furthermore, Helen Ltd, Neste Corporation, Gasgrid Finland Ltd and Vantaa Energy Ltd have in collaboration started preliminary studies on the development of an industrial hydrogen valley in the Uusimaa region. The joint project is a step forward in driving Finland towards becoming a leading hydrogen economy in Europe that creates industrial investment opportunities and supports Finland's and Europe's carbon neutrality goals. Helen has an ambition to become a major player in the hydrogen economy and is planning, in addition to the pilot plant, large-scale hydrogen production at Helen's Vuosaari power plant area in Helsinki.

There are several data centres located in Helsinki. The impact of data centres on increasing electricity consumption has thus far been moderate. However, the number of data centres is expected to increase. At the moment, there are new inquiries amounting to roughly 150–400 MW by 2035, with further increase expected. Pursuant to the European Union's decision, starting from October 2025, new data centres must reuse waste energy if it is technically and economically possible.

1.4. Phenomena that increase electricity consumption

1.4.1. E-mobility

The electrification of passenger car traffic significantly increases electricity consumption in Helsinki. According to Traficom, there were 219,446 passenger cars in traffic in Helsinki at the end of 2023. Of these, 36,591 were electric vehicles. Electric vehicles include both all-electric vehicle and plug-in hybrid vehicles. Currently, the share of electric vehicles in the total number of first-registration passenger cars in Helsinki is roughly 75%.

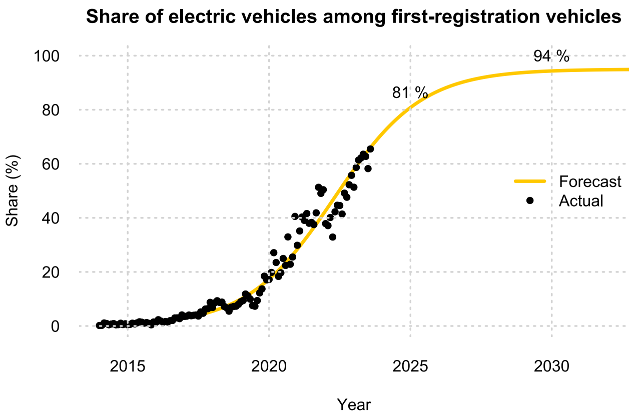

Figure 7. Development of share of electric vehicles among first-registration vehicles in Helsinki. Data: Traficom.

At the predicted registration rate, the share of electric vehicles among all passenger cars in traffic in Helsinki will be more than half in 2028 and approximately 95% in 2035.

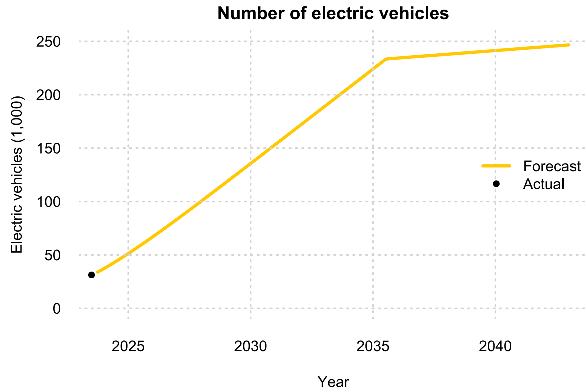

Figure 8. Forecast of the number of electric vehicles in Helsinki. Data: Traficom.

The number of public charging points is expected to increase. The city's goal is that about 10% of charging points are public. At the end of 2023, there were about 150 on-street public charging points in Helsinki. The charging network will be expanded in accordance with Helsinki's general charging station plan. In addition to on-street charging points, there are also charging points in shopping centres, sports facilities and car parks.

The electrification of traffic can also be seen in public transport. Helsinki Region Transport (HSL) has published information about the current and predicted number of electric buses. In 2023, the number of electric buses used on HSL's services was 436, or approximately 34% of all buses. The goal is to increase this figure to roughly 650 by 2025. Electric buses increase electricity consumption in Helsinki especially locally as their charging is usually centralised to depots, some of which are located in Helsinki.

There are plans to build numerous new light rail and tram lines in Helsinki over the next 15 years. Traffic on the Jokeri Light Rail line started in late 2023. The Crown Bridges project includes a new light rail line from the central railway station or Hakaniemi via Korkeasaari to Kruunuvuorenranta and a tram line from Pasila to Yliskylä. Traffic will probably start in 2027. The new Vantaa light rail line would be in use in 2028, running from Mellunmäki via Tikkurila to Helsinki Airport. In western Helsinki, the new lines are a light rail line from Lasipalatsi in the city centre via Munkkiniemi to Kannelmäki as well as a tram line from Eira to Meilahti. It is estimated that the new routes in western Helsinki will be in use in 2030. For roughly 2035, two separate light rail lines are planned: from the central railway station via Tuusulanbulevardi to Pakila and from the central railway station via Viikinmäki to the Malmi Airport area. In commuter train traffic, plans include the new underground Helsinki City Rail Loop, starting from Pasila, but the decision on its construction has not yet been made. The project would include new underground railway stations in Hakaniemi, the city centre and Töölö.

Electricity consumption of Helsinki's harbours is expected to increase as more on-shore power supply connections are built for ships. At the moment, on-shore power supply connections have been built in Katajanokka Harbour and South Harbour. During the current decade, new on-shore power supply connections are expected to be built at least in West Harbour, Hernesaari Harbour and Vuosaari Harbour. The Olympia Terminal at South Harbour will be closed as harbour rearrangements are made. Traffic to and from Tallinn would be concentrated to West Harbour and traffic to and from Stockholm to Katajanokka Harbour. The plan is to dedicate Hernesaari Harbour especially to large foreign cruise ships, which means that a lot of on-shore power may be needed. It is likely that the harbours will need so much power that a high-voltage connection, or even several such connections, will be needed. An EU Regulation requires that, starting from 2030, container and passenger ships with a gross tonnage above 5,000 must use on-shore power supply or other zero-emission technology. An exception may be made, under certain conditions, in a maximum 10% of the port calls of ships of this size until 2035. The possibilities to charge electric vehicles in harbours and use batteries as sources of power in ships are also being explored.

1.4.2. Electrification of heating

Changes in heat production in Helsinki form the most significant entity that increases electricity consumption and transmission in the high-voltage distribution network. In this transition, changes in Helen's district heat production play a particularly prominent role. Helen decommissioned the Hanasaari coal-fired power plant on 1 April 2023. The Salmisaari coal-fired power plant will be decommissioned by 1 April 2025. The decommissioning of these combined heat and power plants will decrease the electricity and heat production capacity in Helsinki. The replacement electricity production capacity is located outside Helsinki, which means that electricity transmission from the main grid to Helsinki will increase. District heat, on the other hand, must be produced relatively close to its consumption sites.

Helen has taken and is taking several different kinds of actions to secure district heat production. Production started in the new bioenergy heating plant in December 2022. In 2021 and 2023, Helen expanded its heat pump and cooling plant located beneath Katri Vala Park. It is the world's largest heat pump plant producing district heating and cooling from purified wastewater. At the time of writing, it is the largest consumer of electricity in Helsinki.

Helen's goal is carbon neutral energy production by 2030. In the short term, the use of coal will be phased out and investments will be made in the production of renewable electricity. In the medium term, Helen will electrify its heat production and use biomass. In the long term, the use of electricity in heat production will be further increased and combustion-based energy production will be phased out by 2040. The goal requires a small modular reactor plant near Helsinki residents. A nuclear power plant producing district heat could potentially be operational in 2036. Helen and Steady Energy have signed a Letter of Intent with the aim of enabling an investment in a small-scale nuclear power plant for heat production.

From the point of view of the electricity network load, heat production solutions based on heat pumps and electric boilers play a particularly significant role. Heat production based on heat pump technology increases electricity consumption. Typically, the amount of heat produced is about 2–3 times the electricity consumed. In addition to the existing Katri Vala heat pump plant located in the central area of the city, the new Eiranranta heat pump plant will be deployed approximately in 2025, featuring also a 30-megawatt electric boiler. Furthermore, the total impact of smaller heat pump plants on increasing electricity consumption could amount to several dozens of megawatts in Helsinki. Helen is currently building an air-to-water heat pump plant in Salmisaari.

In the coming years, heat-producing electric boilers will increase Helsinki's electricity consumption very significantly. The amount of electricity consumed by an electric boiler is equal to the amount of heat it produces. Helen has made decisions on electric boiler investments to be made by the end of 2025, with a peak power of 280 MW. Electric boilers will be built at least in the Hanasaari and [Salmisaari](#) areas and in the new [Eiranranta heat pump plant.](#)

The size and location of the heat pump and electric boiler plants built influence their impacts on the electricity network. Especially plants located in the central area of the city increase transmission in the high-voltage distribution network. Most of the large-scale heat pump and electric boiler plants that already exist or on which decisions have been made are located in the central area, which is also the area with the highest demand for heat. All in all, plants that are completed in 2021–2025 and used for district heat production will increase electricity consumption in Helsinki, at their peak, by more than 350 MW. Together with the decommissioning of electricity production, this will have a very significant impact on transmission in the high-voltage distribution network and also in the main grid. Therefore, reinforcements are necessary in both of these networks.

Besides the heat production investments that have already been decided, additional investments in district heat production are planned for the next few years. When realised, the impact of these additional investments on increasing electricity consumption may rise to hundreds of megawatts, when considering Helsinki as a whole, and this on top of the impact of the investments that have already been decided. This would further increase the need for electricity network reinforcements also in the main grid.

In addition to the heat pump and electric boiler plants used for district heat production that have been covered in this section, Helsinki's electricity consumption is also increased by property-specific heating solutions. An increase in the share of heat pump solutions has been witnessed in both old and new buildings.

In old buildings, ground source heat pumps are usually installed in properties that have oil or district heating, in which case they increase electricity consumption in the short term. In new buildings, they are probably replacing a district heating connection. In the longer term, ground source heating may reduce the use of electric boilers in the district heating network and, as a result, decrease total electricity consumption.

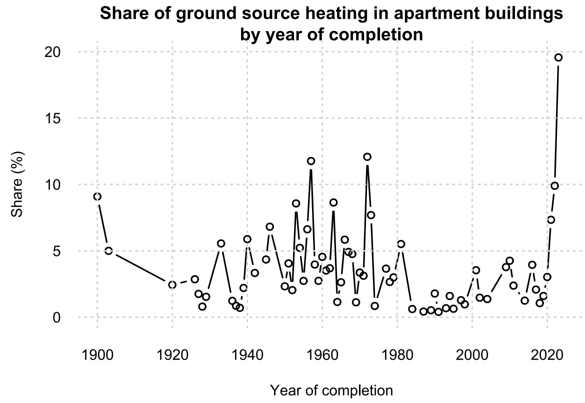

Figure 9. Share of ground source heat pumps (or similar devices) in apartment building properties. Data: Buildings in Helsinki. City of Helsinki Urban Environment Division. City Survey Services.

1.5. Changes in electricity production

1.5.1. Development of distributed generation

In Helsinki, distributed generation is, in practice, solar energy production. With regard to distributed generation, the rated capacity of the panels installed is known. The solar panels installed in Helen Electricity Network's operating area amount to approximately 39 MW. Distributed generation installed during the past year totals approximately 13 MW. At this rate, roughly 130 MW of additional distributed generation would be installed in ten years' time, but the annual installation volume is expected to grow as investment costs decrease. In Helsinki, it has been observed that at the maximum roughly a quarter of the installed production capacity can be seen as power fed into the distribution network. The share of the installed capacity that is visible in the network has increased, but the majority of the production is still used by the producers themselves.

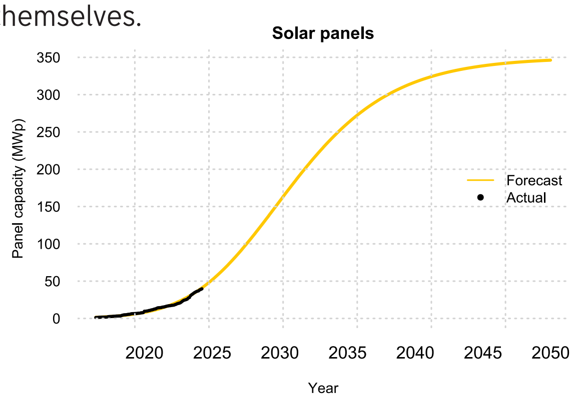

Figure 10. Cumulative rated capacity of installed solar panels and forecast.

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1.5.2. Development of large-scale combined heat and power plants

Currently, there are three combined heat and power plants in Helsinki. Their production capacities are listed in Table 1. Helen decommissioned the Hanasaari coal-fired power plant on 1 April 2023. The Salmisaari coal-fired power plant will be decommissioned by 1 April 2025.

Power plant	Electricity production (MW)	Heat production (MW)
Salmisaari B	160	300
Vuosaari A	165	162
Vuosaari B	510	420

Table 1. Helen's combined heat and power plants in Helsinki - link. -

The decommissioning of power plants has a significant impact on electricity transmission in the high-voltage distribution network. Previously, the wintertime situation in Helsinki was often that the production of electricity exceeded the consumption of electricity and electricity has been transmitted from Helsinki to the main grid. The largest transmission from the main grid to Helsinki has taken place in the summer when combined heat and power plants are not in use. In the future, electricity transmission from the main grid to Helsinki will increase. More electricity will be transmitted in the high-voltage distribution network to the central area of the city as electricity production at the Salmisaari and Hanasaari power plants has ended. Furthermore, the heat production of combined heat and power plants will be largely placed with solutions that consume electricity instead of producing it. Especially heat production that uses heat pumps and electric boilers consumes considerable amounts of electricity. This, too, will increase electricity transmission to the central area of the city.

1.5.3. Long-term outlook of electrical energy consumption

In the long term, electricity consumption will increase due to population increase, changes in heating methods, e-mobility and new solutions deployed by major customers. On the other hand, the decrease in the specific consumption of electricity decreases electricity consumption in services and industry, which can be seen as a decrease in the base consumption.

During the past two years, the price of electrical energy has risen, which has in turn reduced electricity consumption, most visibly in housing. The impact of the electricity price on electricity consumption is being researched so that it can be assessed in more detail. Rising interest rates and the weak economic outlook have influenced construction activity. The impact of decreased construction on electricity consumption will be visible after a long period of time.

