Renewable Energy in Finland 2055:

Strategic Roadmap for Land Use, Regional Development and Geopolitical Dimensions of the Energy Transition

Luke

Abstract

Finland's energy system is undergoing a transformation. Climate goals, geopolitical uncertainty and technological progress are driving the shift away from fossil energy towards a more renewable, electrified and integrated energy system. The strategic roadmap produced in the Natural Resources Institute Finland's REPower research project examines the role of renewable energy in Finland by 2055. The aim of the roadmap is to support decision-making and long-term strategic foresight among significant uncertainties regarding the development of the energy system. The roadmap's vision is to establish an energy system for Finland that is sustainable and supportive of comprehensive security by 2055.

Finland starts from a strong position: in 2024, the share of fossil-free electricity generation based on nuclear, hydropower, wind power, and bioenergy rose to 95%, wind power generation exceeded 20 terawatt-hours (TWh), and the energy system was no longer dependent on energy imports from Russia. The roadmap does not present a forecast; rather, it examines three alternative future pathways, all based on the assumption that carbon neutrality will be achieved by 2050. These pathways are grounded in the greenhouse gas accounting methods in use at the time of writing. Ongoing changes to the accounting framework, particularly in the land-use sector, may affect the calculated timing of carbon neutrality, underscoring the importance of gradual, flexible, and proactive energy policy steering. The pathways differ in terms of the structure of the energy system, the role of renewable energy, the scale of investments, the use of natural resources, and their regional and geopolitical impacts.

The EU compliance pathway is based on the implementation of EU regulatory requirements and moderate growth in wind power. Under this pathway, electricity consumption rises to 152 TWh and wind power generation to 65 TWh. Bioenergy provides system flexibility, and wood fuels remain a significant part of the energy system, particularly in combined heat and power (CHP) production.

The bioeconomy pathway emphasises increasing the added value of biomass in line with the cascade principle, thereby encouraging a greater market-driven allocation of biomass to the production of biochar, biogas, and liquid biofuels, as well as to lignin-based materials. Under this pathway, electricity consumption rises to 159 TWh and wind power generation to

It is possible to implement the energy transition in an ecologically, economically and socially sustainable way — but only if the transition is strategic, holistic and carried out with an awareness of the uncertainties.

72 TWh. The pathway strengthens regional economies and security of supply.

The electrification pathway entails large-scale electrification, with data centres, renewable hydrogen, and synthetic fuels increasing electricity consumption to 215 TWh. Wind power generation reaches 134 TWh, including 14 TWh from offshore wind. The pathway requires substantial investments and integrates Finland more closely into European energy markets. The energy transition is examined through three interconnected areas of change. **In terms of land use and resources**, the expansion of renewable energy increases the pressure on land use, especially from the perspective of wind power siting. The development of wind power has significant impacts on land and marine biodiversity, which is why management of nature impacts requires projects to systematically apply a mitigation hierarchy. In all pathways, the role of bioenergy is increasingly focused on the flexibility and security of supply of the system. **Regional justice** is undermined by the concentration of wind power investments in western Finland, while eastern Finland is left out due to radar constraints, among other things. Successful transition requires inclusive planning practices and fair sharing of the costs and benefits. **Geopolitical** decoupling from fossil energy strengthens strategic autonomy, but the dependence of clean energy technologies and critical raw materials on China introduces new vulnerabilities. This emphasises closer coordination between energy, foreign, and security policy.

Strategic choices are structured across three timeframes: in the short term (2026—2029), establishing a framework for managing land use and strengthening the acceptability of energy projects; in the medium term (2030—2039), resolving the allocation of biomass resources and the scale of renewable energy; and in the long term (2040—2055), developing and deploying technical carbon sinks, deepening international integration and strengthening Finland's role as an exporter of clean energy.

The roadmap extends to 2055, with Finland achieving carbon neutrality by 2050 in the future pathways. Furthermore, the report includes observations on the additional measures that would be required to achieve carbon neutrality by 2035. The additional measures complement the long-term assessment but are not part of the actual pathways.

The key message of the roadmap is that it is possible to implement the energy transition in an ecologically, economically and socially sustainable way — but only if the transition is strategic, holistic and carried out with an awareness of the uncertainties.

The report concludes with eight policy recommendations:

1. Develop national principles for the siting of wind and solar power and link them with proactive grid and permitting planning.
2. Strengthen the proactive assessment of the cumulative impacts of renewable energy projects and consistently apply the mitigation hierarchy.
3. Develop a strategic allocation programme for biomass resources covering both material and energy use.
4. Require all renewable energy projects to ensure meaningful regional participation at an early stage.
5. Develop and implement a model to better assess the regional economic impacts of renewable energy projects.
6. Strengthen research-based communication on energy.
7. Strengthen cross-sectoral foresight on energy, climate, foreign, and security policies.
8. Deepen Nordic cooperation to strengthen electricity networks, storage, and energy system resilience.

Authors
Johanna Routa (ed.)[1],
Sakari Höysniemi (ed.)[1],
Jyrki Aakkula (ed.)[1],
Nelli Eerikäinen[1],
Ilkka Hannula[2],
Niina Kautto[1],
Johanna Kohl[1],
Jani Lehto[1],
Jussi Lintunen[1],
Saara Luukkonen[1],
Olli-Matti Mikkola[1],
Tuomas Niinistö[1],
Saija Rasi[1],
Pasi Rikkonen[1],
Panu Runko[1]
Lauri Sikanen[1],
Lauri Sääskilahti[1],
Anne Tolvanen[1],
Mikko Weckroth[1]

[1] Natural Resources Institute Finland (Luke)
[2] Carbon Economics Ltd

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Kirsi Järvenranta / Luke

Table of contents

1. Introduction

1. Introduction

Europe's energy system is undergoing a profound transformation. Climate goals, geopolitical uncertainty and technological progress are rapidly changing the way energy is produced, transported and used. The energy transition is not just a technological renewal, but a broad societal change that impacts the use of natural resources, regional development, and economic and political relations between nations.

Finland's starting point for the energy transition is strong. Our rich renewable natural resources, a low-carbon electricity system and strong technological know-how create the conditions for change in the energy system and the creation of new industrial value chains. However, the transition is also increasingly linked to energy independence, strategic autonomy and Finland's role as part of the European clean energy economy.

For a long time, Russia played an important role in the EU's energy imports. It covered about 40% of the EU's natural gas imports and about 30% of oil imports just before Russia launched its war of aggression against Ukraine in February 2022. In response, the EU prepared the REPowerEU plan (European Commission, 2022), which aims to reduce energy dependence on Russia, strengthen the EU's energy independence and boost the production of renewable energy. A clear geopolitical dimension has therefore emerged alongside the climate policy objectives. Russia's aggressive sphere of interest policy, the divergence of US values from Europe, and the uncertainty around transatlantic relations, as well as the strengthening of China's geo-economic

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position are challenging the EU's efforts to strengthen its strategic autonomy, meaning its ability to act independently in areas of strategic importance, defend its own interests and reduce harmful dependencies. Therefore, promoting renewable energy is not only an industrial and environmental policy objective, but also a geopolitical goal for Europe.

Finland has been relatively quick to succeed in replacing its energy dependence on Russia, but it is possible that global geopolitical tensions may continue for a long time. This operating environment underscores the need for a transition, that, in addition to pursuing carbon neutrality, also strengthens Finland's geopolitical position and safeguards security of supply. In the spring of 2026, the closure of the Strait of Hormuz and the subsequent rise in oil prices once again demonstrated the concrete effects of geopolitical turbulence and value chain dependencies. In response, the European Commission published the AccelerateEU plan (European Commission, 2026), a complement to the REPowerEU plan. It aims to accelerate renewable energy investments and strengthen the energy system's resilience.

The REPower roadmap, prepared by Natural Resources Institute Finland (Luke), produces research-based information on the impacts, challenges and opportunities of renewable energy in Finland's energy system. The aim is to support decision-making and measures that strengthen Finland's energy independence, the management of land use impacts in the energy transition, promote the phasing out of fossil energy, and strengthen the EU's security of supply.

Given the significant uncertainties surrounding the future of the energy system, the roadmap includes three alternative pathways to 2055. The future pathways describe alternative development paths through which Finland could move towards an energy system that is decoupled from fossil fuels and respond to growing electricity demand and structural changes in industry. In particular, the roadmap analyses the impact of the energy transition on three key areas of change — land use, regional development and Finland's geopolitical position — and identifies key strategic choices over different timeframes.

The roadmap was developed as a project in 2024—2026. The preparation phase involved interactive collaboration with the Clean Energy System Transition (REPower-CEST) project. The roadmap is based on the research data produced in the project and on a strategic and scenario-driven foresight process, which was carried out through workshops involving researchers and stakeholders. The quantitative and techno-economic starting point for the foresight work was the KEITO WAM (With Additional Measures) scenario (Koljonen et al., 2025a), which formed the foundation for the pathways in this roadmap. The KEITO scenario is based on the target of achieving carbon neutrality by 2050. However, greenhouse gas accounting methods are currently under revision, and their effects on the timeline for carbon neutrality had not yet been quantified or published at the time of writing. Consequently, these changes could not be incorporated into the present review. The pathway development was further informed by an analysis of drivers of change, qualitative baseline scenarios, and other techno-economic background calculations.

The analysis of the areas of change also draws on this process and the empirical research conducted within it. The study also looked at scientific renewable energy scenarios drawn up in recent years (Mikkola et al. 2026). They were found to typically frame the future as a pathway driven mainly by techno-economic factors, while paying less attention to the importance of other

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societal factors. Such an approach has not been able to anticipate the kinds of impacts that geopolitical developments have had in recent years. For this reason, the roadmap has also been developed from the perspectives of different disciplines, beyond techno-economic factors alone, with the aim of achieving a deeper understanding of the possible futures of renewable energy. In the roadmap, the transformation of the energy system and the surrounding society and land use is understood as a structural, society-wide, yet strategically managed energy transition that includes both a significant increase in renewable energy production and the phase-out of fossil energy use, as well as a multidisciplinary study of the impacts associated with these changes.

The research underpinning the roadmap examined the impacts of wind and solar energy infrastructure development as part of a clean energy system. The analysis placed particular emphasis on cross-cutting impacts, ranging from changes in land use and biodiversity impacts to regional agency, questions of justice, and the geopolitical constraints shaping the energy transition. In addition, the study explored the role of wood-based bioenergy in the future energy mix, particularly from the perspectives of security of supply and the sustainable sourcing of wood fuels.

This work focuses on the structural development of the energy system. The 2035 carbon neutrality targets of the Climate Act are not included in the analysis. The study of the areas of change does not cover the carbon sinks of the land use sector (LULUCF) or possible changes in logging volumes. Connecting these would require a combined model for land use and the energy sector, which goes beyond the scope of the roadmap. However, the report also includes a separate appendix that examines what additional measures would be required to achieve carbon neutrality by 2035, based on a sensitivity analysis.

The roadmap's vision is to establish an energy system for Finland that is sustainable and supportive of comprehensive security by 2055. In this context, sustainability means that the energy system is simultaneously ecologically, economically, and socially viable. Such a system reduces environmental impacts, ensures affordable energy and the social acceptability of energy projects. It is built in a way that does not compromise biodiversity, the long-term availability of natural resources, or the ability of future generations to make sustainable choices concerning natural resources, energy solutions, and societal development. Resilience is a key enabler of a sustainable and comprehensively secure energy system and strengthening it is increasingly important as uncertainties grow. From the perspective of comprehensive security, the vision rests on the idea that the vital functions of society are safeguarded through cooperation between public authorities, businesses, organisations, and citizens. Reliable access to energy is a central prerequisite for this. The roadmap contributes to this objective by providing knowledge on an energy system whose operational reliability rests on both domestic solutions and international cooperation.

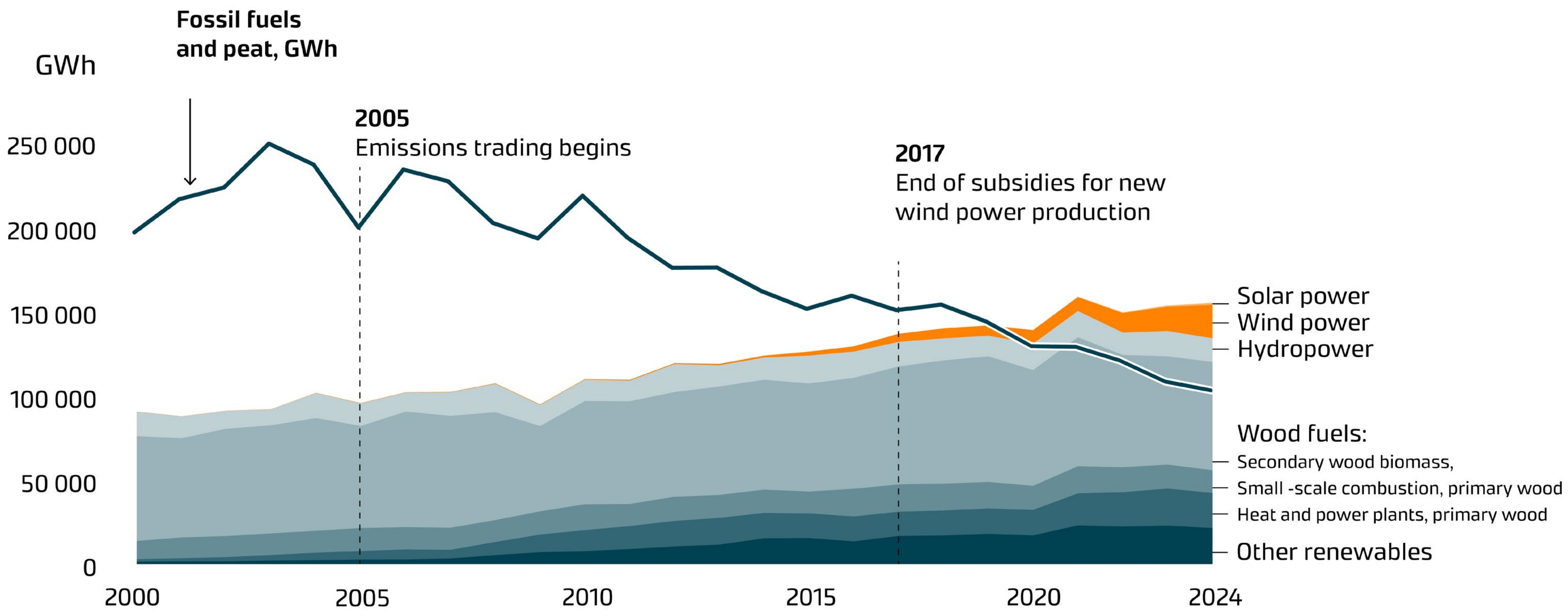
Key term:
Resilience

Energy system resilience refers to the ability of the system to anticipate and withstand various disturbances, crises and changes as well as the capacity to recover from and adapt to them in a way that flexibly safeguards security of supply, a reasonable price level, and the key functions of society. These disruptive, exceptional and transformative situations can be caused by extreme weather events, cyber threats, and geopolitical tensions, among others. Resilience is not limited to technical or material security of supply — it also covers the economic, social, institutional and geopolitical resilience of the energy system. It should be noted that the concept does not have a single accepted definition (Jasiūnas et al., 2021). In this roadmap, resilience is broadly linked to socio-ecological sustainability and comprehensive security, the threats to which are diverse and varied in time scale.

2. 2025 baseline for the energy transition

Renewable energy has significantly displaced fossil energy sources in the 21st century

Energy use in Finland by energy source 2000—2024



2. 2025 baseline for the energy transition

2.1 Transformation of the energy system and the electrification of end use

The energy system comprises a broad entity of four main sectors: power generation, heat generation, industry and transport. During the last decade, the energy system has undergone a significant structural change, especially in electricity production, where onshore wind power has emerged from a marginal mode of production to become a key part of the electricity system. The growth of renewable energy and the displacement of fossil energy sources are not just a recent phenomenon, but part of a longer development cycle in which EU-level instruments, such as the emissions trading, which began in 2005, have also contributed to the energy system's structural change. Renewable energy has become a key replacement for fossil energy, especially in power generation and heating *(Figure 1)*. This change has reduced dependence on fossil fuel imports, lowered the average price of electricity, and rapidly cut specific emissions from electricity production. For example, the share of fossil-free electricity production rose to 95% in 2024 (Official Statistics of Finland (OSF), 2026), which was made possible not only by wind power, but also by nuclear power, hydropower and extensive utilisation of forest industry side streams as energy. In recent years, the average price of electricity and specific production emissions in Finland have been among the lowest in Europe.

While the rapid growth of wind and solar power has pushed the average price of electricity down, price volatility has increased significantly, due to which the debate on security of supply during peak demand has become a key issue. In Finland, the peak in energy demand is during the cold spells of winter, when the need for heat production increases, solar power production is minimal, and periods of calm weather may also reduce wind power production for an extended time. In these conditions, nuclear power, imported energy, and industrial and municipal combined heat and power plants (CHP) play an important role in ensuring security of supply.

Finland's transmission grid is very reliable by international standards. A strong transmission grid and a diverse energy production palette have safeguarded the energy use of both industry and households and supported the energy transition. However, the growing share of wind and solar power requires the expansion and reinforcement of transmission networks.

Decarbonisation of electricity generation and lower prices have made electrification of energy use a key way to reduce the use of fossil fuels in transport, heating and industry. Electric vehicles supplant oil in transport; heat pumps and electric boilers displace fossil fuels, including wood fuels in Finland, used in heating. In industry, electrical solutions, combined with high-temperature heat storage, are what accelerate electrification.

In addition to electrification, heavy use of biofuels supports the transition. Finland's industry has historically used lots of wood-based fuels, as a significant portion of the forest industry's by-products (e.g. bark and sawdust) are used as energy. In 2024, liquid biofuels accounted for about 12% of the energy sources in road transport, with electricity accounting for about 3% and biomethane for about 1%.

Finland also imports a significant amount of energy. For electricity, the other Nordic countries play an important role. However, in terms of fossil fuels, Russia used to be the most significant source of imported energy: it accounted for 34% of the energy consumed in Finland in 2021. By 2024 the situation had changed completely, as Russia's share of imported energy collapsed due to EU sanctions and Finland's decoupling measures. Instead, Norway has risen to become Finland's largest source of energy products.

In addition to the electrification of existing energy consumption, data centres are expected to introduce a spike in the demand for electricity, along with large-scale plans for electrolytic hydrogen production. Since investments in wind and solar power are the cheapest way to add new electricity production capacity, the increase in demand will steer investments in Finland towards onshore wind power above all else. The last power plants covered by the feed-in tariff system were built in 2017, after which the capacity increase has been based on market-based investments. Wind power capacity has multiplied over the past decade, from a few terawatt-hours to more than 20 terawatt-hours. In several different scenarios, the production of wind power is estimated to rise to 60 TWh or even 300 TWh in the coming decades, which would mean a 3–12-fold increase in production and partly also a shift from land to sea (Fingrid, 2025; Finnish Energy, 2024; Koljonen, et al., 2025a). Future development of wind power will have

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significant impacts on land use and coastal waters, the diversity of terrestrial and marine nature and the social acceptability of projects — how these issues are resolved will play a significant role in the next phase of the energy transition.

2.2 New forms of energy security

Due to its strategic importance, energy is also an important socio-political issue. However, in recent decades, socio-political assessments have been limited to economic, environmental and climate perspectives, and geopolitical and security policy dimensions, as well as social and regional justice, have been scarcely taken into account (Höysniemi, 2025; Kivimaa, 2024). Russia's war of aggression in Ukraine, which began in 2022, and the subsequent geopolitical tensions have caused significant changes. Before the war, Europe was heavily dependent on imported Russian energy, which is still used today. However, the European Commission has set a target to stop all imports of Russian natural gas by the end of 2027. Finland was able to replace Russian oil imports relatively quickly. Although imports from Russia have stopped, Russia continues to transport oil and gas along the Baltic Sea, which continues to pose at least an environmental risk.

