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Centre of consumption and production

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Abstract

The role of regions and impactful climate actions in achieving a carbon-neutral Finland

This report is a collection of effective emission reduction measures from research and the climate roadmaps of seven regions. These regions are South Karelia, Pirkanmaa, North Ostrobothnia, Päijät-Häme, Satakunta, Uusimaa and Southwest Finland. The model roadmaps in this report emphasise the role of regional actors such as regional councils, Centres for Economic Development, Transport and the Environment (ELY Centres) and development organisations in achieving carbon neutrality objectives.

Resources available for climate work in regions and municipalities are limited, so it is important to focus them on the most effective measures. Critical measures for reducing emissions from fossil fuels include reducing energy consumption and improving energy efficiency, significantly increasing the share of low-emission energy and the clean electrification of heating, transport and industrial processes. In the land use sector, critical emission reduction measures include the management of emissions from peatland fields and forests and the prevention of deforestation, in particular. As for clean energy production, regional actors' tasks include zoning, developing permit processes and promoting the cooperation, competence and funding of key actors. In transport, emissions are impacted by zoning, sustainable transport programmes and pilot projects. In order to reduce emissions from buildings, regional actors can encourage local property owners to undertake energy renovations.

Regional climate work is a continuous process, as new action plans and measures that affect emissions are implemented out constantly. To ensure the effectiveness of climate work, it is essential that the planned emission reduction measures of the roadmaps progress reliably and quickly towards practical implementation. It is crucial that relevant organisations have sufficient resources for implementing the roadmaps. Concrete investments have a positive impact on regional and municipal finances.

The regions' climate roadmaps focus on climate change mitigation. This report draws attention to synergies between climate change mitigation and adaptation measures. The progress of climate change poses significant risks to people, industries, and nature. These risks can hamper the wider achievement of sustainable development goals. Climate change mitigation and adaptation are essential for both regional economy as well as human health and safety.

The model roadmaps describe the range of climate work and the multidisciplinary issues of carbon neutrality work. In the implementation phase of the climate programmes, it is important to maintain a participatory working method where regions implement climate action in cooperation with national and local stakeholders. The model roadmaps in this report include suitable indicators to support the practical monitoring of climate work and expert assessments of the impacts/effectiveness of individual measures. The model roadmaps lay the foundations for successful climate work.

Keywords: Regions, municipalities, carbon neutrality, climate action, emissions, road maps

Tiivistelmä

Maakuntien rooli ja vaikuttavat ilmastotoimet hiilineutraalin Suomen saavuttamiseksi
Tähän raporttiin on koottu yhteen vaikuttavia päästövähennystoimia tutkimuksista sekä seitsemän maakunnan ilmastotiekartoista. Näitä maakuntia ovat Etelä-Karjala, Pirkanmaa, Pohjois-Pohjanmaa, Päijät-Häme, Satakunta, Uusimaa ja Varsinais-Suomi. Raportin mallitiekartoissa korostuu maakunnallisten toimijoiden, kuten maakuntaliittojen, ELY-keskusten ja kehitysorganisaatioiden rooli hiilineutraaliustavoitteiden saavuttamisessa.

Resurssit maakuntien ja kuntien ilmastotyöhön ovat rajalliset, joten on tärkeää keskittää resurssit kaikkein vaikuttavimpiin toimiin. Kriittisiä toimia fossiilisten polttoaineiden päästöjen vähentämiseksi ovat energiankäytön pienentäminen ja tehostaminen, vähäpäästöisen energian osuuden merkittävä kasvattaminen sekä lämmityksen, liikenteen ja teollisuusprosessien puhdas sähköistäminen. Maankäyttösektorilla kriittisiä päästövähennystoimia ovat etenkin turvemaapeltojen ja -metsien päästöjen hallinta sekä metsäkadon estäminen. Puhtaan energiantuotannon osalta maakunnallisten toimijoiden tehtäviä ovat muun muassa kaavoitus, lupaprosessien kehittäminen sekä keskeisten toimijoiden yhteistyön, osaamisen ja rahoituksen edistäminen. Liikenteessä kaavoituksella, kestävän liikkumisen ohjelmilla ja pilottihankkeilla vaikutetaan liikenteen päästöihin. Rakennusten päästöjen vähentämiseksi maakuntatason toimijat voivat kannustaa alueen kiinteistönomistajia energiaremontteihin.

Maakunnallinen ilmastotyö on jatkuva prosessi, sillä uusia päästöihin vaikuttavia toimintasuunnitelmia ja toimia tehdään jatkuvasti. Ilmastotyön tuloksellisuutta ajatellen on keskeistä, että tiekarttojen päästövähennystoimet etenevät luotettavasti ja nopeasti käytännön toteutukseen. Kriittistä on, että toteuttajaorganisaatioissa on riittävät resurssit tiekarttojen toimeenpanoa varten. Konkreettisilla investoinneilla on alue- ja kuntataloutta vahvistava vaikutus.

Maakuntien ilmastotiekartoissa korostuu ilmastonmuutoksen hillintä. Raportissa kiinnitetään huomiota ilmastonmuutoksen hillintä- ja sopeutumistoimien synergioihin. Ilmastonmuutoksen eteneminen aiheuttaa merkittäviä riskejä ihmisille, elinkeinoille ja luonnolle. Nämä riskit voivat haitata kestävän kehityksen tavoitteiden saavuttamista laajemmin. Ilmastonmuutoksen hillintä ja siihen sopeutuminen ovat välttämättömiä maakuntien aluetalouden sekä ihmisten terveyden ja turvallisuuden kannalta.

Mallitiekartat kuvaavat ilmastotyön laajuutta ja monialaisia kysymyksiä, joiden parissa hiilineutraalisuustyötä tehdään. Ilmasto-ohjelmien toimeenpanovaiheessa on tärkeää jatkaa osallistavaa työskentelytapaa, jossa maakunnat toteuttavat ilmastotoimia yhteistyössä valtakunnallisten ja paikallisten sidosryhmien kanssa. Raportin mallitiekartoissa on mukana ilmastotyön käytännön seurannan tueksi sopivia mittareita ja asiantuntija-arvioita yksittäisten toimenpidekokonaisuuksien vaikuttavuudesta. Mallitiekartat luovat pohjaa tulokselliselle ilmastotyölle.

Asiasanat: Maakunnat, kunnat, hiilineutraalius, ilmastotoimet, päästöt, tiekartat

Sammandrag

Landskapens roll och effektiva klimatåtgärder för att uppnå ett koldioxidneutralt Finland

I den här rapporten har man från undersökningar och från sju landskaps klimatvägkartor samlat ihop effektiva åtgärder för att minska utsläpp. De här landskapen är Södra Karelen, Birkaland, Norra Österbotten, Päijänne-Tavastland, Satakunta, Nyland och Egentliga Finland. I rapportens modellvägkartor betonas landskapsaktörernas, såsom landskapsförbundens, NTM-centralernas och utvecklingsorganisationernas, roll i uppnåendet av målen för koldioxidneutralitet.

Landskapen och kommunerna har begränsade resurser för klimatarbetet, så det är viktigt att koncentrera resurserna till de åtgärder som är mest effektiva. Kritiska åtgärder för att minska utsläppen av fossila bränslen är att minska och effektivisera energianvändningen, att avsevärt öka andelen utsläppssnål energi samt att helt elektrifiera uppvärmningen, trafiken och industriprocesserna. De kritiska åtgärderna för att minska på utsläpp inom markanvändningssektorn är i synnerhet hanteringen av utsläppen från torvmarksåkrar och torvskogar samt förhindrandet av avskogning. När det gäller ren energiproduktion är landskapsaktörernas uppgifter bland annat planläggning, utveckling av tillståndsprocesser samt främjande av samarbete, kompetens och finansiering mellan centrala aktörer. Genom planläggningen, programmen för hållbar rörlighet och pilotprojekten kan man påverka utsläppen från trafiken. För att minska utsläppen från byggnaderna kan aktörer på landskapsnivå uppmuntra områdets fastighetsägare till energirenoveringar.

Klimatarbetet på landskapsnivå är en kontinuerlig process, eftersom det hela tiden utarbetas nya handlingsplaner och åtgärder som påverkar utsläppen. Med tanke på klimatarbetets resultat är det viktigt att åtgärderna för att minska utsläppen i vägkartorna framskrider på ett tillförlitligt sätt och snabbt övergår till det praktiska genomförandet. Det är kritiskt att de genomförande organisationerna har tillräckliga resurser för att verkställa vägkartorna. Konkreta investeringar stärker den regionala och kommunala ekonomin.

I landskapens klimatvägkartor framhävs bekämpningen av klimatförändringen. I rapporten fästs uppmärksamhet vid synergier mellan åtgärder för att bekämpa och anpassa sig till klimatförändringen. Klimatförändringen som fortsätter medför betydande risker för människorna, näringar och naturen. De här riskerna kan störa uppnåendet av målen för hållbar utveckling i allmänhet. Att bekämpa klimatförändringen och anpassa sig till den är nödvändigt med tanke på landskapens regionala ekonomi samt människornas hälsa och säkerhet.

Modellvägkartorna beskriver klimatarbetets omfattning och de sektorsövergripande frågor som kolneutralitetsarbetet omfattar. I genomförandeskedet av klimatprogrammen är det viktigt att fortsätta med ett inkluderande arbetssätt där landskapen genomför klimatåtgärder i samarbete med nationella och lokala intressentgrupper. I rapportens modellvägkartor ingår lämpliga mätare och expertbedömningar av effekterna av enskilda åtgärdshelheter som stöd för den praktiska uppföljningen av klimatarbetet. Modellvägkartorna skapar grunden för ett resultatrikt klimatarbete.

Nyckelord: Landskap, kommuner, koldioxidneutralitet, klimatåtgräder, utsläpp, vägkartor

Preface

This report highlights the most important measures that can be utilized to achieve Finland's national and municipal goals regarding carbon neutrality and emission reductions, with an emphasis on the roles and opportunities of regional actors. The report is particularly aimed at parties promoting regional climate work from decision-makers to those implementing practical measures. In terms of its information content, the report supports the implementation of Finland's climate policy and the EU Green Deal sustainable growth programme. Achieving carbon neutrality in Finland requires fast and significant measures across all sectors. These efforts will strengthen the information base required to affect change on a regional level.

The report was prepared within the Towards Carbon Neutral Municipalities and Regions (Canemure) project with funding from the EU's Life programme. The project has sought to accelerate and support the climate efforts of Finnish regions and municipalities since 2018. The project will continue until 2024.

The report collates the most impactful measures and experiences of seven Finnish regions with regard to regional roadmap efforts between 2019 and 2021. These regions are South Karelia, Pirkanmaa, North Ostrobothnia, Päijät-Häme, Satakunta, Uusimaa and Southwest Finland. Within these regions, the climate efforts of municipalities and other actors have been driven forwards under the leadership of regional coordinators supported by the Canemure-project along with other experts in the respective region. Regional climate efforts have also been supported by a group of experts comprising representatives of the Finnish Environment Institute (SYKE), Natural Resources Institute Finland (Luke), University of Tampere and the Finnish Meteorological Institute. The report was prepared in cooperation with experts representing the regions and various research bodies. Regional coordinators have provided a valuable contribution to the report by analysing and documenting the implementation of regional roadmap efforts by means of their own lower-level figures.

The report presents lessons learned from the roadmap process and the measures selected for the model roadmaps, including responsible parties. The aim of the report is to indicate the kinds of policies, methods and emission reduction measures that make up the regional climate roadmap towards carbon neutrality.

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Authors

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1 Introduction: From climate goals to effective measures

Measures to mitigate climate change and reduce greenhouse gas emissions are urgently needed (see IPCC 2019, COM 2021, Koljonen et al., 2020, for example). The concrete and rapid emissions reduction through climate technologies and sustainable methods is of immediate importance, as the impacts of climate change are already evident in the increased frequency of storms, among other phenomena. To reach the two-degree goal laid down in the Paris Climate Agreement, global emission would need to be reduced to zero within a few decades (Levine & Steele 2021).

Finland strives to be a frontrunner in the mitigation of climate change. On a national level, Finland is aiming for carbon neutrality by 2035. To support the achievement of Finland's climate goals, numerous municipalities and regions are pushing their climate efforts forward and have set their own targets for reducing emissions. Two thirds of municipalities have specified a climate goal either independently or within the framework of regional goals (Sitra 2021). Across the Hinku network in 2021, for example, some 80 municipalities were engaged in efforts to achieve an 80 per cent reduction in emissions between 2007 and 2030. In addition to the municipalities of the regions, five other regions, South Karelia, Kymenlaakso, Päijät-Häme, Pirkanmaa and North Karelia, have committed to the respective Hinku emission reduction goals at the regional level.

The carbon neutrality goal will be reached once the emissions are equal to the net carbon sink at the land use sector (i.e., LULUCF sector. In the context of the LULUCF sector, the net carbon sink status is a situation where the sinks exceed the emission levels as defined in the National Inventory Report of Finland. In order to achieve carbon neutrality, all emissions must be reduced, and the carbon sinks strengthened.

The aim of this report is to support climate change mitigation and adaptation efforts of experts and decision-makers. The model roadmaps include examples of effective climate measures and actors responsible for their implementation. Success in the measures requires strengthening the internal and interregional cooperation of the regions. Due to the urgency of climate change mitigation, it is important to allocate limited local resources towards effective measures in order to halt the warming of the planet. Understanding of the ways in which we can build a climate-friendly society through cooperation between various operators and fields is also needed.

The report was prepared as a collaborative effort of research bodies and regional actors. It gathers the most effective measures and experiences identified through the climate roadmap work conducted by municipalities. Research data and the climate roadmaps of seven regions prepared between 2019 and 2021 were used as the source material for the report's roadmaps. The regions involved in the efforts were South Karelia, Pirkanmaa, Päijät-Häme, North Ostrobothnia, Satakunta, Uusimaa and Southwest Finland.