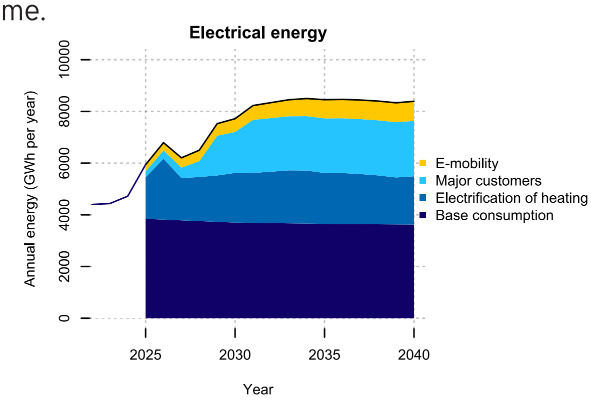

Figure 11. Long-term outlook for electrical energy consumption in Helsinki.

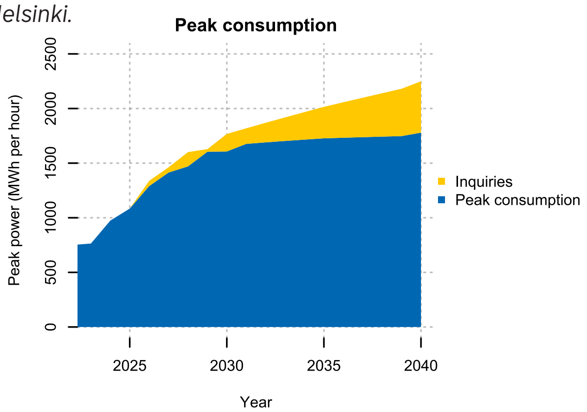

Figure 12. Long-term outlook for peak consumption in Helsinki.

Compared to the previous development plan, the predicted consumption of electrical energy has increased by approximately 20% for 2030 and 35% for 2035. This major change in the forecast is mainly due to the fact that the large-scale heating solutions confirmed in the past two years are based on electricity, at least in the short term.

In the more distant future, there are significant factors that may increase or decrease electricity consumption, depending on how and where they are used. These factors include especially the production and further processing of hydrogen, modular nuclear reactors and the use of the waste heat produced by data centres in the district heating network.

1.6. Requested numeric information

1.6.1. Numeric values for requested information

The verbal descriptions of the numeric values in Table 2 are given further below.

	Current state (2023)	Forecast (2033)
a. Energy transmitted in the network area, MWh		
i. Energy transmitted to network service customers	4,436,000	8,294,538
ii. Energy received from network service customers	1,070,917	152 154
	152,154	481 736
b. Number of customer measurement points	429,930	481,736
c. Distributed generation	945 000	665 000
i. Total rated capacity, kWp	11 293	67 188
a) Connected to a high-voltage network	945,000	665,000
b) Connected to a medium-voltage network	11,293	67,188
c) Connected to a low-voltage network	25,684	152,812
ii. Number	115	650
d) Connected to a high-voltage network	3	1
e) Connected to a medium-voltage network	115	650
f) Connected to a low-voltage network	2,230	12,600
d. Number of connections used for public e-mobility-related charging	130	455

Table 2. Helen Electricity Network's current state and forecast values.

1.6.2. Verbal descriptions of the bases of the numeric values above

Current state

- Energy transmitted and received is measured for each delivery site.
- The number of delivery sites is the number of energy meters installed.
- Information about decentralised production comes from the network information system. Numbers and rated capacities are based on the information provided by customers. A production plant is recorded as connected to a medium-voltage network if the customer's connection where the plant is located is a medium-voltage connection. It is probable that in the internal electricity distribution of the connection point, the production plant is connected to the low-voltage network.
- The number of public charger connections is the sum of those connections in the network information system which mention the charging of electric vehicles (it is not specified which is a public connection and which is a private connection because the network information system does not contain information about which internal electrical installations of the connection point are in private use and which are in public use). According to the network information system, there are 416 delivery sites associated with the charging of electric vehicles as well as 130 connections.

Forecast

- Energy transmitted to network service customers is an estimate of the annual energy of electricity delivery sites. This includes Helsinki's construction forecasts, specific consumption development, the electrification of heating, new solutions deployed by major customers, e-mobility and solar energy production's impact that decreases transmission.
- Energy received from network service customers is an estimate of the annual production of future production plants into the distribution network. It includes large-scale generation and distributed generation.
- The number of delivery sites is an estimate of the number of AMR-meters in use on the basis of Measurement Unit's forecasts. It is based on the history and the general construction development in the city.
- The total panel capacity is a forecast of the perceived production increase rate and its development and the entire Helsinki's solar power potential, approximately 40% of is estimated to be realised. The division between the low-voltage network and the medium-voltage network is assumed to stay in line with the current shares.
- The number of connections associated with charging when growth continues at the same rate as previously.

1.7. Taking weather phenomena into account

In Helsinki, the low-voltage and medium-voltage networks are practically storm-proof due to the high rate of underground cabling. In rare cases, floods may affect the distribution substations and distribution cabinets of the low-voltage and medium-voltage networks. The high-voltage network still largely consists of overhead lines and thus is more vulnerable to weather phenomena.

Strong climate phenomena may involve flooding. Floods may be caused by rising water levels in the sea or the River Vantaanjoki or heavy rainfall. Damage to a major water supply pipeline or a district heating pipeline may cause locally a situation that resembles a flood. Flood levels are taken into account in the overall infrastructure planning. For electricity distribution to properties, it is not enough that the components of the feeding electricity distribution network are protected from floods because electricity supply must also be interrupted when the electrical installations in the customer properties are exposed to flooding water. Consequently, flood preparations are made according to the flood strategy, using comprehensive area solutions, both temporary and permanent (typically flood embankments, pumping stations and sewer improvements). As flood risks are, to a significant extent, managed with actions other than electricity network development and by other parties, the delivery sites located in risk areas are not included in the assessment of whether the quality requirements are met or not. However, the management of risks caused by rising sea water levels is taken into account in this development plan.

The flood map of the network information system shows which sites are exposed to potential rising water levels. In case of a flood, this makes it possible to prioritise sites where the aim is to maintain voltage, by pumping water, for instance, and which sites are made voltage-free when necessary. In properties, property owners are responsible for appropriate action. For this purpose, the City of Helsinki has created instructions on the prevention and control of floods, advising residents on how they can take action to prepare for sea water and major water system floods. The instructions have been distributed to all properties in flood hazard areas.

After the exceptional (recurrence roughly once in 110 years) rise in the sea water level experienced on Finland's south coast in January 2005, the City of Helsinki established a working group tasked with the creation of a flood preparedness and prevention plan for the City of Helsinki. The creation of the plan also entailed the determination of the risk sites in the electricity distribution network in flood-prone areas. The result was the City of Helsinki's flood strategy, which prioritises prevention actions in different areas and provides revised guidelines on the lowest allowed building elevations. In addition, the Uusimaa Centre for Economic Development, Transport and the Environment has created a flood risk management plan for the Helsinki and Espoo shore areas for 2022–2027. The above documents describe different parties' responsibilities as well as the actions to be taken in the event of a flood.

As the climate is warming, changes in extreme temperatures, increasing rainfall and changes in flood boundaries are taken into account in dimensioning. With regard to winds, the area is in coastal circumstances, which is taken into account in 110-kV overhead line network dimensioning.

1.8. Other factors

1.8.1. Monitoring model's impact on the investment capacity

The new monitoring model impairs Helen Electricity Network's investment capacity. Helen Electricity Network has given more detailed public statements regarding the impacts of the monitoring model in the hearing related to the draft confirmation decision for the monitoring methods of electricity distribution network companies in the monitoring periods 2024–2027 and 2028–2031 and the most recent hearing related to changes in the pricing monitoring methods of electricity distribution and high-voltage network operations. As a result of the historically large impairments to the monitoring methods, the profitability of electricity network investments is significantly impaired. Consequently, Helen Electricity Network is forced to adjust its investment programme to secure its financial position in the future. The investment programme adjustment due to the monitoring methods is discussed in more detail in section 4.8.

1.8.2. Services/competence needs

In Finland, distribution network companies largely purchase network construction, maintenance and measurement operations as services from external service providers. Good and highly functional purchasing models and partnerships are crucial for high-quality operations and their continuity. In addition, the service market must be healthy and operational to ensure high-quality operations in the future, too. When it comes to competence, it must be ensured that the company and all service providers have the necessary competence and the continuity of competence is secured. Attracting young people and students in recruitment and enabling the writing of theses and diploma works is important. As a result of the changes in the monitoring methods, investment levels are adjusted significantly, which in turn reduces the resources of electricity network contractors. Electricity network fault repairs and preparedness for exceptional circumstances also rely on contractor resources.

1.8.3. Technology, IT, and information security

Various technological developments which have effects on the development plans are going on in the sector. Here are a few examples.

Along with carbon neutrality goals, electricity distribution companies are also including carbon footprint calculation and minimisation in their action plans. The company's carbon footprint must first be calculated before it can be reduced. Emissions caused by losses and purchases usually play the most significant role. Another aspect related to this theme is the F-gas Regulation. An updated version entered into force on 11 March 2024. The Regulation applies to electricity distribution companies in the respect that it prohibits the installation of new SF_6-insulated switchgear: for medium-voltage installations, the prohibition will enter into force on 1 January 2026 and for 110 kV installations, on 1 January 2028. SF_6-insulated switchgear has been – and still is – used frequently by urban companies and in the main grid. After the above-mentioned dates, companies can install only switchgear that uses alternative gases or compressed air or switchgear that contains a small amount of F-gases if they are competitive from the carbon footprint perspective. This topic still requires more information from the EU Commission to make it possible to conduct impartial comparisons. Helen Electricity Network is about to complete an analysis of the usage strategies of alternatives to SF_6. Alternative transformer insulating materials can also be considered a technological issue that is associated with the carbon footprint. Instead of mineral oil, natural or synthetic esters can be used, with the latter being more suitable for the Finnish environment. Esters are environmentally friendly, have a lower flammability risk and can offer opportunities to reduce fire protection. On the other hand, their price is still higher than that of conventional insulating materials.

Especially when 110 kV transmission network load levels are increasing strongly in Helsinki, the current-carrying capacity of cables and overhead lines should be investigated. Helen Electricity Network has looked into, even with the assistance of consultants, the continuous and emergency current-carrying capacities of 110-kV cables, obtained more detailed information about them and also found possibilities for short-term current-carrying capacities exceeding the rated current-carrying capacity in exceptional circumstances. In overhead lines, the current-carrying capacity depends largely on the outdoor temperature. There are temperature monitoring devices available for both cables and overhead lines; indeed, these are already used in one of the company's 110-kV double cable connections.

Developing and increasing automation requires continuous development work. At primary substations, this means substation automation or a digital substation. In a digital substation, all data communications are digitalised and instrument transformer technology has also been converted to sensor-based. Automation gives more information about the process and its condition as well as incidents, helps reduce age-based maintenance and improves the quality and speed of incident investigation. As for digital substations, Helen Electricity Network has carried out analyses and investigations on adopting the latest technology, but the market is not quite yet mature in this respect. Automation that extends to the distribution network can be called network or distribution substation automation. Automation coverage is expanding in the distribution network and is starting to extend also to the low-voltage network. Automation located deeper in the network must be cost-efficient as the number of sites is high, their size is smaller and their criticality is lower. The company is continuously investing more in developing the low-voltage network management and gaining better visibility into the network. Thanks to the improved electricity quality measurement features of the latest-generation smart meters (being installed) and the new, advanced distribution management system (ADMS) to be deployed next year, the situation can be improved.

Network maintenance and condition monitoring are a crucial aspect of network operations. Last year, a diploma work on this topic was commissioned by the company. One of the findings was that existing condition monitoring data and measurements must be utilised more efficiently. On the other hand, cost efficiency is difficult to achieve for new condition monitoring systems as the number of faults and the volume and costs of maintenance are already low in Helen Electricity Network. Each new system must operate on an economically feasible basis.

Data communications and information security have become increasingly important also in electricity distribution. Automation systems need communications to enable remote use both between and within primary substations. Data communications actions have increasingly become software-related tasks and updates. Consequently, the information security of operational information systems and the related actions are more necessary and on the increase. This work requires increasing cooperation between the IT sector and the OT sector (operational information systems) and also taking this into account in electricity network conditions and network components.

1.8.4. Flexibility

Distribution network companies are encouraged to identify and use flexibility as part of the more efficient use of the network, which benefits both the customer and the network company. At the high-voltage distribution network level, the need for flexibility has quickly become a reality due to the changes in electricity and heat production in the area. The electricity production of combined heat and power plants is being decommissioned and, instead, there will be significant electricity consumption related to the electrification of district heating. In addition, other changes that increase electricity consumption (the electrification of traffic and heating, data centres) are happening on a large scale in the current decade. Electricity transmission from the main grid is increasing. A similar development is taking place also in the operating areas of other network companies and this change poses challenges to the transmission capacity of the main grid, too. In the next few years, the main grid will restrict the increase in consumption in the Helsinki area. Furthermore, Helen Electricity Network's 110-kV network may be subject to bottlenecks in certain special network usage circumstances. In the clean transition and its realisation, the schedule targets are tight and we want to make it possible to connect our customers to the network as quickly as possible. We are jointly seeking solutions to potential, temporally limited special situations in the network, in which the customer is prepared to reduce their electricity consumption flexibly. By utilising flexibility opportunities, customers can be connected to the network faster. In the development of flexible connections and flexibility markets, coordination among the transmission system operator, the distribution network company and customers is especially important. Through the marketplace being developed, both the transmission system operator and the distribution network companies would purchase customers' flexibility capacity when power restriction is needed. On the customer-facing front, this development is guided with customer communications, tariff development and connection size management, among other actions. Through research and development, the sector is aiming at coordinated and market-based flexibility activities. When these activities become an established practice, flexibility can genuinely be considered an alternative to the reinforcement of high-voltage distribution network.

The flexibility of both large and small customers' own electricity consumption has emerged as a phenomenon during strong fluctuations in the price of electrical energy, which became a reality in autumn 2022 and has continued since. Some customers reacted to the price changes by changing their electricity consumption according to energy's spot prices: increasing electricity consumption during hours when the price was lower and decreasing it during hours when the price was higher. Customers have flexibility capacity when it comes to reacting to the price of electrical energy. In the electricity distribution network, reacting to energy's spot prices means more intensive simultaneity of electricity consumption and weaker conventional natural variation of electricity consumption (load variation). In the network, this can be seen as an increasing load during hours when spot prices are low and, in some cases, the overloading of the customer connection or the network. Using this flexibility capacity in the distribution network operations is part of future development work in the customer connection interface services and in the company's internal development projects related to distribution network status information and control, for instance.

