



Distribution grids
enable the energy
transition

caruna

SUMMARY

Finland is undergoing an unprecedented energy transition with the move from fossil sources of energy to renewable ones.

It is estimated that EUR 40 billion will be invested in the energy system over the next few decades.

In this brochure, we discuss the journey to the 2040s and what kind of a world is ahead of us.

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Society will become even more dependent on electricity as emissions are reduced and digitalisation progresses

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The growing demand for electricity will be met with renewable energy, and this requires huge investments in the electricity system

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Electricity cannot be stored in large quantities, which is why the electricity market is in great need of flexibility

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The electrification of heating is accelerating – this requires investments to reinforce distribution grids

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Construction of a carbon-neutral energy system is already underway. The pace must be accelerated in order to achieve the targets set out in the road map.

GRID COMPANY OF THE FUTURE

Today's grid company focuses strongly on improving the security of supply. The grid company of the future will provide a diverse range of services and a platform for the implementation of the energy transition

MESSAGES TO DECISION-MAKERS

To enable investments, the legislation and regulation must be predictable and incentivising investments.



Finland has excellent opportunities to be a model country for carbon-neutral solutions. Electricity grids are a key enabler of the energy transition

Young people have grown up in a world heavily dependent on electricity, where electricity is almost always available. The lack of electricity and access to charging can throw life off track for a while. At the same time, caring for the environment, climate and biodiversity is a matter of course.

There is a will to achieve Finland's climate targets, but very few people know our system in sufficient breadth and detail to keep the ambition level and actions in proportion.

Electricity consumption is projected to increase by more than 50% by 2040. If you're wondering whether that is a lot or a little, it is an enormous amount.

Energy systems must be reformed over the next few decades in order to achieve climate targets and strengthen energy self-sufficiency. Fossil fuels used in heating, transport and industry are the easiest and most cost-effective to replace with technology based on clean electricity.

To achieve the energy transition, record investments of over EUR 40 billion will be made in energy systems by 2035.

Next time you heat your electric sauna or curl up on your home sofa on a freezing day, we hope that you are warmed by the thought that we have done the thinking for you, and you can just sit back and enjoy. It is, however, good to understand the subject in a little more depth.

It is forecast that electricity production in Finland will double. Renewable wind and solar power is cheap and domestic, but production varies greatly depending on the weather. It is also dispersed throughout the provinces, while electricity consumption is increasingly concentrated in population centres. This creates its own challenges for our electricity grids, which need to be reinforced and built further.

Unprecedented fluctuations in electricity production create opportunities for customers to participate and benefit financially from the demand response enabled by automation. Demand response can take the form of timing electric car charging, electric heating or industrial production to such moments when clean electricity is abundantly available.

Electricity grids are a key enabler of the energy transition. Without efficiently functioning electricity grids, electricity is not distributed to where it is needed at a given time. Your electric car has not been fully charged when you should already leave, or surplus heat is wasted even though there is plenty of potential for its utilisation. More information on this subject is provided later in this leaflet. The role of reliable electricity grids grows in a society that is increasingly dependent on electricity.

Electricity grid companies such as Caruna develop their operations to bring thousands of customers' solar panels, accumulators and electric cars onto the electricity market. However, the biggest potential and challenge is

in the electrification of our industry. Grid companies will invest not only in a weatherproof electricity grid, but also in new digital services and cybersecurity.

Investments in the development of electricity grids are the responsibility of Finland's 77 grid companies. Investments require a predictable and motivating operating environment, seamless permitting, new expertise, utilisation of innovations, and new kinds of financial incentives for smart solutions. Investments in energy will take years to implement, and the timeframe set for the energy transition is ambitious. We must start taking action now! If we act together and in a proactive manner, Finland will have excellent opportunities to be a model country for carbon-neutral solutions, where new industry and well-being based on clean electricity are created.