The current emissions across various relevant sectors have served as the starting point for the regional climate efforts. In the context of effective climate work, it is important to determine the emission sources and the potential for emission reductions. There are many factors affecting the regional climate efforts: urban structure (degree of urbanisation and population density), fuels used for producing district heat, geographical location, and economic structure, such as the share of agriculture.

The model roadmaps of the report are collections of climate change mitigation and adaption measures that are part of the overall scheme for achieving the targeted change in sustainability. The model roadmaps include expert assessments on the efficacy of the various measures. The report also highlights the synergies and benefits related to the climate change mitigation and adaptation measures. The model roadmaps in the report are collections of regional climate roadmap measures whereby the role of regional actors, such as regional councils, ELY Centres and development organisations, is emphasised. The model roadmaps also entail indicators which can be used to monitor progress in emission reduction measures and in the regional climate work overall.

2 Effective emission reduction measures to achieve carbon neutrality

2.1 Sources of greenhouse gas emissions

The most prominent source of greenhouse gas emissions is the burning of fossil fuels for energy (IPCC 2014). In the results of the Finnish Environment Institute's (SYKE) regional emission calculations, among the most notable emission sectors include road transport emissions (21.8% of all emissions in 2019) and heating emissions (22.2%), a significant portion of which is due to district heating produced with fossil fuels (Figure 1). According to Statistics Finland, the energy sector produces the largest share of Finland's greenhouse gas emission due to the extensive use of fossil fuels (Statistics Finland 2021a).

In Finland, domestic transport generates about 20% of the total greenhouse gas emissions. In 2019, the greenhouse gas emissions of domestic transport stood at 11,1 million tonnes CO_2-eq (Official statistics of Finland 2020b). Road transport is the most significant source of transport emissions, as it causes more than 90% of the greenhouse gas emissions of domestic transport (VTT LIPASTO 2019). More than 50% of road transport emissions are caused by private cars (VTT LIISA 2019).

The emissions of industrial processes are generated by the production of nitric acid, steel and cement, for example.

The heating of buildings constitutes about 26% of Finland's energy consumption (Official statistics of Finland 2020a). The heating of residential and service buildings available to municipalities, local residents and companies generates significant carbon dioxide emissions each year. In 2018, for example, the respective emissions stood at 7.8 million tonnes, which was 18% of Finland's total CO_2 emissions (Official statistics of Finland 2020b). Alongside emissions during operation, the majority of life cycle are generated in the construction phase (e.g. Koezjakov et al. 2018, Ruuska et al. 2013).

Agricultural emissions (13.7%) are primarily caused by the food digestion of ruminants, use of nitrogenous fertilisers, manure management and the decomposition of organic matter on fields. Agriculture causes about 14% of Finland's greenhouse gas emissions, without the land use sector. In 2019, the greenhouse gas emissions from agriculture stood at approximately 6.6 million tonnes CO_2-eq. The majority of the emissions came from nitrogen added to the soil and the decomposition of peat (55%), the food digestion of production animals (31%) and manure management (11%). (Statistics Finland 2021b) The emissions from energy use in agriculture production were 1 million tonnes CO_2-eq, which is attributed to the energy sector.

In the Finnish land use sector, emissions are mostly generated by the decomposition of organic soil matter (peat) in peatland fields, drained peatland forests and peat production areas. In this context, 'land use sector' means the land use categories (forest land, crop land, grassland, wetlands, settlement and other land) of the land use, land use change and forestry sector referred to in the national greenhouse gas inventory system. Emissions related to cultivation are also reported as part of the land use sector (LULUCF) where the carbon dioxide emission from mineral soil and peatland areas reduce the net sink capacity of the land use sector. In 2019, the land use sector reported a total of 8.6 million tonnes CO_2-eq as emissions from farming lands and grasslands, the majority of which was attributable to the decomposition of organic matter in peatlands. The land use sector is vitally significant because, in addition to carbon sinks, it bolsters self-sufficiency and food security in the areas and supports preparedness for climate change (see Section 3.1.4).

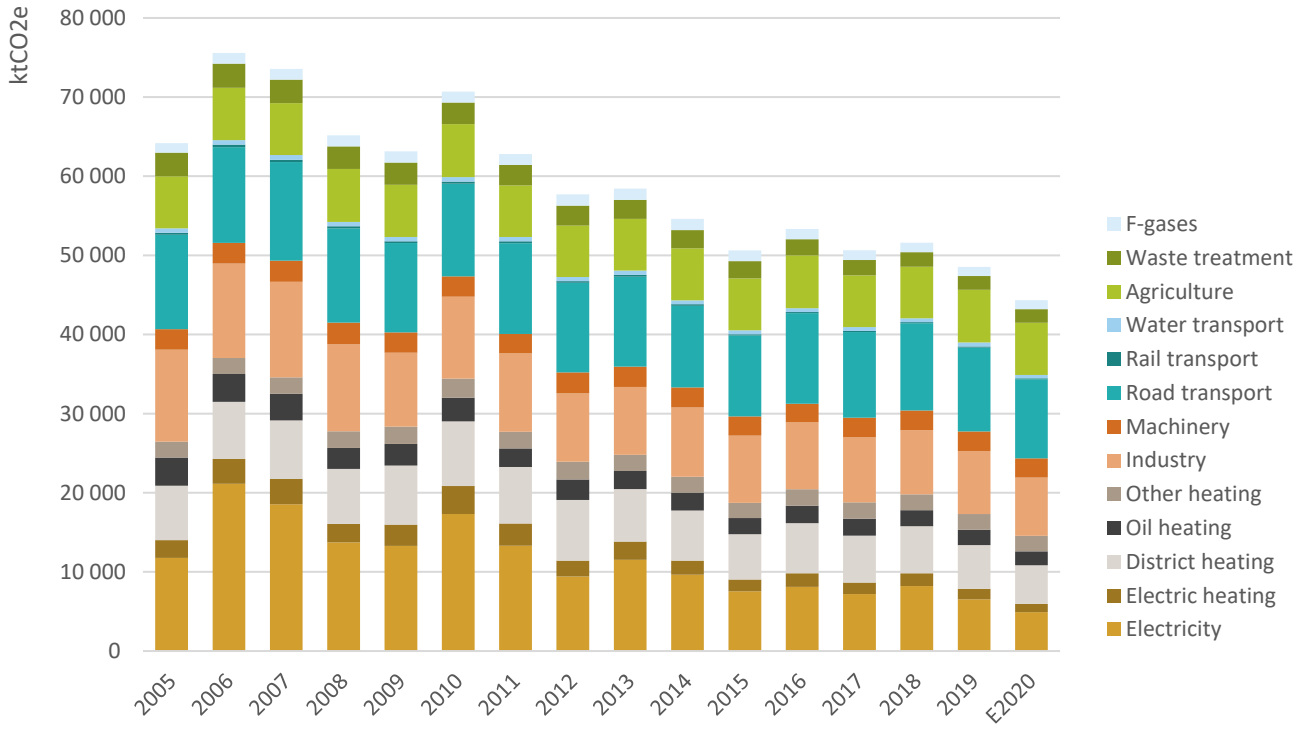

Figure 1. According to the emission calculations of the Finnish Environment Institute, the total emissions of Finnish municipalities in 2019 were 48.6 million tonnes CO_2-eq) (Finnish Environment Institute 2021). The calculation is in line with Statistics Finland's national greenhouse gas inventory of Statistics Finland (Statistics Finland, 2021a).

2.2 Methods and solutions for reducing emissions

Result-oriented climate efforts should focus on the concrete implementation of significant emission reduction measures. Critical measures to curb fossil fuel emissions include reducing energy consumption and increasing its efficiency, substantially increasing the proportion of low-emission energy, and clean electrifying of heating, transport and industrial processes. In the land use sector, critical emission reduction measures include managing emissions from peatland fields and drained peatland forests and mitigating deforestation.

2.2.1 Clean energy production for electrical, heating and gas networks

Emission reduction solutions for energy production have been examined in numerous studies (Koljonen et al. 2019, Rinne et al. 2019, Child 2016). They show that critical measures for reducing emissions are increasing the efficiency of energy use and replacing fossil fuels and peat with low-emission sources in energy production. Based on life-cycle emissions, the energy sources with the lowest emission levels are wind power, solar power, geothermal power, hydropower and nuclear power (Koffi et al. 2017, Schlömer et al. 2014). In terms of heating, the key are heat pumps for industrial facilities and properties, which use low-emission electricity to produce heat from ambient heat from the ground, water and air, and from excess heat generated by society, industry and properties. Heat pumps can be used to utilise excess and ambient heat directly in detached houses and larger residential buildings. However, the heat can also be directed to district heating networks. As regards to gas, the processed products with the lowest emissions are biogas made from organic and agricultural wastes and synthetic gas produced with clean electricity.

The roles of state-level, regional and municipal actors in reducing energy production emissions

In order to reduce emissions from energy production, it is crucial that the measures of state-level, regional and municipal actors support and supplement each other in such a way that they collectively steer relevant actors towards the most efficient emission reduction measures possible. The roles of the actors vary depending on the type of energy production. For example, the responsibilities and promotion measures required by wind power, nuclear power and ambient heat are markedly different.

For example, the roles of energy companies and property owners in the geothermal heat investments can be as follows:

- **On the state level**, it should be ensured that taxation, investment support, R&D grants and permit regulation enable innovative and efficient investments. If this is not the case, it is very difficult, if not impossible, to promote investments on the municipal level.
- **Regional level operators** can enable investments by means of regional land use plans and permits, and by promoting dialogue between energy companies, land use planning officials and permit authorities and funding regional studies and development projects.
- **On the municipal level***,* the role of energy companies and property owners is to carry out the concrete investments that lead to actual emission reductions. It is the role of municipal organisations to enable these investments through land use planning and permit procedures. If an energy company is owned by a municipality, the municipality can also encourage the company towards clean energy investments through corporate governance.

2.2.2. Buildings

The development of the emissions generated by the existing building stock has been examined within the framework of Finland's renovation strategy calculation description indicating its goals (Kangas et al. 2020). According to the strategy, abandoning the use of fossil fuels and transitioning to using low-emission heat pumps are the most important factors in reducing the emissions of buildings. The small-scale production of solar energy also plays an increasing role in this regard. In addition to energy production solutions, other key measures include gradually demolishing buildings with low energy efficiency and improving the space and energy efficiency of the remaining buildings. The improvement of space efficiency is a cost-efficient way of reducing the emissions of buildings. It is advisable to remove vacant buildings from the heated building stock and utilise their usable parts elsewhere.

In the context of new construction, greenhouse gas emissions are generated in the context of forest felling and site preparation. The emissions due to new construction can be reduced by ensuring that building maintenance keeps the existing building stock in usable condition. The factors with the most impact on the life-cycle carbon footprint of new buildings are each building's primary heating system, primary construction material and energy efficiency. In terms of heating systems, solutions based on renewable energy sources must be favoured, and energy efficiency must be considered through sufficient insulation thicknesses and windows with efficient heat insulation. Replacing concrete construction with wood construction, can be used to reduce the fossil emissions new construction (Vares et al. 2017), but the possible long-term impacts of wooden products on the carbon sink of forests must be considered (Seppälä et al. 2019).

The roles of state-level, regional and municipal operators in reducing energy production emissions

Building owners, such as municipalities, can affect building stock emissions through their own choices in the construction and operation phases. The state's role is to steer choices through means such as legislation and strategies, which are implemented through public investment grants, for example.

In the context of the interface between the state-level and municipal roles, building regulation and decrees that guide renovation efforts form the basis for the relevant energy efficiency requirements. These include the decree on improving energy efficiency in the context of renovations and

modifications and the specification for near zero-energy construction. The 2018 amendment to the EU Energy Efficiency Directive (2018/44/EU) requires smart automation and control systems to be installed in large non-residential buildings (total power of heating, ventilation and cooling systems at least 290 kW) by the end of 2024. The automation obligation applicable to many buildings owned by municipalities must be considered especially in conjunction with basic renovations. The energy efficiency of buildings is also regulated by the energy certificate system.

The Finnish state supports housing companies and households through the ARA energy grant, which encourages the elimination of oil heating and the improvement of energy efficiency between 2020 and 2022. Starting from September 2020, a separate grant for replacing oil heating in small residential buildings with other forms of heating has also been available for application. The most cost-efficient way to give up oil heating is to transition to district heating or heat pump solutions when the oil heating equipment reaches the end of its technical life span. Electrical heating can be another justified alternative when the building does not have much service life left. Municipalities in Finland can apply for energy grants for implementing energy efficiency measures and heating system changes from Business Finland. It can also be considered one of the state's roles to support improving the energy efficiency of the building stock in areas where funding on market terms is less readily available due to the low insurance value of the building stock.

Municipalities have many roles in the efforts to reduce the emissions of the building stock. For example, municipally owned rental housing companies and other building stock encompassed by the municipal organisation must be examined so as to give up buildings that are underused and/or in poor condition. Preparing a long-term maintenance strategy for specific properties or all buildings can help developing the energy and space efficiency of the building stock. A strategy can be used to define the staggered improvement of the building stock towards a zero-energy level or make preparations for demolishing buildings and constructing replacements. It is possible to apply for a demolition grant to tear down buildings that are unused and/or in poor condition.

The municipality has to consider the procurement criteria of low-carbon construction in all construction and renovation projects under the Act on Public Procurement. The Competence Centre for Sustainable and Innovative Public Procurement (KEINO) is a good source of support regarding the carbon neutrality goals, resource economy and the circular economy. The Ministry of Employment and the Economy also provides procurement units with good guidelines on how energy efficiency is considered in the context of public procurements.