Customer interface tools are developed with the aim of promoting the flexibility of electricity consumption. The company has developed a power capacity tool for customers' use. With it, customers can estimate the free, non-used capacity of the connection. Thus far, the tool allows the customer to estimate the free capacity of an existing connection when the customer is planning new electric vehicle charging infrastructure to be added to the connection in question. This service promotes the flexibility of the customer's charging infrastructure and charging events. Both the customer and the network company benefit when the free capacity is used first and the reinforcement of the connection or the low-voltage network might not be needed. The tool will be developed further to allow the estimation of electricity consumption when heating methods are changed, for instance.

1.8.5. Reactive power

In addition active power, also reactive power is transmitted in the network. Reactive power is caused by the phase angles of the alternating voltage and the alternating current differing from each other. Reactive power causes additional load and losses in power lines and other network components. Reactive power also influences the voltage of the network: reactive power generation increases the voltage and reactive power consumption decreases the voltage. During the past approximately ten years, the amount of reactive power fed from distribution networks to the main grid has increased during small load, which has increased the voltages in the main grid in some areas. The transmission system operator Fingrid has defined a reactive power window for distribution network companies and other customers, determining the allowed reactive power transmission between the main grid and the customer. If the reactive power window is exceeded, the customer has to pay fees to Fingrid. Consequently, network companies have extensively invested in reactors that prevent the feeding of reactive power into the main grid especially during low consumption. Helen Electricity Network Ltd has also done so.

In Helsinki, the medium-voltage network and the low-voltage network consist almost entirely of underground cabling, as does a lot of the high-voltage distribution network, too. Under medium and high voltage, cables generate a significant amount of reactive power. The reactive power produced and consumed by customers' devices has changed considerably during the past ten years. Especially under low and medium voltage, devices that consume reactive power, or inductive devices, have decreased in number and devices that generate reactive power, or capacitive devices, have increased in number. Reactive power generated by the network and customers' electrical devices is fed into the main grid unless it is compensated. Helen Electricity Network has two 110 kV reactors for compensating reactive power, with a total capacity of approximately 86 Mvar under a typical network voltage of 117 kV.

Among customers connected to low-voltage and medium-voltage networks, the reactive power change trend has continued also in recent years. The change that describes the joint effect of the decrease in inductive reactive power and the increase in capacitive reactive power has been approximately 6 Mvar per year in the entire Helsinki area. There is no evidence of the rate of change slowing down. Furthermore, 110-kV cabling will increase reactive power generation. Due to these factors, the reactor capacity should be further increased. At the moment, it is estimated that before 2030, the need to increase the reactor capacity would be roughly 50 Mvar. The estimate of the required additional reactor capacity has decreased slightly from the previous development plan due to changes in the 110-kV customers' reactive power.

A new phenomenon noticed in late 2023 was that voltages in Southern Finland's main grid decreased to a worryingly low level in circumstances where consumption was high and production was low. In other words, this was an opposite phenomenon to what has been observed before: an increase in voltage when consumption was high. In the near future, decreasing voltages in the main grid may restrict electricity consumption in the Helsinki metropolitan area more than other technical transmission restrictions. Fingrid will invest significantly

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in reactive power compensation to make it possible to increase voltages during high consumption. In the next few years, a large number of capacitors will be added to the main grid to compensate reactive power. In addition, Fingrid is planning to add a static synchronous compensator (STATCOM) to the Anttila substation in 2028. Regardless, reactors will still also be needed during small load. Helen Electricity Network is not planning to add capacitors to the network because voltages in Helsinki remain within the targeted range if the main grid voltage is at the normal level. Power plants and customers could potentially contribute to the main grid voltage by generating reactive power during high load if appropriate incentives are provided.

1.8.6. Utilisation rate

In Helsinki, the proportion of large low-voltage and medium-voltage connections is relatively high. As a result, the dimensioning of these connections is also significant for reserving the distribution network capacity. Conventional connection dimensioning methods take into account the increase in electricity consumption in the connection itself, but during the past 10–15 years, energy efficiency has started to clearly improve especially in the service sector customer segment and specific consumption rates have decreased. It has been observed that in the Helsinki area, major customer connections have free capacity amounting on average to even 4–5 times the measured hourly maximum power rates. Customer connection dimensioning guidelines must be developed and, on the other hand, customers may be offered dimensioning tools as services, based on measured data and likelihood-based load models derived from this data. Helen Electricity Network has concrete tools and plans for helping customers dimension their connection needs more precisely.

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2. Starting points of the electricity distribution network development plan

2.1. Determination of the development zones of the electricity distribution network

2.1.1. Development zones

Helen Electricity Network Ltd's distribution area is divided into two development zones:

the area within the scope of the urban area development plan (1) and the area beyond the scope of the urban area development plan (2). Almost all of the distribution area in the City of Helsinki is within the scope of the urban area development plan. Only a few special areas (including Santahamina and Suomenlinna) and certain islands are beyond the scope of the urban area development plan (see Figure 13). On the map, the areas beyond the scope of the urban area development plan are marked with red.

2.1.2. Grounds for the development zone division

The division into development zones is based on the quality requirement levels defined in the Electricity Market Act, in other words: areas within and beyond the scope of the urban area development plan. Uniform principles are used in both zones, as applicable. Helen Electricity Network's distribution network is located almost entirely within the scope of the urban area development plan and it is developed in the entire area according to the same operational reliability, network planning and construction principles. This means that technical solutions are the same in the entire area mentioned above, apart from minor exceptions. In some areas beyond the scope of the urban area development plan (such as the Santahamina and Suomenlinna islands), the electricity network has already been built and developed in the same manner as in the areas within the scope of the urban area develop-

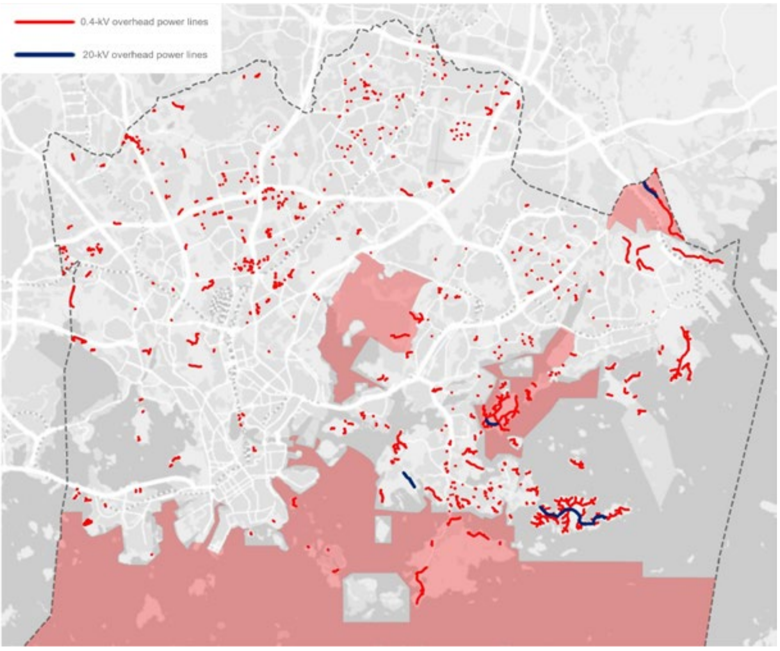

Figure 13. Helen Electricity Network Ltd's development zones and overhead power line network map.

ment plan. Later, the urban area development plan will be expanded to cover these islands and potentially other islands, too. Since the previous development plans, the urban area development plan has been expanded to the Vallisaari and Kuninkaansaari islands.

The above-mentioned Helen Electricity Network's operating area located within the scope of the urban area development plan consists in its entirety of major city area. The area has a high customer and population density. The customer base is dominated by the service sector and outages cause very significant harm to customers, the city and society. Long and extensive outages must be avoided. Consequently, supply reliability criteria that are considerably stricter than the current Electricity Market Act have been observed in Helsinki.

The supply reliability level of the electricity distribution network is measured with the average annual interruption duration per customer, called "System Average Interruption Duration Index" (SAIDI). SAIDI in Helsinki was somewhat over 20 minutes at the turn of the millennium and in the range of 12–15 minutes in the early 2000s. Occasional more extensive distribution interruptions led to it being reasonable and cost-efficient to aim at halving the interruption level to 6 minutes by 2015. In this, several system-technical means were used, too, described in more detail in the following section 2.1.3. Towards the end of last decade, the company managed to lower the SAIDI level as far as to approximately 3 minutes when measured as a 5-year average, even though low-voltage interruptions were also included in the calculation after 2016. The record is 1.23 minutes in 2020. These results are in the top class in Europe. Scheduled low-voltage interruptions must still be added to the above-mentioned figures, with an effect of approximately 1 minute. It can be said that a customer in Helsinki experiences an outage of an average duration of half an hour only once in ten years.

One of the company's own targets has also been the supply reliability target values published by Finnish Energy in 2010. In those, the target level for city environment planning by 2030 has been set at 1 hour of cumulative interruption time per customer per year, which can be exceeded once during a three-year period. This target is pursued with regard to 110-kV and medium-voltage network interruptions; in the low-voltage network, the fault repair times certainly exceed this target. Largely, this target is reached: the 1-hour annual interruption time is exceeded only for a few thousand customers.

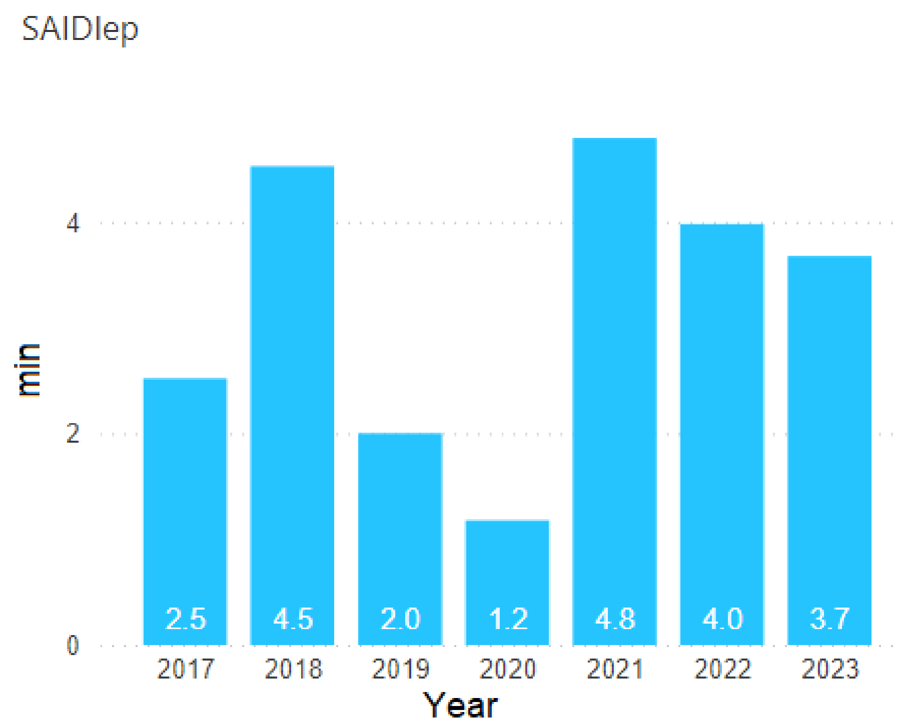

Figure 14. Customer's annual interruption time, energy-weighted (SAIDIep) in 2017–2023.

2.1.3. Description of the factors prevailing in the development zones

The descriptions apply to both development zones.

a. Technical characteristics and network structure solutions of the development zone

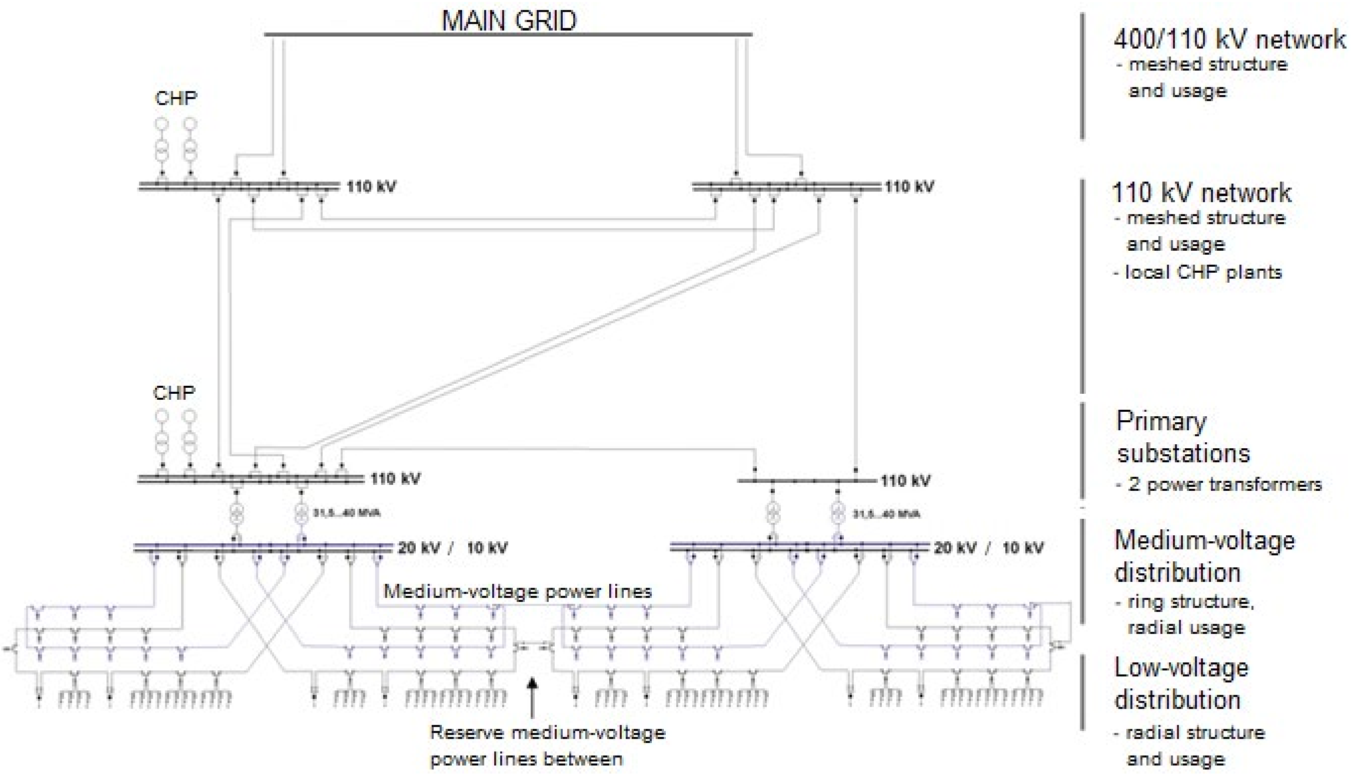

Figure 15. Basic structure of Helsinki's electricity distribution network.