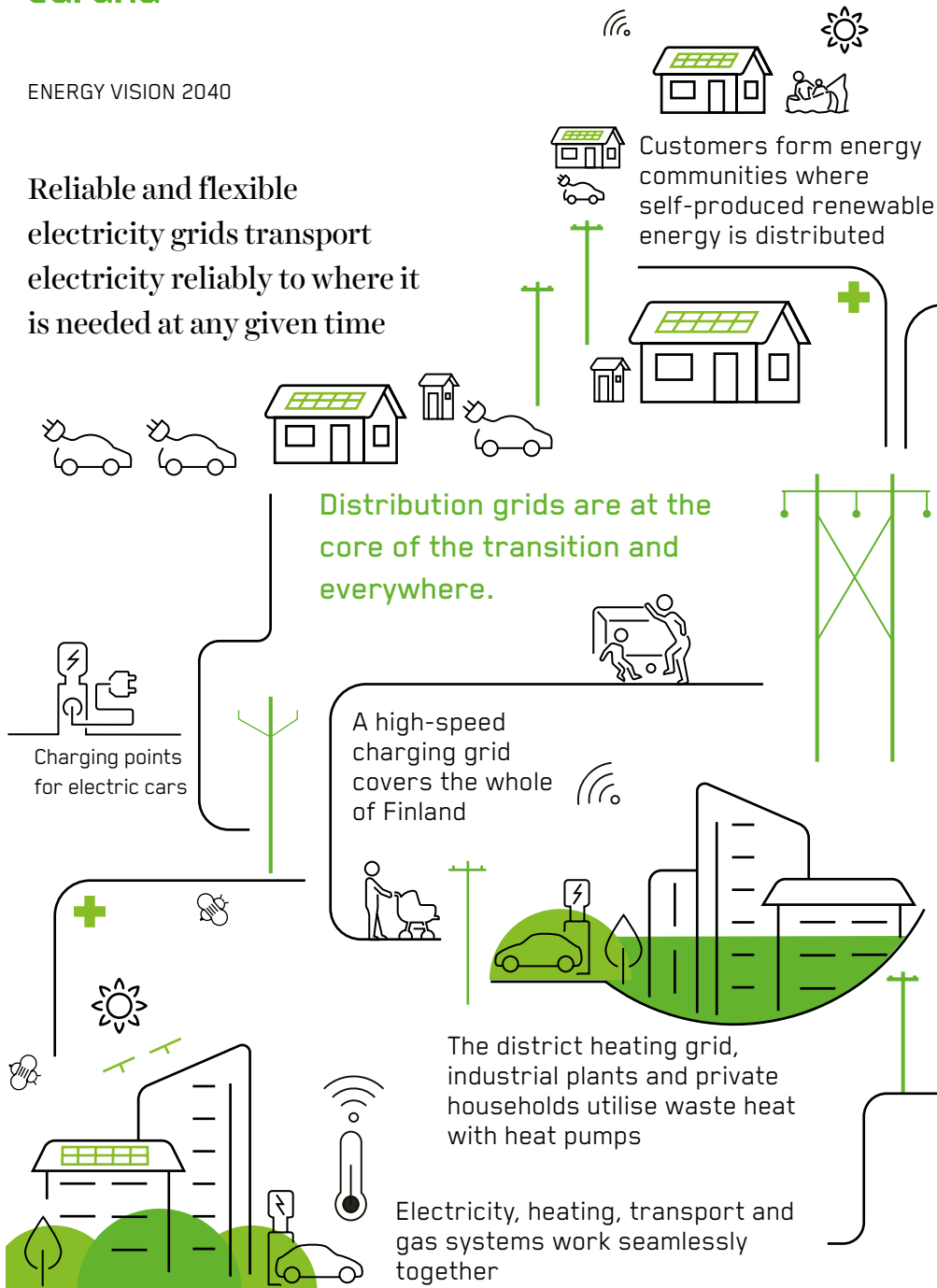
Let's keep in touch!

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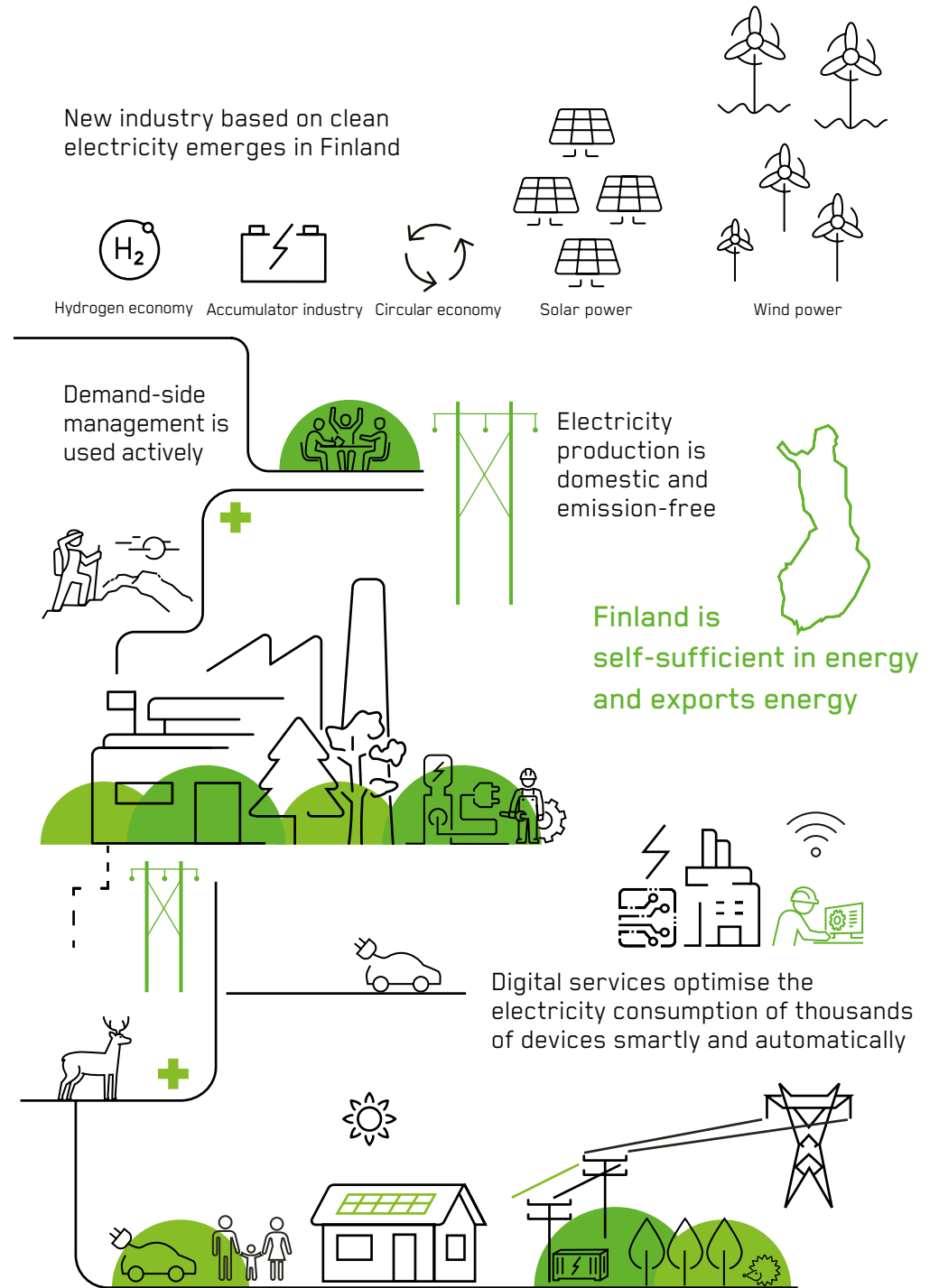
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Reliable and flexible electricity grids transport electricity reliably to where it is needed at any given time