While bolstering the role of renewable energy will reduce dependence on energy imports and exposure to the fossil fuel markets, which is vulnerable to price fluctuations, it will also create new types of vulnerabilities. Global supply chains for clean energy are heavily concentrated, and China dominates the manufacturing and trade of most clean energy technologies. For mass-produced technologies — wind turbines, batteries, electrolysers and solar panels — the three largest producing countries account for at least 70% of each technology's manufacturing capacity, and China dominates all of them.

Consolidation also extends to the critical minerals needed to construct power grids (copper) and batteries (lithium, cobalt, etc.). For example, the Democratic Republic of Congo produces about 70% of the world's cobalt, and only three countries together account for almost 90% of global lithium production (IEA, 2023).

In this system, bioenergy is the exception: supply chains, expertise and markets are national, and they do not involve the same geopolitical uncertainties as many other clean energy technologies. The role of wood energy becomes particularly important in managing peak winter demand, when this domestic and readily mobilised energy reserve supports security of supply at different stages of the transition.

2.3 Social and regional dimensions

Social justice has become a key issue due to the broad societal impacts associated with the energy transition. Rapid development of energy technologies, digitalisation and market transition are a challenge for traditional regulatory models, requiring more flexible and proactive policies. Concurrently, achieving climate goals requires long-term strategic planning that combines aspects of environmental, economic, social and regional justice.

Geographical disparity in Finland's renewable electricity production has an impact on the distribution of costs and benefits between different population groups and regions. Thus, the energy transition is not just a technological change, but it also changes regional power relations and economic opportunities. This can introduce local tensions and require more participatory planning and systematic assessment of acceptability. Reconciling different perspectives also requires a careful assessment of the impact of policy measures: energy policy must be able to safeguard economic competitiveness, emissions reductions, security of supply and social justice at the same time. The energy transition is therefore not only a technical and economic transformation, but also an institutional and social reform.

The starting point of 2025 shows that Finland's energy transition has progressed rapidly. The decarbonisation of electricity production, strong wind power growth and the electrification of end use have reduced fossil dependence and improved competitiveness. At the same time, the energy system has become more electricity-intensive, investment-driven and connected to international technology and material flows.

3. Future pathways

3. Future pathways

This chapter examines three alternative development paths for the Finnish energy system in 2055. The future pathways illustrate different ways for Finland to move towards an energy system that is both decoupled from fossil fuels and capable of responding to growing electricity demand and new industrial opportunities.

What will determine the next phase of the energy transition is largely how Finland solves two interlinked issues: the role of different renewable energy sources in the future energy system, and how we will manage the economic, regional and ecological impacts of the change. Significant additional construction of wind power, the position of bioenergy as a source of regulating and reserve energy, and the magnitude of growth in electricity demand are the key factors that shape the direction of development of the energy system.

Therefore, the starting point does not lead to one predetermined outcome, but the roadmap's foresight process has produced alternative pathways, none of which is expected to materialise exactly as described. The background assumptions of the pathways are essential for describing both the change and the measures required. The differences are not just limited to the choice of energy technology, as they also reflect on land use, biodiversity, regional justice, the industrial structure and Finland's geopolitical position.

The starting point for this roadmap analysis is the **EU compliance pathway**, which serves as a benchmark for the other options. It describes a development path in which Finland achieves the EU's climate and energy policy objectives by 2050 based on current technological developments.

Alongside this reference pathway, we have observed two alternative development pathways, which differ from the reference in certain aspects of the energy system. The **bioeconomy pathway** emphasises an increase in the added value of biomass: part of current energy use is shifted to material use and fuel production, especially metallurgical biochar and synthetic fuels. In addition, lignin is redirected from energy production to high-value products. The **electrification pathway**, for its part, looks at electricity-intensive development, in which renewable electricity production capacity, through onshore and offshore wind and solar power, increases significantly to respond to the large-scale use of electricity in data centres as well as in the production of synthetic hydrogen-based fuels.

The KEITO scenarios (Koljonen et al., 2025a) were used as background material for these pathways. In the KEITO model, forest development in the land use sector was modelled through Luke's MELA model, which uses existing stand structure from National Forest Inventory (NFI) data. New analyses of the models show that previous calculations likely overestimated forest growth and carbon sequestration in the long term. In the calculations made with the updated data, forest sinks do not strengthen over time to the same extent as anticipated in the KEITO scenarios.

3.1 The EU compliance pathway

The reference pathway is based on the KEITO project's WAM scenario, which describes the energy system's development when EU climate and energy regulation is fully implemented and additional national measures are implemented in line with adopted policy decisions.

In the future pathway, the energy system becomes significantly electrified by 2055. Total electricity consumption increases by almost 80% to a level of 152 TWh per year. The growth is particularly focused on transport (88% electrification rate of passenger cars) and the chemical industry. Wind power production grows to 65 TWh, which corresponds to about 40% of electricity production. Solar power complements the production structure, especially from the 2030s onwards *(Table 3.1)*. Nuclear power will remain a significant energy source, which will see investments in both electricity and heat production. The share of renewable energy in final consumption rises to about 75%. The share of fossil fuels in the electricity and heat sectors will decrease to close to zero as soon as in the 2030s. Wood fuels remain a significant part of the energy system, especially in combined heat and power production. In addition to forest chips, the wood burned consists of various forest industry by-products. Constraints will limit additional imports of energy wood to below 2 TWh. Hydrogen use is focused mainly on replacing fossil hydrogen in oil refineries, which does not lead to a large-scale synthetic fuel export industry. Electricity consumption by data centres rises moderately to about 10 TWh.

Bioenergy provides system flexibility and forms a key input for technical carbon sinks. Carbon neutrality will be achieved by offsetting the remaining net emissions from the land-use sector through bioenergy with carbon capture and storage (BECCS). The BECCS capacity in this and other future pathways will rise to about 13 Mt CO_2 by 2055. Fossil carbon capture from the cement industry will stand at 0.4–0.8 Mt CO_2 per year.

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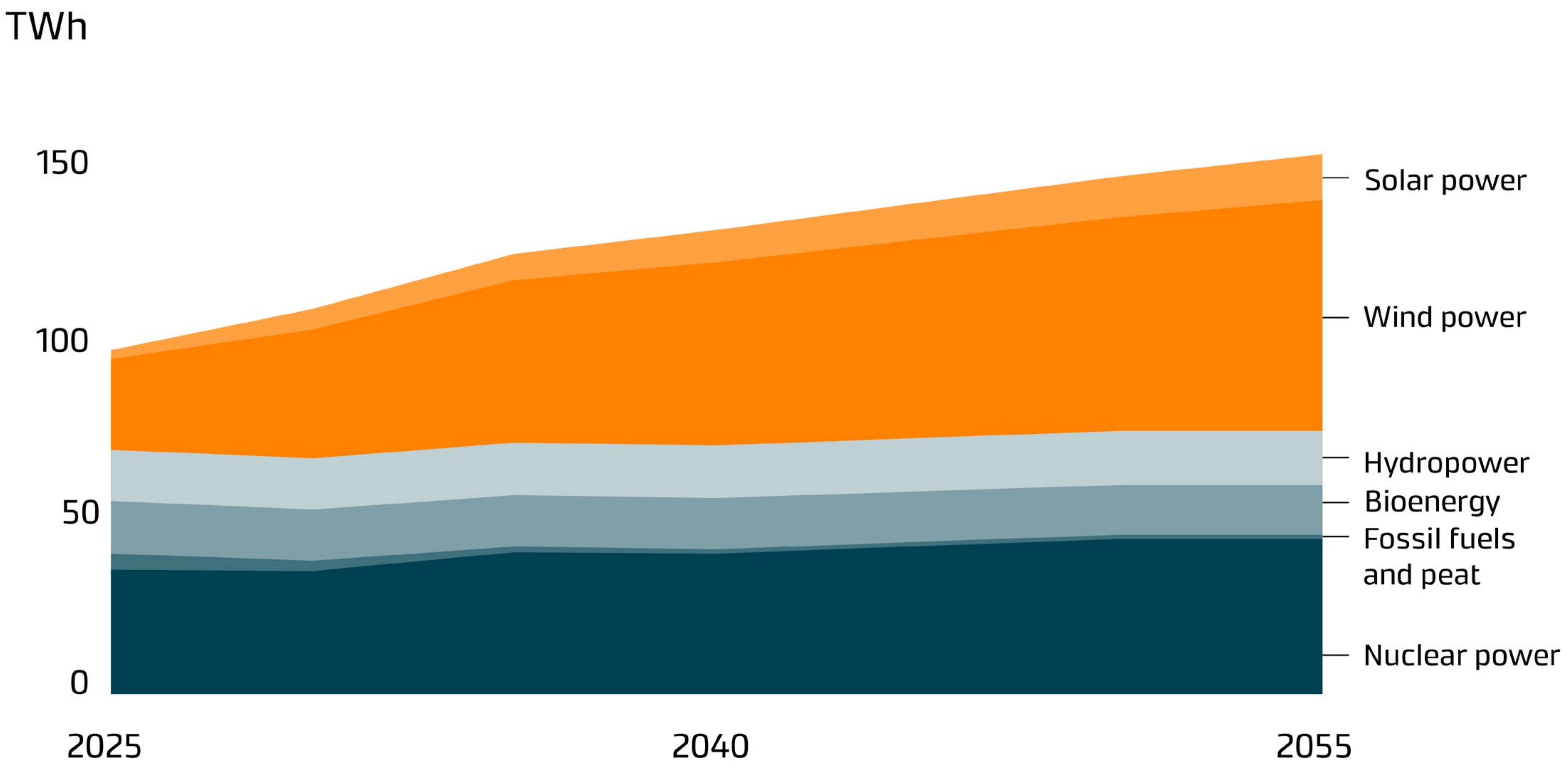
EU compliance pathway

Development of electricity generation 2025—2055, TWh



2055

EU compliance guides the energy transition.

Electricity production grows with renewable solutions and fossil energy will be gradually phased out.

Domestic bioenergy balances the system and supports security of supply alongside the variable renewable production.

3.2 The Bioeconomy pathway

The bioeconomy pathway is based on Finland's transition towards a bioeconomy: a society in which the use of natural resources, energy and industrial production forms a sustainable whole. The replacement for fossil materials and fuels will be both renewable electricity and bio-based products and solutions that strengthen the circular economy. This pathway emphasises the sustainable use of renewable natural resources, the development of bio-based materials, and technological carbon sinks. Energy production and industrial value creation are structured around the cascade principle to direct biomass to material and chemical applications with high added value in market terms. For energy, wood is primarily used when other targets are not technically or economically justified. This strengthens security of supply and accelerates the transition towards fossil-free energy and production systems. Finland's position as a leading bioeconomy actor relies on substantial renewable biomass resources and the ability to process them into higher value-added products.

Demand for electricity will increase slightly more strongly than the reference pathway, to 159 TWh by 2055 (cf. EU compliance pathway ~152 TWh). The increase arises from renewable hydrogen production, which maximises the carbon efficiency of wood-based fuels, as well as a moderate decrease in the energy use of forest chips (Hannula, 2016). Furthermore, the material use of lignin reduces industrial electricity production by about 1 TWh. That reduction is offset by wind and solar power, which will rise to 72 TWh and 14 TWh respectively by 2055 *(Table 3.1)*.

In the pathway, the total use of biomass remains approximately at the level of the EU compliance pathway, with a change in operating structure, away from electricity and heat production towards applications with higher added value. Alongside security of supply, bioenergy continues to play an important role as a Finnish energy source from the perspective of overall resilience.

In the bioeconomy pathway, lignin is a rapidly developing opportunity to produce batteries and carbon materials. It is possible to recover lignin in a form suitable for battery materials, and lignin-based hard carbon has proven comparable to commercial hard carbon in lithium-ion batteries. Lignin can also be made into active carbon materials and biographite, replacing fossil graphite and reducing the need for critical minerals. In this way, lignin strengthens the bioeconomy pathway's goal of increasing the added value of biomaterials and building Finnish, low-carbon technology value chains.

The growing role of biogas complements the pathway: Finnish biogas — especially biogenic and synthetic methane suitable for use in transport and industrial sectors — strengthens energy self-sufficiency and provides a low-emission alternative for sectors that are difficult to electrify. Biogas investments utilise agriculture, industry and waste management side streams, support the nutrient cycle and make the bioenergy base more versatile. Therefore, biogas has a positive effect on regional self-sufficiency and vitality as well.

In the steel industry, electric arc furnaces (EAF) gradually replace blast furnace processes, and about 50,000 tonnes of biochar is used annually as a reducing agent. Biochar is also used to replace 30% of fossil coke in ferrochrome production, resulting in an annual consumption of about 75,000 tonnes of biochar. The metallurgical strength of biochar restricts the increase in replacement rate as it is lower than that of fossil coke.

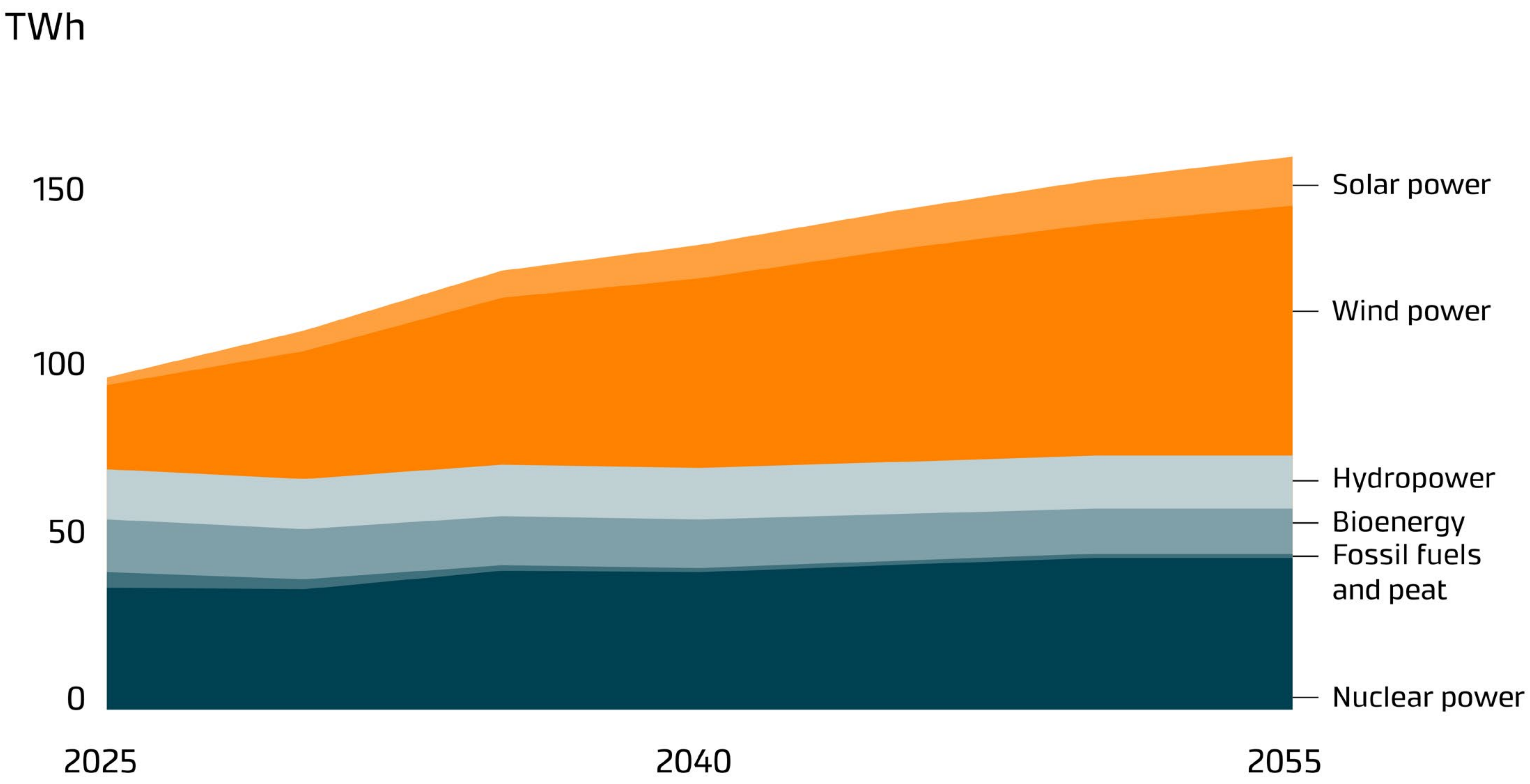
Liquid biofuel production will also use forestry side streams, such as logging residues and small-dimensioned wood at about 1.7 Mm^3 per year. Renewable hydrogen supports this production and improves the carbon efficiency of biomass. It is therefore not just a fossil hydrogen replacement, as it also allows for growth in the value of bio-refining.

Key term:
Cascade Principle

In this roadmap, the cascade principle refers to directing renewable biomasses primarily to applications with higher added value, such as material and chemical production, which have a longer-term impact and higher economic value on market terms, before they are utilised for energy. Implementing the principle revolves around economic profitability, market demand and acquisition costs, supported by public guidance in predictable regulatory and investment environments. Energy use is justified when there are no alternative applications or when biomass plays a key role in the energy system´s flexibility and security of supply.

Bioeconomy pathway

Development of electricity production 2025—2055, TWh

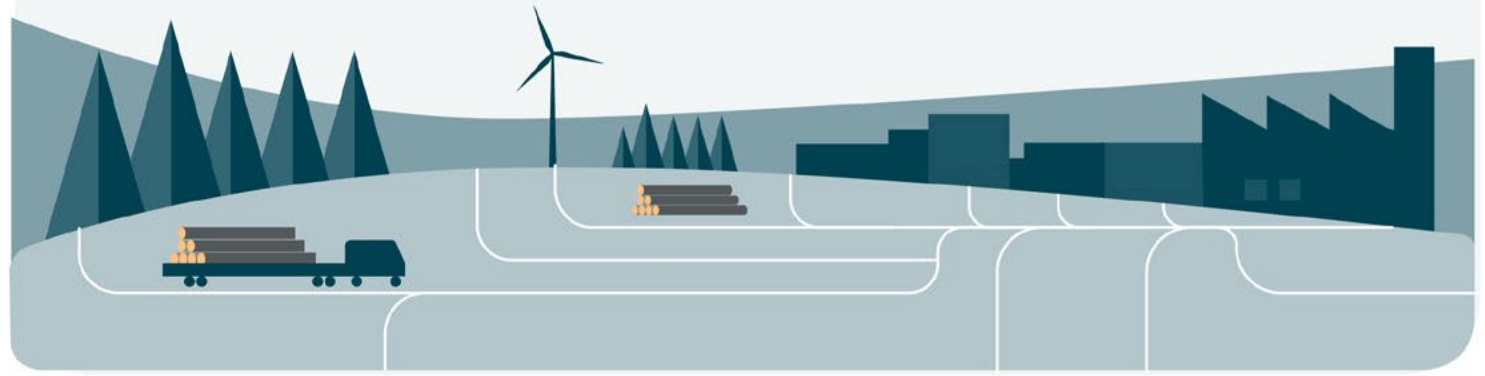


2055

Forest biomass is used especially for products of high added value, bioenergy supports security of supply and system flexibility.

The development of the energy system and the bioeconomy are closely intertwined.

Strengthening of the vitality of the countryside, regional clusters and the economic benefits remaining in Finland.