Figure 15 shows the basic structure of Helsinki's electricity distribution network. Helsinki's electricity network has been and is being built in accordance with the operational reliability principles required by a major city. These principles serve as a basis for the area's electricity network planning principles and more detailed device and system specifications. Electricity network development is customer-oriented as long and extensive interruptions in the capital city have very negative effects. When the customer density is high, electricity distribution interruptions easily become very significant. The management of unexpected and scheduled interruptions is planned on the basis of the customer effects they cause. Interruptions in the 110-kV network should not, as a rule, have any effects on customers. In the medium-voltage network, the fault clearance and connection time, at the maximum, is normally allowed. Only in the low-voltage network, a customer interruption equal to the duration of the repair or the scheduled interruption, at the maximum, is allowed.

In the cable network, repair times are usually long. For this reason, network-based redundancy is needed in 110-kV and medium-voltage networks, to make interruption durations naturally an order of magnitude shorter than in a radial network. Furthermore, the 110-kV network has a special status, as described in the authority's statement regarding electricity network reliability: The intensive consumption concentration of the Helsinki metropolitan area with its significant regional production plants and functions that are important for the functioning of society sets special requirements for the reliability of the meshed 110-kV network. These requirements demand that Helsinki's meshed 110-kV network uses dimensioning principles that are consistent with the dimensioning principles used in the main grid (the Energy Authority's decision, record number 185/429/2003).

Operational reliability and planning principles are realised through the following network principles, among other things:

- Meshing of the 110 kV and medium-voltage network and recoverability in fault situations
- Switchgear assembly redundancy and compartmentalisation, gas-insulated 110 kV switchgear
- Underground cabling in the medium-voltage and low-voltage networks, medium-voltage network backup connections
- Use of automation at all primary substations and increasingly at distribution substations
- Use of alert-sending earth fault protection with medium voltage
- Typical low-voltage network structure (branch line and trunk cable network)

Helsinki has a strong local 110-kV high-voltage network, which transmits power to customers and, on the other hand, power generated by major local back-pressure power plants to the main grid. Thus far, in the winter, the distribution area has produced more power than it has consumed. The 110-kV network is strongly meshed. In the central area of the city, the 110-kV network consists largely of underground cabling. In the suburbs, the 110-kV network consists mainly of overhead power lines. The underground cabling network is being expanded, but new overhead lines are no longer built. The network has larger 110-kV hub stations and smaller line substations. In addition to electricity distribution, the hub station tasks include the transmission of electricity passing through it and, for operational reliability reasons, their switchgear always has two busbars and at least two groups, often more. Already since the end of the 1970s, 110-kV switchgear assemblies have used gas-insulated switchgear, which are smaller, more reliable and lower-maintenance than air-insulated switchgear. In the 110-kV network, preparations for N-1 faults are in place for all interruptions. As far as possible, there are also joint fault preparations.

The aim of the medium-voltage network planning principle is to implement the general medium-voltage distribution network as a radially used ring network, meshed to neighbouring primary substation. Distribution rings and meshes are implemented so that the load of the distribution substation to be replaced can be connected through the distribution network to the neighbouring primary substation.

Primary substations are duplicated with regard to the main transformer capacity, medium-voltage busbars and grouping. The structure of the medium-voltage network is also meshed and its use is based on open rings. At least two cable connections are always built to distribution substations. The medium-voltage network is dimensioned so that an entire primary substation can be fully replaced from neighbouring primary substations. In practice, the medium-voltage network consists completely of underground cabling and its capacity is the same in all parts of the network. In the central area of the city, the distribution voltage is 10 kV due to historical reasons. In other areas, it is 20 kV. Distribution substations are located either in properties or as separate entities. Gas-insulated Ring Main Unit switchgear has been used for a long time already. There are many medium-voltage customers connected to the medium-voltage network.

Urban primary substations are particularly large and have a wide variety of functions. As a result, significant investments have been made in primary substation automation. Nowadays, nearly all primary substations have substation-level data communications based on either IEC61850 or serial data communications. Field equipment is numeric and has many protection and control functions. Investments have also been made in remote use and data communications between primary substations: the solutions used include structurally fault-tolerant optical fibre connections and the company's internal process data communications network. Investments in distribution substation automation have been made for nearly 15 years. At the moment, more than 30% of distribution substations are automated with the aid of remote use connections, medium-voltage fault positioning, alerts and low-voltage measurements. Distribution substation automation yields benefits in both normal use and fault situations. Going forward, the installation of distribution substation automation in new distribution substations is considered on a case-by-case basis.

In an urban medium-voltage network consisting of underground cabling and with an extensive earthing network, alert-sending earth fault protection can be used, in other words: the use of the network can continue in the event of an earth fault. Touch voltages during an earth fault are not a problem because earthing conditions are good and fault currents mainly go to earthing. The fault location is separated without customer interruptions or at the maximum with short connection interruptions; this is achieved in approximately half of medium-voltage network faults. Alert-sending earth fault protection has been used in the 10-kV network for decades. It was implemented also in the 20-kV network when the earth fault current compensation project was completed in 2018.

The structure of the low-voltage network is radial. However, reserve connections to neighbouring power transformer circuits have formed naturally as the network has been built. Some customers are directly connected to the distribution substation's low-voltage switchgear while others are connected to distribution cabinets along the trunk cables of the low-voltage network. There are also reserve connections between distribution transformer circuits, often enabling the recoverability of the transformer circuit load in case of a fault or maintenance. The connections also enable earthing connections required by the extensive earthing network.

In the areas beyond the scope of the urban area development plan, there are no primary substations, only ring/radial medium-voltage networks and low-voltage networks. The 110 kV network extends to both development zones. When the urban area development plan is expanded, the electricity network also expands as part of infrastructure construction.

b. Electricity delivery sites and special electricity consumption needs of the development zone

Helen Electricity Network Ltd's operating area located within the scope of the urban area development plan is in its entirety major city area. The area has a high customer and population density. The customer base is dominated by the service sector and outages cause very significant harm to customers, the city and society. Long and extensive outages must be avoided. Consequently, supply reliability criteria that are considerably stricter than the current Electricity Market Act have been observed in Helsinki.

At the moment, there are some major point loads related to the 110-kV network, but their number will increase in the next few years and the power level of individual point loads will increase up to the over-100-MW category.

In the area within the scope of the urban area development plan, a significant electricity consumption customer group is the private and public service sector, which consumes about 55% of the area's electrical energy. For some of this customer group, electricity plays a highly critical role and tolerance for even short outages is weak. Critical consumption takes place at each substation and in many medium-voltage outputs. On average, each medium-voltage output has at least one medium-voltage connection customer.

In the area beyond the scope of the urban area development plan, there are mainly holiday homes and island residences.

c. Environmental conditions and soil of the development zone

In development zone 1, which covers the area within the scope of the urban area development plan (the colourless area in Figure 13), the environment where the electricity network is located mainly consists of built-up areas, accounting for approximately 70% of the development zone area, when water systems are excluded. The other parts of the zone mainly consist of open spaces with little or no vegetation, bare rock, forests and agricultural areas. However, these parts do not have significant electricity consumption and, as a result, hardly any electricity network. In development zone 1, prominent features include both the high power density of electricity consumption and the density of other infrastructure, which cause considerable costs related to electricity network construction, especially paving and land use costs. The zone also has several significant and critical consumers of electricity.

The top 5 CLC (Corine Land Cover) classes of development zone 1's built-up areas are:

1. Continuous urban fabric (CLC class 111) – 21%
2. Discontinuous urban fabric (CLC class 112) – 27%
3. Industrial or commercial units (CLC class 121) – 23%
4. Road and rail networks and associated land (CLC class 122) – 15%
5. Green urban areas (CLC class 141) – 4%

The classes "Continuous urban fabric", "Industrial or commercial units" and "Road and rail networks and associated land" form approximately two thirds of the built-up areas in development zone 1. In these areas, excavation work is often restricted and it is necessary to build the electricity network under pedestrian and bicycle routes, roads or streets due to city regulations or other infrastructure. These are mainly paved with asphalt and have busy traffic, incurring considerable costs related to planning and building the electricity network, such as paving and traffic control costs. Furthermore, the cable routes in development zone 1 are often exposed to excavation damage due to dense infrastructure and other busy construction activity, which increases costs and the need for maintenance.

In the electricity network company monitoring methods, excavation costs are considered on the basis of the excavation site location and the Energy Authority has specified excavation areas for coming years in more detail. Although the specifications of excavation areas have become more precise, they still do not provide a sufficient description of electricity network construction costs in Helsinki's urban areas. This means that, for instance, in Helsinki's apartment building areas, the electricity network cannot be built at the cost level defined in the monitoring methods. Helen Electricity Network's view is that taking continuous urban fabric (CLC class 111) into account in excavation costs would improve the cost correlation of the monitoring methods, enabling the sustainable and profitable development of the electricity network in Helsinki in the future, too.

Development zone 2, which mainly consists of the area beyond the scope of the urban area development plan (the red area in Figure 13), is dominated by sea and islands. Approximately 96% of the area consists of water systems. When water systems are excluded, the five largest CLC classes are the following:

1. Coniferous forest (CLC class 312) – 29%
2. Mixed forest (CLC class 313) – 13%
3. Bare rock (CLC class 332) – 9%
4. Industrial or commercial units (CLC class 121) – 8%
5. Non-irrigated arable land (CLC class 211) – 13%

In development zone 2, distances are long, the customer density is low and the construction of the electricity network between islands requires special solutions, such as underwater cables, which makes construction expensive. In addition, challenges associated with electricity network maintenance increase due to distances and accessibility. However, there are not as many critical customers in the zone as in development zone 1.

Helen Electricity Network's 110-kV high-voltage distribution network is mainly located in development zone 1, where the power density of electricity consumption is high and electricity consumption is critical due to numerous significant and critical users of electricity, for instance. The criticality of electricity consumption and security of supply has required that the structure of the high-voltage distribution network is as reliable as possible. The criticality of Helsinki's high-voltage distribution network will become even more prominent in the future as the electrification of heating will make district heat production increasingly dependent on electrical energy. This development will increase electricity consumption and make the reliable operation of the high-voltage distribution network in all situations even more important.

In the structure of Helsinki's 110-kV overhead power line network, attention has been paid to the proximity of the sea and the strengthening of extreme climate conditions. These factors have been taken into account in standard-compliant maximum wind load, for instance. Due to numerous intersections of major traffic arteries, the 110-kV overhead power line network has exceptionally many tensioning towers to ensure that, in case of an accident, tower damage can be confined as small an area as possible. Towers used must be exceptionally tall free-standing steel towers with short cable span distances to make rights-of-way narrower and to secure the safety of city residents. Due to the growth of the city, short line transfers, encompassing a couple of tower spans, are often necessary.

In the 110-kV cable network, heavy protection (concrete channel and pipes) is mainly used due to numerous intersections and nearby construction activity. For some cable connections, there is no space available above the ground and, as a result, cables are placed in rock tunnels. Usage rights and restrictions for the most significant transmission cable connection routes have been acquired through expropriation.

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d. Impacts of the operating environment change forecast (described in section 1) in the development zone

As described in section 1, electricity consumption will increase in Helsinki due to neighbourhood and complementary construction, the electrification of traffic and the energy transition. This increase will take place in all areas within the scope of the urban area development plan, more in some, less in others.

Already in 2024, there will be new major point loads in Helsinki's high-voltage distribution network in the form of new 110-kV connections. Within a few years, it will be a question of several hundreds of megawatts of load from electric boilers and heat pumps. These secure city heating power in the district heating network when back-pressure power plants using fossil fuels are decommissioned. The Hanasaari power plant was decommissioned in spring 2023 and the Salmisaari B power plant will be decommissioned in spring 2025. As a result, a significant amount, nearly 400 MW, of electricity production will be eliminated from the network, being replaced by electricity consumption amounting to hundreds of megawatts. This more than doubles the 110-kV network's electricity transmission power and will pose challenges to the current transmission capacity even at the main grid level.

2.1.4. Basic numeric information about the development zones and figures describing the network

a) Network in the development zone

i) Average age

Development zone 1:

Low-voltage network

- The average age of overhead low-voltage lines is approximately 35 years.
- The average age of underground low-voltage cables is approximately 24 years.

Medium-voltage network

- The average age of overhead medium-voltage lines is approximately 32 years.
- The average age of underground medium-voltage cables is approximately 23 years.

Development zone 2:

Low-voltage network

- The average age of overhead low-voltage lines is approximately 37 years.
- The average age of underground low-voltage cables is approximately 32 years.

Medium-voltage network

- The average age of overhead medium-voltage lines is approximately 40 years.
- The average age of underground medium-voltage cables is approximately 25 years.

ii) Average technical service life

The average technical service life in development zone 1 is approximately 55 years.

The average technical service life in development zone 2 is approximately 45 years.

b) Length of the electricity distribution network

i) Medium-voltage

In development zone 1, there are about 3 km of overhead medium-voltage line network and about 1,637 km of underground medium-voltage cabling network, in other words: a total of about 1,640 km of medium-voltage network.

In development zone 2, there is about 1 km of overhead medium-voltage line network and about 55 km of underground medium-voltage cabling network, in other words: a total of about 56 km of medium-voltage network.

ii) Low-voltage

In development zone 1, there are about 61 km of overhead low-voltage line network and about 4,544 km of underground low-voltage cabling network, in other words: a total of about 4,604 km of low-voltage network.