Measured based on population, the energy efficiency agreement for the municipal field covers about 70% of Finnish municipalities. Other rental buildings, rental housing companies and owners of public buildings are covered by the real estate sector's energy efficiency agreement. The energy efficiency agreements oblige building owners to ensure energy efficiency measures in the properties specified in the agreements. Municipalities that have joined the municipal energy efficiency agreement are eligible for Business Finland's increased energy grant for conventional energy efficiency investments. Energy grants are also available for measures implemented as ESCO (Energy Service Company) services. Municipalities can also order optional energy and renewable energy analyses on their buildings to help target emission reduction measures.

2.2.3 Transport

Transport emissions can be reduced in three ways: 1) reducing transport journeys that cause emissions, 2) improving the energy efficiency of vehicles, and 3) using forms of energy with lower greenhouse gas coefficients.

Transport emissions can be reduced efficiently by transitioning from fossil fuels to low-emission or emission-free technologies, such as electric cars, and renewable fuels, such as biogas. However, the availability of sustainably produced biofuels is very limited, which is why they should be primarily used

in long-distance road transport as well as in sea and air transport, which are difficult to electrify. The energy efficiency of vehicles and the alternative means of propulsion are mainly affected by the EU's emission limits, which guide car manufacturers towards producing vehicles with lower emissions. The vehicle and transport service procurements of public organisations, in turn, are steered towards lower emissions by the EU directive on the promotion of clean and energy-efficient road transport vehicles (Ministry of transport and Communications 2019).

The renewal of the Finnish vehicle stock is slow, which is why acquisitions of newer and electric cars is supported through a variety of measures, such as emission-based taxation and subsidies for purchasing electric cars, and by supporting the building of a charging and fuelling infrastructure for alternative propulsions. The energy efficiency of passenger cars can also be improved by increasing the number of passengers in individual cars through carpooling arrangements, for example. According to an analysis prepared by the Finnish Climate Change Panel, changing the ways of using passenger cars, which includes the increased prevalence of carsharing alongside carpooling, is the most cost-efficient way for our society to reduce traffic emissions (Liimatainen et al. 2015). However, the shift in the methods of using passenger cars will require a significant change in people's behaviour.

In order to reach the emission reduction goals imposed on traffic, it is not enough to modernise the vehicle stock towards lower emissions. It is also vitally important to stop the increase in vehicle use (Ministry of Transport and Communications 2020). High-emission passenger car traffic can be effectively reduced by impacting the modal split and the distances driven. The key factors impacting the choice of mode are time and effort. For walking, cycling and public transport to provide a genuinely viable alternative to driving, they must be fast and effortless options. The modal split is also substantially impacted by the travel distance. For distances less than a kilometre, walking and cycling stand at 76%, for distances of 1–2 kilometres they are at 48%, and for distances of 5–7 kilometres, the share drops to 15% (Finnish Transport Agency 2018). A dense and mixed urban structure enables short distances between various functions and services. Density is also a requirement for profitable public transport that provide a high service level. Impacting the modal split will take significant investments in promoting sustainable modes of transport in both national and municipal transport policies (Ministry of Transport and Communications 2020).

In addition to emission reductions, promoting sustainable modes of transport and increasing the utilisation rate of cars will provide our society with other substantial benefits, such as improved traffic safety, the freeing-up of urban space, and a reduction in traffic noise and other emissions that are hazardous to health. An increase in walking and cycling will also have other notable positive impacts on national health through increased physical activity (Ministry of Transport and Communications 2018).

The roles of state-level, regional and municipal operators in reducing traffic emissions

On a national level, traffic emissions can be reduced through economic steering (i.e. taxation or allowances) targeted at vehicle acquisition and use, and through regarding various modes of transport as employee benefits and work travel expenses, for example. The decision on the maintenance and development of the national transportation network are also made on a national level. The state can promote public transport in urban areas by increasing government grants for public transport and improving the public transport infrastructure. In particular, fast public transport links between cities (such as the One-hour Turku-Helsinki Rail Link and Suomirata under planning) require national decisions. National measures can also include developing unified payment and travel information systems and steering the development of a charging and fuelling infrastructure for alternative propulsions. The energy efficiency of road transport has been improved by increasing the dimension- and mass specifications of lorries. The Finnish state is also involved in the preparation of a national transport system plan and the preparation of land use, housing and transport (LHT) agreements with the largest city regions.

On a regional level, area-wide development can be achieved through regional land use plans and regional strategic programmes. In addition to this, regional transport system planning can be leveraged

to impact the regional development goals for transport. For example, regions can promote a dense and mixed urban structure and focus functions around stations and public transport hubs.

Municipalities can impact the urban structure, the preconditions for walking, cycling and public transport, and the appeal of driving through parking policies, tram systems, public transport streets, public transport lanes, and benefits related to public transport. Municipalities focus land use in areas that are easily accessible by sustainable modes of transport. Moreover, municipalities can impact the emissions of heavy traffic by steering urban logistics and investing in building a charging infrastructure for electric vehicles. Decisions on the powertrains used in each municipality's vehicle fleet and any transport services purchased are made on a municipal level. Municipalities can also make their vehicles available to private persons for carsharing during evenings, for example.

2.2.4 Agriculture

The practices of agriculture are heavily steered by subsidy policies and related funding, which is why many of the measures listed in roadmaps require EU-level and national policies to support them. Thus far, regions and municipalities have been able to guide agricultural production to a limited degree. Among regional bodies, ELY Centres (Centres for Economic Development, Transport and the Environment) have a role distributing the funding related to the environmental steering of agriculture. Perhaps the best way for municipalities to impact agriculture is through municipal food procurement. That said, the most important operators in this regard are landowners, whose decisions affect the largest source of emissions in agriculture: the soil itself. This is why information-based guidance plays an important role. By developing this guidance, it is possible to impact landowners either directly or indirectly through advisory organisations and financing bodies. Various trials and networks can strengthen competence of actors. Examples of these include projects of the rural development programme and the Carbon Action network of farmers.

2.2.5 Forests

Finland's forests currently function as a carbon sink, meaning that the trees and soil in forest areas absorb more carbon than they release back into the atmosphere each year. The carbon sequestration by forests, as well as the emissions from them, are reported within the land use sector (LULUCF). In 2019, the net carbon sink of Finnish forests stood at 22.9 million tonnes CO_2 eq, without wood products. In addition to this, wood products sequestered 3.4 million tonnes CO_2 eq (Official statistics of Finland 2021). The carbon sink of forests is mainly due to the fact that during recent decades, the total annual growth of Finnish forests has exceeded the total drain, which has served to increase the total amount of forest resources. However, there are large local and regional differences in the level of carbon sink, which result from factors such as history of forest utilisation, differences in the development stages of tree stands, the climate and local growth conditions. It is important to note that forestry plays a key role with regards to the development of carbon storage and sinks in Finland. The annual variation in the greenhouse gas balance of Finnish forests is primarily driven by annual variation in harvests. In the longer term, felling activities steer the development of the age structure of forests and impact carbon sinks of the future.

A special characteristic of Finnish forestry is the large percentage of drained peatland forests in the total forest area. The total carbon dioxide, nitrous oxide (N_2O) and methane (CH_4) emission from forestry drained peatland sites is at 7.5 million tonnes CO_2 eq a year, which is why they are extremely significant in terms of the greenhouse gas balance of Finnish forests (Statistics Finland 2021a). In drained peatlands, the soil is a major carbon storage, which is susceptible to dispersal. When a peatland area is drained, the water level draws down and oxygen concentration increases in the peat layer that is left above water, which accelerates the decomposition of peat as carbon dioxide into the atmosphere. Furthermore, the greenhouse gas emission of drained peatlands also vary according to nutrient content

(Ojanen et al. 2010). In nutrient-poor drained sites, the CO_2 emissions of the soil are lower than in more nutrient-rich sites. As regards peatland forests, it is important to note that short-term and long-term climate goals can lead to differing decisions on the climate-friendly management of such areas. In the short term, peatland forests are typically a net sink due to the rapid tree growth, and the sink can be increased by means of ash fertilisation. Before long, however, the peat layer will be entirely depleted, if the drainage is maintained with efficient ditching or the evapotranspiration of the growing tree stands is high (Ojanen & Minkkinen 2020).

In terms of aiming for carbon neutrality, it is important to find the best solution for maintaining and strengthening the existing carbon storages and sinks on a regional level and find ways of preventing and reducing emissions. It is also vital to coordinate different and often conflicting goals, as forests are extremely important for regional trade and industry through the utilisation of timber, and for other ecosystem services provided by forests. Lehtonen et al. (2020) have estimated the emission reduction opportunities of the Finnish land use sector and highlighted the most significant impacts of other forest-related goals.

The most significant forest-related climate actions Finland aims to take by 2035 include for example preventing deforestation by avoiding the clearing of forests for construction or agriculture, maintaining the soil of heath forests by lengthening the rotation times and reducing the collection of felling waste, and increasing the retainment of both healthy and rotted trees. Increasing the amount of durable wood products was also estimated to have a significant impact on climate goals, but it should be noted that this necessitates a change in the forest industry's production structure.

The positive benefits of foresting, fertilisation, wetlands and tending of seedling stands are largely realised over the long term. In addition to this, establishing conservation areas and extending rotation times can have significant impacts on the reaching of climate goals, but these measures can also lead to increased felling in other areas. The emissions of peatland forests can be reduced through moderate drainage and by maintaining the trenches only as much as is necessary to ensure tree growth (Ojanen and Minkkinen 2020). The aim of continuous cover forestry is to achieve drainage that is sufficient for tree growth by maintaining constant transpiration, which eliminates the need for ditch network maintenance (Nieminen et al. 2018). Ash fertilisation can also be a means for bolstering the carbon sink of peatland forests in the short term, but there is currently not enough research data on the long-term effects on peat loss. The greenhouse gas emissions from the continuous cover forestry of peatland forests are currently being actively researched. Lehtonen et al. (2020) estimated continuous cover forestry to be in a significant role with regard to Finland reaching its climate goals.

The roles of state-level, regional and municipal operators as regards the climate impacts of forests

The majority of Finland's productive forest land is privately owned, and there are more than 600 000 private forest owners in the country. The state owns about 25% of forest land, with the share of public operators, such as municipalities, parishes, foundations and jointly-owned forests, standing at about 5%. This means that impactful climate actions are strongly focused on measures affecting private forests and policies that impact the decision-making of forest owners. Ultimately, forest owners make their decisions based on their own interests and the goals they have set for their forest ownership. The results of a recent survey indicate that forest owners see timber production as the most important goal for themselves and Finland as a country. However, more than 50% of forest owners were also interested in producing carbon sequestration and biodiversity services in their forest areas (Koskela et al. 2021). The decisions of forest owners can be steered through e.g. subsidies, conservation compensations, and forestry best practices. Possible compensation related to carbon sequestration may also be significant in terms of reaching climate goals in the future. Even though there is relatively little forest area in non-state public ownership, the relevant public operators are well positioned to act as pioneers and trailblazers in climate-friendly forest management on a wider scale. Direct benefits in the form of enabling carbon compensation measures are also possible.

2.3 The environmental impacts of climate change mitigation efforts

The other environmental impacts of mitigation efforts are connected to impact chains of various ecosystem services, such as natural diversity, water quality, land use (incl. construction) and the sufficiency of natural resources. Taking into account ecosystem services in achieving the emission reduction goals serves the achievement of the United Nations Sustainable Development Goals (Agenda 2030). Especially in the long term, they can be seen to impact health, well-being and subsistence of regions and their residents. Sustainable Development Goals promote adaptation to the impacts of climate change in various areas of society.

Emission reduction methods can have many, mostly positive, environmental impacts. Measures to reduce emissions and increase carbon sinks improve air quality, improve water bodies and support natural diversity in the areas restored. However, afforestation can also have impacts which temporarily weaken biodiversity (e.g. due to loss of natural agricultural environments and increased nutrient load on water bodies), which is why their impacts must be assessed based on the latest research data and regional or local characteristics.

3 Preparing for the impacts of climate change: synergies of mitigation and adaptation measures

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Climate change creates pressure to change societal structures, as the impact of extreme weather events and changing climate increase the vulnerability of people, sources of livelihood and nature (Lilja-Rothsten 2019). Climate change mitigation is often considered a priority, but the rise in weather and climate extremes highlight the importance of implementing adaptation measures. In Finland, local adaptation to climate change is emphasised in the National Climate Change Adaptation Strategy 2022 (Ministry of Agriculture and Forestry 2014) and in the EU Strategy on Adaptation to Climate Change (COM (2021) 82 final). Regional climate efforts primarily focus on mitigation measures, but all roadmaps must also consider adaptation to climate change. Of the seven regions involved in the Canemure project, only some have taken adaptation measures into account, even though many of the regions have engaged in adaptation planning, for example, through regional climate risk identification and strategy efforts. In a climate-proof regional structure, it is important to address the practicalities of emission reductions and to manage the weather and climate risks indicated by regional risk assessments at the same time. The availability of regional data and the improved engagement of the regions strengthen understanding, operational capabilities, and fair deployment of climate measures.

The synergy between mitigation and adaptation opens new sustainable business opportunities and financially sustainable solutions, which are equally important on both Finnish national (Ministry of Agriculture and Forestry 2014) and EU level (European Commission 2019) adaptation schemes. In addition to assessing the current situation, it is important to prepare for the risks revealed by various climate scenarios and minimise the costs caused by them, which also impacts the productivity of investments in the long term. At the same time, this enables better adaptation to risks which are already realising in the current climatic conditions. Finland supports adaptation, for example, through innovation support in the form of regional development funding. It is important to determine the impacts of climate change on infrastructure, supply chains, raw material availability, international and domestic markets and working conditions in different sectors. The Finnish Climate Change Panel has compiled relevant information on financial impacts, steering methods, and regional adaptation measures into its report SUOMI *(Climate change adaptation tools, costs and regional dimensions)* (Gregow et al., 2021).