3.3 The Electrification pathway

The electrification pathway is based on the EU compliance pathway's structure, but uses the production potential of renewable electricity significantly more extensively in industrial value creation. In this pathway, the Finnish electricity system's capacity increases to a level that enables the large-scale operation of data centres, renewable hydrogen production, and carbon dioxide-based synthetic e-fuels.

Total electricity consumption in this pathway increases massively to around 215 TWh by 2055 (cf. EU compliance pathway ~152 TWh). There are two particular factors that contribute to this increase: significant expansion of data centres and the use of biogenic carbon dioxide and hydrogen to produce synthetic fuels. Data centre electricity consumption rises to about 35 TWh per year (approximately 7 GW capacity, 60% utilisation rate). Annually, 4 Mt CO_2 of biogenic carbon dioxide, produced by pulp mills, is processed into synthetic fuel, which requires about 30 TWh of electricity for hydrogen production. Wind power production grows to 134 TWh by 2055 (65 TWh in the EU compliance pathway), of which 14 TWh (about 10%) will be offshore wind. Solar power production grows to 21 TWh *(Table 3.1)*. The pathway does not assume the construction of additional nuclear power. The electricity system becomes the backbone of the energy system, with a high share of wind power increasing the need for system balancing.

Heat production becomes strongly electrified as electric boilers and heat pumps that use waste heat from data centres become more common, significantly displacing the annual use of wood fuels compared to the EU compliance pathway. The role of wood fuels in energy production focuses on security of supply and management of peak consumption.

The energy system is characterised by a significant steady increase in electricity demand (data centres) and significant supply fluctuations in renewable production, caused by changing weather conditions. This future pathway emphasises, on one hand, periods of abundant renewable production in relation to current demand, and on the other hand, periods of low renewable production. Periods of abundant renewable energy are maximised with scheduled consumption at these times and by shifting energy to periods of lower production, utilising both short and long-term storage of electricity and heat.

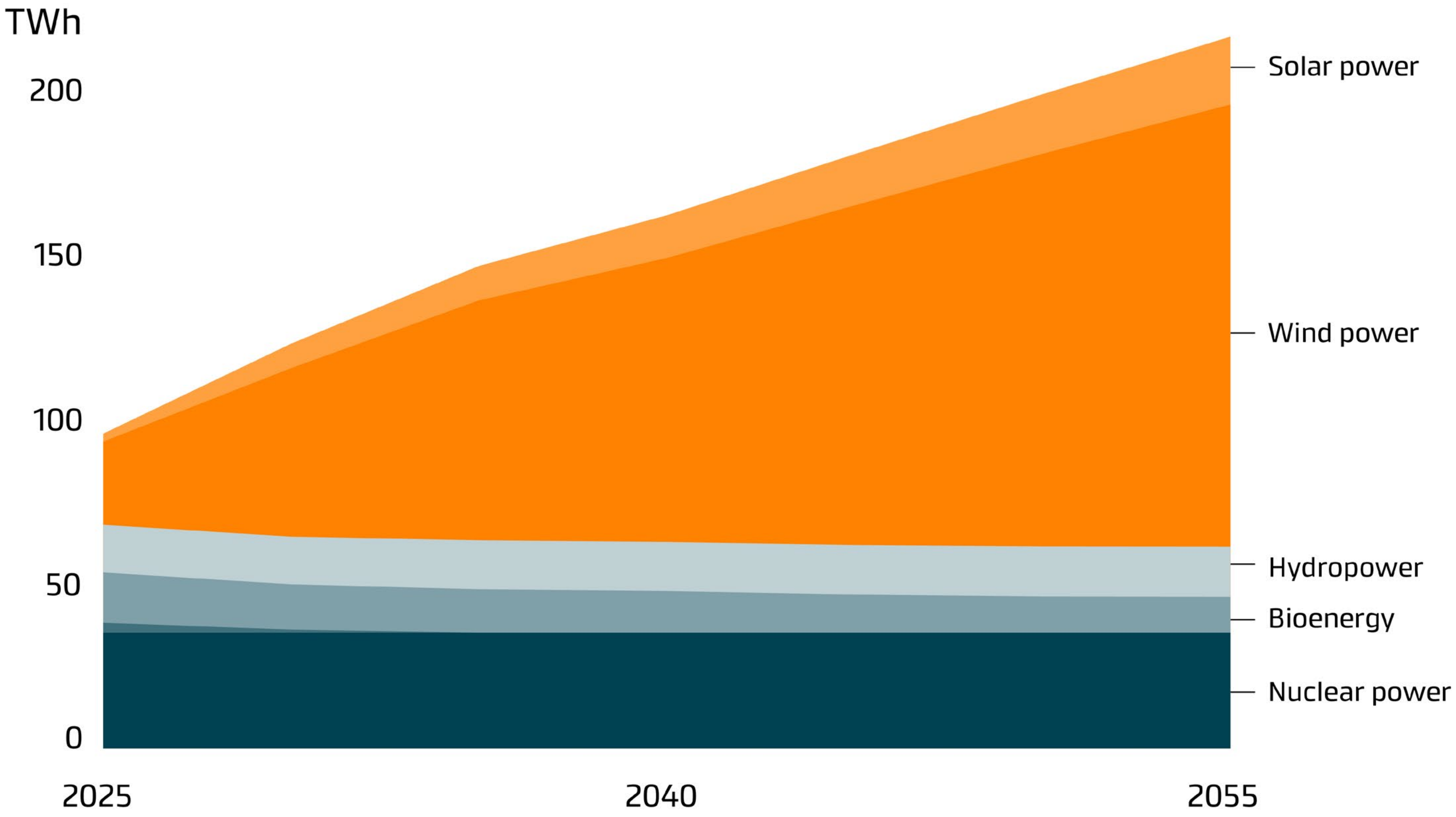
Managing winter peak consumption relies on the geographical diversification of onshore and offshore wind power, stronger transmission connections, and long-term storage of heat and renewable fuels. Prolonged periods of low renewable production and cold spells emphasise the role of wood energy (both forest chips and forestry side streams), imported electricity and the management of power use in data centres as well as the use of their backup power plants.

Hydrogen takes a significantly expanded role compared to the EU compliance pathway. Hydrogen is not restricted to being a replacement for fossil hydrogen; it also enables the large-scale conversion of point sources of biogenic carbon dioxide into synthetic fuels or fertilisers.

The annual use of wood fuels for heat and electricity production is clearly lower than in the other pathways, but short-term use during peak demand remains an important part of flexibility in the system. As in the other pathways BECCS capacity in 2055 will be at 13 Mt CO_2, mainly at pulp mills.

Electrification pathway

Development of electricity generation 2025—2055, TWh



2055

Electricity consumption will grow significantly due to the needs of data centres and the renewable hydrogen required for e-fuels.

The energy system is built on large-scale renewable production, grids, energy storage and flexibility.

With clean electricity and power-intensive industries, exports and investments will grow all the while increasing the dependence on the development of international energy markets.

3.4 Strategic choices across pathways

Strategically, the future pathways represent different ways for Finland to position itself in the energy transition, despite all achieving the EU's climate and energy targets.

The EU compliance pathway is based on the implementation of regulation and the growth of wind power. Reducing the use of fossil energy, promoting electrification and increasing the share of renewable energy without significantly expanding the scale of the system is central to the pathway. The primary way to strengthen strategic autonomy is to replace imported fuels and grow Finnish renewable production.

In the bioeconomy pathway, the strategic emphasis is on Finnish natural resources and increasing their added value. Instead of burning forest chips in heat and power plants, the use of wood focuses instead on more advanced uses, such as biochar and renewable fuels. In this pathway, strategic autonomy is built primarily on strengthening the national resource base, which will not significantly change Finland's position in the European energy market.

In the electrification pathway, the strategic focus shifts to large-scale production of renewable electricity and its industrial utilisation. The strong growth in electricity demand, the location of data centres and the production of hydrogen and synthetic fuels link Finland more closely to the European energy and industrial markets. This can strengthen Finland's role as part of the EU's clean energy industrial transformation, but also increase dependence on investment flows, international supply chains and access to technology. Strategic autonomy in this pathway is built primarily on EU integration, cooperation in the Nordic electricity market and competitive renewable electricity production.

All pathways share the objective of carbon neutrality, but differ in the energy system's structure, resource use and international positioning.

Table 3.1 Key differences in the energy system across the 2055 future pathways

	EU compliance pathway	Bioeconomy pathway	Electrification pathway
Electricity generation (TWh)	152	159	215
Share of wind (TWh)	65	72	134, of which 14 offshore
Share of solar (TWh)	13	14	21
Data centres (TWh)	10	10	35
Electricity consumption of synthetic fuels (TWh)	2	6	30
Replacing the energy of forest chips with electricity (TWh)	0	4	14
Total use of forest chips (million m^3/year)	13	12.5	2.2
Bio-CO_2 recovery and conversion to fuel ($MtCO_2$/year)	0.2	0.2	4
Bio-CO_2 recovery and storage ($MtCO_2$/year)	13		
Carbon neutrality	Achieved by 2050 (based on the KEITO WAM scenario; the impacts of methodological refinements of GHG calculation currently being worked on at Luke in the future pathways is that they are unlikely to lead to calculated carbon neutrality by 2050, even if fossil emissions from the energy system are reduced)		

3.5 Pathway uncertainties

There are several uncertainties about global and national operating environments that impact long-term energy system planning and the realisation of pathways, costs and societal acceptability. These uncertainties are not just technical or economic, they are linked to broader forces of change in climate, policy and technology. In the energy transition, timing is crucial: abundant resources alone do not create competitiveness. Instead, it arises from the ability to transform the resources into a functional entity that serves the market and society at the right time. This highlights the importance of strategic foresight, identifying investment windows and understanding the ever-changing operating environment in all future pathways.

The foresight work identified several forces of change and related uncertainties. Here, we describe the key uncertainties that can have a decisive impact on the realisation of the pathways.

Climate change increases uncertainty in energy system planning. Climate continues to change despite mitigation measures. The acceleration of global warming increases and intensifies extreme weather events, such as storms, heavy rains, floods, heat waves and droughts that burden energy infrastructure and can impair wind power production conditions or the availability of biomass, among others. Growth in the share of renewable energy in electricity production also increases fluctuation in production due to weather. A weakening or abrupt slowdown of the Atlantic Meridional Overturning Circulation (AMOC) — one of the key tipping points of Earth's systems — could significantly change weather conditions in Northern Europe. As a result, winters could become significantly colder and longer, and heating demand, for example, could suddenly increase (Nummelin et al., 2026), highlighting the flexibility needs of the system and the importance of back-up power. Changes like these emphasise the need to design and build energy systems that are flexible and consider systemic impacts to withstand both slow-moving and sudden climate risks, and take land use, security of supply and resilience into account as part of the whole. This is linked to the European Commission's resilience by design principle, according to which all investments that are "vulnerable or exposed to climate impacts must be designed to face and withstand climate risks that could materialise in their lifetime, without unacceptable loss of their value or utility" (European Commission: Directorate-General for Climate Action, 2025, p. 56).

Of the geopolitical uncertainties, wars around the world represent the most significant risk, the expansion of which would inevitably have an impact on energy issues in Finland as well (Mikkola et al., 2026). The resolution of the war in Ukraine will impact the comprehensive security architecture of Europe and, therefore, energy policy. Continued wars in the Middle East will have an impact on the cost of imported energy. The divergence in US-European values may also impact the availability of US energy in European markets. An energy system that relies on Finnish renewable energy production safeguards against these uncertainties. However, China has announced that it will resolve the Taiwan issue by 2049, and the use of military force cannot be ruled out until then. This is likely to have significant impacts on the global economy as well as on the value chains of critical minerals, components and renewable energy.

The geopolitical struggle of the energy transition also takes place in the information dimension, that is, at the level of images and information. Fossil energy advocates are trying to slow down the energy transition to prolong the era of fossil energy. The financial

> Abundant resources alone do not create competitiveness. Instead, it arises from the ability to transform the resources into a functional entity that serves the market and society at the right time.

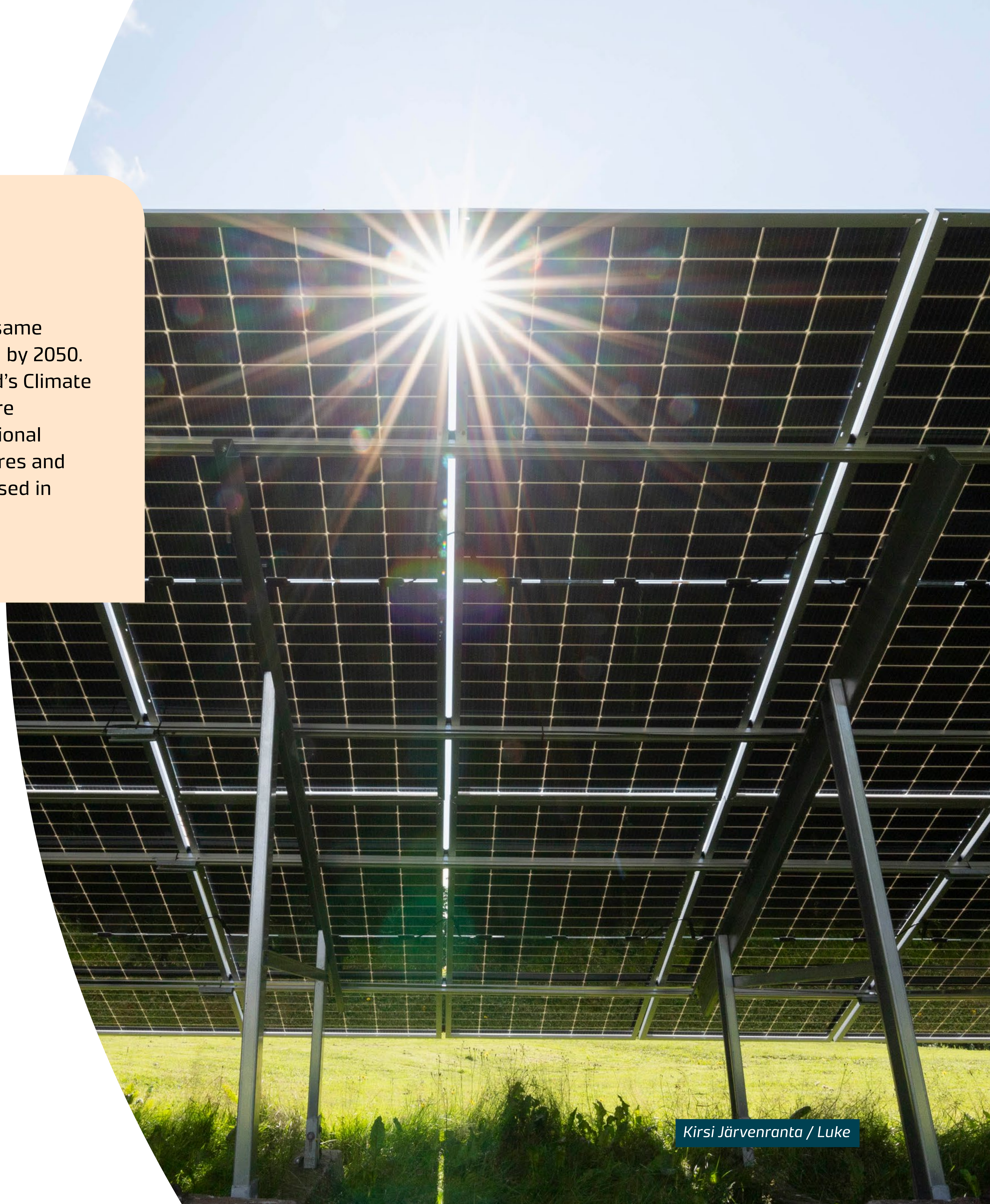
and administrative system of fossil energy exporting countries is based on their revenues, the dwindling of which is often a threat to an authoritarian regime. That is why they are trying to exaggerate the disadvantages of the energy transition and to minimise the benefits.

The information dimension is related not only to the interests and divisions between states, but also to the divisions within societies. Attitudes towards renewable energy and the green transition are often intertwined with broader political and social tensions, where energy policy can be framed as part of a populist conflict between elites vs. the people or cities vs. the countryside. In this case, the green transition may be interpreted as a project driven by urban centres, political elites or international actors, which may sow distrust of energy policy and reinforce political polarisation (Weckroth & Ala-Mantila, 2022). At the same time, social media platforms and AI-based algorithms can strengthen polarising communication environments and accelerate the spread of false or misleading information on energy and climate issues (Van Der Linden et al., 2017).

Furthermore, the electrification of societies and the rapid spread of artificial intelligence will grow the demand for electricity and can reshape the labour market in ways that divide socio-economic groups and regions into winners and losers of the energy transition. This can reinforce experiences of regional and social injustice, as well as deepen political divisions around energy policy. At the same time, a deteriorating shared knowledge base becomes a significant risk: if research-based discussion weakens, both democratic decision-making and long-term planning and steering of the energy transition become more difficult.

Carbon neutrality 2035 — further measures needed:

Each future pathway starts in the same place: carbon neutrality is achieved by 2050. However, the 2035 target in Finland's Climate Act will not be achieved in the future pathways without significant additional measures. These additional measures and how to implement them are discussed in more detail in *Annex 1*.



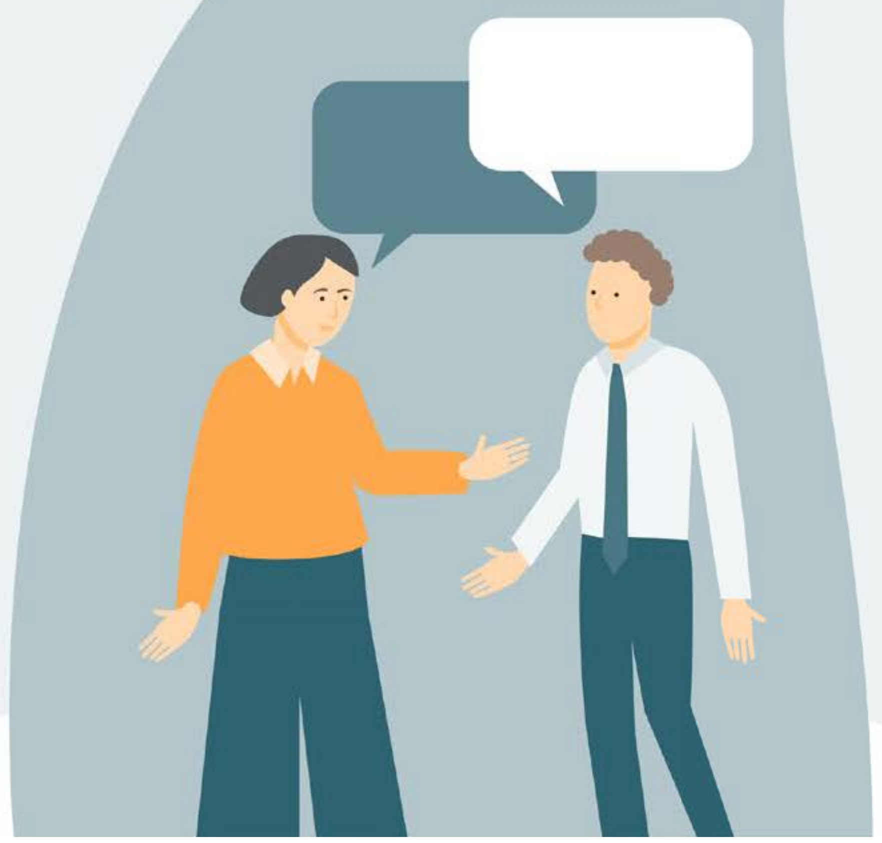
Kirsi Järvenranta / Luke

4. Energy transition from the perspective of the three areas of change

A sustainable energy system that promotes comprehensive security is built on three areas of change

Regional agency and justice

Fair sharing of the costs and benefits of renewable energy, and local communities are included in the planning and implementation of the energy transition.