In development zone 2, there are about 17 km of overhead low-voltage line network and about 49 km of underground low-voltage cabling network, in other words: a total of about 66 km of low-voltage network.

c) Length of network that fulfils the operational quality requirements

i) Medium-voltage

In development zone 1, about 1,640 km of the medium-voltage network fulfil the quality requirements of electricity distribution network operations.

In development zone 2, about 55 km of the medium-voltage network fulfil the quality requirements of electricity distribution network operations.

ii) Low-voltage

In development zone 1, about 4,585 km of the low-voltage network fulfil the quality requirements of electricity distribution network operations.

In development zone 2, about 66 km of the low-voltage network fulfil the quality requirements of electricity distribution network operations.

d) Number of connections

i) In the area within the scope of the urban area development plan

There are 36,601 connections in the area within the scope of the urban area development plan.

ii) In the area beyond the scope of the urban area development plan

There are 303 connections in the area beyond the scope of the urban area development plan.

e) Number of electricity delivery sites

i) In the area within the scope of the urban area development plan

There are 429,030 delivery sites in the area within the scope of the urban area development plan.

ii) In the area beyond the scope of the urban area development plan

There are 981 delivery sites in the area beyond the scope of the urban area development plan.

f) Number of electricity delivery sites that fulfil the operational quality requirements

i) In the area within the scope of the urban area development plan

In the area within the scope of the urban area development plan, there are 428,873 delivery sites that fulfil the quality requirements of electricity distribution network operations.

ii) In the area beyond the scope of the urban area development plan

In the area beyond the scope of the urban area development plan, there are 959 delivery sites that fulfil the quality requirements of electricity distribution network operations.

g) Amounts of underground cabling

i) Medium-voltage

In development zone 1, there are about 1,637 km of underground medium-voltage cabling network.

In development zone 2, there are about 55 km of underground medium-voltage cabling network.

ii) Low-voltage

In development zone 1, there are about 4,544 km of underground low-voltage cabling network.

In development zone 2, there are about 49 km of underground low-voltage cabling network.

h) Length of overhead power lines located in forests

i) Medium-voltage

In development zone 1, there are about 2.9 km of overhead medium-voltage line network located in forests.
In development zone 2, there are about 0.4 km of overhead medium-voltage line network located in forests.

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ii) Low-voltage
In development zone 1, there are about 19 km of overhead low-voltage line network located in forests.

In development zone 2, there are about 14 km of overhead low-voltage line network located in forests.

i) Length of overhead power lines along roads

i) Medium-voltage
In development zone 1, there is 0 km of overhead medium-voltage line network along roads.

In development zone 2, there are about 0.6 km of overhead medium-voltage line network along roads.

ii) Low-voltage
In development zone 1, there is 0 km of overhead low-voltage line network along roads.

In development zone 2, there are about 3 km of overhead low-voltage line network along roads.

j) Length of overhead power lines that fulfil the quality requirements

i) Medium-voltage
In development zone 1, there are about 2.8 km of overhead medium-voltage line network that fulfil the quality requirements.

In development zone 2, there are about 0.4 km of overhead medium-voltage line network that fulfil the quality requirements.

ii) Low-voltage
In development zone 1, there are about 41 km of overhead low-voltage line network that fulfil the quality requirements.

In development zone 2, there are about 17 km of overhead low-voltage line network that fulfil the quality requirements.

k) Key figures of Helen Electricity Network's high-voltage and medium-voltage networks:

	Length	Average age
110-kV overhead power lines	130 km	32 years
110-kV underground cabling	81 km	19 years
110/20-kV main transformers	50	20 years
Gas-insulated 110-kV switchgear	19	29 years
Air-insulated 110-kV switchgear	2	44 years
20-kV and 10-kV switchgear	27	27 years
Distribution substations	1,900	19 years

Table 3. Key figures of Helen Electricity Network's high-voltage and medium-voltage networks.

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2.2. Development strategy for the network located in the electricity distribution network development zone

The development strategy applies to both development zones.

2.2.1. Planning criteria that fulfil the operational quality requirements

a. 6-hour quality requirement

The distribution network is developed according to the planning criteria described in section 2.1.3 a. The main development need is associated with the 110 kV network as it will be subject to hundreds of megawatts of new heating load. As there will be a lot of load in the southern parts of the central area, for instance, this will create a need for new primary substations as well as 110 kV transmission connections and their reinforcement. In addition, main grid connection development will be needed.

The medium-voltage network is developed according to connection needs and neighbourhood construction. In addition, there is also network topology development. In the near future, primary meshing development areas include the Meilahti, Laajasalo and Vuosaari distribution areas.

b. 36-hour quality requirement

The distribution network is developed according to the planning criteria described in section 2.1.3 a. The 36-hour quality requirement area is decreasing as the expansion of the urban area development plan proceeds. Even in the 36-hour area, the aim is to fulfil the 6-hour quality requirements of the major city area as far as possible.

2.2.2. Consideration of special characteristics in network planning

a. Joint construction and connections to other network operators' networks

Helen Electricity Network participates in the City of Helsinki's Yhteinen kunnallistekninen työmaa (Joint municipal engineering worksite) concept. In it, it is agreed that builders of civil engineering networks cooperate. The parties maintain information about their future construction projects in the joint Louhi service, delimited geographically and temporally, enabling other parties to adjust their own projects to form a joint worksite. The network construction projects in the Louhi service are also visible in the verkkotietopiste.fi service. In addition, in the city's neighbourhood construction projects, the construction needs of infrastructure operators are determined (general municipal engineering plan, KYS).

b. Flexibility services

Helen Electricity Network monitors the development of flexibility services actively; however at the moment, they are still in the early stages of development from the network planning point of view. More detailed information about flexibility services and both completed and ongoing experiments and analyses are provided in sections 5 and 6 of this development plan.

c. Sites that are critical to the functioning of society

Helen Electricity Network carries out regular cooperation with parties that operate in Helen Electricity Network's distribution area and are crucial for society. These parties are divided into the following main groups:

- underground networks
- teleoperators
- social welfare and healthcare services
- media houses
- authorities
- traffic
- energy companies
- electricity network companies.

The location and type information of the critical sites are used in defining disconnection groups, creating contingency plans and planning network work interruptions, for instance.

d. Energy efficiency actions

For a long time already, loss management and reduction have been goals when minimising both financial and environmental impacts. Low loss levels have been guaranteed by the fairly low load level, enabled and also required by distribution network redundancy, and low-loss components, such as transformers. As a whole, losses in Helen Electricity Network's distribution network are only a little over 2%. As part of Helen Ltd's Energy Efficiency Agreement, Helen Electricity Network reports its annual energy efficiency improvement measures. At the beginning of this year, a tool was introduced for reviewing and optimising customers' connection capacity. With it, the customer sees the free capacity of their connection precisely and, as a result, unnecessary connection expansions can be avoided and the customer's needs can be met optimally. In the future, the purpose is to develop a tool for assessing the connection size of new connections with the help of existing typical load graphs.

2.3. Calculation of network life cycle costs in the development zone

Development zone life cycle costs refer to costs that arise from sources such as investments and various in-use costs over the review period.

a. Definition of life cycle cost factors

The cost efficiency comparison has been conducted according to the Energy Authority's development plan regulation, in which life cycle costs include:

- investment (planning and construction)
- operational expenses (condition inspections, maintenance and fault repair)
- harm caused by interruptions (Customer interruption cost, CIC) with the Energy Authority's CIC values (price of undelivered energy)

b. Joint construction in the calculation of life cycle costs

In investments, the aim is joint construction in accordance with the City of Helsinki's Yhteinen kunnallistekninen työmaa (Joint municipal engineering worksite) concept. The benefits of joint construction can be seen in investment costs.

c. Other network solutions in the calculation of life cycle costs

As described in section 3, Helen Electricity Network's densely built distribution area, 1-kV electricity distribution or electricity storage, for instance, do not constitute genuine alternatives to the normally used network construction solutions and there are no suitable flexibility services available in the market either.

d. Monitoring of life cycle costs

The actual life cycle costs and their cost efficiency are monitored as part of the company's reporting of financial and other key figures. The improvement of cost efficiency is also included in long-term network construction and maintenance partnership agreements.

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3. Cost comparison of the solution used in the electricity distribution network development zones

3.1. Solutions in the development zone

a. Solutions used

Both development zones use underground cabling, overhead lines and overhead cables as solutions. Wider rights-of-way are used in 110 kV networks. By far the most significant solution is to use underground cabling.

b. Solutions excluded from the comparison

In practice, underground cabling is the only network construction option in most areas within the scope of the urban area development plan because street plans determine the potential locations of underground civil engineering networks and overhead power line solutions cannot be used. The Electricity Market Act's 6-hour quality requirement in areas within the scope of the urban area development plan also means that, in practice, underground cabling must be used.

Coated overhead line is not used because overhead cable requires less maintenance and is more durable in the windy archipelago.

No need for 1-kV electricity distribution or 1.5-kV direct current systems has been perceived in Helen Electricity Network's distribution area because a voltage decrease in the low-voltage network remains acceptable in the densely built urban area where the distribution substation density is also high.

Thanks to Helen Electricity Network's comprehensive underground cabling and the reserve feeding connections of ring networks, the quality-enhancing benefits offered by electricity storage facilities remain both minor and not cost-efficient. In the example solution, the savings potential with regard to costs related to harm caused by interruptions (CIC) is minor when compared to the costs of the required battery systems.

There are no flexibility services that would be a suitable alternative to network investments available in the market at the moment. Helen Electricity Network monitors the development of services actively and is involved in operational development through pilot projects.

3.2. Description of the electricity distribution solutions proposed for the development zones

a. Solution with lowest life cycle costs

Helen Electricity Network's network area consists of urban network located mainly in the area within the scope of the urban area development plan and the same solutions are generally used for electricity network construction in the entire network area and, consequently, in both development zones, too. In Helen Electricity Network's network area, the high number of low-voltage connections encourages the use of numerous distribution substations and distribution cabinets. The low-voltage and medium-voltage networks are built with underground cabling, with the exception of certain special sites, due to the densely built urban environment. At Helen Electricity Network, the optimal network structure suitable for the urban environment has been studied in previous years in several theses, and in recent years in publications such as the following: Distribution Automation and Self-Healing Urban Medium Voltage Networks, Kaupunkikeskijänniteverkon optimointi (Optimisation of Urban Medium Voltage Network)

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To ensure capacity during network faults, distribution networks are built as ring networks. In the event of a fault, power supply to customers can usually be routed from other transformer circuits through division boundary changes. If the low-voltage network cannot be replaced through adjacent transformer circuits when an investment project is carried out, the aim is to use reserve power machinery, if necessary.

The majority of the investment costs of the solution arise from the planning and construction of the distribution network. Helen Electricity Network's investment projects use distribution substations located in properties and as separate entities. In this respect, solution costs arise also from space fees associated with property distribution substations and permit and location fees associated with separate distribution substations. In some investment projects, costs only arise from the refurbishment of cables in the existing distribution network. The operational costs of the solution are very low when compared to investment costs and consist of proactive maintenance (condition inspections, service), repair maintenance and compensation paid for harm caused by interruptions (CIC).

b. Alternatives to the lowest-cost solution

Alternatives to investment that are implemented in Helen Electricity Network's network area are underground cabling networks with distribution cabinets (solution 1, lowest cost) or distribution network construction without distribution cabinets (solution 2) and by installing cabling to new connections directly from distribution substations' low-voltage switchgear.

In solution alternative 2, medium-voltage cabling was carried out in the same manner as in the selected lowest-cost solution 1. The difference compared to the implemented solution is low-voltage network construction without distribution cabinets. This implementation method increased the cabling and earthworks costs of the investment project, due to the larger amount of cabling from distribution substations to low-voltage connections.

Cabling routes in Helsinki are influenced by many factors, such as the placement of other civil engineering solutions in the street area, urban area development plans and their changes as well as the city's own guidelines and regulations regarding the placement of civil engineering solutions. As a rule, electricity network cables are placed under pedestrian and bicycle routes so that fault repairs can be carried out without interrupting vehicle traffic. In some cases, it is not possible to use the most direct route as it would pass through a city-owned park area, for instance, where cables cannot be placed. Cables cannot be placed near trees either as tree roots would be damaged in connection with excavation and, in the event of a fault, it is not advisable to use mechanical excavation near the roots.

3.3. Comparison of the life cycle costs of the development zone

a. Description of a project that is typical to the development zone and that is used in the cost comparison

In the selected solution 1, the renewal of the distribution network was carried out using underground medium-voltage and low-voltage cabling networks and low-voltage distribution cabinets installed in appropriate locations. The route choices in the solution used the routes of the existing distribution network. When distribution cabinets are used, connection cables are significantly shorter and fewer distribution substations are needed because several connections can be fed from the same distribution cabinet and distribution substations' low-voltage switchgear can be used more efficiently.

b. Comparison of a project that is typical to the development zone

The total costs in the different solutions are:

- Solution 1 (optimal network structure): EUR 480,000
- Solution 2 (without distribution cabinets): EUR 617,000

4. Long-term plan

According to Helen Electricity Network's long-term plan, gross investments in network assets in 2024–2033 are approximately EUR 310 million. Replacement and change investments (approximately EUR 230 million, Figure 16) include significant network change investments that enable the city's development and the green transition as well as investments related to the renewal of the ageing electricity network. Many of these investments are allocated to the 110 kV high-voltage distribution network, primary substations and electricity meters. Network asset expansion investments (Figure 17) make it possible to build new residential areas in the city.

These investments enable the city's growth and it is estimated that approximately EUR 80 million will be used for these investments in the said period, allocated mainly to the construction of new medium-voltage and low-voltage networks and distribution substations. New construction consists of approximately 200 km of medium-voltage network, 400 km of low-voltage network and 200 distribution substations. In the next ten years, approximately EUR 15 million will be used in the maintenance and inspection of network assets.

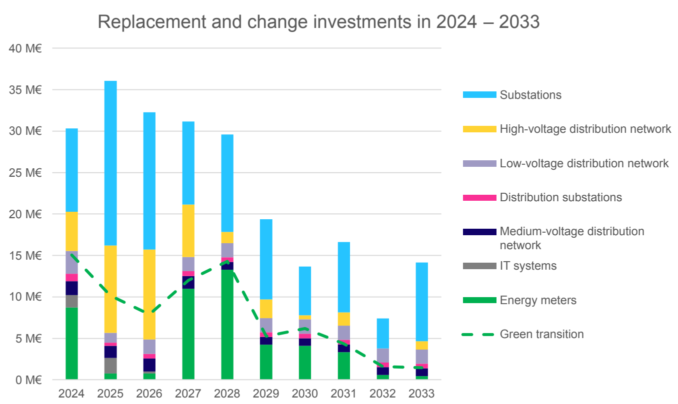

Figure 16. Helen Electricity Network's replacement and change investments in network assets and the share of the green transition in 2024–2033.