In different sectors, taking into account the impacts of climate change, translates into preparation for a variety of extreme weather and disturbances, such as interruptions in the production and supply of energy and the flow of information and goods (logistics), and increasing problems with private and public transport. Long-term weather trends may impact people's well-being, productivity of livelihoods and costs of various operations. In fields involving natural resources, droughts will necessitate preparation for forest fires and, conversely, for increased precipitation and the lack of ground frost during mild winters. Changes in precipitation (winters), wind conditions and heatwaves are also important in adaptation of the built environment. (Sf. Tuomenvirta et al., 2018, Jylhä et al., 2020). Adaptation measures in the health and welfare sectors can alleviate the increase of disadvantageous, health effects cause by heatwaves and urban heat islands (Ruuhela et al. 2021), accidents in slippery conditions (Hippi et al. 2020), and moisture damage and indoor air issues in buildings (Tuomenvirta et al., 2018). Nature-Based Solutions, such as urban wetlands, which reduce stormwater damages, offer a variety of benefits for climate-proof urban structures (Jokinen & Heikkinen 2019, Paloniemi et al., 2019).

It is increasingly important to build a cooperation network of regional and local actors and deploy inclusive modes of operation, as local and regional actors have not had sufficient tools for adapting to climate change (Lilja-Rothsten 2019). Considering risk management of critical infrastructure, the cooperation between the public and private sector must be tightened even further and the division of responsibilities between authorities must be clarified (see Mäkinen et al., 2019) to ensure climate change adaptation with due consideration to specific local conditions. This means close cooperation and effective coordination between various administrative levels (local–regional–national) as well as efforts to strengthen steering effects and reporting. Concrete adaptation measures are implemented on the local level, yet regions and ELY Centres hold substantial authority with regard to land use planning, strategic steering and guidance. Ensuring contact and cooperation between cities and municipalities is an essential part in improving regional climate expertise. Ensuring contact between cities and municipalities and building cooperation are essential aspects in improving regional climate expertise. One aim of the roadmap work is to increase awareness and information-based steering regarding between mitigation and adaptation and the risks affecting various sectors, so that they can be taken into account alongside emission reduction measures.

The following list presents key questions in this regard (Hildén et al., 2021, Piiroinen et al., 2021):

- What are the most prominent weather and climate risks in the area (e.g. heat, flood/drought, fire, biological risks/diseases, pests)?
- How has the area prepared for possible disturbances caused by weather and climate risks?
- On what kinds of assumptions/scenarios is the assessment of climate impacts based? What is the expected scope/significance of the impacts in the climate conditions of the future?
- Has the compatibility of the emission reduction measure with the regional or local adaptation plans been taken into account? How is the measure positioned in relation to them? (synergy/conflict)
- Can the vulnerability to risks caused by climate change be alleviated?

3.1 Weather and climate risks caused by climate change and opportunities to promote adaptation and preparedness in different sectors

3.1.1 Energy production

The most obvious impacts of climate change on energy production concern prolonged heatwaves and milder winters, which can reduce heating needs during winter months but, correspondingly, increase the need for air conditioning and cooling energy due to hotter summer seasons (Añel et al., 2017). This may increase monthly variation in electricity consumption and result in rapid and dramatic heat fluctuations (e.g. rarer below-zero conditions and longer heatwaves) which cause consumption peaks that may burden energy production capacity, especially in the context of the transition to variable renewable energy capacity. More frequent heatwaves and droughts caused by climate change may complicate cooling at power plants and lead to production interruptions due to environmental and safety reasons, if there is a shortage of cooling water or its temperature is too high (see Cook et al., 2017, Rübbelke & Vögele 2011). For example, the operation of nuclear power plants can become more difficult if the temperature of the seawater used for cooling increases too much (Rübbelke & Vögele 2011). For buildings, the growing need of cooling energy due to heatwaves can be partially reduced by means of passive solutions, such as structures which provide shade and, if necessary, reflect solar radiation (see Wahlgren et al., 2008). This promotes adaptation to the changing climate and mitigation of climate change by improving energy efficiency.

Adaptation to climate change in energy production is related to strengthening energy security and the security of supply. Key factors for security of supply include various energy storage solutions,

flexible consumption and smart energy systems that support energy security and adaptation to fluctuation in renewable energy production throughout society and various sectors (industry, heating of buildings). The replacement of fossil fuels with renewable energy as the energy system is electrified will eliminate some combined heat and power production utilities, which may impede the effective operation of the energy system in the context of demand peaks (e.g., extremely low temperatures) (Koljonen et al., 2019). If carbon-neutral energy sources/fuels are unavailable, the necessary backup power must be obtained from other sources, such as neighbouring countries. This may increase exposure of industry to price spikes and interruptions in the security of supply and lead to production losses (Hildén ym., 2016).

Storms and other extreme weather events (snow and ice accumulation, icy rain) exacerbate the vulnerability of energy transmission and distribution systems, which can, on a regional level, be partially prevented by increasing the local production of renewable energy (see Tuomenvirta et al., 2018). Recent years have seen an increase in underground cabling, the deployment of various backup systems, such as generators set on farms and fireplaces in homes, and the small-scale production of energy (i.e. decentralised energy production). The impacts of climate change on the production of wind power and hydropower particularly in the Nordic countries can also impact Finland (Kopsakangas-Savolainen & Svento 2013a, 2013b). Preparedness for disturbances can be bolstered through energy efficiency and modes of operation that save energy, and by securing the distribution of fuels and/or energy products.

In the future, tightening international regulation and various crises may increase interruptions in energy supply, which will impact supply chains and prices (e.g. Russian natural gas), among other things. This can also affect Finland's import-dependent energy production. The melting of Siberia's permafrost and the vulnerability of gas and oil fields can weaken security of supply in Finland. Adaptation capability and energy security/security of supply can be promoted by increasing the domestic production of clean energy such as solar, wind, and hydro power and supporting research, development and innovation (RDI) efforts related to new fuels (power-to-X/green hydrogen), with due consideration to the requirements of energy storage and flexibility to balance out fluctuating production and to ensure adaptation to spikes in energy demand (see Erkamo et al., 2021, Hakala et al., 2021).

3.1.2 Buildings (built environment)

Mild winters which have become more common due to climate change, reduce the total heat energy demand of buildings (Jylhä et al., 2015). However, they also result in fast temperature variation (freeze-thaw cycles) and increase moisture stress, which can lead to indoor air issues (Tuomenvirta et al. 2018). Correspondingly, more severe and prolonged heatwaves increase the cooling needs of buildings (Tuomenvirta et al. 2018). This may increase energy consumption especially in the years to come, as active cooling systems will be needed alongside ventilation and sun protection (e.g. shading devices), to prevent the overheating of homes (Finnish Meteorological Institute 2021).

Climate change can manifest itself as shifts in local microclimates in the form of stronger winds and heavier precipitation (Wahlgren et al., 2008). Windier conditions may increase the cooling effects on buildings and heat losses resulting from increased convection and uncontrolled ventilation as air pressure fluctuations grow in various building sections. Wind and wind-driven rain (WDR) may also result in moisture damage when moisture penetrates building structures. Due to stronger rains, air impurities can also carry airborne impurities into buildings with air currents (Wahlgren et al., 2008). Warming climate and increased precipitation in winter affect the durability of buildings and the maintenance required to prevent surface and facade damage (see Pakkala 2020). This increases the need for more frequent maintenance cycles and monitoring building damage more actively (ibid.).

In the context of energy efficiency renovations, more attention should be paid to cooling needs as well as materials and structures which enable good ventilation. Increased precipitation as a result of elevated temperatures during autumn and winter months may aggravate exposure to microbial growth in

structures. In addition, wind-driven rain (WDR) and sleet before the freeze-thaw cycles can increase the frost weathering damage on facades and wall surfaces (Wahlgren et al., 2008).

Climate change can cause alterations in soil properties and flood risk areas. This can make soil prone to collapse, in the same way as the lack of ground frost in winter. Furthermore, the impacts of drought on the bearing capacity of soil may make buildings and infrastructure more vulnerable to damage. (Tuomenvirta et al., 2018). Climate change can also cause changes in floodplains and flood exposure, particularly through increased winter flows (frost-related floods), which increases the need to consider flood protection in zoning and risk management of industrial facilities. Rising temperatures and increasing floods may also change raw water quality and thereby require changes in water management.

The design of sustainable buildings can be supported by utilising weather data produced by the Finnish Meteorological Institute to assess the energy needs and physical functionality of buildings in current and future climate conditions. Average weather conditions were described in four separate climate zones (represented by Vantaa, Jokioinen, Jyväskylä and Sodankylä, for example), and the material can be used as a basis for energy calculations to assess the heating and cooling needs of buildings (Jylhä et al. 2020). In addition to this, weather data can be used to anticipate developments and prepare risk assessments on future weather conditions in 2030, 2050 and 2100 within the framework of three emission scenarios (Finnish Meteorological Institute 2020). In the future, the weather data materials can be edited according to user needs in order to determine the projected weather range of buildings and structures, for different applications. This will enable better assessment of the risks that climate change causes to construction and buildings (ibid).

As such, the suitability of the building structures and materials for future climate conditions should be considered during basic renovations and maintenance repairs, and the design of new buildings should pay attention to locations and sufficient storm water management solutions (see Ministry of the Environment 2015). Flood risks are prevalent in densely built areas, where natural drainage conditions have changed and the need for controlled flood water drainage routes and solutions has increased (Association of Finnish Local and Regional Authorities 2012). Furthermore, heavier precipitation may raise the surface level of water bodies and the sea level in coastal areas (see Veijalainen et al., 2012), which must be taken into account in zoning when determining building placement and the lowest construction elevations (Parjanne & Huokuna 2014). The repercussions of climate change and communication about risks may reduce the value of buildings in flood risk areas (Votsis & Perrels 2016). Heavy rain, storms and substantial one-time accumulations of snow and water may burden the sewer networks of urban areas and the durability of structures (Ministry of the Environment 2015). Alongside the state and municipalities, private operators and municipal residents are also responsible for storm water management. The Land Use and Building Act, which is currently under renewal, will lay down provisions on the implementation of climate change adaptation measures, as heavy rains have increased in Finland.

Ensuring that urban spaces serve multiple purposes and buildings can be flexibly modified for a variety of purposes promotes the creation of climate-proof living environments. The modification of spaces will enable adaptation to the impacts of climate change, the changes brought about by a low-carbon lifestyle (e.g. shared use and the sharing economy) and the development needs of urban spaces. In a Canemure sub-project guidelines for climate-proof cities are being developed in cooperation with the Finnish Meteorological Institute, Finnish Environment Institute, urban planners and other relevant stakeholders (Tikkakoski et al., 2022, Lilja & Tikkakoski 2021).

3.1.3 Transport

Traffic is directly exposed to weather conditions, and disturbances caused by them can easily impact the functional capabilities and overall safety of society. For example, smooth and effective links for passenger transport and delivering goods and data are prerequisites for operations in other fields. Factors that are significant in terms of the vulnerability of traffic include the properties of vehicles and transport

corridors and the working conditions of drivers, the traffic flow, and the available weather data. Increased precipitation, freeze-thaw cycles and extreme weather events impede the maintenance of transport corridors and increase repair deficit and the prevalence of various types of surface damage and wear, which impacts the safety and fluency of traffic. Especially in winter seasons, increased fast shifts in general weather conditions may cause frequent freeze-thaw cycles, which makes road maintenance more difficult (e.g. anti-slip treatments and the clearing of heavy and quickly accumulated snow covers). Due to increased precipitation, rising groundwater levels and floods may reduce the bearing capacity of roads as the depth of the ground frost changes or ground frost is not formed at all. The increase in extreme weather events may cause underpasses, roads and streets to flood, ground structures to collapse, sewers to become clogged or roadsides to erode. Moreover, the high temperatures increased by heatwaves may result in driver fatigue, vehicle malfunctions, road surface cracking, and damage in bridges and other structures. The changes make the driving conditions more challenging and accident prone for passenger and goods transport and increase the road repair deficit on a regional level. (Tuomenvirta et al., 2018).

The immediate adaptability of traffic can be improved, first and foremost, by developing winter maintenance and investing in real-time communications regarding weather data and warnings through digitalisation, for example. As regards to road maintenance, weather risks in winter can be reduced through quality management measures related to icy, dry and wet conditions, in addition to reduced driving speeds. Accident and damage risks due to heat can be reduced through the choice of asphalt and its bonding agent. (Tuomenvirta et al., 2018). Alongside emission reductions, developing the preconditions for walking, cycling and public transport can increase regional resilience in the efforts to improve the accessibility of transport modes and fluency of transport chains (Sihvola ym., 2021). With the modernisation of the vehicle stock and the increased use of low-carbon power trains, the sufficient coverage of the EV -charging network and biogas fuelling network must be ensured. In addition to this, the transition to low-carbon traffic must consider the different circumstances of areas in terms of urban structure and accessibility of public transport (Rehunen et al., 2018, Tiitu et al., 2018). Consideration of these circumstances can prevent regional disparities and deficits in transport services and opportunities (Tiikkaja et al., 2019). The development of rail traffic must bolster its reliability in changing climate conditions where fast freeze-thaw cycles and temperature variations, heavy precipitation and snowfall, and accumulations of ice and leaves impair driving conditions and safety and increase costs. Stronger weather extremes also pose challenges to maritime transport. For example, storm winds, high waves, changes in sea level and fog make navigation more difficult. Pack ice and challenging weather conditions may reduce the travel speeds of ships. (Tuomenvirta et al. 2018, Gregow et al. 2021). The slowing down of maritime traffic and port operations impact the industry.