Sustainable land use and resources

Land use is reconciled with the energy transition so that new production is appropriately sited, cumulative impacts are minimised, and natural values are protected.

Geopolitics and security

Renewable energy reduces dependence on energy imports and strengthens the strategic autonomy of Finland and Europe. Energy policy plans are closely linked to foreign and security policy to strengthen security of supply and crisis resilience.

4. Energy transition from the perspective of the three areas of change

4.1 Sustainable land use and resources

Technological solutions alone will not create the energy transition, as it will also require extensive land and marine areas, biomass resources, infrastructure investments and local acceptability in the areas affected by the energy transition. Therefore, land-use interests, the sustainability of natural resources, and economic impacts impose fundamental limits to the energy system's development.

In particular, the expansion of wind and solar power will change land use priorities and increase the need for planning at different regional levels. At the same time, projects increasingly need adequate connections and transmission capacity from the power grid, as well as the correct timing of investments. Without proactive cooperation between the grid and zoning, bottlenecks arise, which impair the cost-benefit ratio and local acceptability of the projects. At the same time, bioenergy — a key part of Finland's energy mix — is linked to forest use, carbon capture, and the future of the bioeconomy. The energy transition thus impacts biodiversity, ecosystem services, and regional vitality.

In addition, new renewable energy technologies, such as renewable hydrogen, biochar, and carbon capture, are changing the role of biomass and electricity in how industry creates value. The impacts of these solutions range from land use to supply chains and investment structures. The growth of offshore wind power is shifting some of the land-use pressures to marine areas, which requires the coordination of maritime spatial planning with nature conservation, fisheries and maritime transport, as well as port, maintenance and logistics investments in coastal areas.

Observing this area of change thus combines three interlinked perspectives:

1. Land use impacts of renewable energy,
2. The economic and ecological sustainability of biomass resources
3. Investment and supply chain structures for the energy transition.

Together, these determine the conditions for the energy system to expand sustainably and in a socially acceptable way. The vision of the area of change sums up the state of the energy system from the perspective of the area in 2055.

Vision of the area of change

In Finland, land use of renewable energy is ecologically sustainable, regionally balanced and socially acceptable. Expanding the energy system is based on holistic planning, which takes biodiversity, ecosystem services, regional vitality and the energy system's security of supply into account. Proactive planning and permitting procedures are crucial for timing investments with expansions of grid and storage capacity.

Bioenergy, wind and solar power, as well as the new technologies connected to them, are used in a way that directs limited natural resources to applications with the highest possible added value and that achieve carbon neutrality goals without an overall degradation of nature.

Next, we will look at the land-use, ecological and economic framework conditions that are required to implement the vision and goals in practice.

4.1.1. Land use impacts of renewable energy

Wind and solar power are key forms of energy in the renewable energy system. They are also new forms of land use, the siting of which must take the needs of existing land use as well as environmental and nature impacts into account.

Since Finland is a forested country, wind and solar power are sited mainly in forests. There, they compete with forestry and bioenergy production, safeguarding of biodiversity, recreational use and, in northern Finland, with reindeer herding. When placed in an agricultural environment, they can have an impact on food production. Siting in the immediate vicinity of cities, population centres and highways is restricted for safety and acceptability reasons (Luukkonen et al., 2026). While offshore wind is on the rise, it is not yet cost-effective compared to onshore wind. Growth in offshore wind requires further research into marine ecosystems and cost-effectiveness, as well as the reconciliation of maritime spatial planning with nature conservation, fisheries and maritime transport.

In practice, wind power is mainly sited outside population centres, on the edges of municipalities and provinces. Siting in a remote area usually requires clearing for power transmission lines and roads, which may increase the deforestation caused by wind power more than the turbines themselves (Tolvanen et al., 2025). In principle, solar power plants can be sited closer to the built environment and large urban centres in terms of landscape damage, but they are also usually located outside urban areas in forests, former peat production areas, or fields.

The natural impacts of land-based wind power include degradation and fragmentation of habitats, disruptive noise and light pollution (Tolvanen et al., 2023), as well as impacts on water systems, especially during the construction phase. These make it more difficult for animals to move, cause avoidance behaviour as well as fatal collisions, which weaken populations and increase endangerment. The impacts of offshore wind power include clouding of water during construction, underwater noise, and changes in seabed habitats (Lappalainen et al., 2025). To birds, barrier effects, habitat loss and collision impacts are similar to those of onshore wind power. The environmental impacts of solar power include the loss and fragmentation of forest habitats, barriers to animal movement, and harm to water bodies when constructing on peatlands (Muhonen, 2024). However, research on the effects of offshore wind and solar power in particular is incomplete, and there is no information about the long-term effects of any of these three forms of energy production or the potential habituation of animals to them.

In the **EU compliance** and **bioeconomy** pathways, wind power production increases to 65—72 TWh and solar power to 13—14 TWh. The vast majority of wind power production is onshore. The planned act on regional management proposes a safety distance of 1.25 kilometres from settlements. If this happens, more wind power production will move to Northern Finland. This means energy production areas will move farther away from the users of energy, which in turn increases the need to build transmission lines and thus the impacts on land use.

The key methods to manage the nature impacts of wind and solar power are a comprehensive assessment of cumulative impacts and a mitigation hierarchy. Assessing cumulative impacts requires a review of wind farms and solar parks and their impacts on habitat connectivity beyond administrative and project boundaries. This requires a comprehensive vision of land use needs, improved cooperation between actors and authorities

Since Finland is a forested country, wind and solar power are sited mainly in forests. There, they compete with forestry and bioenergy production, safeguarding of biodiversity, recreational use and, in northern Finland, with reindeer herding.

across different areas, and detailed guidelines for an environmental impact assessment (EIA) to support the assessment of cumulative impacts.

There are three steps to the mitigation hierarchy. Natural impacts are primarily avoided by siting energy production in areas that already have weaker diversity, such as wastelands. In the case of *mitigation*, animal detection, expulsion and collision avoidance devices, which reduce the impact mortality of birds on wind turbines, are some of the methods that should be used. *Compensation* is only an option when avoiding habitat loss or mitigating the impacts is not possible. The remaining impacts can be compensated by creating high-quality habitats in nearby areas through protection or restoration. Compensation requires a spatial examination of the impact, compensation areas and their natural state. It also requires governance tools to finance practical conservation and restoration measures.

Each pathway places a different emphasis on the coordination of land use and natural resources. **In the bioeconomy pathway**, the land use needs of wind and solar power may, to some extent, have an impact on the availability of wood as areas become unavailable for forestry. **In the electrification pathway**, the production of onshore and offshore wind and solar power will increase significantly compared to the current situation. This pathway features extensive enough a space requirement for energy production and data centres that managing the cumulative impacts and adequacy of the areas for the mitigation hierarchy may prove to be difficult. Underground cabling can help to partly control the growing space need for power transmission lines. Offshore wind power transfers some of the land use pressure to the sea, where it must be coordinated with other marine uses.

Table 4.1. Total land use of the renewable energy and transmission network in Finland: current state in 2025 and future pathways in 2055.

	Current state in 2025	EU compliance pathway	Bio-economy pathway	Electrification pathway
Wind (onshore)				
Project area, km^2	940–1,410	2,500–3,700	2,700–4,100	4,600–6,800
Direct built-up area, km^2	20–55	50–150	55–165	90–275
Solar power				
Land area, km^2	~5*	150–225	160–240	240–360
Transmission network (400 kV main power lines)				
Length, km	5,400	6,400–7,100	6,600–7,400	8,300–10,000
Clearing (35 m), km^2	190	225–250	230–260	290–350
Entire transmission line right-of-way (55 m), km^2	300	355–390	365–410	460–550
Total (project area + solar power + transmission line right-of-way)				
Area, km^2	1,245–1,715	3,005–4,315	3,225–4,750	5,300–7,710
Percentage of Finland's land area	0.4–0.6	1.0–1.4	1.1–1.6	1.7–2.5

Key term:
Mitigation hierarchy

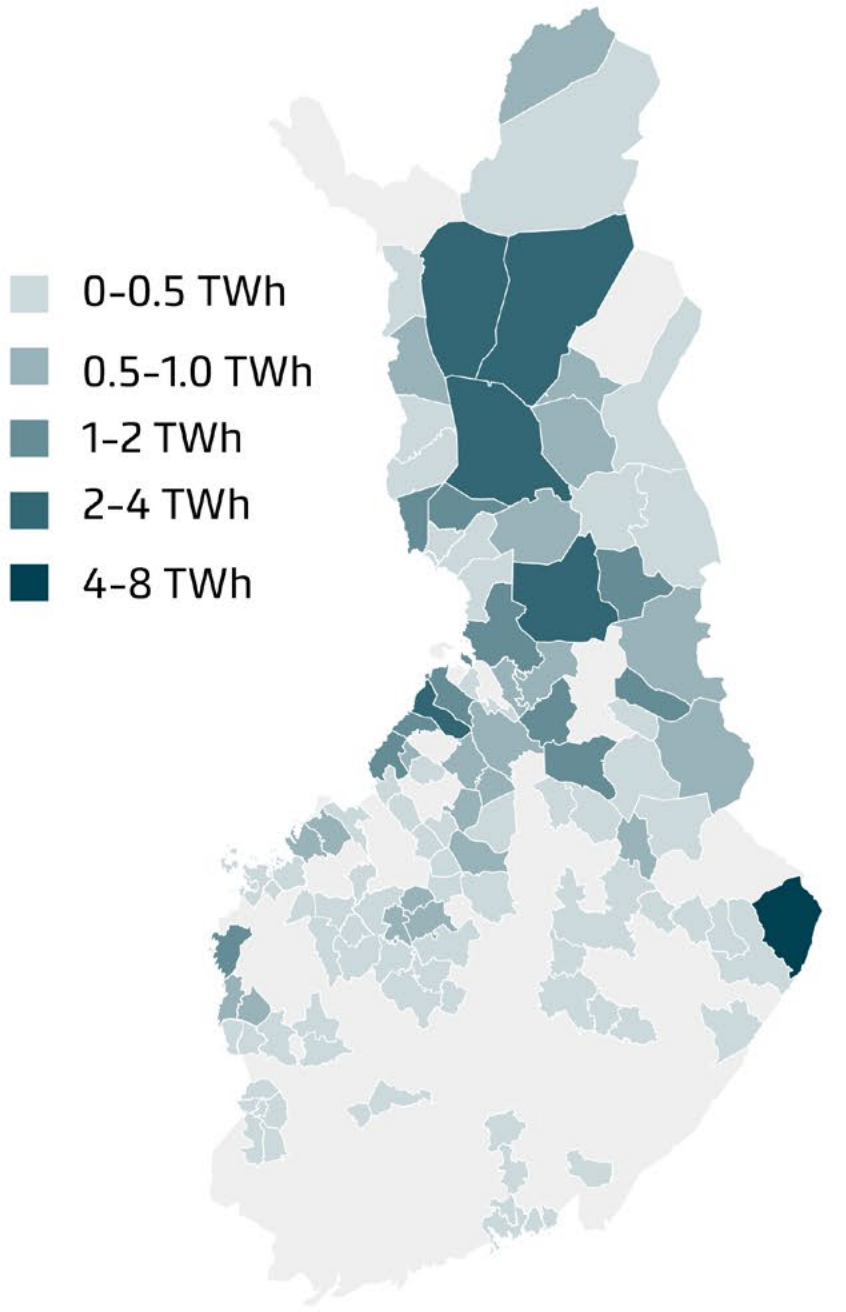
In this roadmap, the mitigation hierarchy refers to a principle applied to renewable energy projects, which aims to minimise the harm to nature. This is done by primarily avoiding, secondarily mitigating, and only finally compensating for harmful impacts on biodiversity and the environment. The principle guides the planning, siting and implementation of projects in a way that identifies and considers the impacts proactively throughout project development and lifecycle.

* Currently, the land area of solar power covers only power plants of industrial size (~0.35 GW at the end of 2025); small-scale production (approx. 1.15 GW) is mainly sited on rooftops and does not occupy new land.

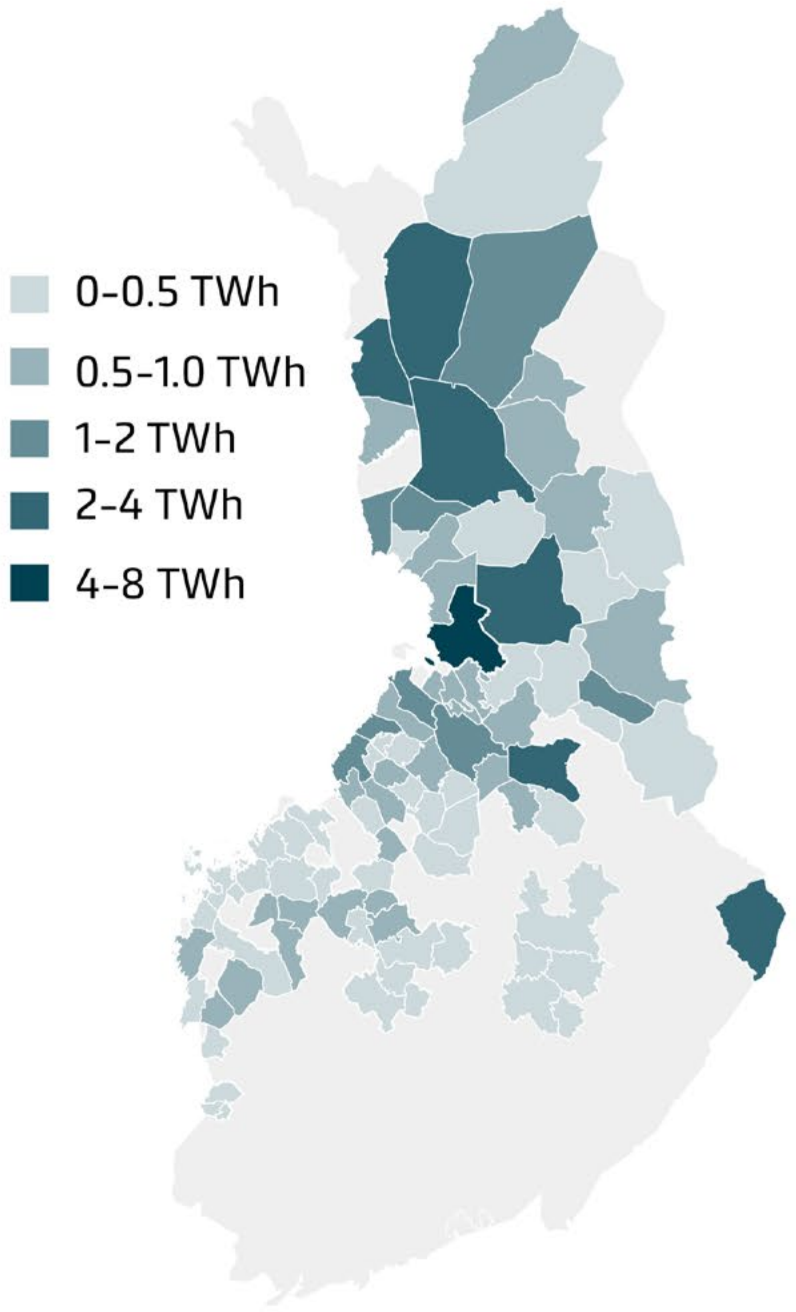
The amount of wind power development and the minimum distance from residential areas has an impact on the regional siting of wind power

Possible siting of wind power in the EU compliance pathway and the electrification pathway, and at two minimum distances from settlements.

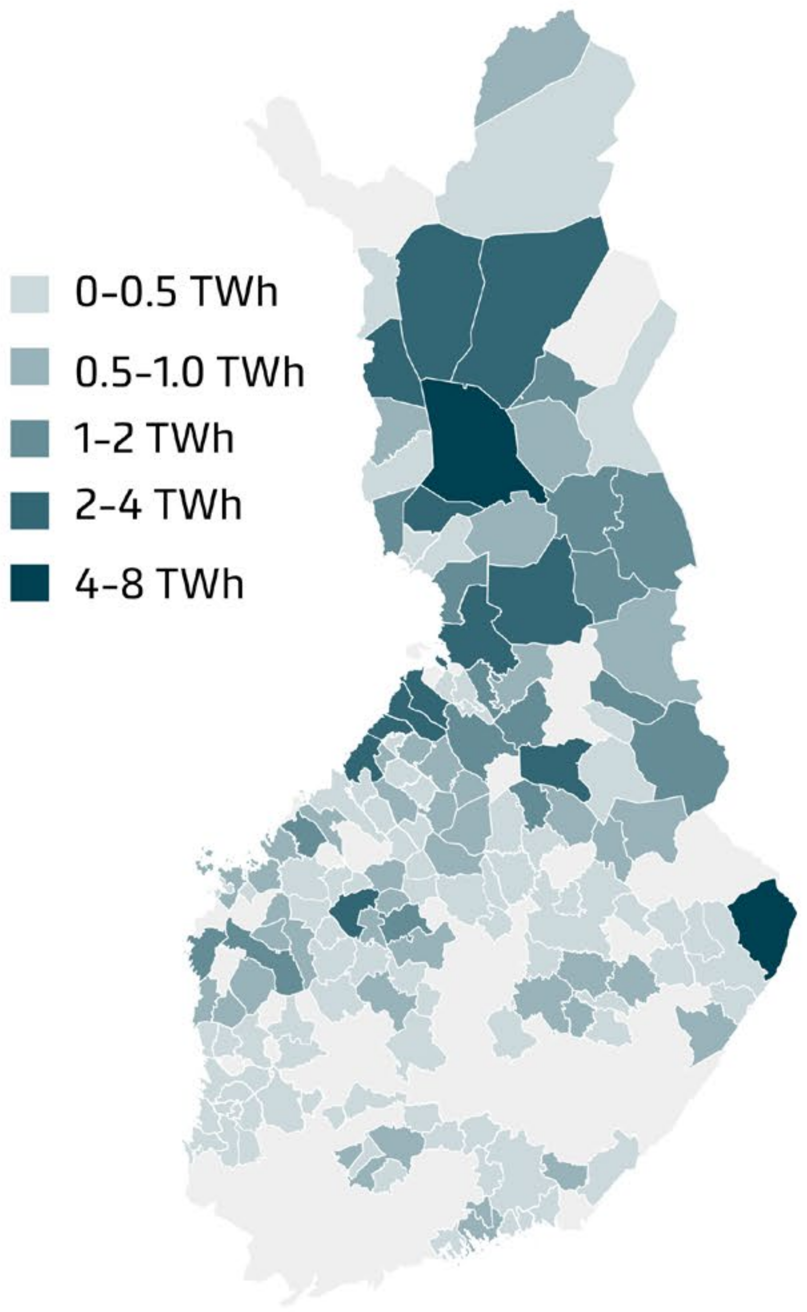
EU compliance pathway
(wind power production 65 TWh)
600 m from settlements