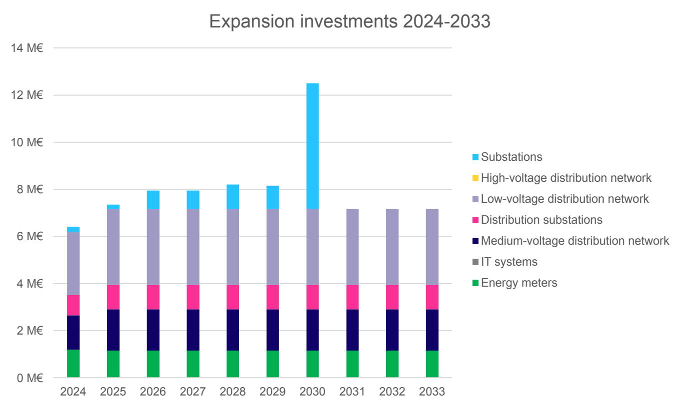

Figure 17. Helen Electricity Network's expansion investments in 2024–2033.

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4.1. Use of funds in different periods

a. High-voltage distribution network

i. Investments
a) 2014–2021: EUR 24.8 million
b) 2022–2028: EUR 36.1 million
c) 2029–2036: EUR 5.6 million

ii. Maintenance
a) 2014–2021: EUR 0.59 million
b) 2022–2028: EUR 0.63 million
c) 2029–2036: EUR 0.90 million

b. Primary Substations

i. Investments
a) 2014–2021: EUR 49.8 million
b) 2022–2028: EUR 74.9 million
c) 2029–2036: EUR 40.4 million

ii. Maintenance
a) 2014–2021: EUR 3.6 million
b) 2022–2028: EUR 8.9 million
c) 2029–2036: EUR 9.3 million

c. Medium-voltage distribution network

i. Investments
a) 2014–2021: EUR 30.5 million
b) 2022–2028: EUR 14.8 million
c) 2029–2036: EUR 7.5 million

ii. Maintenance
a) 2014–2021: EUR 0.05 million
b) 2022–2028: EUR 0.09 million
c) 2029–2036: EUR 0.12 million

d. Distribution substations

i. Investments
a) 2014–2021: EUR 22.8 million
b) 2022–2028: EUR 6.2 million
c) 2029–2036: EUR 4.4 million

ii. Maintenance
a) 2014–2021: EUR 0.29 million
b) 2022–2028: EUR 0.32 million
c) 2029–2036: EUR 0.80 million

e. Low-voltage distribution network

i. Investments
a) 2014–2021: EUR 38.0 million
b) 2022–2028: EUR 22.8 million
c) 2029–2036: EUR 13.7 million

ii. Maintenance
a) 2014–2021: EUR 0.25 million
b) 2022–2028: EUR 0.29 million
c) 2029–2036: EUR 0.35 million

4.2. Delivery sites that fulfil the quality requirements at the points of time laid down in section 119 of the Electricity Market Act

a) In the area within the scope of the urban area development plan

i) 31 December 2023
On 31 December 2023, the area within the scope of the urban area development plan had 428,873 delivery sites that fulfil the quality requirements.

ii) 31 December 2028
On 31 December 2028, the area within the scope of the urban area development plan will have approximately 463,900 delivery sites that fulfil the quality requirements.

b) In the area beyond the scope of the urban area development plan

i) 31 December 2023
On 31 December 2023, the area beyond the scope of the urban area development plan had 959 delivery sites that fulfil the quality require ments.

ii) 31 December 2028
On 31 December 2028, the area beyond the scope of the urban area development plan will have approximately 1,000 delivery sites that fulfil the quality requirements.

c) In areas subject to a quality requirement level based on local circumstances

i) 31 December 2023 0
ii) 31 December 2028 0

4.3. Electricity distribution network that fulfils the quality requirements at the points of time laid down in section 119 of the Electricity Market Act

a) Medium-voltage, km

i) 31 December 2023
On 31 December 2023, approximately 1,695 km of the medium-voltage network fulfilled the operational quality requirements.

ii) 31 December 2028
On 31 December 2028, approximately 1,730 km of the medium-voltage network will fulfil the operational quality requirements.

b) Low-voltage, km

i) 31 December 2023
On 31 December 2023, approximately 4,651 km of the low-voltage network fulfilled the operational quality requirements.

ii) 31 December 2028
On 31 December 2028, approximately 4,790 km of the low-voltage network will fulfil the operational quality requirements.

4.4. Rate of underground cabling in the electricity distribution network at different voltage levels after actions, at the points of time laid down in section 119 of the Electricity Market Act

a) Medium-voltage, %

i) 31 December 2023
On 31 December 2023, the rate of underground cabling in the medium-voltage network was approximately 99.8%.

ii) 31 December 2028
On 31 December 2028, the rate of underground cabling in the medium-voltage network will be approximately 99.8%.

b) Low-voltage, %

i) 31 December 2023
On 31 December 2023, the rate of underground cabling in the low-voltage network was approximately 98.3%.

ii) 31 December 2028
On 31 December 2028, the rate of underground cabling in the low-voltage network will be approximately 98.7%.

4.5. New production and new loads that are estimated to connect to the network and that will require significant distribution network investments in the next ten years

As described in sections 1 and 2, in the future, energy production will, to a significant extent, move from current fossil sources to energy production that consumes a lot of electricity (heat pumps, electric boilers, hydrogen production), which require significant investments especially in the 110-kV network. In the ten-year period, not only several heat production plants but probably also data centres will connect to the high-voltage distribution network. Cruise ships' transition to on-shore power supply according to the EU Directive will also presumably require 110-kV connections. The above require the reinforcement of the high-voltage network in the north-south direction, in other words: from the main grid connection points to the central area of the city, as well as the reinforcement of the cable network in the central area.

In addition to heavy, passenger car and rail traffic, the electrification of traffic also takes place as ships start using on-shore power supplies and ship and ferry traffic becomes increasingly electric. These cause an estimated increase of a few dozen megawatts in electrical power by 2033.

According to the City of Helsinki's latest housing production forecast, serving as a basis for the development plan's expansion investment programme, new housing totalling 5.4 million square metres of floor area will be built in Helen Electricity Network's operating area in the next ten years. The volume is approximately 15% less than in the previous forecast published two years ago.

The slightly lower housing production in the next few years will mostly be due to the market situation, although the city's forecast does not actually take economic cycles into account. The volume of projects taking place in the coming years can be estimated on the basis of building permits, plot reservations and neighbourhood construction projects. On the basis of them, the actual volume now seems to be lower, which is reflected in the latest forecast. Other housing construction challenges in the coming years include, for instance, the termination of the Hitas price regulation system and the state's actions to discontinue right-of-occupancy housing production. The city has plans for construction in both of these housing ownership forms.

According to the City of Helsinki's housing production forecast for 2020–2035:

In Helsinki, the entire city's future housing construction is summarised in an annual housing production forecast. The forecast is drawn up for the next fifteen years at a minimum and it is used for purposes such as creating and monitoring the housing and related land use implementation programme (AM) and bringing Helsinki's population forecast to an area level.

The housing production forecast is based on project-level information in the housing production project register (ATO). The register contains information about the housing-related floor area defined in the urban area development plan. The floor area is used as the basis for calculating estimates of the number of apartments to be completed.

The timing of housing construction is determined primarily on the basis of information about the city's neighbourhood construction projects. The timing takes into account several construction-related details, such as opportunities created by investments, the municipal engineering state of the construction areas and construction preparation needs. The timing is also specified in more detail on the basis of information obtained directly from building developers and construction companies.

Register information is continuously updated. Over a long term, the forecast may change as the information on which it is based changes and becomes more precise. In addition, it is influenced by potential complaints related to the urban area development plan and factors related to land ownership, among other things. The forecast takes into account the construction opportunities allowed by the urban area development plan but does not estimate the impact of economic cycles on construction volume, for instance.

The city has not produced a similar-level forecast of the construction office, service and commercial properties. It is assumed that this kind of construction develops in line with housing construction development.

4.6. Significant distribution network investments to be made for connecting new capacity and new loads in the next ten years

a. In the next 0–5 years

To connect new production and new loads, it is estimated that during the period under review, investments in the 110 kV and distribution networks will amount to approximately EUR 30–40 million, of which investments in distribution substations and the medium-voltage network will account for roughly EUR 20 million.

b. In the next 6–10 years

To connect new production and new loads, it is estimated that during the period under review, investments in the 110 kV and distribution networks will amount to approximately EUR 20–30 million, of which investments in distribution substations and the medium-voltage network will account for roughly EUR 20 million.

4.7. Description of connecting new production and new loads in the network area

a. Geographical location of investments

Heat generated for the district heating network with industrial-scale heat pumps and electric boilers will be decentralised throughout the city. The largest centralised solutions are built close to heat consumption sites in the current energy production areas (Salmisaari and Hanasaari) and near peak heat plants. Large compressors intended for cooling are usually located by the sea near the district cooling network.

According to the City of Helsinki's housing production forecast for 2020–2035 (Figure 18), in the next ten years, half of new housing construction will be built in new areas and along urban boulevards (Tuusulanväylä and Vihdintie). However, the effects of boulevard construction will be visible only in the latter part of the ten-year period and onwards. New areas in Helsinki include Kalasatama, Koivusaari, Kruunuvuorenranta, Kuninkaantammi-Honkasuo, Pasila and areas around West Harbour and Malmi Airport. In the next ten years, the net transmission capacity need at the primary substation level will increase by 30–40 MW.

Suburban regeneration is the City of Helsinki's new way to develop residential areas. It is carried out to increase resident satisfaction and to attract new residents to areas. Malminkartano, Kannelmäki, Malmi and Mellunkylä have been selected as suburban regeneration areas. The city's goal is to increase housing in these areas by one third by 2035 .

Complementary housing construction has been made possible in Helsinki throughout Helen Electricity Network's operating area along good public transport connections. During this decade, the amount of housing construction along the Jokeri Light Rail line is equal to the amount of neighbourhood construction in areas around West Harbour or the entire Pasila area.

Electricity connections serving ship traffic will mainly be located in the harbours of the central area of the city.

b. Free network capacity to connect new production and new loads

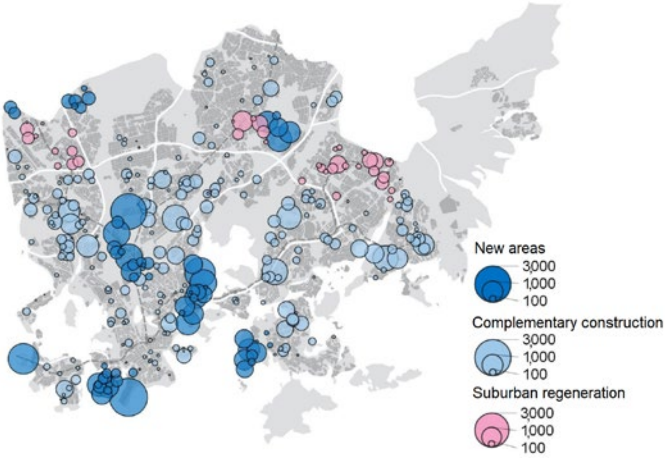

Figure 18. City of Helsinki, housing production forecast for 2020–2035 (1 July 2020), apartments to be completed, by zoning areas, 2020–2035. Asuntotuotantoennuste 2020-2035 (Housing production forecast for 2020–2035)

At the moment, there is, in principle, a lot of free capacity in the 110-kV network if we look at the normal network situation in which there are no faults or scheduled interruptions in the network. However, the amount of free capacity differs in different parts of the 110-kV network. To illustrate this, various transmission interfaces have been defined (see Figure 19). The transmission capacity in a situation in which there are no faults of interruptions in the network is called the N-0 capacity.

In the 110-kV high-voltage distribution network, Helen Electricity Network's level of fault preparedness is such that the worst individual fault does not normally cause a transmission interruption to customers. In the worst fault or interruption situation, the transmission capacity of the network is substantially lower than in a normal situation. The transmission capacity of the worst fault or interruption situation is called the N-1 capacity. Also the N-1 capacity is presented separately for each transmission interface. Previously, the network was dimensioned so that in the worst fault or interruption situation, none of the components are subject to overloading and there is no need to restrict consumption. In practice, this has meant that the N-1 capacity must correspond to the highest consumption in the network. However, exceptions to this principle can be made with flexibility (demand response). The N-1 limit describes how much non-flexible load there can be in the network. If a customer is capable of restricting their power consumption quickly in case of a fault, at the maximum the N-0 transmission capacity can be reached, in theory. In the tables, it can be seen that in 2025 and 2026, free capacity in a N-1 situation is negative. This is resolved with temporary flexibility agreements, with which power supply to new consumption sites can be restricted in case of a fault or an interruption.

In addition the 110-kV network, the increase in electricity consumption is restricted by the transmission capacity of the main grid. At the moment, the capacity of the 400/110-kV transformers that feed power to Helsinki and Vantaa is insufficient. Fingrid is seeking a significant capacity increase by the end of 2026. However, even after this, the main grid, as a whole, still restricts transmission more than the 110-kV network. Fingrid's starting point has previously been that main grid transmission must always be restricted in advance within the N-1 transmission capacity, whereas in restriction situations in Helen Electricity Network's 110-kV network, it is considered possible to act in a reactive manner when a fault occurs if this can be done in a reliable and sufficiently fast manner. On the basis of the most recent discussions, Fingrid also considers it possible that in normal usage circumstances, the N-1 capacity could be exceeded slightly if, in the event of a fault, sufficiently fast and reliable measures can be taken.

During high consumption, the voltage in the main grid may become too low. These voltage problems may restrict transmission even more than the capacity of 400/110-kV transformers. Helen Electricity Network's view is that during this decade, the main grid probably restricts electricity consumption in Helsinki significantly more than Helen Electricity Network's own network. In the comparison table, the main grid restrictions are presented according to the most optimistic scenario, in which two new main grid 400/110-kV transformers are deployed by the end of 2026 and, in addition, voltage problems are resolved quickly so that the capacity of the new transformers is immediately fully available. Considerably more pessimistic scenarios regarding the transmission capacity of the main grid are also possible according to the information available at the time of writing.