The increased frequency of extreme weather phenomena is likely to result in higher susceptibility to accidents, damages, and delays, which increase the costs incurred by society and individuals alike (Tuomenvirta et al. 2018). Risk management can be promoted through good urban planning, developing traffic infrastructure maintenance, increasing awareness of traffic safety, and providing users with real-time traffic and weather information. For industry, risks may be caused by increasing logistical costs, the infrastructure required to cope with various disturbances (e.g. storage) and problems with the global supply chains of raw materials. (Tuomenvirta et al. 2018, Hildén et al., 2016)

3.1.4 Agriculture

Climate change mitigation measures together with changing climate conditions create substantial challenges for agriculture that is sustainable in terms of the climate, environment, and production. Agriculture has an important role in securing primary production. The implementation and mobilisation of mitigation measures require updates to support structures but also providing farms with relevant advice and training. On the other hand, the deployment of renewable energy and increased carbon sequestration

also create opportunities for changing production and improving productivity and product quality through reduced energy and nutrient consumption (see MTK 2020). For example, by increasing the production and use of biogas, farms can lessen their dependence on fossil fuels and limit the related costs while reducing farm-specific greenhouse gas emission (REM 2021, Luostarinen & Pyykkönen 2016). The production of biogas together with other energy solutions can support the energy self-sufficiency of farms, reduce the need to clear fields for manure spreading, cut back nutrient loads, and promote circular economy (i.e. nutrient circulation), which in turn reduces the use of chemical fertilisers and the emissions caused by their production and use (Luke 2020a, Nevzorova & Kutcherov 2019, Prochnow et al., 2009).

The weather variations, more frequent of extreme weather conditions and higher average temperatures resulting from climate change increase risks related to crop losses and cause general uncertainty regarding the productivity and profitability expectations of agriculture. Risks in the weather-dependent sector are exacerbated by changes in precipitation, floods, and temperature variations as mild winters become more commonplace, reducing or increasing the transience of snow covers, and as the pooling and refreezing of melt water on fields impede the overwintering of cultivated plants. Periods of drought and heat during the growing season, combined with rain showers may disrupt the continuous water supply of plants and hamper water management on fields. Prolonged growing periods can enable growing more productive late-harvest plant species, but the risks caused by variation in winter conditions may also make it more difficult to increase the prevalence of autumn-sown and perennial plants without a significant boost in winter resilience through plant breeding (Peltonen-Sainio et al., 2017).

The climate risks affecting cultivation can be prevented or alleviated by ensuring the good growing condition and water management of fields, among other measures. The means for achieving this goal include diversifying field use through crop rotation, increasing year-round plant coverage, reducing soil preparation by increasing no-till farming and agroforestry,[1] and maintaining the good condition of the drainage system. These measures simultaneously promote the maintenance of the soil structure, its carbon stores and fauna, which in turn improves the weather resilience of the cultivated fields. The Carbon Action regenerative cultivation network can contribute to supporting the implementation of mitigation and adaptation measures in agriculture (Heinonsalo 2020, Nevalainen et al., 2021). In agriculture, significant synergy benefits can be achieved in mitigating and adapting to climate change by supporting adaptation to weather extremes through cultivation that regenerates the soil. Maintaining biodiversity is essential for agricultural production to adapt to the impacts of climate change, and it is equally important to retaining important ecosystem services (crop pollination, biological pest control) and the species populating the agricultural environments. Measures important to maintaining biodiversity include increasing and maintaining traditional biotypes, perennial meadows and nature management fields (Hyvönen et al., 2020). Maintaining the diversity of agricultural environment supports the natural habitats of many species and, on the other hand, pollinators play an important role in terms of crop yields (Härjämäki 2014, Luke 2020b).

Efforts are being made to restore areas that have been removed from peat or agricultural production into their natural states and regenerate dried peatlands by restoring water flow to them. There is currently not enough research data on the impacts of restoration (Ojanen et al., 2021). However, restoration efforts can help achieve many benefits of the ecosystem service provided by peatlands (Kareksela et al., 2021). Restoring degraded soil ecosystems through afforestation or the reintroduction of water to drained peatlands can support carbon sequestration, flood control and the protection of coastal areas, improve water quality, reduce erosion and support plant pollination. Restoration measures also create new jobs and sources of livelihood (Pörtner et al., 2021). Restoration and measures to improve the conditions of habitats (e.g. conservation efforts) must be coordinated with other land use arrangements in the area to minimise any effects that may hamper any local economic activities. Due to the relative lack of

[1] Information about agroforestry in Finnish: Sekaviljelyllä satovarmuutta ja ympäristöhyötyjä, Agrometsätalouden monet mahdollisuudet

agricultural wasteland, measures such as the afforestation of mineral soil have negative impacts on the biodiversity of agricultural nature, as many traditional biotypes are endangered. However, the afforestation of peat lands can be justified for climate-related reasons, and it can yield positive impacts on forest nature and the condition of water bodies. As such, the correct targeting of the measures is extremely important as afforestation can, for example, bridge isolated forest islands but also increase forest area that does not promote biodiversity and replaces valuable heritage landscapes, unless they are excluded from the coverage of the afforestation arrangements. (Peltonen-Sainio et al., 2017, Lehtonen et al., 2021)

In the future, it may be possible to improve the preconditions for adaptation and risk management in agriculture through plant breeding and the cultivation of entire new species that support reliable farming in changing weather conditions. Alongside diversified cultivation, another important means of increasing resilience in the sector is the development of various insurance solutions to provide farmers with crop security and crop damage insurance policies in case of extreme weather events, plant diseases and damage caused by new invasive species. The severity of droughts and, most of all, abnormally long periods of drought can be reduced by increasing research on the impacts of dry periods, improving water management, developing weather forecasts which facilitate general preparedness and preparing water regulation practices (Tuomenvirta et al., 2018). In addition to the improved availability of climate data, more detailed crop model sensitivity analyses (regarding changes in temperature and precipitation, for example) can help farmers adapt to the risks caused by the impacts of climate change (see Pirttioja 2021).

3.1.5 Forests

Thus far, climate change has had a positive impact on forest growth in Finland, but it has also increased the risks caused by diseases and pests. The increased carbon dioxide concentration of the atmosphere and lengthened growth periods combined with higher average temperatures and nitrogen deposition have accelerated tree growth in most areas. This development is likely to continue if favourable growth conditions, such as a suitable moisture balance and nutrient supply, can be secured (Peltonen-Sainio et al., 2017, Gregow et al., 2021). In addition to forest growth, the changing climate impacts the decomposition rate of organic matter, and increasing risks of damage, such as forest fires, can significantly impact the size and permanence of carbon storages (Saksa et al., 2020). For example, milder winters and increased precipitation are already presenting problems to forestry as an increasing share of harvesting now has to be done when the soil is thawed. Lack of ground frost makes both timber harvesting as well as related logistical and supply chain arrangements more difficult (Tuomenvirta et al., 2018, Peltonen-Sainio et al., 2017).

The impacts of climate change may weaken the health of forests and make them more exposed to various risks and damages caused by insects and diseases. The risk of invasive pests is mainly caused by the growth of international plant trade. However, milder winters, increased precipitation, receding snowline and lack of ground frost create favourable conditions for the spreading of new pest species and plant diseases from the south to the north (Peltonen-Sainio et al., 2017). Lack of ground frost in winter also increases the risk of wind damage, as it prevents trees from anchoring intothe soil. Winds are typically strongest from late autumn to early spring (Peltonen-Sainio et al., 2017), which is why winter storms can cause widespread damage (Lehtonen et al., 2020). Forest growth can also suffer fromprolonged drought periods, especially in spruce forests in Southern Finland, but the lack of moisture can also limit pine growth in dry areas of Southern Finland. Dryness increases the risk of forest fires. Moreover, drought combined with rapid weather changes can cause soil nutrient imbalance and growth problems (Peltonen-Sainio et al., 2017).

In forest management, it is beneficial to assess the possible threats and risks of climate change to the trees in the area. This enables the identification of key factors in order to promote preparedness and adaptation to changing habitats. The choice of tree species and seeds can support sapling stands which

can better adapt to the changing climate and environment. This supports tree health, good growth and carbon sequestration capacity. Means such as controlling the density of growing trees, maintaining a diverse range of deciduous trees, and regulating the timing and implementation of harvests can be used to support the vitality of forests and reduce risks related to plant diseases, invasive species and extreme weather conditions. Correctly timed thinning, which involves removing trees that are sick or in poor condition, can free up more growing space for healthier trees. The choice of thinning method and the timing of the felling can reduce the risk of storm damage and root rot, but also exposure to wind damage, when felling areas are designed according to the local topology and sharp changes in patterns are avoided (Tuomenvirta et al.,, 2018, Peltonen-Sainio et al., 2017). On the other hand, thinning reduces the carbon sinks of the forest area in question (Helin et al., 2016). key to the adaptation of commercial forests are Nature-Based Solutions which combine water protection, natural diversity and the values and preferences of forest owners. Continuous cover forestry can be defined as a Nature-Based Solution (Salmi et al., 2019). For example, the link between the treatment of peatlands and nutrient sequestration is currently being studied within the OPERANDUM project in order to manage hydrometeorological risks through continuous cover forestry (www.operandum-project.eu).

Weather and climate have central impact on the occurrence of nature types and species. Changing climate conditions can weaken the living conditions of various species, causing endangerment of some species while benefitting the prevalence of southern and invasive species. The primary means for protecting natural diversity is by building a comprehensive network of conservation areas. However, since the protected area is limited even in the best-case scenario, measures are also required in commercially used areas. This means developing forest use towards improved identification of the dependencies between climate change mitigation, adaptation, and natural diversity to pay more attention to maintaining important ecosystem services in the context of forest use (Tuomenvirta et al., 2018). As such, protecting forest nature and preventing the loss of biodiversity requires more active management of commercial forests through means that can be deployed cost-effectively in areas which are less suited to timber production, for example. In addition to this, measures can be taken in locations near conservation areas and as part of good forest management practices. The key measures include retaining ecologically valuable forest nature types and structural characteristics, such as large old trees, deciduous trees, dead wood and blueberry and lingonberry coverage, and maintaining the quality of weakened natural areas, restoring them where necessary. The same measures also support the survival of endangered or at-risk species. (Kärkkäinen et al., 2021)

Maintaining the diversity of the tree and animal species of forest and tree health has been identified as part of systematic forest management efforts as vital and diverse forests are more resistant to storm damage, periods of drought and pests (Tapio 2019). To determine the risk probabilities and regional differences, a broad range of background information is required on the risks impacting forests and the protective measures needed. Through risk analyses, local operators, forest owners and authorities can anticipate and prevent forest damage, especially if the risk analyses are regionally precise (they can even be focused on specific forest stands, such as wind damage maps). (Lehtonen et al., 2020.). In terms of retaining the carbon sink capacity of forests, forest management should favour lighter soil cultivation measures, afforestation, and the management of forest damage risks by selecting regionally appropriate forest management methods. In the short term, the fastest way to increase the carbon sink capacity of forests is to extend the rotation periods and reduce harvesting (Saksa et al., 2020). The Ministry of Agriculture and Forestry has released an information package on the bases of sustainable management and use of forests (Tapio 2019).

Forest management measures conducted in peat land forests play a key role in forest management which promotes mitigation of and adaptation to climate change. They can significantly impact climate emissions, other environmental effects, such as nutrient exports to water courses, and efforts to maintain the diversity of vegetation/nature (see Heiskanen et al., 2020). In peatland areas the soil stores more carbon than the trees since peat holds many times more carbon than the trees, even if the area has been

drained (incl. areas with a thin peat layer) (Saksa et al., 2020). Emissions and carbon losses of peatlands can be reduced by avoiding excessive drainage, highly elevating water levels and maintaining the carbon sequestration capacity of surface vegetation by favouring continuous cover forestry (Saksa et al., 2020). These methods also serve to maintain and increase biodiversity. Wood ash fertilisation reduces the acidity of the soil, and if water levels are regulated, it promotes the carbon sequestration of trees in the short term but can also result in more carbon being released from the soil (Ojanen et al., 2019). On the other hand, an increase in plant litter on the ground promotes the carbon sequestration capacity of the soil (Huotari 2012). That said, repeated ash fertilisation can lead to ecosystem-based carbon losses (Ojanen et al., 2019). Correctly implemented ash fertilisation has not been found to cause significant nutrient exports to water courses in the short term (Piirainen et al., 2013), but there is very little data available on long-term impacts. The risk of nutrient exports may increase in sites with high levels of nitrogen in soil (Huotari 2012). To prevent nutrient leaching, the amount and quality of ash used in forest fertilisation must be regulated, which is why clear limit values have been set for heavy metal contents (Huotari 2012).

3.2 Emission reduction measures that promote adaptation to climate change

In the context of climate change mitigation efforts, it is important to promote adaptation to the ongoing change in order to prevent risks and maximise beneficial synergies between actions (see Landauer et al., 2019, Wreford 2012, Viguié & Hallegatte 2012, Wahlgren et al., 2008). When planning and implementing emission reductions, it is possible to locally promote regional adaptation capabilities, i.e. flexibility to changes or resilience against the changing climate. This means taking increasing weather extremes into account to avoid or at least alleviate their detrimental effects (Tuomenvirta et al., 2018). On the other hand, the beneficial synergies of mitigation and adaptation measures should be identified and strengthened (see Landauer et al., 2019, Zhao et al., 2018). Mitigation measures which renew the energy system, increase the efficiency of energy consumption, unify the urban structure, change motive power of vehicles, decrease transport performances and promote carbon sequestration in agriculture and forestry can all support adaptation to climate change. However, the coordination of these aspects requires careful planning and cooperation between various sectors (see Landauer et al., 2019).