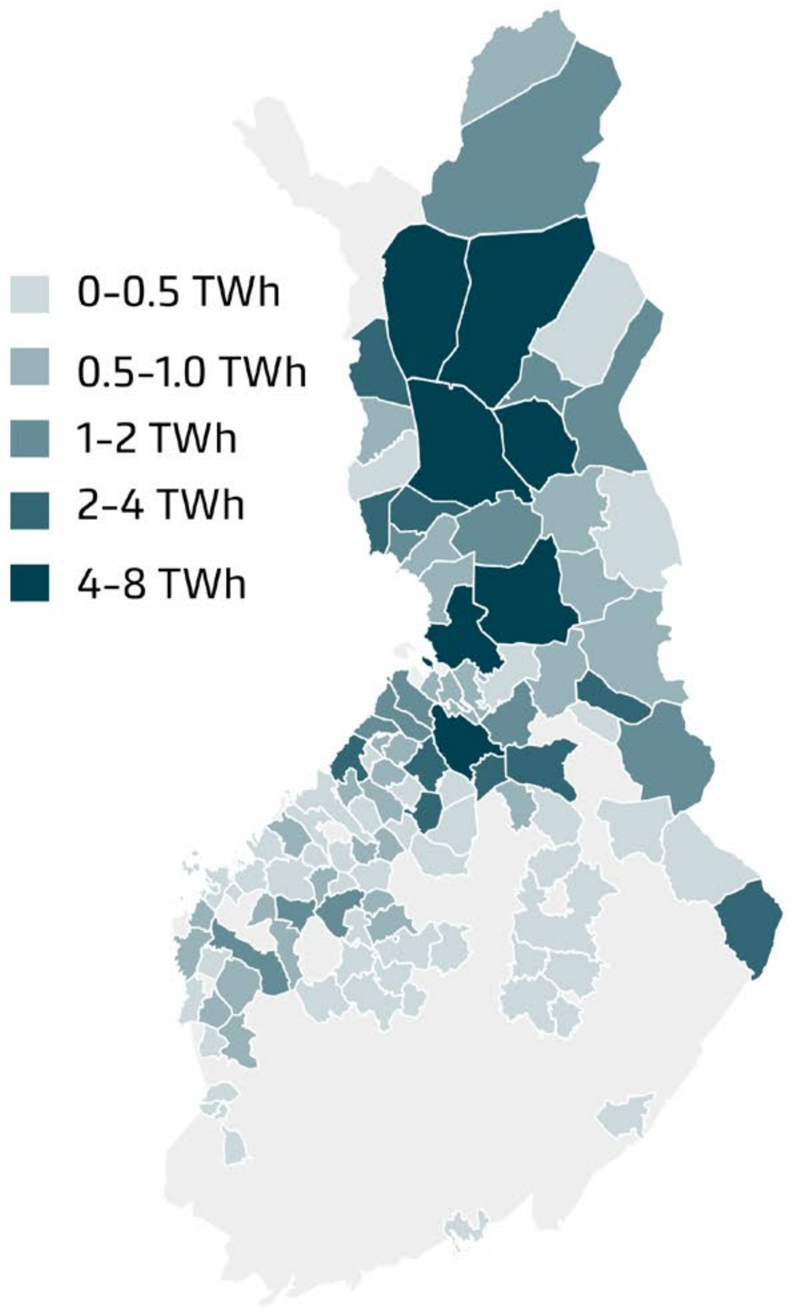
EU compliance pathway
(wind power production 65 TWh)
1250 m from settlements



Electrification pathway
(wind power production 120 TWh)
600 m from settlements



Electrification pathway
(wind power production 120 TWh)
1250 m from settlements



**The calculation is based on the annual power of one 6.6 MW wind turbine, averaging 20 GWh (35% of the total annual power of the turbine). Individual wind farms are dimensioned for at least 10 turbines. Wind farms are sited, under consideration for regional restrictions (roads, protected areas, airports, two distance limits from housing, etc.), as close as possible to high-voltage lines until the necessary nationwide energy production (65 TWh or 120 TWh) is met. Municipal borders did not play a role in the siting of wind farms; that is, if a municipality lies on the edge of a wind farm and only one turbine falls within it, it will be coloured pale on the map. The calculations do not consider the restrictions imposed by the Defence Forces on Finland's eastern border.*
Figure: Jouni Karhu

4.1.2. Economic and ecological sustainability of biomass resources

Sustainable use of wood-based biomass resources requires that forest growth, biodiversity and carbon sinks form the ecological basis that allows economical optimisation of the added value and energy use. The use of energy wood does not, in principle, threaten carbon sinks, biodiversity, soil condition or water management, provided that logging focuses on side streams, residues and small-dimensioned wood, and that harvesting methods follow good practices for the protection of habitats and soil (e.g. tree retention, strip road planning). Risks to economic and ecological sustainability increase when a comprehensive assessment is not carried out on how wood is directed from the perspective of added value, market situation and environmental impacts, or where logging targets sensitive habitats without adequate conservation measures.

Bioenergy used in Finland consists mainly of wood fuels, which are by-products of forestry and the forest industry, making it an economically efficient and ecologically justifiable part of the energy system. What supports the use of wood in energy production is abundant availability in Finland and a large and distributed heat and power plant system. However, in the coming years, the strong growth of wind power and the electrification of heat production will reduce wood fuel use in electricity and heat production (Niinistö, Anttila, Kaseva, et al., 2025). Despite this, wood-based energy is expected to remain a key part of Finland’s energy system, and in addition to security of supply, its importance comes to the fore as a regulating power. This role is an essential part of the economic sustainability and security of supply of biomass resources, as it requires functional and profitable supply chains, even when the continuous annual use of bioenergy decreases.


Lauri Sikanen / Luke

Increasing fluctuations in wood fuel use, especially forest chips, weaken the operating environment for energy wood supply chains. Rapid growth in the use of Finnish forest chips and energy wood procurement in the 2020s has focused not only on small-diameter wood from silvicultural logging but also on timber, which is suitable for processing by the forest industry. While the use of forest chips will decrease in the coming years due to electrification of the energy system, longer storage times for energy wood and increased terminal storage will maintain pressure on the energy use of larger-diameter industrial timber (Niinistö, Anttila, Kaseva, et al., 2025; Niinistö, Anttila, Sikanen, et al., 2025). Therefore, the technical and financial conditions for the procurement of logging residues and small-diameter solid wood should be strengthened (Niinistö et al., 2026). These raw material flows support the management of young forests, reduce the need for energy use of merchantable timber, and thereby improve forest growth and carbon sinks in the long term. At the same time, they improve the overall economic efficiency of biomass resource use and reduce storage risks.

In addition to wood-based biomass, a key part of the economic and ecological sustainability of biomass resources has to do with solutions based on organic waste and side streams from agriculture, industry and communities. Using waste and side streams as new products and energy supports nutrient and carbon recycling, reduces emissions, and improves regional self-sufficiency in both the energy and food sectors.

Technically complete solutions, such as biogas production, make it possible to reduce dependence on fossil fuels in the short term as well. It is possible to refine biomethane from biogas and synthetic fuels from carbon dioxide by-product of this process. These are particularly important in transport, industrial processes and applications critical to security of supply, where electrification is technically or economically difficult. A decentralised production structure and the ability to store and move fuel improve the energy system's flexibility and resilience.

Biogas, liquid biofuels and synthetic fuels play a complementary role in the energy system. The significance of these mostly has to do with resource efficiency and the fact that existing waste and side streams can be used in energy production without additional pressure on the use of forest resources. All sustainably available biomasses support the transition towards products with higher added value in the bioeconomy pathway, while strengthening the energy system's economic sustainability and security of supply.

In every pathway, bioenergy remains a part of Finland's energy system. In the **EU compliance pathway**, wood-based bioenergy functions above all as a flexible and adjustable form of production, the use of which varies according to electricity prices and weather conditions. This places a higher importance on storage times and terminal logistics. Improving procurement conditions for logging residues and small-dimensioned wood (cost-effective harvesting and logistics solutions) as well as regional terminal capacity are key to operational reliability. The use of organic waste and side fractions supports regional energy self-sufficiency.

In the **bioeconomy pathway**, the use of bioenergy also remains at a significant level. However, in the long term, the use of solid wood fuels in electricity and heat production will decrease significantly as other renewable electricity solutions become more widespread and energy efficiency improves. The overall use of bioenergy remains high and biomass is increasingly directed to products with higher added value. In addition to biogas, the demand for more advanced bio- and synthetic fuels is expected to increase in maritime and air transport, i.e. in applications where electrification is difficult. Correspondingly, the demand for biomass is also growing as a raw material for biochar production, which is used in the steel industry among others.

In the **electrification pathway**, the annual use of bioenergy decreases significantly due to the electrification of the energy system and the growth of wind power. This trend challenges the conditions for the sustainable operation of energy wood supply chains, especially in cases where the aim is to direct fractions other than industrial timber to combustion. With weaker foresight on usage volumes and the use focusing on occasional consumption peaks, the storage times of wood fuels extend and the importance of terminal storage increases. At the same time, it becomes more difficult to secure the supply of bioenergy if continuous demand and the profitability of supply chains deteriorate too much, highlighting the need to maintain at least a critical level of use and storage. The potential of biogenic carbon capture is effectively exploited both as technical carbon sinks and as a fuel feedstock.

The strategic importance of bioenergy varies from industrial value creation to ensuring system resilience and security of supply, but it retains its important role as part of a low-carbon energy system in all options.

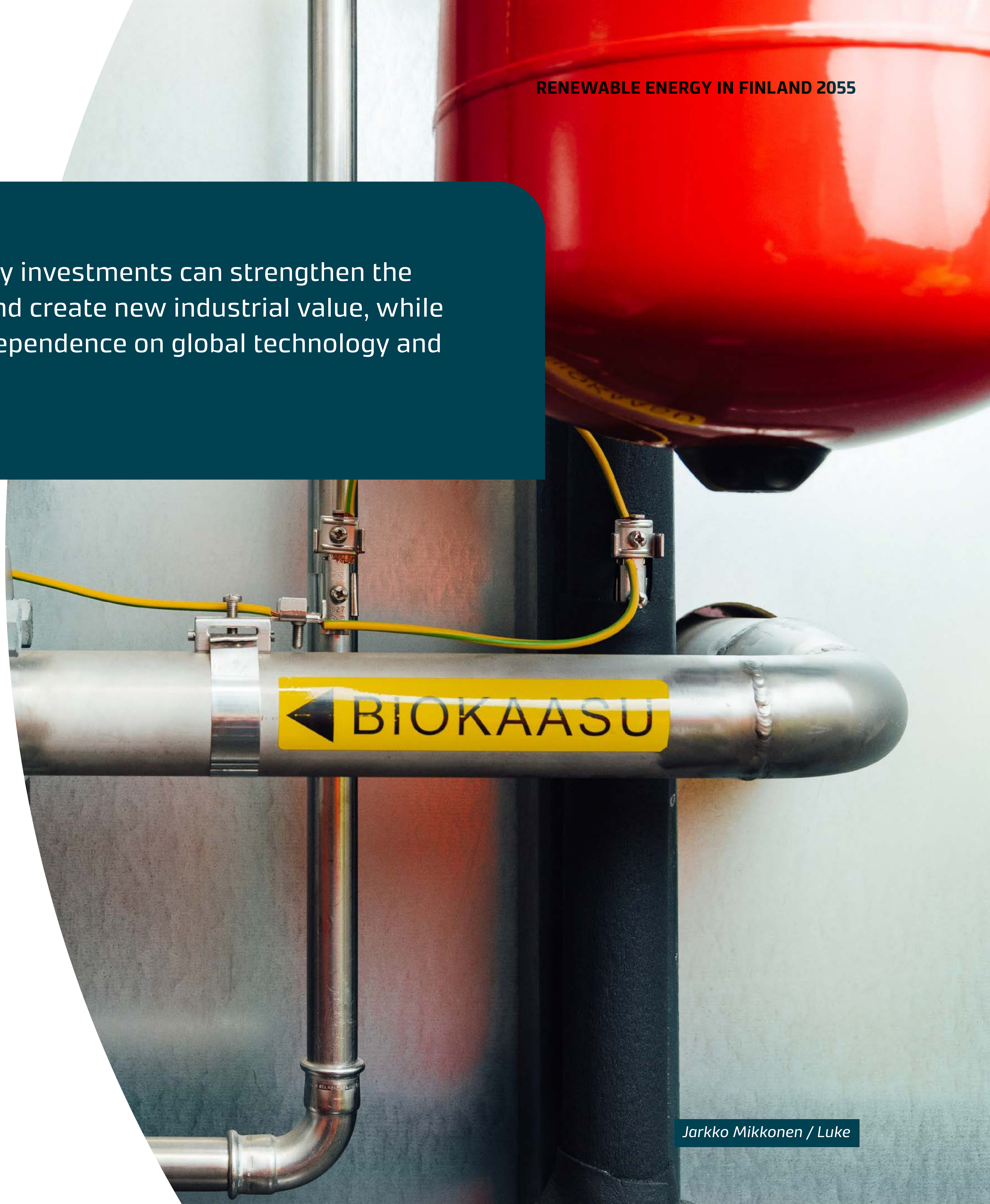
4.1.3. The energy transition: investment needs, economic impacts and supply chain risks

The transition from fossil fuels to renewable energy requires massive investments in infrastructure, such as power plants, energy grids, flexible consumption solutions and storage technologies. The timing, allocation and financing models of the investments will have a decisive impact on the energy transition´s cost-effectiveness and competitiveness.

The economic impacts are related to the overall scale of investments, access to funding, sustainability of supply chains and regional vitality. Renewable energy investments can strengthen the Finnish market and create new industrial value, while also increasing dependence on global technology and material flows. Bioenergy supports a decentralised regional economy, as its value chains are linked to Finnish natural resources and local employment.

With the growth of weather-dependent renewable production, the average price of electricity in Finland has decreased, with higher price volatility as a knock-on effect. This volatility encourages investment in flexible energy solutions and storage. Long periods of low prices undermine the profitability of wind and solar power, while creating the conditions for electricity-based, cost-competitive operations, such as electric boilers, heat pumps, hydrogen production and data centres. In the long term, the market mechanism balances price fluctuations and steers the system towards a balance where increasing both production and demand is profitable.

Renewable energy investments can strengthen the Finnish market and create new industrial value, while also increasing dependence on global technology and material flows.



Jarkko Mikkonen / Luke

In the **EU compliance pathway**, total energy consumption decreases, but electricity consumption increases by about 50% between 2025 and 2055. Investments focus on electricity production, supporting electrification and reducing emissions from networks and heat production. The financing needs are relatively predictable and the investments are largely focused on the modernisation of existing infrastructure and new electricity generation capacity. The most significant new investment is the creation of carbon capture and storage capacity for pulp mills.

The **bioeconomy pathway** would invest in more biochar production and the production of wood-based biofuels and biogas. Some of the wood-burning heat and CHP plants, which are approaching the end of their service life, are expected to be shut down, and replacement investments will focus on other energy sources. Raw material supply chains have a significant employment impact, especially in sparsely populated forested areas. Stumpage earnings from energy wood are distributed widely across society through a large number of forest owners. There is a particular impact on the price development of raw material from the demand for traditional forest industry products and wood paying capability. The employment impact of biogas investments is focused on agricultural areas. The pathway will strengthen regional economies and Finnish employment more than other options.

The **electrification pathway** requires significant investments in wind power, power grids, data centres, hydrogen production and synthetic fuel production plants. For example, wind power capacity would increase from the current 9.5 GW to 45 GW. At current costs, this means over €40 billion in investments, some of which will be directed towards constructing offshore wind and related infrastructure. Furthermore, the electrification pathway requires extensive use of various energy storage technologies and electricity demand response. Investments rely heavily on international capital, global technology markets and supply chains, which increases economic dependence on external factors while having the opportunity to create significant new industrial value. Due to the high level of investment, the total costs and financing needs of the pathway are significantly higher than others. Realising this trend requires that price estimates for both electricity producers and users of future electricity enable profitable operations. Strong growth of the electricity market requires that the demand response to electricity prices is able to prevent periods of unprofitable low prices from the perspective of wind and solar power. In addition, physical and virtual power purchase agreements (PPA) and possibly government-funded contracts for difference (CFD) will be necessary to support investment risk mitigation.

Particularly in the electrification pathway, investments are so significant that funding would largely be sourced from outside Finland. In this context, it should be noted that foreign data centre operators may charge a lower price for services provided at Finnish data centres, resulting in limited value added generated within Finland. However, wind power and hydrogen economy plants increase Finland's gross domestic product, but the transfer of capital income to foreign owners means that Finland's gross national income will see a notably lower impact. The use of forest biomass as a source of regulating power requires investments in maintaining and developing the electrical capacity of CHP plants, and in terminal operations to achieve the necessary, short response times in regulating power production. The more the ownership and financing is Finnish, the easier it is to keep the economic benefits of value creation in Finland.

4.2 Regional justice and agency

The energy transition is both a national strategic project and a local social change process that everyone will be able to see in their daily lives and landscapes through changes in land use. While climate and energy targets are set at national and EU levels, their implementation is decided in regions - regional councils, municipalities and local communities. Therefore, changing the energy system does not target or proceed in each region evenly, as its benefits, costs, investments and land use impacts are allocated in different ways to different areas.

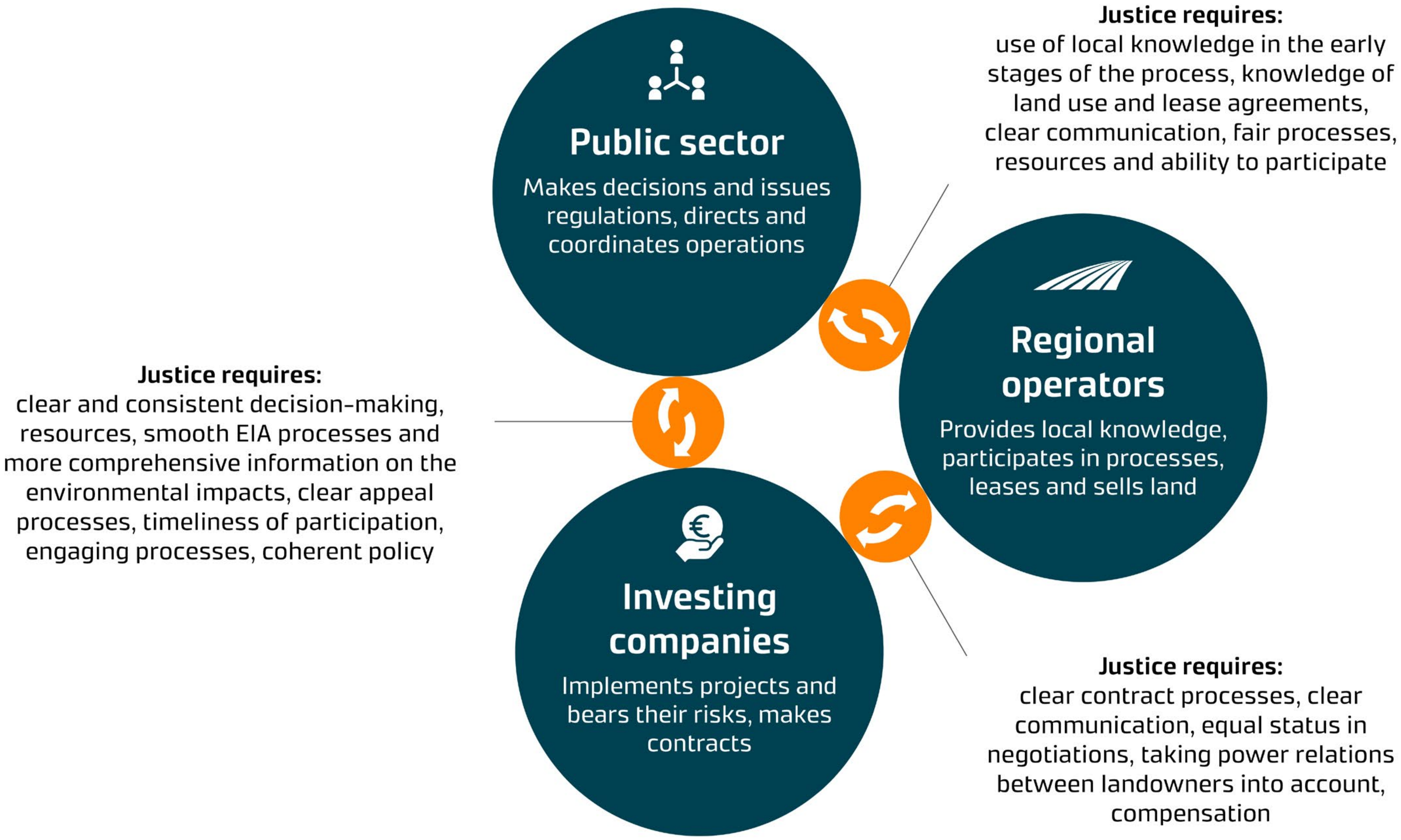
In concrete terms, regional agency means the opportunities that municipalities, regional authorities, companies, landowners and residents have to influence the direction and implementation of the energy transition, as well as how effective these opportunities are perceived to be and how they are used (Bridge et al., 2013; Höysniemi et al., 2026; Runko & Mustalahti, 2026). Justice means the way the costs and benefits of the energy transition are divided and whether decision-making is perceived to be transparent, inclusive and equitable (Lyytimäki et al., 2023). These are issues that municipalities and regional councils resolve through land use planning, permit processes and local negotiations.