The free capacity development presented in Tables 4–6 reflects Helen Electricity Network's current investment plan and the best understanding regarding Fingrid's future investments. With regard to new 110-kV customer connections, the tables only include those that have been decided and have a connection contract. In addition, there are inquiries and projects, some of them at very advanced stages of planning, amounting to several hundreds of megawatts. Helen Electricity Network updates its investment plans according to customer needs, as necessary. However, it must be kept in mind that network reinforcements typically take several years. Helen Electricity Network can influence Fingrid's investment plan by communicating customer needs clearly and by highlighting on every occasion the need for reinforcing the main grid as soon as possible.

The free capacity tables above describe free capacity for electricity consumption. Analyses have focused on this because a significant amount of

Figure 19. Transmission interfaces of Helsinki's 110-kV network.

Year	Entire Helsinki	Interface 1	Interface 2	Interface 3
2024	561	558	553	216
2025	433	433	303	11
2026	352	352	231	40
2027	794	794	539	79
2028	778	778	534	317
2029	979	839	552	318
2030	967	829	554	320
2031	1141	1141	472	321

Table 4. Predicted free capacity of the 110-kV network in 2024–2031 in different transmission interfaces in a N-0 situation (a situation in which there are no faults or scheduled interruptions in the network). The capacity is always the state at the beginning of the year in question.

Year	Entire Helsinki	Interface 1	Interface 2	Interface 3
2024	88	88	88	88
2025	-172	-172	-172	-172
2026	-254	-254	-254	-254
2027	254	254	15	-74
2028	238	238	10	10
2029	361	265	42	42
2030	349	255	44	44
2031	482	482	37	37

Table 5. Predicted free capacity (+) or capacity shortage (-) of the 110-kV network in 2024–2031 in different transmission interfaces in a N-1 situation (a situation in which there is the worst individual fault or interruption in the network). The capacity is always the state at the beginning of the year in question.

Year	Entire Helsinki, main grid restriction, the most optimistic estimate	Entire Helsinki, 110-kV restriction	Interface 1	Interface 2	Interface 3
2024	-4	88	88	88	88
2025	-264	-172	-172	-172	-172
2026	-335	-254	-254	-254	-254
2027	216	254	254	15	-74
2028	199	238	238	10	10
2029	185	361	265	42	42
2030	174	349	255	44	44
2031	441	482	482	37	37

Table 6. Predicted free capacity (+) or capacity shortage (-) of the main grid and the 110-kV network in 2024–2031 in different transmission interfaces in a N-1 situation (a situation in which there is the worst individual fault or interruption in the network). The capacity is always the state at the beginning of the year in question.

electricity production has been and is being decommissioned in Helsinki and there has been hardly any inquiries regarding new large-scale electricity production plants. With the decommissioning of the Salmisaari and Hanasaari power plants, the southern parts of Helsinki, within the transmission interfaces 2 and 3, have, from the transmission point of view, several hundreds of megawatts of free capacity for electricity production. However, when it comes to new, large-scale electricity production plants, impacts on short-circuit currents must also be considered. As a large amount of electricity production will still remain in the Vuosaari area, significant amounts of electricity production cannot currently be added there.

Distribution network capacity map

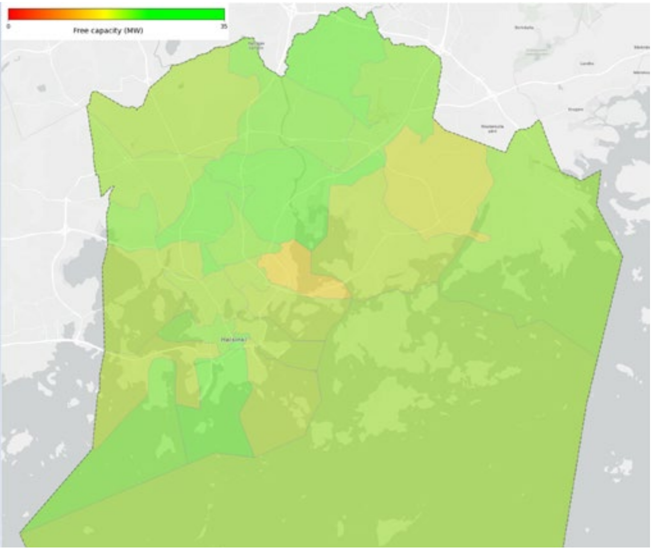

Figure 20. Free distribution network capacity for each primary substation feed area.

Figure 20 shows the free (medium-voltage and low-voltage) distribution network capacity for each primary substation feed area. Free capacity illustrates the free capacity of the primary substation, by feed area, taking into account the actual peak load of the distribution area during the past 12 months and estimating the total share of the power transformer capacities that can be replaced in case of a fault according to operational reliability principles. This total share has been estimated to be on average 60% of the power transformer capacity of primary substations if the primary substation has more than one power transformer. If all primary substations were at 100% load, neighbouring primary substations and other power transformers of the same primary substation could not feed the interrupted load for a sufficiently long time, thus causing potential electricity quality problems. In general, it can be noted that Helsinki's distribution network has plenty of free capacity in the electricity network. Naturally, free capacity of the high-voltage distribution network, described above, sets restrictions on additional loads in the distribution network. Decentralised microgeneration of electricity can be connected to the distribution network throughout the entire network area.

4.8. Impacts of the changes in the monitoring methods of electricity network operations on Helen Electricity Network's investment programme for 2024–2036

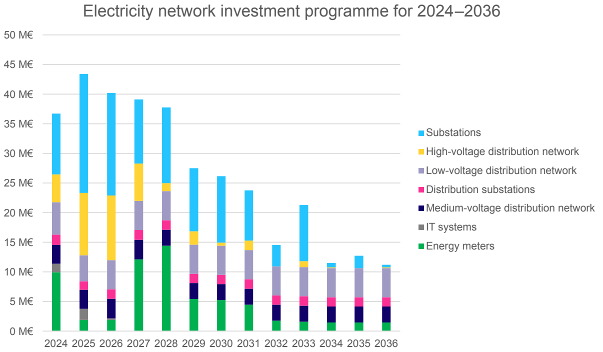

Figure 21. Helen Electricity Network's current financing-restricted investment programme for 2024–2036, adjusted to the new monitoring methods.

The network service pricing of electricity network operations is strictly regulated by the Energy Authority and this regulation is based on electricity market legislation, among other things. The Energy Authority defines the monitoring methods of electricity network operations in a confirmation decision, which confirms the methods for determining the network operator's revenue from network operations and the fees collected for transmission services (among other things, the valuation bases for capital employed, the method for determining the acceptable return on capital employed and various network operations incentives.) On the basis of the methods, the allowed annual net sales of the network company is calculated and then monitored in four-year monitoring periods. The confirmation decision is valid for eight years (two four-year monitoring periods). After a monitoring period ends, the Energy Authority provides each network company with a monitoring decision, determining whether the network company's pricing has complied with rules and regulations during the period. Any excessive payments collected (surplus) must be refunded to the customers during the next period as lower prices and, similarly, any deficit can be collected retrospectively from customers as higher prices during next periods.

Financing of investments

The monitoring methods for electricity distribution network operations for the sixth and seventh monitoring periods, in other words: for 2024–2031, were confirmed at the end of 2023. The confirmed monitoring methods contain significant changes compared to the supervision methods applied before this. These method changes impair the profitability of Helen Electricity Network's investments, especially in the long term, and decrease the allowed net sales intensively. Helen Electricity Network must adjust its finances to the limits set by the monitoring model. For the financing of operations to be on a sustainable basis, the company's investments and operations as a whole must be profitable. Without considerable changes to the investment programme, Helen Electricity Network's finances are not sustainable.

The historically large impairments to the monitoring methods take place in a situation in which the clean transition and the electrification of heating in Helsinki bring about significant additional investment needs in the coming years, especially in the high-voltage distribution network. These additional investment needs were not fully visible in the previous electricity network development plans submitted in 2022 because after these development plans were submitted, the electricity network investment needs required for enabling the clean transition have further increased in Helsinki. Helen Electricity Network's view is that the unprecedented tightening of the monitoring methods in a situation in which investment needs have increased significantly is a substantial risk to the progress of the clean transition and to the supply reliability and security of supply in Helsinki's electricity network under unstable global circumstances. The monitoring model should promote the green transition while also encouraging sustainability and emissions reduction in electricity network construction and maintenance.

The changes in the electricity network monitoring methods have significant impacts on the profitability of electricity network investments and, as a result, Helen Electricity Network is forced to adjust its investment programme due to economic reasons. In practice, investment programme adjustment means that the electricity network investment programme's replacement investments in the coming years have been cut and postponed, which will naturally increase the electricity network maintenance backlog. The increasing maintenance backlog will have negative effects on the supply reliability and security of supply of Helsinki's elect-

ricity distribution in the future as the significance of security of supply in electricity distribution will increase substantially due to the electrification of heating, for instance. Naturally, this development cannot continue for long and the monitoring model should be changed to give network companies the preconditions to fulfil all their statutory obligations, both with regard to the connection of new consumption into the network and the maintenance of the electricity network.

Investment programme changes in 2024–2036

Helen Electricity Network has modelled the development of its electricity network's state and condition with two investment scenarios:

1. Tarve (Need), the needs-based investment programme
2. Uusi (New), the current financing-restricted investment programme adjusted to the new methods

In the first, needs-based investment programme scenario, electricity network development has been modelled with an investment programme that includes investments necessary for the technical and economic maintenance of the electricity network in the long term. In this scenario, the plan is to implement the investment programme so that we make the investments required by the green transition while also maintaining high supply reliability and security of supply with a sufficient volume of maintenance investments.

The second investment programme, adjusted to the new methods (the programme on which the current electricity network development plan is based), models an investment programme that includes the investments that are financially possible with the new monitoring methods, i.e. the investments that Helen Electricity Network can carry out within the framework of the new, confirmed monitoring methods, taking into account that the electrification of heating has significantly increased the investment needs of the electricity network investment programme in the past few years. In practice, the change in the investment programme is reflected in the fact that it has been necessary to cut the volume of electricity network replacement investments dramatically and to postpone them, i.e. a maintenance backlog is generated during this period.

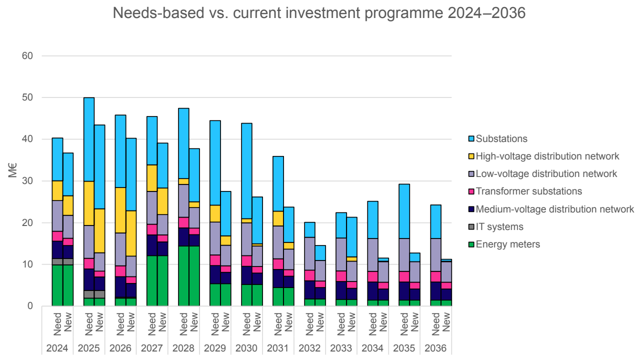

Figure 22. Needs-based investment programme and the financing-restricted investment programme that is possible with the new monitoring methods.

Figure 22 shows the differences between the needs-based investment programme (Tarve) and the investment programme that is possible with the new monitoring methods (Uusi), i.e. the current investment programme. IT system investments related to the renewal of energy meters and network management, for instance, remain unchanged, but it has been necessary to significantly cut the volume of the replacement investments associated with the high-voltage distribution network and the distribution network and to postpone their implementation schedules.

In the new investment programme, the overall investment level has been adjusted by approximately EUR 128 million in 2024–2036. Of this sum, roughly EUR 57 million is associated with the high-voltage distribution network investments and roughly EUR 71 million with the distribution network investments.

Maintenance backlog development in 2024–2036

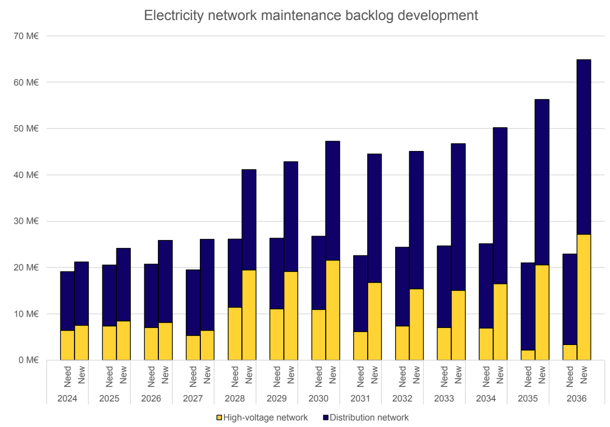

Figure 23. Development of Helen Electricity Network's maintenance backlog in the needs-based investment programme and the investment programme that is possible with the new monitoring methods.

The increase of the electricity network maintenance backlog naturally has impacts on risks associated with supply reliability and security of supply. It increases the amount of repair maintenance and, in the long term, leads to the gradual degradation of supply reliability. However, in the short term, the condition of Helen Electricity Network's network is good and the risk of long major faults is small and we can fulfil the quality requirements set for distribution network operations. In the long term – within the framework of the current monitoring method – this will become increasingly difficult.

The even otherwise apparent need to change the monitoring method is further highlighted by the fact that the significance of the supply reliability and security of supply in the electricity network will increase substantially in the future. With the electrification of heating in Helsinki and other electrification development, even a short interruption in electricity distribution may have considerable impacts on society. Helen Electricity Network has analysed the impacts of electricity distribution interruptions in Helsinki over a long period of time and has observed that the actual harm caused by such interruptions in Helsinki is considerably larger than what the national estimates indicate. This is due to, for instance, there being a considerable number of critical electricity delivery sites, as defined in the Government Decree, in Helsinki. In the future, the economic harm caused by potential major electricity distribution faults in Helsinki would be even more significant because even a short interruption in electricity distribution may cause an interruption in heat distribution in an extensive area. Figure 24 shows the change in the value of harm caused by an interruption to Helsinki's electricity distribution customers in a potential major fault with different interruption durations in 2023 and 2034.