By increasing efficiency in the use of energy and materials, it is possible to reduce the consumption of natural resources and promote a more sustainable way of life. Urban planning can optimise the traffic flows, energy and materials and utilise the opportunities provided by local conditions. In addition to this, it is important to account for regional and local risk factors, such as microclimate conditions. Climate-proof urban and regional planning considers the opportunities of green structures, such as forest management that supports carbon sequestration, securing and maintaining green areas in built environments, and the special characteristics of lakes and rivers in the management of climate risks (HSY 2021, Veijalainen et al., 2020). In agriculture, the methods of carbon storing in cultivation (i.e. carbon farming) can reduce nutrient leaching, prevent harmful impacts on water systems and maintain key ecosystem services, all of which support adaptation to changing climate conditions.

Many measures that promote climate change mitigation, such as renewable energy solutions and changes in land use, may also improve security of supply in energy production, stormwater management or the living conditions of species either temporarily or in the long term (Auvinen et al., 2020, Wahlgren et al., 2008, Wahlgren 2006). For this reason, it is important to identify synergies between mitigation and adaptation and minimise any conflicts between measures that may arise when the direct or indirect environmental impacts and overall sustainability is not considered sufficiently in the planning stages. Most of all, securing natural biodiversity is extremely challenging (see Auvinen et al., 2020, for example), as retaining the natural habitats of species may require changes to the practices of agriculture, forestry, and hunting (Tuomenvirta et al., 2018).

Board 1.

Key emission reduction measures that promote adaptation

- Forestry that promotes carbon sequestration and adaptation, strives to minimise forest damage and considers diverse structural variation in tree stock, maintaining and increasing the share of mixed forests, and measures that maintain the health of the trees and diversity.
- Forest management in drained peatlands to minimise peat decompositions: ensuring the management and protection of water systems in peatland forests by avoiding trench restoration and favouring continuous-cover forestry.
- Planning the use of peatlands and water management on the catchment area level.
- Discontinuing the peat production and restoring fallow lands to support diversity.
- Controlled drainage at peatlands reduces the loads to water courses.
- Carbon farming and other soil improvement measures that, for example, increase the amount of organic matter and maintain plant coverage, promote the growth conditions of the soil and reduce nutrient loadings.
- Replacing fossil fuels with biomass, particularly by utilising the side streams of agriculture in such a way that the nutrient circulation of organic materials is improved at the same time.
- Decentralised production of renewable energy, improvement of energy efficiency by increasing the utilisation of waste heat, and energy storage (incl. back-up systems and demand-side flexibility) promote energy self-sufficiency and preparedness for disturbances and reduce dependence on imported energy.
- Developing wetland cultivation and the use of biochar; the use of willow in for instance agroforestry
- The energy efficiency measures related to buildings to consider increased cooling and shading needs by more prevalent heatwaves.
- Sustainable land use and transport planning which leaves enough space for green networks and structures and prevents any changes in land use that may compromise biodiversity.
- Utilising Nature-Based Solutions in urban structures, such as fostering natural wetlands.
- Taking accessibility into account in regional planning and construction, particularly from the perspectives of light traffic and public transport.

4 The greenhouse gas emissions and climate efforts of regions

4.1 The emissions and socio-economic characteristics of regions

This report examines the emissions and climate efforts of the regions of South Karelia, Pirkanmaa, North Ostrobothnia, Päijät-Häme, Satakunta, Uusimaa and Southwest Finland. There is some variation in the regions' emission profiles. The current emission volume, the emission sources and the potential sectors where emission could be reduced must be known in climate roadmap process. There are many factors affecting the emissions and potential for reductions: urban structure (degree of urbanisation and population density), fuels used for producing district heat, geographical location (heating needs) and economic structure (share of agriculture, for example).

The differences in the socioeconomic characteristics of the regions include the degree of urbanisation and economic characteristics (Figure 2) and population (Figure 3). For example, the calculated per-capita GDP has been shown to correlate statistically with emission reductions (Karhinen et al. 2021). The gross value added and degree of urbanisation were above the Finnish average in almost all of the regions (five out of seven).

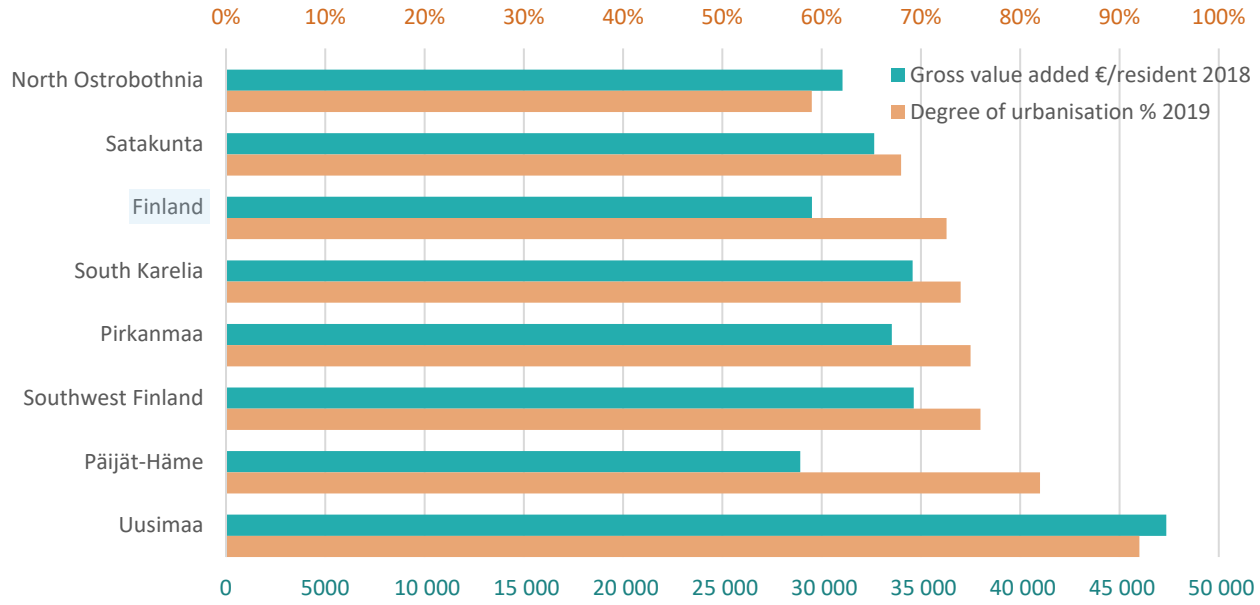


Figure 2. Regional differences in degree of urbanisation and gross value added (SYKE & Statistics Finland 2021a).

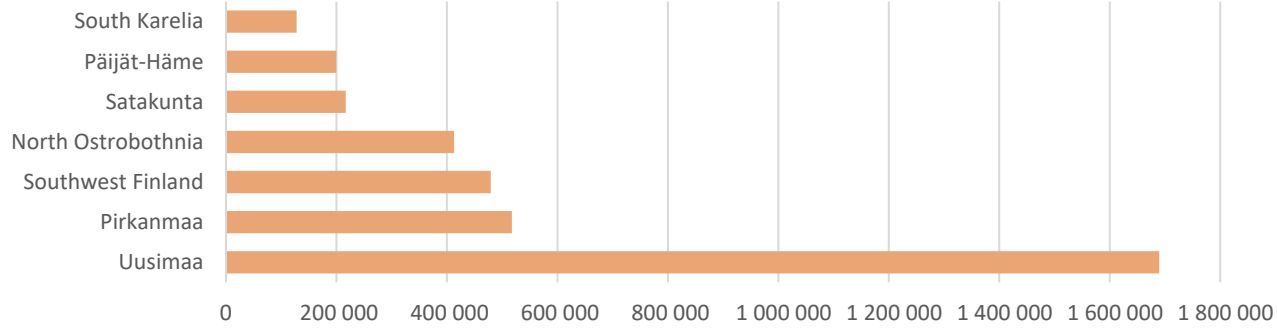


Figure 3. The populations of the regions in 2019 (Statistics Finland 2021c).

4.2 Emission profiles and key figures of the regions

Across all of the regions examined, road transport, district heating and electricity are the largest emission sectors and thereby key in terms of achieving the relevant goals (Figure 4). In all regions expect Uusimaa, agriculture is also a significant source of emissions.

It is important to monitor the efficacy of the measures with data on emissions and other essential indicators. As regards buildings, the indicators examined across the regions include the number of buildings with a geothermal system and the area-specific use of heating oil. The Canemure project regions have more energy class A buildings than the Finland on average (Figure 5). The number of geothermally heated buildings is increasing at a good rate through the country (Figure 6). The use of oil for heating is decreasing in all regions (Figure 7). The development indicator for renewable energy is the production volume of wind power per resident. There are plenty of regional differences in this regard, since wind power production is focused on regions on the western coast of the country, especially in North Ostrobothnia (Figure 8). The shares of cars that use alternative propulsions are still low all over Finland, but there are regional differences (Figure 9).

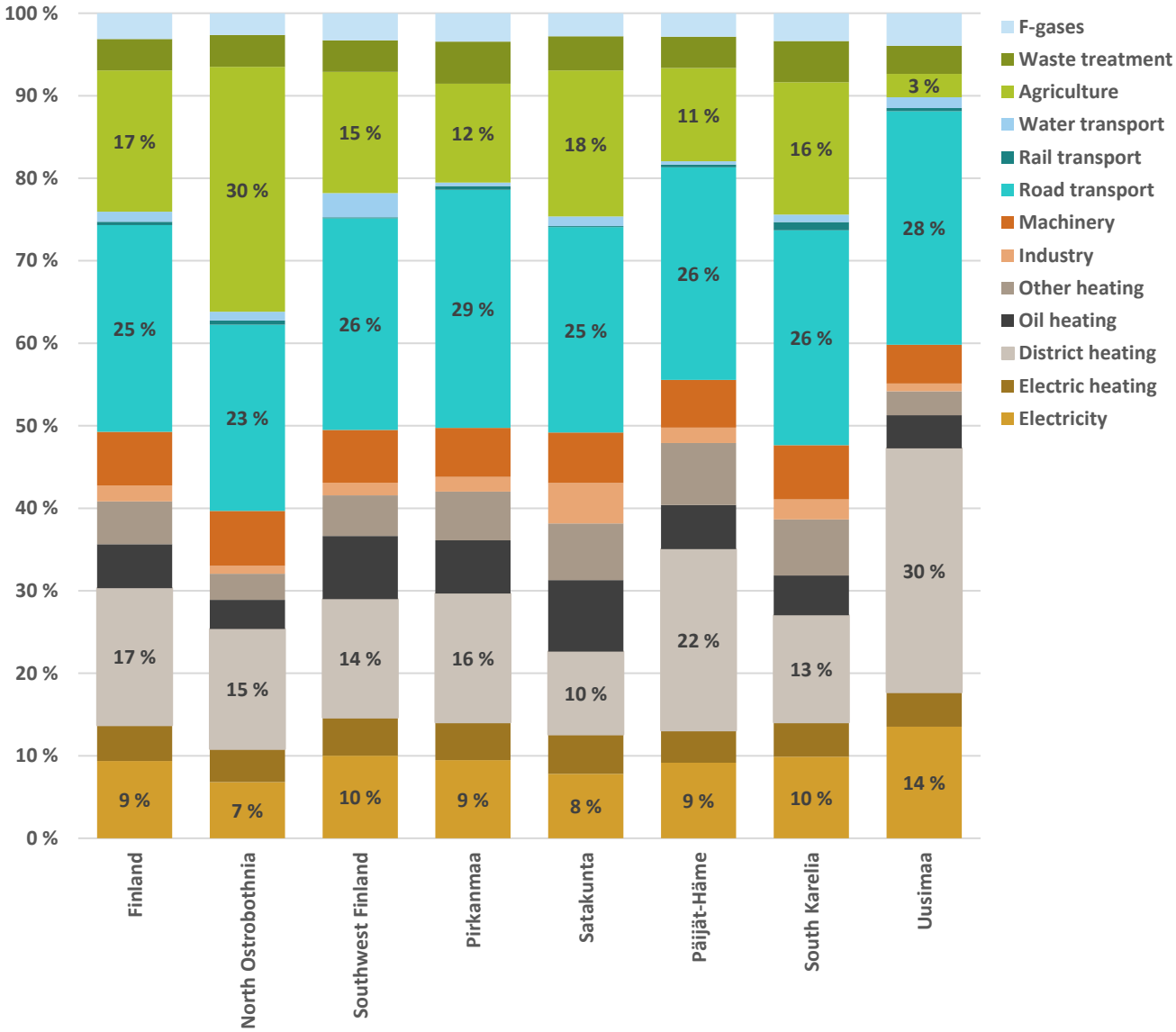


Figure 4. The relative shares of the regions' emission sectors in 2018 (Finnish Environment Institute 2021)[2].