The energy transition will restructure the area-related power relations of society. There are several levels of government that simultaneously guide and enable the transition: at the national level through energy and climate policy and industrial strategies, at the regional level through strategies and development tools, and locally through municipal land use planning, zoning and permit processes. By nature, the transition of the energy system is a question of multi-level management, where decisions and interests at different levels shape concrete implementation of the energy system (Bridge et al., 2013).

At the same time, the spatial structure of the energy system is connected to broader inter-regional relationships and dependencies. Renewable energy production, such as wind and solar power, is often sited in different areas than where the energy is consumed, which are typically large urban centres and industrial hubs. The energy transition is thus inevitably also linked to the urban-rural relationship and its ties and tensions (Weckroth & Ala-Mantila, 2022). Furthermore, the question of the centralised or decentralised nature of the energy system is explicitly spatial: a decentralised energy system that is based on renewable energy can support and build a more balanced regional structure and create new opportunities for local agency through energy communities, prosumerism and new production chains among others (Markard et al., 2012).

While climate and energy targets are set at national and EU levels, their implementation is decided in regions - regional councils, municipalities and local communities.

Regional justice requires genuine cooperation and agency



An energy transition that is perceived as fair at the local level requires collaboration and empowerment. The image features highlights from interviews with regional actors on process, management, and acceptability factors that impact regional justice.

In practice, however, investments in the energy transition are often unevenly distributed to the regions. In Finland, green transition investments have in many places focused especially on southern and western Finland. In terms of the energy system, institutional constraints also reinforce regional differences, which include security policy restrictions on wind power siting in eastern Finland. Therefore, the need for coherent policy as well as management and planning at multiple levels of government comes to the fore in steering the energy transition: local land use planning, regional development and national energy and climate objectives must all be aligned. At the same time, a fair transition stresses that the energy transition — a major societal transformation — should at least not increase inequality between regions or exacerbate tensions between the state and regional and local levels (Weckroth et al., 2025).

From these starting points, this area of change examines regional and multi-level agency as well as the dimensions of social and regional justice in the energy transition. When discussing regional agency, it is worth remaining aware of the regional characteristics and contexts of Finland's different regions in relation to business and the environment, among others. Attention focuses on how the costs and benefits are distributed at different regional levels and between regions, how decision-making processes are perceived, and what opportunities different actors have to influence the direction of the energy transition.

Vision of the area of change

An energy transition achieved by 2055 has promoted and strengthened the experience of regional and social justice for different actors. Power grids, transmission lines and other energy infrastructure provide equal development opportunities for different regions. Regional targeting of advantages and disadvantages has reduced interregional and urban-rural tensions and has enabled the strengthening of regional self-sufficiency. Local communities and regional actors have become active participants in the energy transition, rather than remaining passive recipients of development projects and their impacts.

4.2.1. The role of regional agency

Regional agency refers to the resources, powers and influence that different regions and groups of actors have in directing and implementing the energy transition (Bridge et al. 2013). In Finland, municipalities and regional councils are the key actors in land use planning, zoning and permit processes. They allow for the siting of renewable energy production as well as transmission connections and other infrastructure. In addition, regional development companies often play an important role in identifying and connecting the needs between different actors. However, there are differences in administrative capacity, starting points and resources between regions and municipalities, which has an impact on how actively they can improve their vitality (Paananen & Airaksinen, 2014). This also affects the possibilities to use energy projects as part of regional development of vitality.

Regional agency also links to local economic structure and energy infrastructure, which determine the opportunities for the regions to participate in the energy transition and to take advantage of the economic and social impacts arising from it. The role and differences of each region's local operator networks can have a significant impact on the region's ability to take advantage of green transition opportunities (Roessler, 2026). The regional operator network also defines both the vision of the transition and the conditions to benefit from the transition. In regions with strong industrial activity or existing energy production, the energy transition may appear as an industrial investment opportunity. Elsewhere, it may be seen as a question of land use or from the perspective of local livelihoods, such as tourism or agriculture and forestry. Therefore, regional agency does not only mean decision-making power, but also the ability to identify, form and leverage strategic partnerships, attract investment and reconcile local and national goals.

The material on energy transition management collected during the roadmap highlights the risks of public resources scarcity. The workload of land use and control authorities will increase as the energy transition progresses, highlighting the importance of strengthening administrative capacity, proactive planning and co-developing impact information. Experiences of acceptability and justice are largely generated in the relationships between actors (Figure 6). These experiences can also have a local impact on project progress and the kinds of projects municipalities want for their regions.

At the moment, the energy transition has divided Finland, with most of the wind power investments having been concentrated in Western Finland, and Eastern Finland being left by the wayside. The foremost reasons for this are the focus of the transmission grid on Western Finland and restrictions of the Defence Forces' radar surveillance in Eastern Finland. On the other hand, Northern Finland is under the greatest pressure and expectations for renewable energy production due to the large available land area and development of the transmission network. Compared to wind power, solar power will be more evenly sited geographically across Finland, but the emphasis will be on southern Finland. The current and short-term overview of the development of energy and grid infrastructure does not seem to introduce significant advances for wind power investments in Eastern Finland, unless the restrictions related to radar surveillance can be solved. However, in the medium and long term, the land areas of Eastern Finland can have new potential for renewable energy production. The current state also has some impact on siting the hydrogen and carbon dioxide economy and other green transition projects. The availability of the transmission network, inexpensive renewable electricity and biogenic carbon dioxide are key to implementing new investments in industry. Therefore, from an investment perspective, the energy transition puts the regions in an unequal position.

The excessive geographical concentration of renewable energy production in Western or Northern Finland would also entail a risk of social and political conflict. If the costs and benefits of energy production are not felt to be evenly distributed, such as in a situation where the production region experiences bears the cost but the energy and its benefits are transferred to growth centres or outside Finland, there is both a risk of social injustice and an increase in support for political movements that oppose renewable energy and the green transition.

Wind power production is focused on Northern and Western Finland

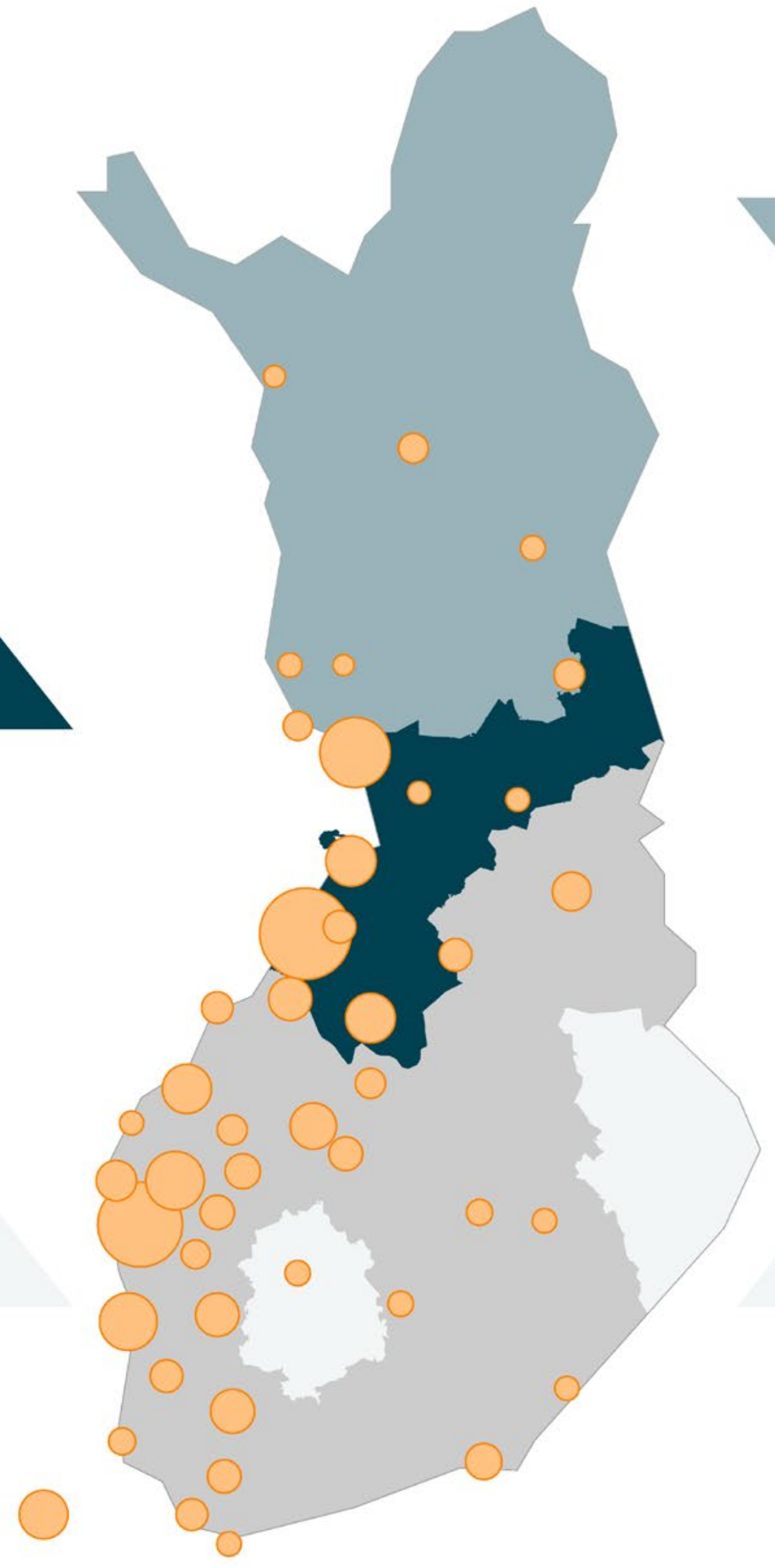
Siting of wind power plants in Finland and production capacity in four regions

Northern Ostrobothnia

Wind power generation 2024: 6,936 GWh

Pirkanmaa

Wind power generation 2024: 82 GWh



Lapland

Wind power generation 2024: 2,093 GWh

North Karelia

Wind power generation 2024: 0 GWh

Wind power generation is concentrated in coastal areas and Western Finland.
The figure shows wind power production (GWh) in the case regions of the REPower project in 2024, as well as the regional siting of wind turbines as point data (Finnish Energy 2026; Renewables Finland 2026).

All of Finland

Wind power generation 2024: 20,237 GWh

1,000 2,000 3,000 4,000 5,000

: Siting of wind turbines

Regional agency develops in different ways under the future pathways.

In the **EU compliance pathway**, regional agency remains largely dependent on existing institutional structures. The energy transition´s progress is mainly based on implementation of EU-level obligations in national policies, which leaves limited opportunities for regions to play an active strategic role. The lack of coherent policy between different levels of government leads to disparate regional progress in the energy transition, which slows down the regeneration of regional agency and the ability to respond to the opportunities offered by the transformation. However, it remains possible that investments will be spread more evenly across Finland, if a resolution to key region-specific bottlenecks is found. Instead, the development of the green transition and electricity-intensive industries have a general impact on the development of electricity demand and adequacy, which may, in turn, have a knock-on effect on regional development, especially from the point of view of energy investment.

The **bioeconomy pathway**, would especially strengthen regional agency in areas that rely heavily on the forest bioeconomy. The energy transition is linked to existing natural resource and industrial structures, whereby regional actors — municipalities, companies and landowners — have an active stake in developing value chains and targeting investments. Strengthening regional agency also shows through deeper integration of regional perspectives and identities in national energy policy decisions. For example, the chemical industry and the manufacturing of biochar and renewable fuels create opportunities for the regions. They are partially clustered in places where the existing industrial structure supports new investments and development. Finland has seen progress in investments into the development of new bio-based materials, creating new development prospects for the forest industry in particular. The production of biogas and of bio and synthetic methane, and the needs of industry, support the vitality of rural areas where this production is located.

In the **electrification pathway**, regional agency expands and diversifies significantly because of the rapid change in the energy system. Strong growth in renewable energy production and demand requires strong policy coherence as well as multi-level and cross-sectoral governance. Regions are not only targets for the implementation of energy policy, but key strategic actors that implement the energy transition. There is an aim to steer the regional distribution of investments as evenly as possible, with consideration for regional strengths, local resources and identities, which strengthens the role of regions in reshaping the energy system. However, regional differentiation based on local strengths may take place due to the energy transition. Some regions may remain primarily production regions, but large-scale production of synthetic fuels could be a new opportunity for these areas.

The future pathways feature a range of options for the regions. What largely influences this development is the regions' own starting points and, in the big picture, the pace and scale of the energy transition. Large-scale investment can spark discussions around justice, acceptability, and environmental values, which are necessary to consider as part of investment siting and development work to ensure the system promotes comprehensive security and takes not only techno-economic factors but also environmental and social development aspects into account.

The excessive geographical concentration of renewable energy production in Western or Northern Finland would also entail a risk of social and political conflict.

4.2.2. Issues of regional justice

Justice is generally considered through four different dimensions: distribution, procedure, recognition, and restoration (Lyytimäki et al., 2023).

Distributive justice is concretely about the distribution of costs and benefits. In the context of renewable energy, it mainly focuses on the distribution of economic costs and benefits to use the produced energy, compared to the perceived disadvantages, such as landscape impact, concerns about property value, or negative perceptions about changes in land use. In addition to distributive justice, the most significant injustice towards landowners arises when it comes to procedural justice. Landowners have relatively little bargaining power over project developers, unless they own significant land in the project area. What also impacts acceptability are perceptions of the transparency of projects and the energy transition. For example, inadequate or confusing planning and construction regulations may have a negative impact on the landowners' perceived legal protection and the justice of projects.

If the construction of wind power projects is concentrated in Northern Finland, the importance of recognition and restorative justice of renewable energy projects will also increase due to the cultural-historical characteristics of the region and the related livelihoods. Recognition justice involves acknowledging values, perspectives, cultures, and needs, allowing the consideration of both Sámi communities and livelihoods typical of Northern Finland, such as reindeer herding. Through compensatory justice, energy production projects take into consideration and aim to compensate for injustice that has already occurred. To enable a fair energy transition, it is crucial to draw on experiences, especially in Northern Finland, from decisions related to hydropower that have caused feelings of injustice, and to strive for more just procedural and distributive operating models in new projects.

To promote distributive justice, it is necessary to create regional benefit models that systematically expose the impact of energy projects on tax revenue, employment, and regional vitality and steer towards a more even distribution of benefits between production and consumption-oriented areas. Benefit models are linked to zoning and proactive planning, and take not only local residents and landowners into account, but also the areas affected by infrastructure, such as transmission lines.

All pathways emphasise the need to reinforce processes that ensure the realisation of different dimensions of justice.

The **EU compliance** and the **bioeconomy pathway** will improve social justice and acceptability by consolidating existing practices and processes that encourage participatory planning, based on the justice of distribution and procedure. They would establish contractual frameworks based on national norms and standards for wind and solar power projects to mitigate the most blatant process injustice. To improve transparency and open communications in projects, the developers must also inform landowners outside the project area in a timely manner about possible transmission line options.

In the **electrification pathway**, the significant increase in renewable energy production and demand highlights the importance of land use planning, permit processes and local negotiations, as well as developing and improving of all dimensions of justice. This requires significant additional resources at all administrative levels, as well as a review of the impacts at system level, to take the interlinked effects of wind and solar power, bioenergy and the related energy and electricity grid infrastructure into account. In addition, the major change in land use also highlights the need to take advantage of local financial and operational compensation and benefit mechanisms.

In the electrification pathway, improved opportunities to organise will strengthen the negotiation position of landowners in potential wind and solar power areas. Were landowners to organise, it would allow for earlier and more meaningful participation in project preparation and better consideration of the livelihoods, values and needs of nearby communities. This also creates a foundation for comparing project developers in terms of compliance with procedural justice and is thus an opportunity to tender projects on the terms of landowners and local communities.

In addition, harmonised contract terms reduce inequality between landowners and reduce the risk of social conflicts at the local level.

4.3 Geopolitics and security

Global great power struggles and geopolitical developments will inevitably reflect on the energy transition and its framework conditions. Geographical features have a significant impact on Finland's geopolitical position and the energy transition´s progress. On the one hand, Finland belongs to the Nordic region, which is geostrategically unified, especially from the point of view of energy, security and infrastructure connections, while on the other hand, Finland is logistically dependent on the stability of the Baltic Sea. Finland's membership in NATO brings new needs to defence planning for logistical solutions that are closely linked to energy issues (Mikkola, 2026).

The energy transition highlights differences between countries in terms of technological capability and political will to use natural resources and critical raw materials, which are needed not only in energy but also in the defence industry. The geopolitics of renewable energy will change geopolitical positions between countries, resulting in new flows and trade relations in critical raw materials, green hydrogen or expertise in clean technologies, among others. Renewable energy value chains create new dependencies, which will be paramount to identify (Höysniemi, 2025). This is reflected in shifts in the nature, routes and volume of trade and investment, as well as in potential geopolitical objectives to control new territories and resources. The energy transition to low-carbon, electrified societies will change relations between states and their geopolitical struggles. However, a low-carbon world is not necessarily less prone to conflict.

In the energy transition, Finland and the EU's relations with Russia and great powers such as the United States, China, and India will change. To achieve strategic autonomy, relations must be weighed realistically from the perspective of EU energy policy. A return to Russian fossil energy imports would weaken strategic autonomy. The replacement should primarily be an increase in renewable energy production, energy efficiency and reducing energy consumption, not by importing fossil energy from other places. China's dominant value chains in renewable energy and critical minerals allow the country to control dependencies and extend its impact beyond energy policy. The development of the US value base has now set it apart from Europe, with no return to the former transatlantic relationship. China-dominated value chains and the development of US policy highlight the need for a determined European industrial policy and a balance between strategic autonomy and interdependencies.

It is clear that to maintain defence capability, fossil fuels will be needed for decades, but development into non-fossil military solution capabilities is needed. Finland has built its military deterrent on its strong defence capability and NATO membership. Finland has been estimated to be one of the winners of the energy transition from a geopolitical perspective, due to its high share of renewable energy and strong technological expertise. However, recent Finnish energy policy foresight has taken less account of the geopolitical background factors. Therefore, addressing this lack of coherent policy is one of the key challenges (Höysniemi, 2025; Mikkola, 2026). However, it is worth it for Finland to promote the renewable energy system, while maintaining a strong willingness to defend the country. The energy transition must not compromise independent defence capability.