New industry based on clean electricity emerges in Finland



Society will become even more dependent on electricity as emissions are reduced and digitalisation progresses

THE ENERGY TRANSITION INCREASES ELECTRICITY CONSUMPTION

Achieving carbon-neutrality targets requires changes in transport, industry and heating. Replacing fossil fuels in a cost-effective way is based on technology operating on electricity. Electricity consumption is estimated to increase by up to 50% by the year 2040 if Finland reaches its climate targets in the set timeframe.

In certain branches of industry (for example bakeries, dairies, as well as wood and paper industries), the importance of natural gas has been great. Dependency on natural gas is decreased by the electrification of processes.

Locally, the changes can be significant. The electrification of heating and urbanisation will concentrate electricity consumption increasingly in cities, whereas decentralised electricity production will emerge more in rural areas.

Megatrends affecting the energy system

CLIMATE CHANGE

Every effort must be made to slow down global warming, but we must also adapt to its inevitable consequences.

SECURITY OF SUPPLY

National energy security, cybersecurity and resilience of the physical infrastructure must be improved.

DIGITALISATION AND TECHNOLOGY

New technologies and digitalisation shape the energy system and society, creating new business opportunities.

URBANISATION

Energy consumption concentrates in cities and electricity production in rural areas. An efficient and smart electricity system is increasingly important to achieve a balance between consumption and production.



DEPENDENCE ON THE ELECTRICITY SYSTEM IS INCREASING

An energy system that is heavily reliant on electricity means that demands on the reliability of the electricity system will increase. Already now, the critical functions of society, such as hospitals, telecommunications grids and payment systems, are vulnerable to prolonged power cuts. In an electrified society, the impact will extend faster to transport, heating, and industrial performance.

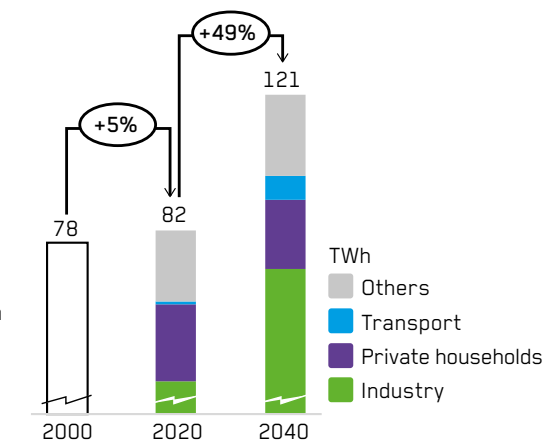
The electricity system faces new risks. Climate change increases extreme weather phenomena, which challenges the operation of electricity grids and weather-dependent electricity production. Cyber threats can endanger the security of both companies and private individuals. It is therefore essential to strengthen the security of supply and the resilience of the electricity system.

ENORMOUS INVESTMENTS IN ELECTRIFICATION

Changes in energy production, transmission and consumption are unprecedented, both in size and schedule. By 2035, the energy sector will invest EUR 40 billion - more than any other sector - to achieve the carbon-neutrality target. As the electricity system

plays a key role in the energy transition, a large part of the investments will be linked in one way or another to the electricity system. The investments of the three largest distribution grid companies alone will amount to EUR 3.2 billion by 2035. For the investments to be realised, the operating environment must be predictable and motivating.

Electrical energy consumption increases (TWh)

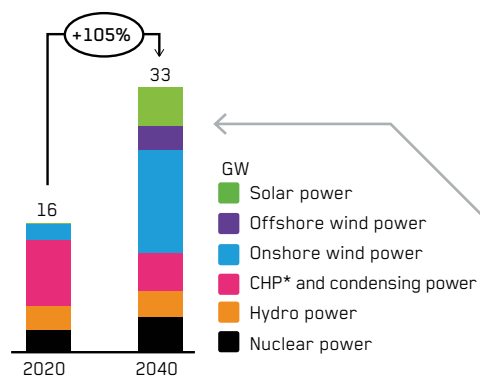


The growing demand for electricity will be met with renewable energy, and this requires huge investments in the electricity system

ELECTRICITY PRODUCTION CAPACITY WILL DOUBLE

Due to growing demand, electricity production will need to increase strongly in the coming years, and electricity production capacity must more than double compared to today. Finland has an excellent opportunity to build clean electricity production, especially wind and solar power. However, the building will take time. Permit processes and municipal requirements can delay building by years.