[2] Based on Hinku calculation rules, without wind power compensations, and the emission factor electricity includes wind power. Greenhouse gas emissions of municipalities and areas

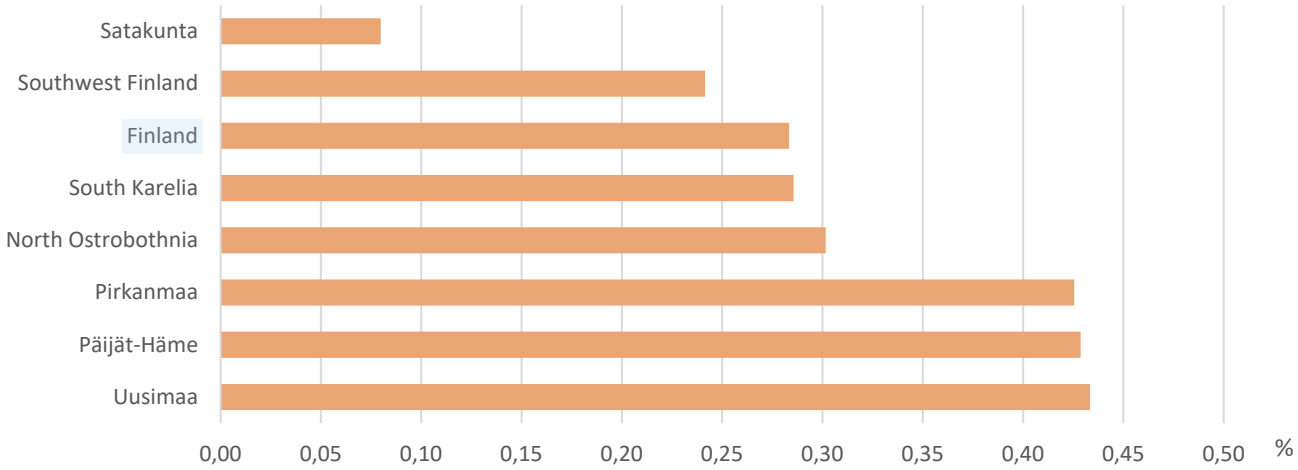


Figure 5. Percentage share of energy class A buildings of the building stock in the examined regions and in Finland on average in 2018 (Finnish Environment Institute 2022).

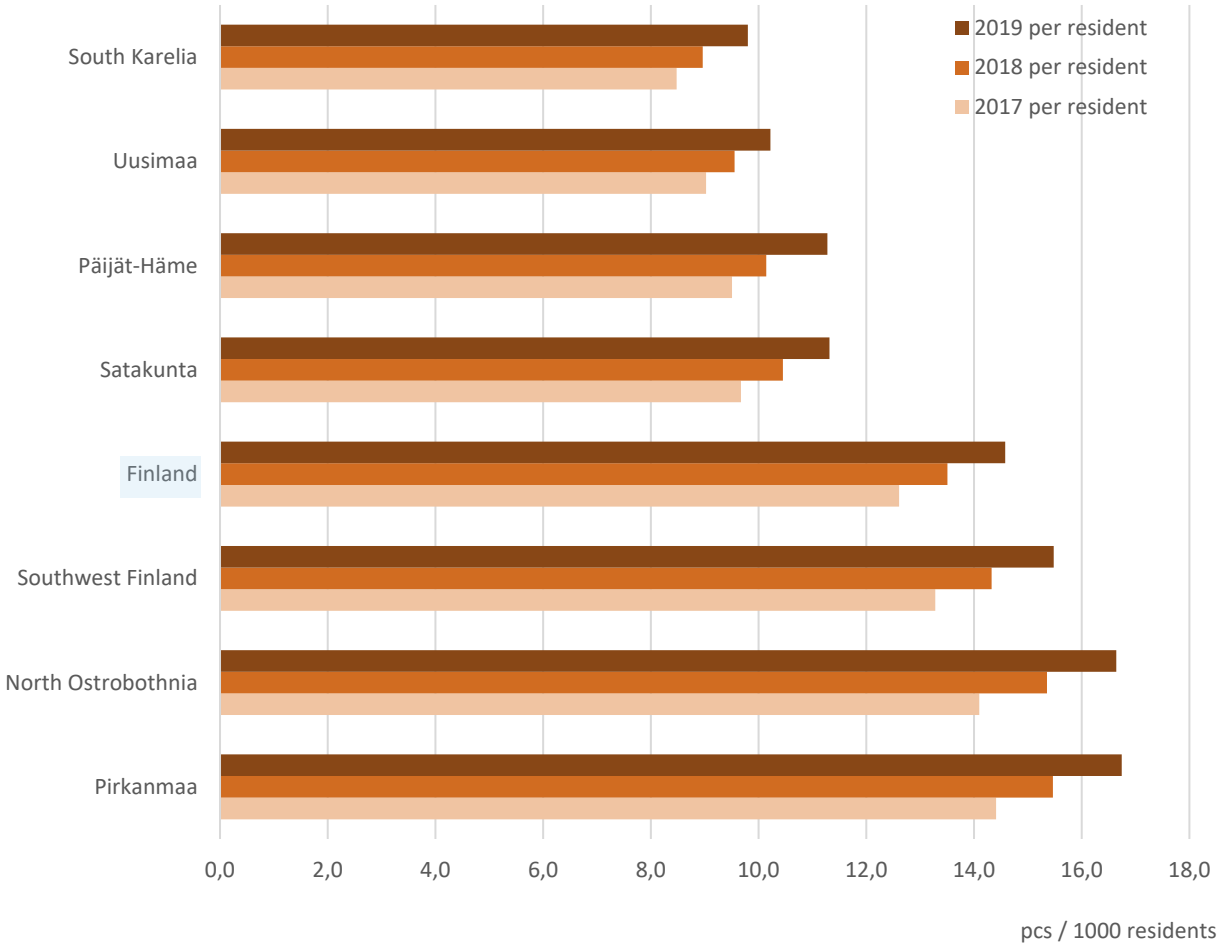


Figure 6. Buildings with ground source heating in the examined regions and in Finland on average per 1 000 residents in 2017–2019 (Finnish Environment Institute 2022).

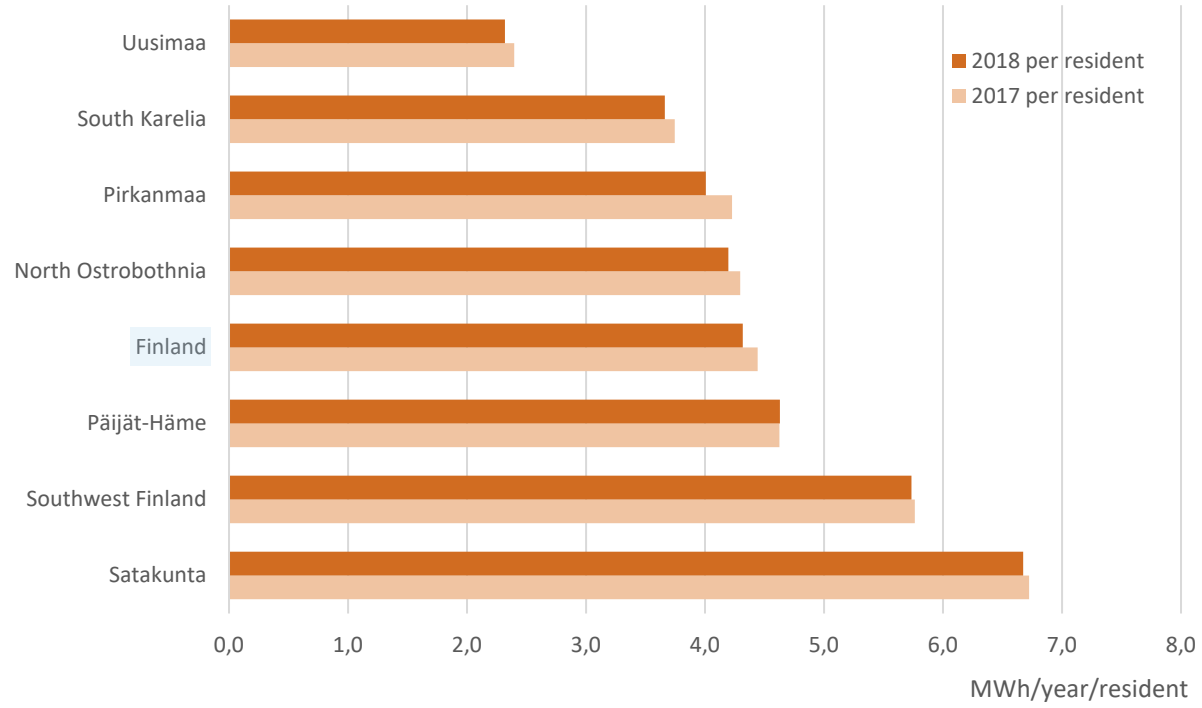


Figure 7. Use of oil for heating MWh/year/resident in the examined regions and in Finland on average in 2017 and 2018 (Finnish Environment Institute 2022).

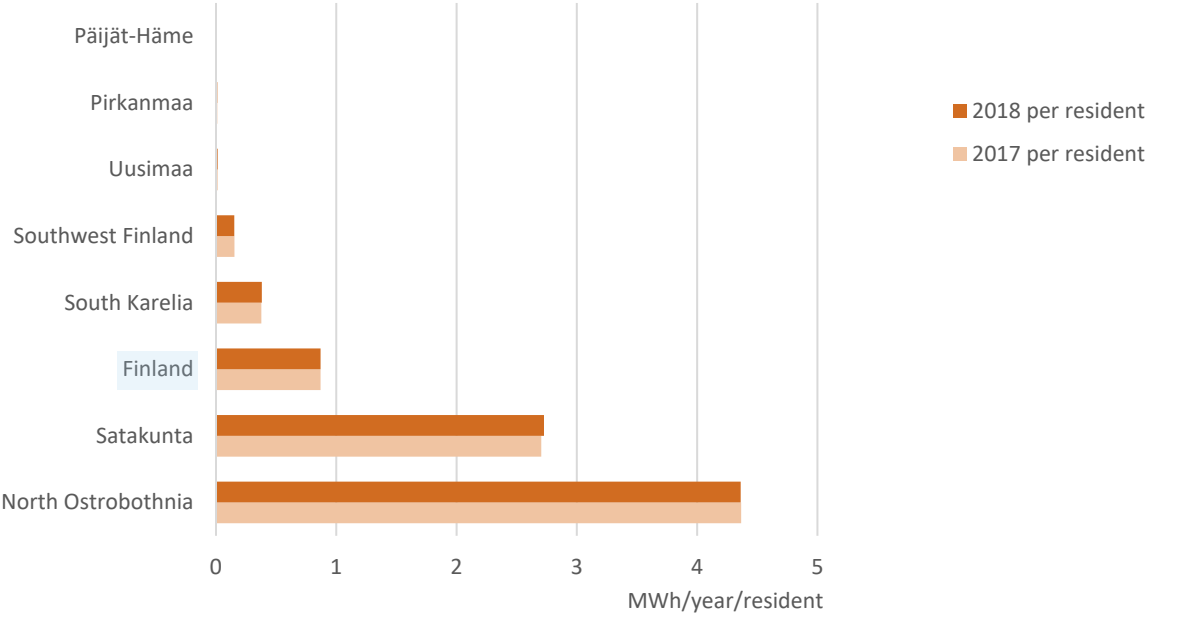


Figure 8. Wind power production MWh/year/resident in the examined regions and in Finland on average in 2017 and 2018 (Finnish Environment Institute 2022).

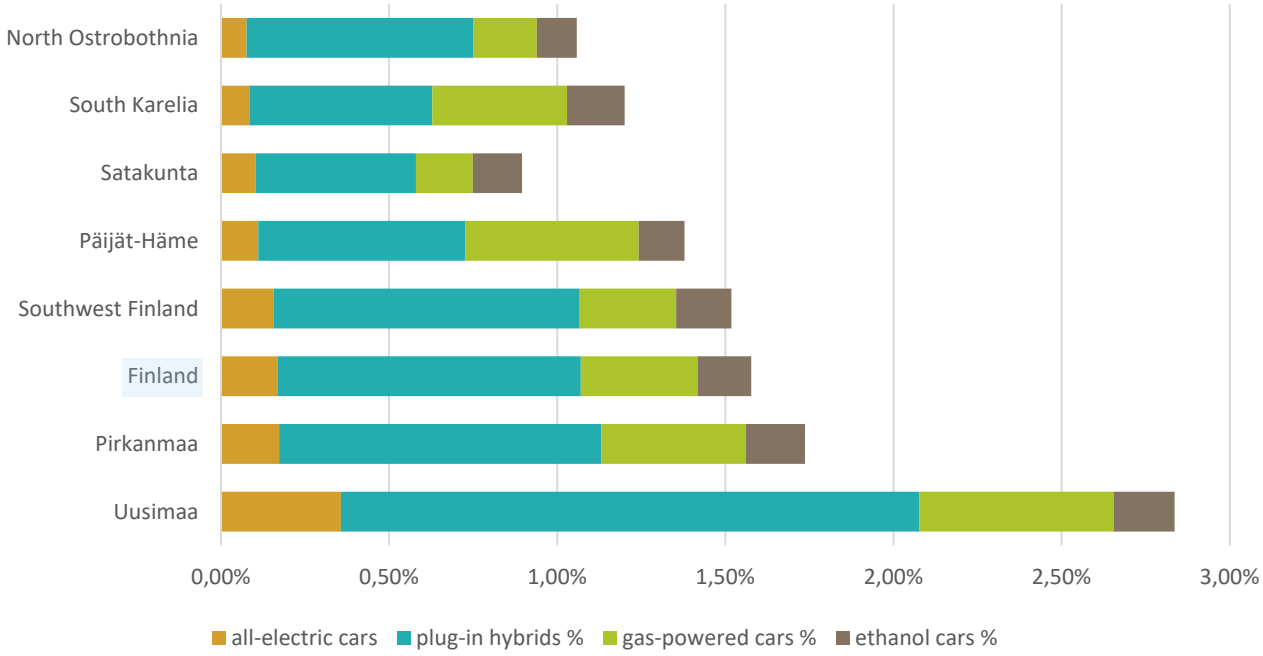


Figure 9. Shares of alternative fuels and technologies in on-the-road car fleet in the examined regions and in Finland on average in 2019 (Finnish Environment Institute 2022).