Vision of the area of change

Finland works actively through the European Union on renewable energy geopolitics. The energy transition strengthens Finland's strategic autonomy in cooperation with a geostrategically unified Nordic region. The energy transition must not undermine security policy solutions. There is continuous dialogue between foreign, security and defence policy, energy policy, and other strategic sectors that affect Finland's geopolitical position. Finland's position is strengthened by taking advantage of the opportunities of the energy transition, such as the export of hydrogen products.

The **EU compliance pathway** aims to strengthen Finland's geopolitical position primarily by reducing the use of imported fuels and boosting renewable energy production in Finland. However, without a significant expansion of the energy system, the means to promote strategic autonomy may remain limited. The Nordic countries continue to be Finland's key reference group in energy geopolitics, supported by their common geostrategic position. In the compliance pathway, challenges to foreign and security policy objectives may arise from the fact that the market cannot produce the most sustainable solutions from the point of view of geopolitics and comprehensive security.

The **bioeconomy pathway** aims to strengthen Finland's geopolitical position by using the national resource base, which at the same time strengthens security of supply and the energy system's resilience. The pathway will not significantly change Finland's position in the European energy market, keeping Finland closely linked to Nordic geostrategic unity.

Like the electrification pathway, the bioeconomy pathway is an opportunity to export renewable fuels, which may strengthen Finland's geopolitical position. However, this pathway emphasises a more balanced approach than the electrification pathway between biomass-based solutions, which are based on national innovations, and technologies that focus on exports and imports.

In the **electrification pathway**, Finland's geopolitical position is founded on networks that deepen the connection to the European energy market. It emphasises risk management in supply chains, as components and raw materials of the energy infrastructure are highly dependent on imports. Strengthening our geopolitical position requires a stable European and Baltic operating environment.

The growth of offshore wind power, brought about by the electrification pathway, extends the control needs of the energy infrastructure to the sea, which is also reflected in defence arrangements. The potential of this pathway for the export of Bio-CO_2-based fuels may strengthen Finland's geopolitical position. However, this requires a prudent attitude towards planned hydrogen pipelines towards the Baltics and Central Europe to not position Finland solely as a producer of raw hydrogen.

The rapid electrification of society, especially in this pathway, poses challenges to the current security of supply model.

Finland has been estimated to be one of the winners of the energy transition from a geopolitical perspective, due to its high share of renewable energy and strong technological expertise.

5. Strategic choices and measures

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The energy transition is not driven solely by technological development and market forces, as it also requires strategic choices from public governance through energy and climate policy, regulation, and investment and infrastructure solutions. Finland can achieve its climate and energy targets through different future pathways that differ in terms of energy system structure, natural resource use, regional justice, investment scale, and international interconnections. However, this requires consistent and long-term decision-making.

Studying the areas of change shows that the energy transition has wide-ranging effects on land use, regional development, social acceptability and Finland's geopolitical position. The roadmap has identified the key strategic choices that are needed to realise the future pathways and the goals related to the areas of change. The choices are divided into the short (2026–2029), medium (2030–2039) and long term (2040–2055), and are reviewed through goals based on the visions for the areas of change.

The key goals of **Sustainable land use and resources** are:

- Extensive assessment of the land use impacts of wind and solar power at the provincial and regional level. The assessment takes the combined project impacts on nature into account, which are minimised in accordance with the mitigation hierarchy.

- Sustainable and resource-smart use of biomass resources. The role of wood-based bioenergy focuses on security of supply, flexibility and utilisation of side streams to also keep their use sustainable in the long term.

The key goals of **Regional justice and agency** are:

- A regionally sustainable energy transition is based on justice and equal opportunity. It takes the different starting points of the regions and the diversity of actors into account.

- Comprehensive consideration is given to social acceptability by examining both production methods and the related infrastructure. At the project level, participatory processes and open communications, where impacts are assessed before, during and after the implementation, are what support this.

The key goal of **Geopolitics and securit**y is:

- Examination of the development of renewable energy as a geopolitical measure, with a key focus on managing the dependencies in relation to self-sufficiency and security of supply. Finland's energy and climate policy and foreign, security and defence policy objectives must support each other.

5.1 Short-term strategic choices and measures (2026—2029)

In the short term, strategic choices are primarily about creating the conditions for the ongoing energy transition. In each future pathway, preparatory measures are launched along the same lines: developing siting principles, implementing the mitigation hierarchy, developing participatory processes and strengthening intersectoral foresight. Where they differ significantly are in the scope and focus.

For **land use and resources**, all pathways would implement nationwide siting principles for wind and solar, harmonise zoning, permit processes, and grid connections as well as apply the mitigation hierarchy. The priorities of the measures differ: In the EU compliance pathway, siting is primarily directed to already weakened areas within the framework for controlled growth of onshore wind. In the bioeconomy pathway, the same principles are extended to cover the growth of wind and solar power required by the pathway (72 TWh of wind power by 2055), with a concurrent focus on promoting the cascading use of biomass, improving the harvesting of logging residues and small-dimensioned wood, and starting recovery pilots of biogas, biochar and CO_2. The electrification pathway features the broadest scale of land use planning: the initiation of transmission grid reinforcements, offshore wind siting control, principles of port and maintenance logistics, as well as space reservations for hydrogen, warehouses and data centres. As the annual use of bioenergy decreases rapidly in the electrification pathway, securing supply chains and terminal capacity for security of supply situations must begin early.

In terms of **regional justice and agency**, all pathways will develop models for early participation and lay the foundations for a fair distribution of costs, benefits, and financial compensation. At the same time, the aim is to close the gap between regions in the siting of renewable energy production to prevent the permanent accumulation of investments and their benefits only in certain regions.

In the EU compliance pathway, the focus is on reducing the perception of a merely formal consultation and narrowing regional disparities related to the accessibility and capacity of electricity transmission networks. In the bioeconomy pathway, justice is linked to the construction of regional bioeconomy and circular economy clusters: it would strengthen the roles of municipalities, forest owners, farms and industry to keep benefits in the regions. In the electrification pathway, the scale of investments (increase of wind power capacity to 134 TWh) alone requires substantially more extensive involvement and resourcing of permit administration in the short term than the other pathways. Each pathway makes research-based information on the impacts of the energy transition transparently available as part of project and region-level communications.

Regarding **geopolitics and security**, each pathway explores ways to coordinate energy, climate and security policies, strengthen security of supply and cybersecurity, and launches Nordic planning to coordinate electricity grids and storage solutions. This stage is where the differences between the pathways start becoming apparent: In the EU compliance pathway, the emphasis is on breaking away from fossil dependencies, the bioeconomy pathway would secure the Finnish resource base and increase energy self-sufficiency, and the electrification pathway would focus on the security review of international supply chains and data centres.

The pathway-specific short-term strategic choices are broken down by area of change in Table 1 of Appendix 2.

5.2 Medium-term strategic choices and measures (2030—2039)

In the medium term, we will move from establishing the framework to implementation and scaling: consolidating the control frameworks, participation practices and foresight structures created in the short term stage, which lays down the structural choices of the energy system. Strategic choices have a particular link to the allocation of biomass resources, the scale of renewable energy production and regional distribution of the economic impacts of the energy transition.

For **land use and resources**, the differences between pathways grow significantly wider. The EU compliance pathway would establish regional steering of wind and solar power as part of land use, energy and forest policy. The use of biomass focuses on flexibility and peak consumption as alternative forms of renewable energy production become more common. At the same time, promoting the procurement and use of logging residues and small-dimensioned wood helps reduce pressure on the energy use of industrial timber. In the bioeconomy pathway, market values increasingly direct biomass to products with higher added value. The commercialisation of biochar, biogas, lignin-based materials and advanced biofuels is progressing, and CO_2 capture, utilisation of side streams and renewable hydrogen solutions are being developed to improve the carbon efficiency of biomass. The electrification pathway would transition to the implementation phase of offshore wind power, large solar parks, data centres and hydrogen production areas, and build the core network, long-term storage and flexibility to support the strong growth in electricity consumption. In each pathway, application of the mitigation hierarchy continues and expands as part of EIA practices.

Regarding **regional justice and agency**, the 2030s are a critical stage, where practices established in the short term become a part of normal project implementation. The EU compliance pathway would establish fair transition practices — local benefit mechanisms, financial compensation and impact monitoring — and extend early participation practices to EIA and town and country planning. In the bioeconomy pathway, regional bioeconomy and circular economy clusters scale up into industrial ecosystems, which ensures the employment, contractual and tax benefits of biorefining investments in the regions. In the electrification pathway, the significant scale of investment requires improving landowners' organisational opportunities, additional resources for permit administration, and expanding cost-benefit models to also cover the regional impacts of data centres and synthetic fuel production. All pathways establish regional cost-benefit models as a systematic assessment tool.

In terms of **geopolitics and security**, the 2030s will highlight the significant role of the European hydrogen backbone and Finland's position in green hydrogen production and its applications. From the point of view of Finland's geopolitical position, it would be more advantageous to use domestically produced electrolytic hydrogen in processed products and aim to export them through our own ports. In the EU compliance pathway, energy policy is permanently linked to the framework of strategic autonomy and supply chains are decentralised. The bioeconomy pathway seeks a balance between Finnish innovation and EU integration: expansion of biomass-based product exports without weakening Finnish security of supply. The electrification pathway would see deeper integration between the EU, the Nordic countries and the Baltic states, while managing technology dependencies, security risks of data centres and availability of critical components. Geostrategic coherence with the Nordic and Baltic countries is a strategic priority in all pathways.

The pathway-specific medium-term strategic choices are broken down by area of change in Table 2 of Appendix 2.

5.3 Long-term strategic choices (2040—2055)

In the long term, the energy transition is not linear, as the energy system develops through continuous reforms and technological breakthroughs. During 2040—2055, there will be a systematic assessment of the short-term solutions, along with updates based on new information, market signals and global changes. Therefore, long-term strategic choices are particularly related to the final scale of the energy system, technical carbon sinks, investments to overhaul bioenergy plants, and Finland's international position.

For **land use and resources**, the 2040s will bring two structural turning points. Firstly, many biomass fuel plants built during the bioenergy boom will begin to approach the end of their service life, and the importance of using biogenic carbon dioxide comes to the fore when deciding on whether to overhaul or decommission the plants. Secondly, offshore wind power becomes a significant form of energy, which transfers land-use pressures to marine areas. In the future pathways, BECCS is integrated into the climate and energy system. Bioenergy will instead focus on market-based flexibility, peak consumption and technical carbon sinks. In the bioeconomy pathway, biorefineries form its core: the carbon efficiency of biomass fuels has increased, and sectors that are difficult to electrify rely on Finnish side streams. In the electrification pathway, there is coordination between offshore and onshore wind farms, solar parks, hydrogen production areas and data centres, and large-scale needs will inform the construction of the trunk network and long-term storage facilities; overhaul investment decisions for bioenergy plants are made based on a security of supply assessment. In all pathways, the mitigation hierarchy has been established as a permanent part of project life-cycle management.

For **regional justice and agency**, the long-term goal is to distribute the costs and benefits of the energy transition regionally in a controlled manner and to fully establish participation practices, benefit models and financial compensation regardless of the region. In the EU compliance pathway, labour has been divided among the regions and there is a regional balance of production, consumption and storage. In the bioeconomy pathway, regional bioeconomy and circular economy clusters are established industrial ecosystems whose benefits remain in the regions and where farms, forest owners, waste management and industry operate in the same value chains. In the electrification pathway, energy justice processes are a permanent part of investments, and the organisation of landowners, the resourcing of permit administration and the harmonisation of contract terms are established practices. Across all pathways, evidence-based energy communication is a permanent part of energy policy measures.

In terms of **geopolitics and security**, Finland's position may change from an energy importer to an energy exporter in the long term, which highlights the importance of energy policy as a component of foreign and security policy. In the EU compliance pathway, strategic autonomy has strengthened as imported fuels have decreased, and integration with the EU, Nordic countries, and Baltic States is coherent and cross-sectoral. In the bioeconomy pathway, Finland's profile in the EU is that of a bio-society, whose energy independence and strategic autonomy rely on a domestic resource base. In the electrification pathway, Finland is a clean energy export economy that processes hydrogen and electricity into products of higher added value and exports e-fuels, hydrogen products and products of energy-intensive value chains to Europe. In all pathways, the Nordic energy system cooperation is well established to cover transmission networks, storage, resilience and protection of critical infrastructure.

The pathway-specific long-term strategic choices are broken down by area of change in Table 3 of Appendix 2.

6. Recommendations for decision-makers

6. Recommendations for decision-makers

This chapter is a summary of the key measure recommendations of the previous chapter, which can support Finland's transition towards an energy system based on renewable energy by 2055. The recommendations are based on the report's analysis of pathways and three areas of change. They put together the measures necessary for all the considered developments.

Coordination of land use, ensuring the energy system's flexibility and security of supply, strengthening regional justice and proactive management of dependencies in a changing geopolitical environment are particularly foci for steering the energy transition. The recommended measures are structured according to these three strategic change areas. Each recommendation will include its primary time span and the essential responsible parties.

1 Develop national principles for the siting of wind and solar power and link them with proactive grid and permit planning

Governance and management of renewable energy projects require coordination between land use, permit processes, development of the power grid and timing of investments. In practice, the phases related to project permits, evaluations and official reviews proceed as a coordinated and predictable system, without the need to deal with separate parallel processes.

Principles and proactive planning accelerate project progress, reduce uncertainty, and create predictable and controlled expansion of the energy system. In addition to production, the siting principles consider related infrastructure, such as transmission networks, storage and flexibility solutions, and security of supply and resilience to disturbances in the system, as well as preparedness for periods of peak demand and low production. This creates a level playing field for investments across the country.

Responsibility for coordination: Ministry of Economic Affairs and Employment, with the Ministry of the Environment and the Ministry of Agriculture and Forestry.
Project parties: regional councils, municipalities, Fingrid and energy companies.
Time span: launch in the short term (2026—2029),
become established in the medium term (2030—2039).

2 Strengthen proactive assessment of the cumulative impacts of renewable energy projects and consistently apply the mitigation hierarchy

It will be necessary to carry out more systematic and extensive impact assessment in planning renewable energy projects. This is vital to identify project impacts on nature, other land use, local communities and the economy in a timely manner and to consistently manage them.

In practice, impacts are examined both at project level and at regional and national level, taking synergies into account. The assessment is based on regional and national baseline studies, which are supplemented with project-specific studies, reducing redundant work and improving comparability of the assessments. The mitigation hierarchy - avoidance, mitigation and, ultimately, compensation - is applied consistently across the project life cycle. The assessment also takes the effects on functionality and flexibility of the energy system into account, such as the availability, storage and adjustable capacity of bioenergy.

Responsibility for coordination: Ministry of the Environment.
Project parties: environmental and permit authorities, counties, municipalities, research institutes, project developers.
Time span: launch in the short term (2026—2029), application in the medium term (2030—2039) and long term (2040—2055).

3 Develop a strategic allocation programme for biomass resources covering both material and energy use

The role of bioenergy will change with the progress in electrification, but it will retain its importance as a factor in system flexibility, security of supply and an energy source for hard-to-electrify sectors. This requires a more systematic and strategic allocation of biomass resources to maximise their overall value and impact.

The programme supports the use of biomass on market terms in accordance with the cascade principle; that is, to primarily direct biomass to applications with higher added value and only to energy use when there are no alternative uses or they are economically less profitable. At the same time, it secures the functioning of energy wood supply chains in a changing demand environment, strengthens the utilisation of waste and side streams, and ensures terminal and storage capacity to maintain the role of bioenergy in the security of supply. It also strengthens long-term foresight and predictability of the investment environment, which supports the development of biomass value chains in different regions and resilience of the energy system.

Responsibility for coordination: the Ministry of Agriculture and Forestry with the Ministry of Employment and the Economy.
Project parties: Natural Resources Institute Finland, forest industry, energy companies, regional forest centres, economic development centres.
Time span: launch in the short term (2026—2029), update in the medium term (2030—2039).

4 Require all renewable energy projects to ensure meaningful regional participation at an early stage.

Renewable energy projects require binding participation in the earliest stages of preparation to improve project acceptability and ensure a fair perception of the distribution of costs and benefits. Zoning and permit processes must become better at considering the distribution of costs and benefits, opportunities for participation, and the principles of recognition and restorative justice.

In practice, project preparation must be genuinely participatory and begin before key solutions are finalised. Project impacts will be made transparent and negotiated with local actors as part of planning and permit processes. The different starting points of landowners and other local stakeholders are considered in contract models, compensation, and economic measures.

Particularly in areas with significant pressure for renewable energy production, such as Northern Finland, the participation model must integrate the perspectives of Sámi communities, reindeer herding, and other local livelihoods into project planning and decision-making. This bolsters legitimacy of the projects and reduces the risk of social conflicts.

Responsibility for coordination: Ministry of the Environment.
Project parties: municipalities, regional councils, project developers, state permit authorities.
Time span: launch in the short term (2026—2029), become established in all projects the medium term (2030—2039).

5 Develop and implement a model to better assess the regional economic impacts of renewable energy projects

The economic impacts of renewable energy projects should be made more visible and comparable, and they should be systematically used in decision-making. This is important to identify and consider the benefits of the projects for the regions and link them to zoning, proactive planning and regional development.

In practice, this means developing regional benefit models that describe the impact of renewable energy projects on tax revenue, employment and regional vitality, and supporting a more even distribution of benefits. The models are linked to zoning and proactive planning, and take not only local actors, such as residents and landowners, into account, but also the areas affected by infrastructure, such as transmission lines and the power grid.

The goal of the benefit models is to strengthen local and regional value chains and ensure that renewable energy investments support long-term regional development and a fair transition. In particular, new value chains linked to the bioeconomy and the circular economy, carbon capture and utilisation, and renewable energy can create permanent jobs and vitality even in sparsely populated areas.

Responsibility for coordination: Ministry of Employment and the Economy.
Project parties: municipalities, regional councils, regional development actors, energy companies.
Time span: develop in the short term (2026—2029), national scale-up in the medium term (2030—2039).

6 Strengthen research-based communication on energy

A successful energy transition requires researched knowledge and effective communication for citizens to have the opportunity to understand its effects and participate in a debate that is based on reliable information.

Research institutes and authorities produce transparent situation information on the progress, costs and impacts of the energy transition and make available. Particular attention is paid to producing regional information to connect the discussion to local experiences. This creates understanding, trust, and opportunities for participation.

Responsibility for coordination: the Prime Minister's Office and the Ministry of Employment and the Economy.
Project parties: research institutes (e.g. Luke, VTT, Syke), Motiva, regional councils, communications authorities.
Time span: launch in the short term (2026—2029), maintained continuously.

7 Strengthen cross-sectoral foresight on energy, climate, foreign, and security policies

Examine the geopolitical and security policy impacts of the energy transition as a whole by strengthening intersectoral foresight and coordination. This ensures that energy policy choices support security of supply, comprehensive security and strategic autonomy in a changing operating environment.

In practice, dependency management, critical raw materials, supply chains, cybersecurity, and climate risks are systematically incorporated into the situational awareness of decision-makers, using either existing structures or enhanced cooperation.
At the same time, assessment of these effects should strengthen expertise at the regional and municipal level. This improves the situational awareness of decision-makers and their capability to prepare for uncertainties.

Responsibility for coordination: the Prime Minister's Office.
Project parties: Ministry of Economic Affairs and Employment, Ministry of Foreign Affairs, other key ministries, defence administration, regional councils, research institutes.
Time span: launch immediately in the short term (2026—2029), maintained continuously.