Most of the growth comes from renewable energy (GW)



* Combined heat and power production

FUTURE PRODUCTION WILL BE DECENTRALISED AND WEATHER-DEPENDENT

The electricity production of the future will be very different from today. Whereas in the past, electricity was mainly produced in large individual power plants in cities, in the future, electricity will be produced in thousands of small power plants, mainly in rural areas. In the past, electricity production could be adjusted to meet consumption needs; in the future, the majority of production will vary according to the weather. Although renewable electricity production is more inexpensive and more environmentally friendly than the old one, its poor adjustability and lower predictability pose challenges for balancing the electricity system. The challenges in planning the capacity of the electricity grid brought by the energy transition have a much bigger impact than just the increase of electricity consumption. Electricity consumption and electricity grids must adapt to the new situation.

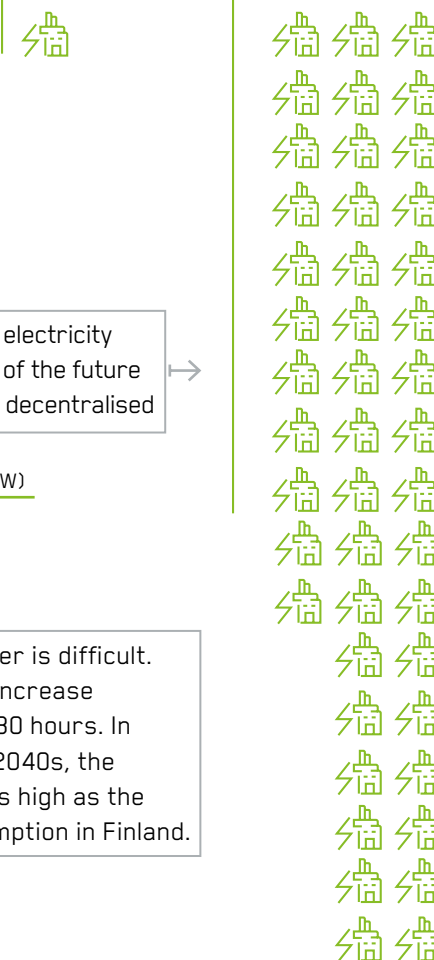
As electricity production grows, electricity grids must be sized to meet maximum instantaneous demand

ELECTRICITY GRIDS ARE A CRITICAL ENABLER

Both the transmission system and local distribution grids are critical to enabling the energy transition. Large wind farms and electrifying heavy industry are connected to the transmission grid. Distribution grids enable bi-directional distribution and the connection of all new technologies, such as hundreds of thousands of electric cars and solar panels, to the electricity system. The development of technology and digitalisation also guide the operations of electricity grid companies to more efficient grid infrastructure management and higher-quality service.

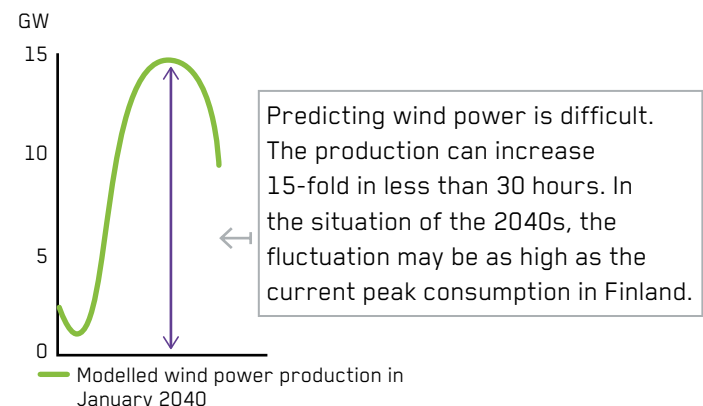
The number of electricity production sites will multiply

2022 < 50 000
2040 > 450 000



Renewable electricity production of the future will be very decentralised

Fluctuations in electricity production will increase (GW)



Electricity cannot be stored in large quantities, which is why the electricity market is in great need of flexibility

CUSTOMERS SHOULD PARTICIPATE IN THE ELECTRICITY MARKET

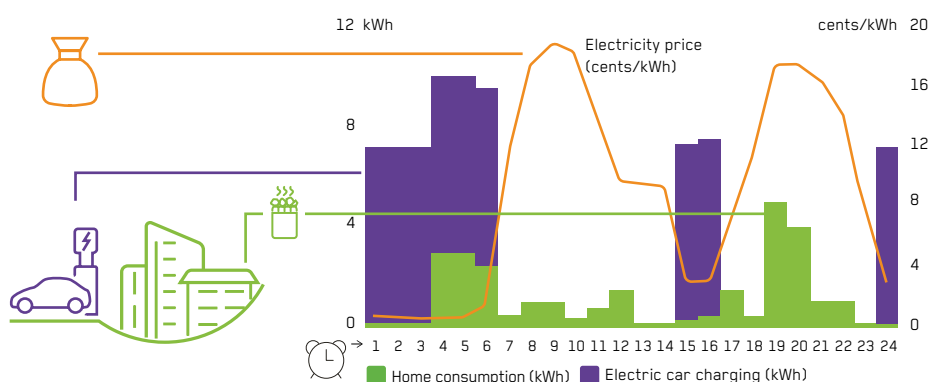
The energy transition and digitalisation create new opportunities for customers to participate in the electricity market. With the growth of variable electricity production, a lot of demand response is needed in the electricity market in order to keep the electricity system balanced and reliable. Demand response means that customers use automation to time their electricity consumption to moments when clean and inexpensive electricity is abundantly available.

There is a lot of potential for demand response in an electrifying society. Industrial plants can shut down production

processes, causing electricity consumption to decrease. Electrically operated heating, such as heat pumps and water boilers, can be switched on and off quickly, as heat is easy to store for later use. Smart charging of electric cars is also easy to schedule smartly. Small amounts of electricity can also be stored in electricity storages.