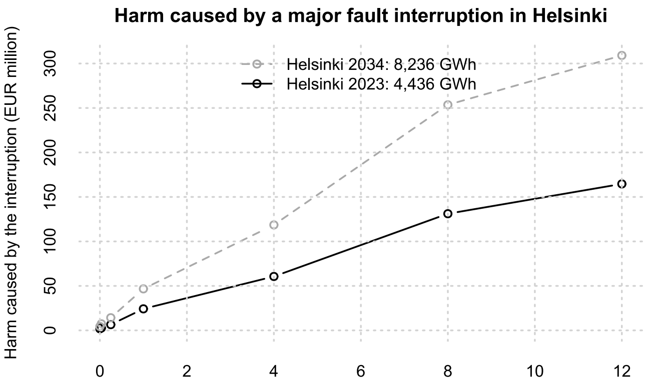

Figure 24. Harm caused by a potential major fault interruption in Helsinki in 2023 vs. 2034

The window for achieving the basic goal of the green transition, i.e. carbon neutrality, is strict both in Finland and in Helsinki. As we do not want to delay the ongoing transition, Helen Electricity Network's future investment programme focuses on enabling it. The levels of investments especially in the high-voltage distribution network will be significantly higher in the future than the investments made by Helen Electricity Network in the last few years. The considerable increase in the investment levels is due to the gigawatt-scale change in electricity transmission needs that has taken place in less than two years. In other words, electricity network investment needs have increased considerably at the same time when the investment environment has been made significantly tighter. Due to the impairments to the monitoring methods, we are forced to postpone electricity network maintenance investments. In the short term, the resulting supply reliability risk can be managed but, in the long term, the monitoring model does not enable sustainable operations. Together with other electricity network companies, Helen Electricity Network has applied for a change to the monitoring methods so that they would enable the profitable development and maintenance of electricity networks to the necessary extent.

5. Electricity distribution network development actions during this and next year

5.1. Investments and maintenance to meet and maintain the network quality requirements and to maintain capacity needs during this and next year

a. High-voltage distribution network

i. Investments EUR 15.3 million
ii. Maintenance EUR 0.23 million

b. Primary substations

i. Investments EUR 29.9 million
ii. Maintenance EUR 2.23 million

c. Medium-voltage distribution network

i. Investments EUR 3.1 million
ii. Maintenance EUR 0.03 million

d. Distribution substations

i. Investments EUR 1.3 million
ii. Maintenance EUR 0.19 million

e. Low-voltage distribution network

i. Investments EUR 4.0 million
ii. Maintenance EUR 0.09 million

5.2. Delivery sites that fulfil the quality requirements after this and next year's actions

a. In the area within the scope of the urban area development plan

On 31 December 2025, there will be 442,900 delivery sites that fulfil the quality requirements.

b. In the area beyond the scope of the urban area development plan

On 31 December 2025, there will be 1,000 delivery sites that fulfil the quality requirements.

5.3. Actions during this and next year

During this and next year, actions are almost entirely targeted at the development zone within the scope of the urban area development plan.

In the 110 kV network and primary substations, 110 kV cable transfers and underground cabling of 110 kV overhead lines related to the development of the city will be carried out. In addition, 110 kV power lines and primary substation safety systems will be renewed and primary substations will be renewed and expanded.

The length of the new medium-voltage cable network built is about 20 km and that of the existing network renewed is about 30 km. The length of new low-voltage cable network built is about 70 km and that of existing network renewed is about 90 km. Approximately 25 new distribution substations will be built and roughly 35 existing distribution substations will be renewed.

The maintenance plan costs consist almost entirely of the maintenance of primary substation properties and the maintenance of primary and secondary equipment. The second largest cost item is the maintenance of high-voltage networks and the third largest is the maintenance of distribution substations. The remaining costs are associated with the maintenance of medium-voltage and low-voltage networks.

Maintenance in the development zone beyond the scope of the urban area development plan consists of the proactive distribution network maintenance.

5.3.1. Electricity distribution network that fulfils the quality requirements after this and next year's actions

a) Medium-voltage, km

On 31 December 2025, approximately 1,710 km of the medium-voltage network will fulfil the quality requirements of electricity distribution network operations.

b) Low-voltage, km

On 31 December 2025, approximately 4,710 km of the low-voltage network will fulfil the quality requirements of electricity distribution network operations.

5.3.2. Rate of underground cabling in the electricity distribution network at different voltage levels after this and next year's actions

a) Medium-voltage

On 31 December 2025, the rate of underground cabling in the medium-voltage network will be approximately 99.8%.

b) Low-voltage

On 31 December 2025, the rate of underground cabling in the low-voltage network will be approximately 98.5%.

5.3.3. Share of planned joint construction

The share of planned joint construction is roughly 190 km, which accounts for approximately 90% of total investments.

5.3.4. Actions promoting joint construction

Helen Electricity Network Ltd participates in the City of Helsinki's Yhteinen kunnallistekninen työmaa (Joint municipal engineering worksite) concept. In it, it is agreed that builders of civil engineering networks cooperate. The parties maintain information about their future construction projects in the joint Louhi service, delimited geographically and temporally, enabling other parties to adjust their own projects to form a joint worksite. The network construction projects in the Louhi service are also visible in the national verkkotietopiste.fi service. The implementation time span of the investment plans published in the Louhi service ranges from approximately one year to several years. In addition to the Louhi service, Helen Electricity Network's network construction partner sends email communications about future investment projects to infrastructure builders operating in the area of the City of Helsinki for potential joint construction. In these projects, the implementation time span ranges from a few weeks to a few months

5.3.5. Significant distribution network investments to be made for connecting new capacity and new loads during this and next year

During this and next year, EUR 5.5 million will be invested in the network for connecting new capacity and new loads.

New heat production plants will be connected to the 110 kV network, which will require expansion investments at primary substations. New loads connected to the distribution network will require expansion investments in the medium-voltage cable network and distribution substations in different parts of the city.

5.3.6. Use of flexibility services during this and next year

a. Analyses and pilot projects related to the use of flexibility services

The aims of flexibility-related analyses have been to create flexibility models and gain information about the impacts of flexibility on connections and further on network load levels and dimensioning. Analyses have been made about the division of flexibility use roles among different parties and about potential future flexibility products. Development work seeks the better utilisation of the current transmission capacity.

The development trend is leading towards flexibility services and flexibility markets. In the next few years, flexibility will be realised especially in the 110-kV high-voltage distribution network. In the operating area, electricity transmission from the main grid will increase at an unprecedented volume when district heating becomes electricity-based and large-scale local electricity production ends. In the realisation of the clean transition, the schedule targets are tight and we want to make it possible to connect our customers to the network as quickly as possible. We are jointly seeking solutions to potential, temporally limited special situations in the network, in which flexibility is needed from customers in power restriction situations. With this approach, customers can be connected to the network faster. In development work, coordination among the transmission system operator, the distribution network company and customers is especially important. This kind of need for power restriction/flexibility has extremely quickly become a reality. Our company develops short-term electricity consumption forecasting combined with continuous power division calculation, updates current-carrying capacity limits of different parts of the network, identifies network power restriction situations and flexibility needs as well as develops cooperation among the network company, the transmission system operator and customers to successfully handle power restriction situations. Acute actions must be taken immediately. In the longer term, the solution may be national, commercial flexibility market activities. There is no such marketplace in Finland yet. Through the marketplace, both the transmission system operator and the distribution network companies would purchase customers' flexibility capacity when power restriction is needed. The "Market for network congestion management" project is being prepared. It would test the functionalities of a commercial marketplace in case of main grid and distribution network bottlenecks. The experiences gained in the project would be used when aiming at national flexibility market activities.

We are analysing price flexibility in electricity consumption. Strong fluctuations in the price of electrical energy became a reality in autumn 2022 and has continued since. Some customers reacted to the price changes by changing their electricity consumption according to energy's spot prices: increasing electricity consumption during hours when the price was lower and decreasing it during hours when the price was higher. Customers have flexibility capacity when it comes to reacting to the price of electrical energy. In the electricity distribution network, reacting to energy's spot prices means more intensive simultaneity of electricity consumption and weaker conventional natural variation of electricity consumption (load variation). In the network, this can be seen as an increasing load and, in some cases, the overloading of the customer connection or the network. The starting point is that the company uses flexibility to find a tool for load management; however on the other hand, there are changes in electricity consumption that create new peak loads caused by simultaneity of electricity consumption. In general, more information is needed about the extent of flexibility for flexibility service development needs. More clarity regarding the assessment of flexibility-related power is gained in background analyses. Through the Electricity Research Pool, Helen Electricity Network participates actively in LUT University's project launched in autumn 2023, which analyses the impacts of electricity market price volatility on electricity consumption flexibility and further on the electricity distribution system, focusing on low-voltage customers. The first findings of this project will be available in late 2024. The same theme will be studied in Helen Electricity Network's own analysis focusing on high-voltage customers during 2024. Through the Electricity Research Pool, the company is also involved in the "Kansallisen kuormitusohjaus-rajapinnan kaupallistaminen" (Commercialisation of the national load control interface) project in early 2024. Related to potential flexibility services, this project looks into what a jointly defined interface to customers' flexibility resources should be like.

At the moment, Helen Electricity Network does not use flexibility services for which there are cost or profitability calculations, nor are such services available in the market.

6. Electricity distribution network development actions during the previous two years

6.1. Investments and maintenance to meet and maintain the network quality requirements and to maintain capacity during the previous two years

a. High-voltage distribution network

i. Investments EUR 2.3 million
ii. Maintenance EUR 0.07 million

b. Primary substations

i. Investments EUR 6.7 million
ii. Maintenance EUR 2.9 million

c. Medium-voltage distribution network

i. Investments EUR 7.6 million
ii. Maintenance EUR 0.02 million

d. Distribution substations

i. Investments EUR 3.2 million
ii. Maintenance EUR 0.32 million

e. Low-voltage distribution network

i. Investments EUR 13.7 million
ii. Maintenance EUR 0.07 million

6.2. Delivery sites that fulfil the quality requirements after the previous two years' actions

a. In the area within the scope of the urban area development plan

On 31 December 2023, the area within the scope of the urban area development plan had 428,873 delivery sites that fulfil the quality requirements.

b. In the area beyond the scope of the urban area development plan

On 31 December 2023, the area beyond the scope of the urban area development plan had 959 delivery sites that fulfil the quality r equirements.

6.3. Actions during the previous two years

During the previous two years, approximately 99% of the actions were taken in the development zone within the scope of the urban area development plan and approximately 1% in the development zone beyond the scope of the plan.

In the development zone within the scope of the urban area development plan, primary substation protection systems were renewed in the 110 kV network and primary substations, 110 kV cable transfers were carried out due to the development of the city, primary substations were renewed and a new primary substation was being built.

In the development zone within the scope of the urban area development plan, the length of new medium-voltage cable network built was 19 km and that of existing network renewed was 47 km. The length of new low-voltage cable network built was 70 km and that of existing network renewed was 150 km. A total of 16 new distribution substations were built and 55 existing distribution substations were renewed.

In the development zone within the scope of the urban area development plan, the maintenance plan costs consisted almost entirely of the maintenance of primary substation properties and the maintenance of primary and secondary equipment. The second largest cost item was the maintenance of distribution substations. The remaining costs were associated with the maintenance of high-voltage, medium-voltage and low-voltage networks.

In the development zone beyond the scope of the urban area development plan, renewal work was carried out on 1 km of existing medium-voltage cable network and 3 km of existing low-voltage cable network. One existing distribution substation was renewed. Maintenance work consisted of the maintenance of overhead power line networks.

6.3.1 Electricity distribution network that fulfils the quality requirements after the previous two years' actions

a. Medium-voltage, km

About 1,695 km of the medium-voltage network fulfil the quality requirements of electricity distribution network operations.

b. Low-voltage, km

About 4,651 km of the low-voltage network fulfil the quality requirements of electricity distribution network operations.

6.3.2. Use of joint construction

The amount of joint construction used in investments was roughly 220 km, which accounts for approximately 70% of total investments.

6.3.3. Significant distribution network investments made for connecting new capacity and new loads during the previous two years

In the high-voltage network, a new primary substation was being built and current production-use connections were converted into consumption use, due to new district heat production solutions and sea traffic's on-shore power supply connections.

New loads connected to the distribution network required expansion investments in the medium-voltage cable network and distribution substations in different parts of the city.

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6.4. Use of flexibility services during the previous two years

a. Analyses and pilot projects related to the use of flexibility services

JIn 2022 and 2023, the main focus in flexibility service use analyses and pilot projects was on the electrotechnical analyses of flexibility, from both the customer's and the network company's perspective. A list of flexibility projects analyses that Helen Electricity Network has carried out or participated in can be found below. Increasing flexibility

Through the Electricity Research Pool, Helen Electricity Network participated in Enerim's flexibility project (10/2021–4/2022), which defined a market-based flexibility product for peak cutting and its requirements regarding product measurement, verification, data exchange and data platforms. Also through the Electricity Research Pool, the company participates in LUT University's project launched in autumn 2023, which analyses the impacts of electricity market price volatility on electricity consumption flexibility and on the electricity distribution system, focusing on low-voltage customers. The first findings of this project will be available in late 2024.

As a flexibility pilot, Helen Electricity Network is looking into an office property's smart grid (battery, electric vehicle charging, solar energy production), testing the technical multi-functions (flexibility, peak cutting, reactive power, own use, frequency market activities) of the flexibility solution in question. This entity models an energy community and the potential benefits of flexibility are shared by different parties (the network company, the property owner, the tenant, the frequency market operator). For a network company, a particularly interesting aspect is the management of connections and distribution network dimensioning.

When it comes to the charging of electric vehicles, the company conducted an extensive customer survey in autumn 2022 to analyse flexibility in electric vehicle charging and to deepen the company's customer insight, with the goal of guiding the charging event (timing and charging power need) in a manner that benefits both the customer and the network company. The same theme was studied from another perspective in the analysis of the minor customer tariff development.

6.5. Actual results compared to the previous development plan

The actual investment costs of primary substations and the 110 kV network have remained lower than the costs presented in the 2022 development plan because the project schedules have been extended and specified in more detail. In other respects, the investments described in the 2022 development plan have been realised as planned.

During the previous two years, actual primary substation maintenance has exceeded the 2022 development plan.

The amount of the medium-voltage network that fulfils the quality requirements is higher than what was presented in the 2022 development plan because some of the sea cable network in the sea areas in front of Helsinki was transferred to Helen Electricity Network's ownership in 2023. In other respects, the construction of network and delivery sites that fulfil the quality requirements has been realised as planned in terms of the construction volume.

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https://www.helensahkoverkko.fi/en