8 Deepen Nordic cooperation to strengthen electricity networks, storage, and energy system resilience

Nordic cooperation strengthens the flexibility, security of supply and cost-effectiveness of the energy system. Finland and the other Nordic countries must establish a pragmatic common approach for eliminating bottlenecks in power grids, storage solutions, the role of decentralized production and strengthening energy system resilience.

Through cooperation, we must coordinate the regional siting of production, consumption and industrial investments to ensure sufficient energy supply, mitigate price fluctuations, and strengthen security of supply throughout the Nordic region. The work will primarily use existing Nordic cooperation structures without creating a new administrative level, while deepening regional integration.

Responsibility for coordination: Ministry of Employment and the Economy.
Project parties: Energy authorities of Finland and other Nordic countries, transmission grid operators, security of supply operators, EU cooperation.
Time span: launch in the short term (2026—2029), deepen in the medium term (2030—2039) and long term (2040—2055).

Appendix 1. Further measures to achieve carbon neutrality by 2035

Future pathways have been developed to achieve carbon neutrality by 2050. However, Finland's Climate Act sets a target for 2035, which is exceeded by about 40 million tonnes in all future pathways (Mt CO_2-eq). The measures are divided into increasing reductions in fossil emissions, accelerating technical carbon sinks, and strengthening forest carbon sinks.

Measures in the energy sector

Additional measures in the energy sector would result in a total reduction of approximately 4.5 Mt CO_2-eq in emissions: Early replacement of SSAB's electric arc furnaces in Raahe, tightening the obligations on CCS and distributing biofuels for traffic in Kilpilahti.

SSAB Raahe has two coal-fired blast furnaces, the replacement of which is scheduled for 2035—2040 in the future pathways. Accelerating the second investment to 2035 will result in an additional reduction of nearly 2 Mt CO_2-eq. According to SSAB's April 2024 press release, the investment in Raahe will only proceed after sufficient experience is gained from their project in Luleå, Sweden. The full capacity of Luleå will be ready in 2029, making the 2035 target tight but possible.

Emissions from the Kilpilahti refinery and the Borealis petrochemical plant can be reduced by capturing CO_2 emissions from the industrial area by 2035 (90% CCS); an additional reduction of 1.3 Mt CO_2-eq.

The obligation to distribute biofuels for transport will rise to 30% by 2030 in the future pathways and will remain at that level. A 50% increase would result in an estimated additional reduction of 1.3 Mt CO_2-eq.

BECCS: accelerating technical carbon sinks

The future pathways show that BECCS capacity will be 1.8 Mt CO_2-eq in 2035 and will increase to approximately 13 Mt CO_2-eq by 2050. Accelerating the investments by 15 years — that is, introducing the entire 2050 level by 2035 — would achieve an additional reduction of approximately 11 Mt CO_2-eq.

The biggest challenge is not capture technology, but value chain infrastructure and regulation. The typical implementation period of infrastructure projects is at least 6—7 years, which means additional measures would have to begin without delay. Investments require stable regulation and effective financial incentives.

Availability of geological storage capacity is a major source of uncertainty. According to Kujanpää et al. (2023), Finland's 13 Mt CO_2-eq BECCS target alone would exceed the estimated free storage capacity for all of Northern Europe in 2030. New storage projects in Denmark may increase capacity, but these remain uncertain. Therefore, the implementation of additional measures depends crucially on international negotiations: Finland should actively develop the CO_2 storage market and regulation (e.g. liability issues, supranational CO_2 accounting).

Large-scale storage of biogenic CO_2 also reduces the possibilities to process captured CO_2 into, for example, e-fuels.

Additional measure	Mt CO_2-ekv.
Baseline (net emissions 2035)	40
1. SSAB - Raahe	–1.9
2. Kilpilahti CCS (90%)	–1.3
3. Distribution obligation 30→50%	–1.3
4. BECCS acceleration	–11.0
Additional measures, total	**–15.5**
Net emissions in 2035 after additional measures	**24.5**

Strengthening forest carbon sinks and impacts on the national economy

In practice, strengthening forest carbon sinks would reduce the amount of logging. The effect is stated as a factor of 1.8 t CO_2/m^3 (Koljonen et al. 2025, p. 114). Without further action, net emissions in 2035 (about 40 Mt CO_2-eq) would require a reduction in logging to a level of about 58 million m^3 which would be 28% less than in the baseline pathway and 22% less than the average for 2022—2024. The combined effect of energy and BECCS measures (15.5 Mt CO_2-eq), in turn, would allow carbon neutrality at the level of about 67 million m^3 of logging, which is 17% lower than in the baseline pathway and 9% lower than in previous years - a return to the logging volumes of about ten years ago.

Even a moderate carbon price encourages carbon sequestration in forests (e.g. Pohjola et al. 2018), which makes it a cost-effective tool. However, when implemented on a large scale, the decrease in logging would be a negative shock to national and regional economies: it would reduce the forest industry's production, investments and export income and cause knock-on effects in subcontracting chains, employment and the current account (Mönkkönen et al. 2026, Kniivilä et al. 2022). The impacts extend to the entire forest-based bioeconomy and energy system, and the reduction in domestic wood supply may be offset by increased logging abroad (logging leakage), which partially cancels out the global climate benefits.

A decrease in the level of logging also impacts the energy transition and industrial value chains: less biogenic carbon for producing less sustainable aviation and synthetic fuels, reduced availability of bioenergy and forest industry side streams, which limit the development of bio-based chemicals, materials and processed products (Arasto et al. 2024). Rapid carbon neutrality through forest sinks may thus weaken possibilities to replace fossil raw materials in the long run.

Investments

Carbon neutrality by 2035 will require significant investments in a short period of time. SSAB's arc furnaces in Raahe and the Kilpilahti CCS are discrete, company-led investment decisions. BECCS is on a different scale: it requires simultaneous investments in dozens of pulp mills, port terminals and ship transportation, as well as strong, predictable policy instruments with the support of international agreements.

In terms of the economy, the additional measures mean significant short-term costs but long-term strategic opportunities. The EU Carbon Boundary Mechanism (CBAM), which obliges coal-intensive imports into the EU to pay a carbon cost equivalent in the EU Emissions Trading System, improves the competitiveness of low-carbon steel, and early investment in CO_2 infrastructure can turn Finland into the Baltic Sea's BECCS hub. However, reducing logging levels would reduce the forest industry's production and export revenues in the short term.

2050 and carbon neutrality

With the MELA updates, Finland would no longer be carbon neutral in 2055 with the logging volumes of the KEITO-WAM scenario. According to our estimate, carbon neutrality in 2050 and 2055 would be achieved by logging volume of approximately 70 million m^3 which is somewhat lower than in recent years, but recovering from the 2035 level.

Calculation assumptions

Initial situation: Estimates show Finland's net greenhouse gas emissions in 2035 to be ca. 40 Mt CO_2-eq: ETS and burden-sharing sector 20.4 Mt CO_2-eq; net emissions of the LULUCF sector approx. 21 Mt CO_2-eq, and BECCS baseline –1.8 Mt CO_2-eq.

SSAB Raahe: Replacement of the second blast furnace with an arc furnace is assumed in the future pathways for 2035—2040. The additional action brings both investments forward to 2035; an additional reduction of 1.9 Mt CO_2-eq (half of the mill's total emissions 3.8 Mt CO_2-eq in 2022).

Kilpilahti CCS: 90% capture from the combined emissions of the Neste refinery and Borealis petrochemical plants (approx. 1.4 Mt CO_2-eq in 2035); an additional reduction of 1.3 Mt CO_2-eq.

Distribution obligation: In the future pathways, the obligation will rise to 30% in 2030 and remain at that level. The increase to 50% is aimed at the already reduced fuel base (approx. 45% electrification rate of passenger cars in 2035). Additional reduction of 1.3 Mt CO_2-eq.

BECCS acceleration: The future pathways show that the BECCS capacity will be 1.8 Mt CO_2-eq in 2035 and will increase to approximately 13 Mt CO_2-eq in 2050. The additional action accelerates the 2050 level by 15 years, with an additional reduction = 13 Mt – 1.8 Mt ≈ 11 Mt CO_2-eq.

Net carbon sink of forests: The pathways are based on the KEITO-WAM scenario (Koljonen et al. 2025a). The net carbon sink estimates of the KEITO work are outdated due to the development of the MELA model; new calculations have not been made for forest carbon balance in the KEITO-WAM scenario. In this report, a rough estimate of the net carbon was prepared based on the MELA results service and unpublished test runs of the KEITO LTS-BIZ scenario (Koljonen et al. 2025b). At the KEITO-WAM logging volumes, the net carbon sink of forests would be weaker than the KEITO report estimates by 5.5 Mt CO_2-eq in 2035 and 14 and 16.5 Mt CO_2-eq in 2050 and 2055, respectively. The logging volume in the scenario is about 81 million m^3 per year throughout the review period.

Logging factor: The ratio of change in the net carbon sink rate and logging volume in forests was estimated with a standard coefficient of 1.8 t CO_2 -eq/m^3 (Koljonen et al. 2025a, p. 114), i.e. a reduction of one million cubic metres in logging volume strengthens the net carbon sink rate by 1.8 million tonnes of CO_2 -eq. The coefficient includes changes in the net carbon sink of trees and soil and takes changes in growth into account. Estimates calculated using a standard coefficient are on the order of magnitude, whose reliability decreases over time or when logging volumes differ significantly from the reference situation. In addition, the net carbon sink of wood products was expected to weaken moderately as logging volumes decline.

Appendix 2. Strategic selections for each pathway

Table 1. Short-term strategic choices (2026—2029)

	Land use, sustainability and economic impacts	Regional agency and justice	Finland's geopolitical position
EU compliance pathway	• Principles of placement, assessment of synergies and mitigation hierarchy for wind and solar power. • Synchronization of land use planning, permit processes and network connections; projects primarily focus on already weakened areas.	• Create models to fairly distribute benefits, disadvantages, and compensations; reduce regional disparities in network access. • Link early involvement to project cost-benefit models, where participation is linked to compensation, local benefits and the implementation method, thus boosting the experience of genuine interaction and reducing the number of quasi-hearings. • Make research-based information on the impacts of the energy transition transparently available as part of project and region-level communications.	• Coordinate energy, climate, industrial and security policies; decide to permanently break away from fossil dependencies. • Strengthen the security of supply, cybersecurity and supply chains of critical components in line with the EU framework. • Launch Nordic planning to remove bottlenecks in power grids and coordinate storage solutions.
Bioeconomy pathway	• Introduce siting principles and mitigation hierarchy for the growth of wind and solar power in the bioeconomy pathway (72 TWh wind power in 2055). • Cascading use of biomass: promote market-based redirection of wood to sites of higher added value based on an overall assessment, taking economic boundary conditions in addition to wood properties into account. • Improve harvesting of logging residues, small-dimensioned wood and side streams; biogas, biochar and CO_2 capture pilots. • Secure the role of bioenergy security of supply: sustainable raw material flows, terminal and warehouse infrastructure in case of a disturbance.	• Strengthen the role of municipalities, forest owners, farms and industry in bioenergy and biogas projects. • Build regional clusters of bio and circular economy, which keep employment, contract models and benefits in the region. • Link assessment of the bioeconomy´s regional impacts to the utility models; make research data transparently available.	• Investment in domestic solutions to increase energy independence and reduce fuel and technology risks. • Prioritise biochar, biogas and renewable fuels for hard-to-electrify sectors; grow domestic processing into export products. • Launch Nordic cooperation to reconcile biomass-based solutions with biogas.
Electrification pathway	• Reinforce the transmission grid and underground cabling; siting control of offshore wind, principles for port and maintenance logistics; site reservations for hydrogen, warehouses and data centres. • Consistent mitigation hierarchy for on and offshore wind and solar projects. • Secure bioenergy supply chains and terminal capacity for the security of supply	• Local acceptability: open interaction and cost-benefit analysis that guides cost-benefit compensation mechanisms at the local level, launching the energy justice process. • Resources for participation and permit management at the investment scale (increase in wind power capacity to 45 GW). • Make research data on regional impacts transparently available and use it to keep the conversation from drifting away from local experiences.	• Further processing of hydrogen in Finland into marine and aviation fuels; critical assessment of hydrogen pipeline and data centre solutions. • Targeted security survey of supply chains and data centres for the risk profile of the electrification pathway. • Launch Nordic planning to reconcile transmission grids and storage solutions to support significant growth in electricity use.

Table 2. Medium-term strategic choices (2030—2039)

	Land use, sustainability and economic impacts	Regional agency and justice	Finland's geopolitical position
EU compliance pathway	• Establish regional control of wind and solar power as part of land use, energy and forest policies; coordinate the grid, storage and electrification of heat production. • Target the use of biomass in market terms to flexibility, peak consumption and as BECCS feedstock; strengthen forest energy supply chains and promote the conditions for directing wood to high-value processing. • Continue to apply the mitigation hierarchy as part of the project lifecycle and expand the assessment of synergies to EIA practices.	• Establish fair transition practices: make local cost-benefit compensation mechanisms and impact monitoring a systematic and binding part of project implementation and permanently integrate early participation into EIA and town and country planning practices • Target network and energy transition investments keep differences in labour, municipal economy and production-consumption areas manageable. • Establish regional utility models as an evaluation tool that will make impacts on tax revenue, employment and vitality visible.	• Permanently link energy policy to the strategic autonomy framework of Finland and the EU; reduce technology and fuel dependencies. • Decentralise supply chains for critical components, fuels, and digital infrastructure; strengthen cyber security and the security of supply. • Deepen Nordic cooperation to strengthen transmission networks, storage and system resilience.
Bioeconomy pathway	• Promote the commercialisation of biochar, biogas, lignin materials and advanced biofuels, creating preconditions for directing biomass towards higher added value than energy use. • Build CO_2 capture, utilisation of side streams and renewable hydrogen solutions to improve the carbon efficiency of biomass and to support hard-to-electrify sectors. • Consistently apply the mitigation hierarchy to the growth of wind and solar power required by the bioeconomy pathway	• Scale up regional bioeconomy and circular economy clusters into industrial ecosystems, creating cost-and-benefit advantages that make the sharing of side streams and biomass attractive; link farms, forest owners, waste management and industry to the same value chains. • Ensure that the employment, contractual and tax benefits of biorefining investments remain in the regions with regional benefit models and proactive siting guidance, not allowing development to focus on just a few nodes. • Systematically apply benefit models in assessing the economic and employment impacts of bio-clusters.	• Expand the export of biomass-based fuels, biochar and bio-based materials to the EU market without weakening domestic security of supply. • Balance strategic autonomy and EU integration based on domestic innovation; avoid dependence on import technologies and raw materials. • Deepen Nordic cooperation in the export logistics of biomass-based solutions and in the cross-border utilisation of biogas.
Electrification pathway	• Implementation phase of offshore wind, large solar parks, data centres and hydrogen areas: coordinate the locations with maritime spatial planning, nature and land use. Build the trunk network, long-term storage and flexibility. • Apply the mitigation hierarchy to large-scale wind, solar and offshore wind projects, where managing synergies is particularly difficult. • Secure minimum capacity of bioenergy supply chains and terminals for security of supply as the annual use of bioenergy decreases.	• Regionally balance the siting of power-intensive industry, data centres and hydrogen; establish local benefit models so that the investment benefits are also shared with the production areas. • Strengthen opportunities for landowners to organise and increase the resources of the permit administration to manage the scale of the investments. • Establish utility models as an evaluation tool that will also cover the regional impacts of data centres and synthetic fuel production.	• Strengthen the infrastructure of ports, transmission networks and fuel processing so that Finland can export e-fuels and not remain a producer of raw hydrogen. Deepen the integration with the EU, the Nordic countries and the Baltic countries. • Manage technology dependencies, data centre security risks and the availability of critical components. • Deepen the Nordic cooperation regarding bottlenecks in transmission networks, long-term storage and system resilience.

Table 3. Long-term strategic choices (2040—2055)

	Land use, sustainability and economic impacts	Regional agency and justice	Finland's geopolitical position
EU compliance pathway	• Integrate BECCS as part of the climate and energy system; bioenergy use will focus on market-based flexibility, peak consumption and technical carbon sinks; forest energy use will focus on logging residues and small-diameter wood as procurement practices evolve and alternative uses become stronger. • Form a unified entity of land use, networks, storage, and electrifying heat, in which renewable production, natural values, and security of supply are balanced under changing conditions. • The mitigation hierarchy is well established as a guiding principle that is applied and updated as part of all renewable energy project's lifecycle management.	• Regional division of labour and fair transition practices constitute a permanent but evolving policy framework where participation, benefit models, compensation and impact monitoring are updated based on changes in the energy system and regional experiences. • Control and coordinate production, consumption and storage regionally in the long term to keep the costs and benefits of the energy transition under control in changing market, climate and security of supply conditions. • Research-based communications on energy and regional interaction support acceptability, but managing conflicts and regional tensions requires continuous monitoring and corrective action	• Integration with the EU, Nordic countries and Baltic States is coherent and cross-sectoral; geo-political, foreign and security policy assessments are permanently integrated into energy policy. • Strategic autonomy has strengthened with the decrease in imported fuels; technology dependencies are identified and managed as part of a continuous geopolitical assessment • Nordic energy system cooperation is well established and covers networks, storage, resilience and the protection of critical infrastructure and is adapted to changing security and market environments.
Bioeconomy pathway	• Promote market-based diversion of biomasses to a higher degree of processing in accordance with the cascade principle, taking technical and economic aspects into account; support the scaling up of biochar, biogas, lignin materials, advanced fuels, CO_2 capture and renewable hydrogen solutions. • Biorefining is at the heart of the pathway but carbon efficiency, use and value creation of biomass will be adapted as technologies and demand change. • The mitigation hierarchy remains a permanent guiding principle, the application of which will be refined based on experience and research data.	• Regional bioeconomy and circular economy clusters function as permanent industrial ecosystems, whose structures are developed to meet changing market demand, raw material flows and regional competitive advantages. Actively monitor and guide the position around benefits, especially in situations where investments, processing and expertise threaten to focus on just a few nodes. The innovation wave strengthens the ability to scale solutions to international markets. • Farmers, forest owners, waste management and industry operate in the same value chains; biorefining strengthens the vitality of the countryside.	• Expand the export of biorefined products, bio-based materials and fuel solutions for hard-to-electrify sectors, while maintaining domestic security of supply and a secure base of resources. • Finland's profile in the EU is that of a bio-society, whose energy independence and strategic autonomy rely on a domestic resource base. • Nordic cooperation also covers the export logistics of biomass solutions and the cross-border utilisation of biogas.
Electrification pathway	• Dynamic siting and coordination of on and offshore wind, solar parks, hydrogen zones and data centres are in relation to grid capacity, natural values and security of supply needs. • Develop the core network, long-duration storage and flexibility solutions to meet the growing scale and uncertainties of the system. • Siting guidance and maritime spatial planning limit negative impacts on nature; the mitigation hierarchy is well established as part of all projects. • Maintain and check the minimum capacity of the bioenergy supply chains based on security of supply assessments, which are used to make renewal investment decisions for bioenergy plants.	• Manage the regional siting of power-intensive industry, data centres and hydrogen and, if necessary, adjust the siting to maintain a balance between regional loads, benefits and infrastructure needs • Energy justice processes are an established part of investments; however, their effectiveness is regularly assessed based on regional experiences, costs and system changes. • Organising landowners, resource allocation to permit administration and harmonising contract terms are established practices.	• Industrial and geopolitical positioning based on clean energy exports: refine hydrogen and electricity products with higher added value. Management of supply chain, cyber and data security risks. • Finland is a clean energy export economy: e-fuels, hydrogen products and products from energy-intensive value chains to Europe. • Nordic energy system cooperation is well established: transmission networks, storage, resilience and critical infrastructure.

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