Huge fluctuations in electricity production make electricity prices volatile and the value of flexible electricity increases. Consumers are sorely needed in the electricity market – both end-customer and industry. Distribution grid companies should therefore modernise their services so that every willing party can easily get on board.

Charging an electric car changes the electricity consumption of a home



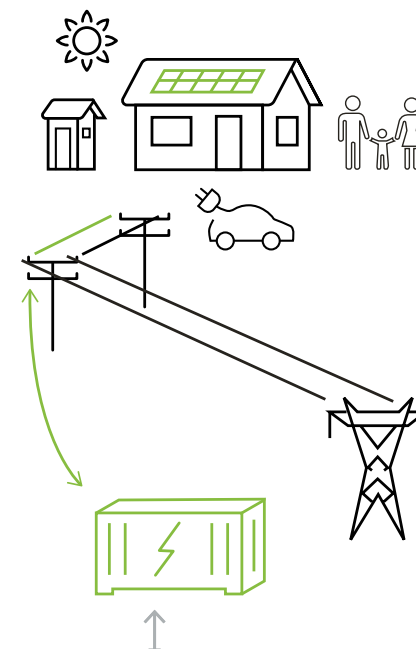
THE NUMBER OF ELECTRICITY PRODUCERS WILL MULTIPLY

The production of renewable electricity and energy self-sufficiency is strengthened by promoting energy communities in which own electricity production is distributed among the members of the community.

As decentralised electricity production increases, the impact on the distribution grid must also be taken into account. For example, on sunny summer days, solar power stations produce more electricity than the owners consume. Electricity fed into the grid may cause voltage problems, and the distribution grid company must ensure that the technical requirements for the electricity system are fulfilled.

An alternative to a traditional grid investment is to invest in an electricity storage that stores surplus electricity during the day and then supplies the electricity to customers later on. The cost of the electricity storage may be lower than that of grid investments. Unfortunately, the distribution grid does not currently have incentives to invest in smart, cost-effective solutions for customers.

The production of solar panels can be stored in electricity storages



An electricity storage can be used for the needs of the distribution grid, and it can balance fluctuations in production and consumption in the entire electricity system.

Smart charging of electric cars will bring savings to consumers and balances the electricity system

CHEAP HOURS SHOULD BE USED FOR CHARGING

Optimising the charging of an electric car according to the electricity price brings energy cost savings of up to 40-50% compared to uncontrolled charging. Optimisation with automatic digital services does not require any effort from the customer: The car is connected to the home charging station and the system takes care of the timing of the actual charging event.

When an electric car arrives in the house, the outlets for block heaters and cables should be replaced with devices that can withstand heavier loads. At the same time, it may be necessary to increase the size of the electricity connection so that charging does not interfere with other everyday electricity consumption.

CHARGING ENERGY SUFFICES AT AN ANNUAL LEVEL, MOMENTARY RESTRICTIONS MAY OCCUR

At an annual level, charging energy for electric cars is not a problem. If all passenger vehicles in Finland were electric cars, Finland's gross consumption would increase by about 10%.

For the electricity system, instantaneous charging power can become a problem if electricity is simply not available when electric car drivers want it. For the local

distribution grid, high instantaneous charging power may create local bottlenecks, and all charging power cannot be passed on to customers.

The charging power of electric cars is significant: the total charging power of 700,000 electric cars is estimated at 4.5 GW. The amount is greater than what Finland's hydro power plants can produce at full capacity.

SMART CHARGING IS THE KEY TO OPTIMISING THE OPERATION OF THE GRID

Electricity grids are sized to meet likely peak consumption. If peak consumption increases with the charging of electric cars, electricity grids must be reinforced. Reinforcement can mean ordering a larger transformer, for example, even if the previous transformer has decades of service life left.

The effects of electric cars have been studied in Norway, where electric cars already accounted for 22% at the end of 2021. According to the study, charging



Electric car charging points can increase connection power by as much as 60% in housing companies

electric cars can increase distribution grid investments by 7% if smart solutions are not taken into account. In Finland, such an increase would mean an additional investment of hundreds of millions of euros for distribution grid companies.

The balancing of electricity consumption in the property grid has previously been addressed by so-called alternation, where the electric heating and the electric sauna are not simultaneously switched on. With regard to electric cars, smarter and more dynamic solutions are needed in order to realise the benefits of electric cars and keep the costs low for customers.

Various electric powers

Current charging powers

car heater 0.8 kW

electric sauna stove 7 kW

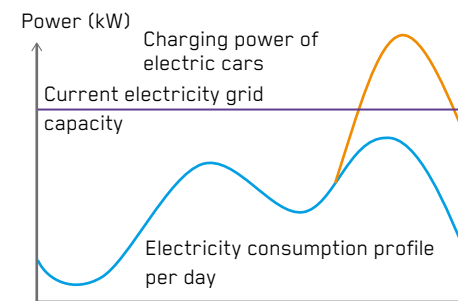
home charging point 7-11 kW

business premises charging points 11-22 kW

high-power chargers
100-300 kW



Due to the charging power of electric cars, the distribution grid must be reinforced



The electrification of heating is accelerating – this requires investments in distribution grids

Climate targets drive energy companies to give up district heating produced by combustion. The number of different kinds of heat pumps is increasing both in properties and in district heating.

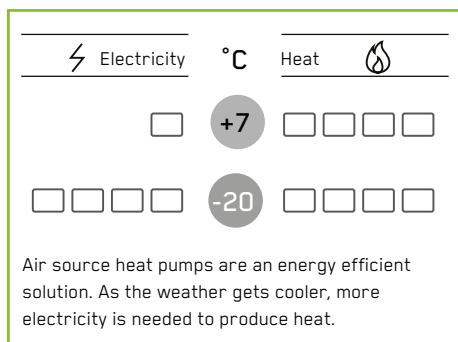
The carbon-neutral district heating of the future will utilise society's waste heat and ambient heat with the help of heat pumps. From an environmental point of view, the electrification of heating is excellent, because it improves energy efficiency.

HEAT PUMPS ARE BECOMING MORE COMMON IN HOMES

Electric heating traditionally refers to either direct or storage electric heating. Air source heat pumps and ground heat are also electric heating, and they can use electricity to utilise the low ambient temperatures to produce heat and cooling. Currently, there are nearly one million air source heat pumps and 180,000 ground source heat pumps in Finland. The growth prospects are quite dramatic. According to Sulpu, the Finnish Heat Pump Association, investments in heat pumps will amount to around EUR 10 billion in Finland this decade, and heat pumps will cover as much as 30% of the heating needs of buildings.

For electricity grids, the development means that the consumption peak in cold

winters will increase. Traditionally, electricity grids are sized according to winter peak loads so that there is enough heat for everyone.



THE ELECTRIFICATION OF DISTRICT HEATING CHALLENGES THE DURABILITY OF THE DISTRICT GRID

Combined heat and power production in power plants will decrease significantly in the near future due to the climate targets. At the moment, as much as a third of combined heat and power production is produced with fossil fuels. In future, heat will no longer be produced by fossil combustion but increasingly using clean electricity (heat pumps, electric boilers and waste heat from data centres).

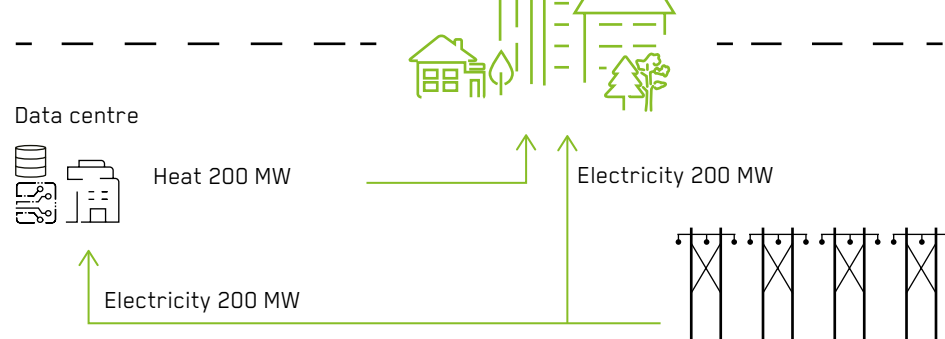
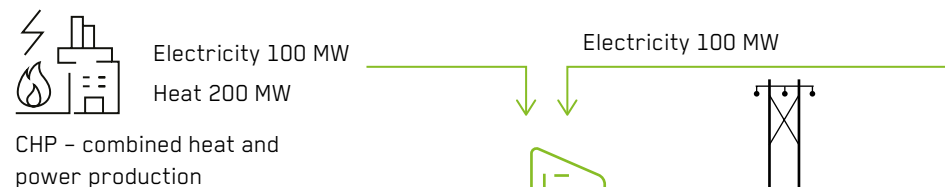


The local impact on the electricity grid can be significant. Electricity will no longer be produced within the same grid area, and electricity needed for heating will be distributed from further away. The transmission capacity of the high-voltage distribution grid must be strengthened. For example, Caruna estimates that in the case of Espoo alone, the investments will amount to EUR 200

The role of waste heat from data centres in district heating will grow.

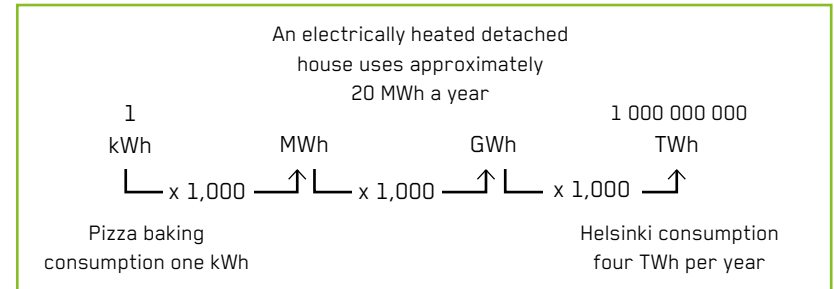
million during the 2020s on average. Electricity grid reinforcements, i.e., thicker cables and larger secondary substations, require a permit process. Achieving carbon-neutrality targets requires that the challenges with regard to schedule and use of city space can be resolved.

CURRENTLY



IN THE FUTURE

Construction of a carbon-neutral energy system is already underway. The pace must be accelerated in order to achieve the targets set out in the road map.

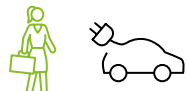


- 2020**
- Grid companies invested EUR 690 million in 2020, most of which was related to weather-proofing.
 - 2,600 MW of wind power has been installed, annual production 8 TWh



- 2030**
- Investments relating to weather-proofing (EUR 9.5 billion) largely completed.
 - There are more than 4,200 public charging stations across Finland
 - EUR 15 billion has been invested in wind power, resulting in 7,000 MW being installed.
 - Electricity storages provide flexibility with 500 MW of power

- 45,000 electric cars
- 290 MW of wind power has been installed, annual production 0.3 TWh
- 1,100,000 heat pumps have been installed



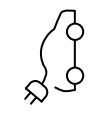
2025



System level

Customers

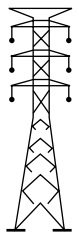
- use of coal in energy production will end
- Investments in the distribution grid related to the energy transition, EUR 3,000 million
- Energy communities have been established in housing companies
- Total number of ground source heat pumps is 270,000 and their electricity consumption 1.9 TWh



- 700,000 electric cars
- Solar power production has increased 7-fold to 2 TWh
- Energy communities participate in the electricity market

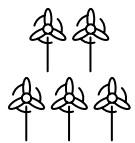
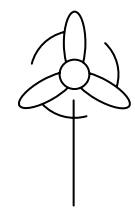


- 2040**
- Finland is carbon-negative
 - Investments relating to the energy transition (EUR 14 billion) largely completed.
 - 121 TWh of electricity is consumed, increase +50% compared to 2020
 - 5 GW of solar power has been installed, which is 1.5 times the entire hydroelectric power capacity. Solar power produces 3 TWh of electricity



2035

- Finland will be carbon-neutral in 2035
- The hydrogen economy consumes 15 TWh of electricity, almost the same amount as the entire forest industry in 2020
- 11,000 MW of wind power installed, annual production 35 TWh
- The first small nuclear power plants produce district heating and electricity
- Fingrid's new transmission connections (1,700 MW) to Sweden and Estonia are in use



Today's grid company focuses strongly on improving the security of supply. The grid company of the future will provide a diverse range of services and a platform for the implementation of the energy transition

IMPROVED SECURITY OF SUPPLY

Electricity grid companies have invested EUR 6.5 billion during the period 2010-2020. Investment amounts have increased by 50% from 2012 onwards. Cabling of overhead lines and widening of the line corridors of existing overhead lines have significantly decreased the power cuts experienced by customers. For example, storm Aapeli in 2019 and storm Aila in 2020 created storm winds that were record high. However, extensive power cuts were avoided, mainly as a result of the grid companies' security of supply investments.

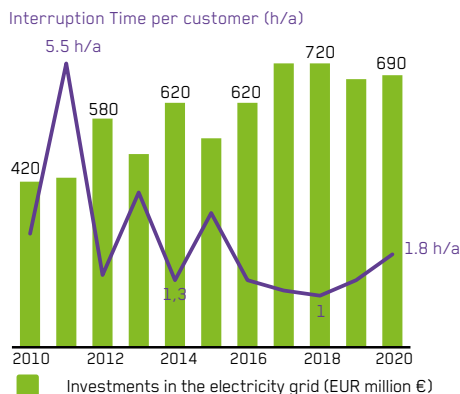
Caruna has also rapidly upgraded its electricity grid to make it weatherproof, and this has significantly reduced the number and duration of faults in comparison with previous storms. In addition, automation has been increased in the electricity grid, enabling electricity to be restored more quickly. At the beginning of 2010s, about 60% of Caruna's customers were within a grid area covered by the criteria for the security of supply under the Electricity Market Act (6/36 hours). In 2020, the security of supply criteria were fulfilled already for over 90% of our customers.

IMPLEMENTATION OF THE ENERGY TRANSITION REQUIRES NEW INVESTMENTS

The implementation of the energy transition will require enormous investments, of which some 14 billion will be allocated directly to distribution grid companies. The distribution grid company of the future will not only distribute electricity, but will also offer customers the opportunity to participate in the development of a green energy system.

A large part of the future energy system changes will concern precisely the operations of local distribution grid companies. The number of customers producing solar power in Caruna's grid will reach 50,000 by 2030, and electricity will flow in both directions in the distribution grid. At the same time, electric

Investments have improved the security of supply

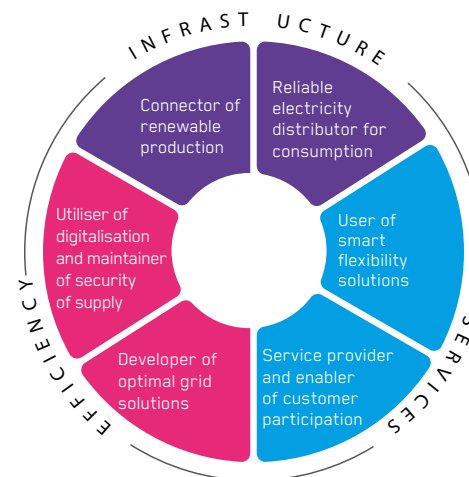


cars already amount to a fourth of the cars in use in Finland. Chargers require a lot of instantaneous power from the electricity grid. The electrification of district heating with electric boilers and various kinds of heat pumps will also bring new large electricity consumption sites to the grid, which distribution grid companies will have to accommodate in the electricity grid.

Variable electricity production and consumption require smart electricity grid control. The distribution grid will utilise industrial scale and private household electricity storages. The distribution grid company of the future will also provide a diverse range of services for its customers, from energy saving services to a range of flexibility services. For example, some of the consumption of customers can be aggregated through operators that collect larger entities from small loads.

Huge investments in both infrastructure and services require efficient operations from grid companies. Digitalisation is one of the key tools for efficiency gains, enabling more efficient use of electricity grid infrastructure and better services for customers.

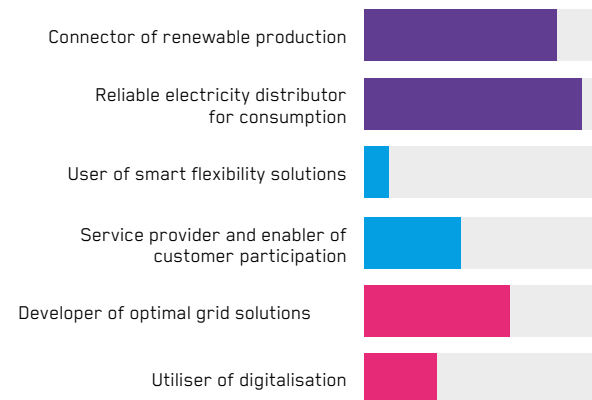
The operating conditions of the future distribution grid company in terms of expertise, ICT systems, investment opportunities and regulation must be in order to distribute electricity to customers reliably and at a reasonable cost.



Investment volumes in the next ten years



Grid companies have the most room for development in the use of smart solutions, services and digitalisation



Regulation must enable electrification and the introduction of new technologies

Finland is a forerunner in the large-scale development and application of smart energy solutions. Regulation has a significant impact on the fight against climate change and the achievement of energy self-sufficiency. To maintain Finland's pioneering position, legislation and regulation must be developed:



✦ **Different energy systems** (gas, heat, electricity, transport) **must be planned as a whole, not as separate systems.** It is most beneficial if the entirety is well thought out from the start and it is developed under market terms. Electricity grids play an important role in interconnecting different energy systems.

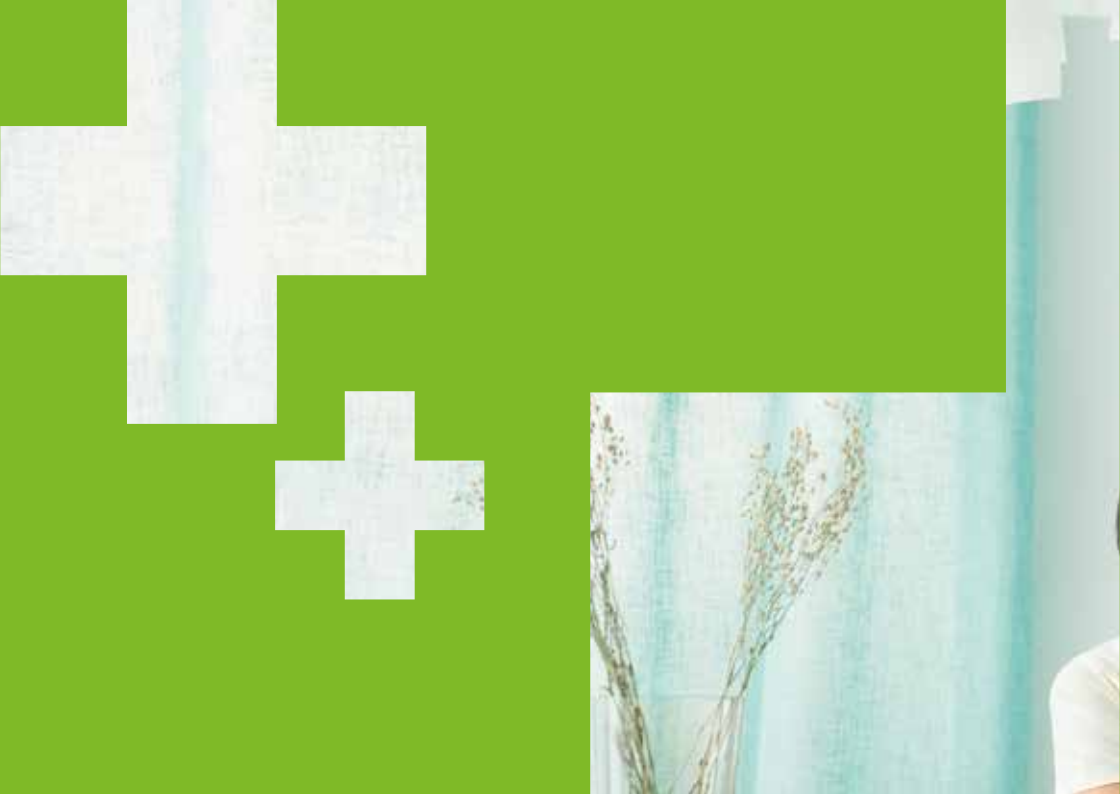
✦ **Investments in the development of the physical electricity grid are long-term and in order to attract investments, the operating environment and legislation must be predictable and motivating.** In addition to grid investments, regulation must support smart digital solutions, the use of flexibility and the development of services.

✦ **The permission process of the production and transmission of clean energy must be speeded up** to ensure that the climate targets are met within the set ambitious timeframe. Stricter building requirements can raise the level of investment costs by up to a third.

✦ **Regulation must provide financial incentives for electricity grid companies to carry out pilot projects and innovations.** By updating practices, electricity grid companies improve service quality, implement environmentally friendly solutions and reduce customers' costs.

To enable investments, the operating environment and legislation must be predictable and incentivizing investments





Caruna distributes electricity and develops a smart electricity grid, providing its customers with sustainable and reliable electricity that is worth its price.

We have the resources, expertise and partnerships to develop an energy system that gives a clear shape and direction to a sustainable energy transition and helps households, communities and society move towards energy independence.

It is our way of securing common standard of living that withstands change in a sustainable way.

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