4.3 Carbon sinks of forests in the regions

The carbon sink of each region's forests is largely dependent on the forest area, age structure and amount of fellings. In terms of aiming for carbon neutrality, it is important to strive to maintain or increase carbon storages on a regional level. In many cases, maintaining and strengthening the carbon storages and sinks of forests require supporting decisions, measures and guidance as well as coordination with the commercial use of the forests. Alongside the trees, the soil in forest areas is a significant carbon storage, and the use of forests also impacts soil carbon sinks and emissions. In mineral soil areas, the carbon storage of the soil follows the carbon storage of the trees with some delay and becomes saturated when the forest has been mature for a long period and has time to grow without clear cuttings with short intervals. In nutrient-rich drained peatland forests, on the other hand, the plant litter from the trees is insufficient to replace the loss of "old peat" (i.e. organic matter accumulated before the drainage), which is why these areas are an emission source when used for forestry.

Especially in the regions of Southern Finland, the total annual growth of the forests has been close to the total drain in the analysis period, which is why changes in tree volume and, as a result, changes in carbon storages have not been significant in the past decade (Figure 10).

In all regions, especially in Southern Finland, a significant portion of the forests are owned by private parties (Figure 11). This means that the need for advice, various incentives and steering methods may be considerable if there is willingness to substantially increase the carbon sink or protected areas. Only small areas of forests are owned by municipalities and joint municipal authorities. The state's role as an owner is significant especially in North Karelia and North Ostrobothnia, which manages forests through state-owned enterprise Metsähallitus. Based on this, the significance of the cooperation between the state and municipalities is significant in these regions with regard to reaching the climate and conservation goals.

The amount of conservation areas in all of the examined regions is below the Finnish average (Figure 12). In the future, climate criteria could be applied in the prioritisation involved in selecting conservation areas.

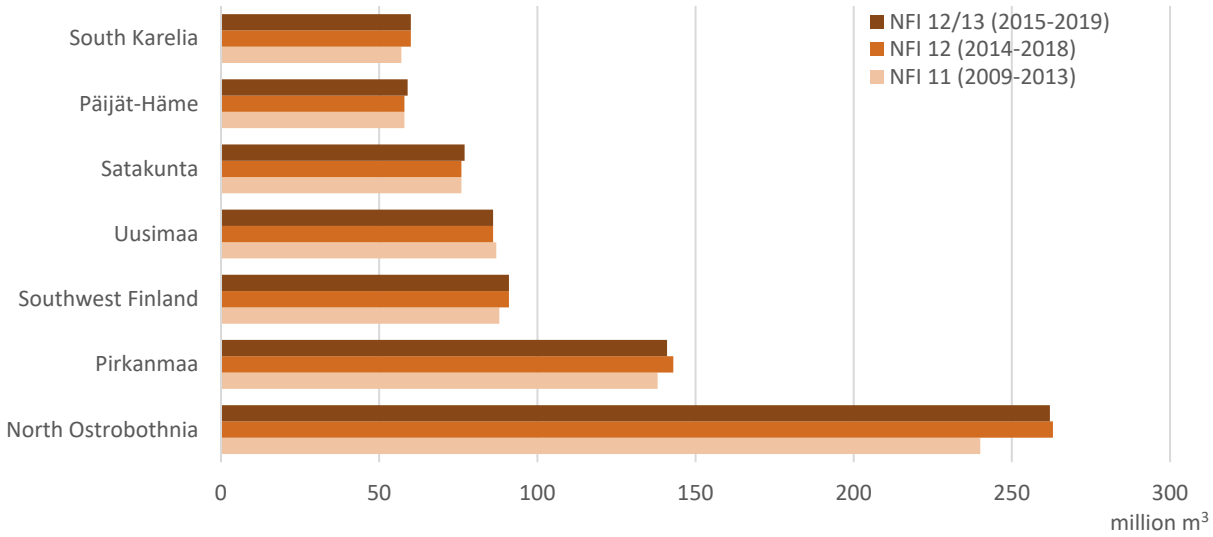


Figure 10. Development of growing stock volume on forest land and on poorly productive forest land (million m^3) in the National Forest Inventories (NFI 11–13) (Ihalainen et al. 2019).

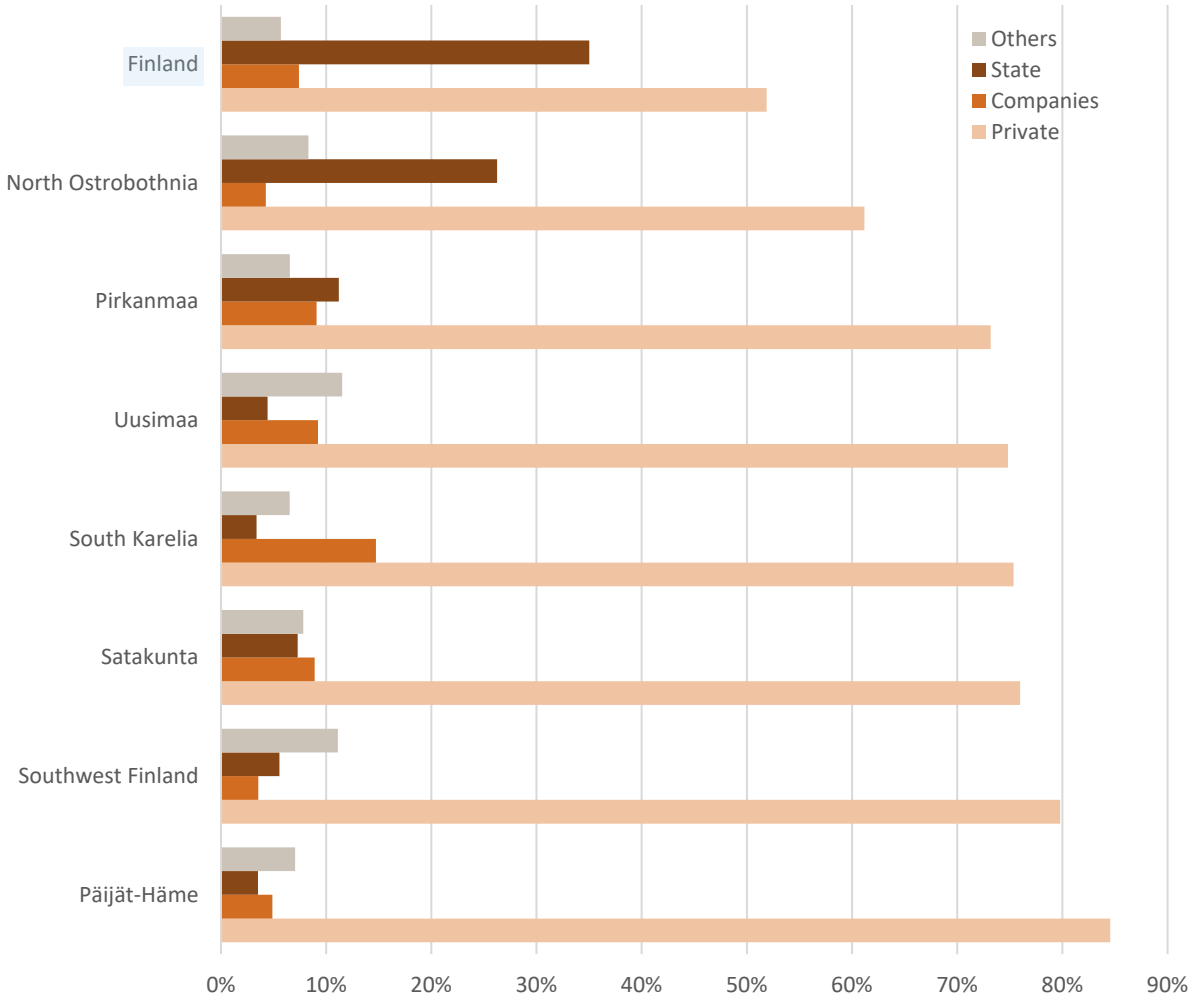


Figure 11. Ownership of forest land in the examined regions and in Finland as indicated by the forest inventory NFI 12 (2014–2018) (Ihalainen et al. 2019).

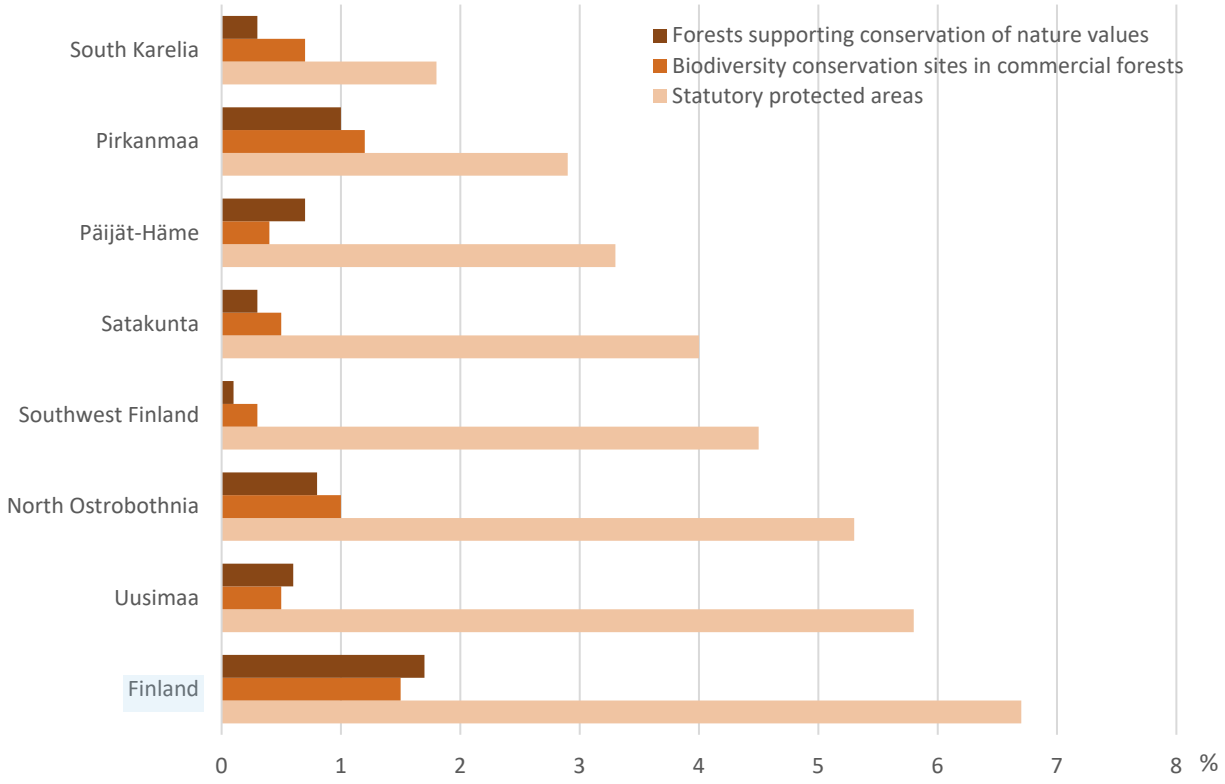


Figure 12. Protected areas, biodiversity conservation sites in commercial forests and areas supporting conservation of nature values; percentage of forest land in the examined regions and in Finland as indicated by the National Forest Inventory NFI 12 (2014–2018) (Ihalainen et al. 2019).

4.4 Assessment of the regions' emission reduction gap

Teemu Helonheimo, SYKE

The regions' emission reduction gap. i.e. the need for additional emission reductions, was assessed based on the actual emissions of 2017 (Figure 13), planned emission reduction measures and the emission reduction yielded by the national climate policy.

The emission reduction potential of planned measures was assessed by SYKE experts. For this purpose, a listing of decided and planned emission reduction measures in 2019–2020 was collected from the municipalities of the regions, managed by the regional climate coordinators of the Canemure project.

There was a great deal of regional variation in the quality and quantity of the collected measures. There were many reasons for this, such as the fact that the areas were different, there were no ready-made listings of the measures so the regional coordinator had to collect them from the municipalities directly, and it was difficult to determine the measures that would reduce emissions. The measures leading to an emission reduction that could be easily examined were assessed, but the majority lacked any numerical data to support the assessment of emission reductions. The listing also included measures that do not actually reduce emissions or that had already been implemented. These were excluded from the assessment. The majority of the listed and assessed measures were related to the energy use of buildings, energy production and transport. The assessment of the measures utilised direct data on actual emission reductions and, in the case of lacking information, estimates based on generalised emission factors and assumptions.

Finland's Medium-term Climate Change Policy Plan (KAISU) (Ministry of the Environment 2017) and the goals of its basic scenario (With Existing Measures WEM) until 2030 (Table 1) were included in the consideration of emission development. The assumed emission reductions by 2030 were added to the emission reduction potentials of each region. For each region, the reduction was compared to the

emissions of 2007. If the KAISU plan's basic scenario (WEM) indicated a lower reduction than the actual emission reduction between 2007 and 2017, the plan did not impact the assessment for the sector in question. On the other hand, if the actual emission reduction was lower than the assumed development according to WEM of the KAISU plan, the reduction potential was calculated according to KAISU.

Transport and areal use was aggregated from the following subsectors: new propulsions, energy efficiency of vehicles and transport system. Road, rail and water transport were included in this sector. Agriculture covers the respective emission sector. Oil heating, electrical heating and other heating were included in the calculation for individually heated buildings. Waste management covers the emission sector of the same name. Industry and machinery cover the emission sectors of industry and machinery.

Across the seven regions, the planned measures were estimated to reduce emission by roughly 4.7 Mt (22%), KAISU measures were estimated to reduce emissions by 3.9 Mt (18%) and thus the total reductions were estimated to stand at 8.6 Mt CO_2-eq (40 %). Despite the approximate nature of the assessment, the results indicate the scale of the emission reduction potential and help to estimate the quality and quantity of the additional measures needed. At the same time, an indicative understanding was reached on how far towards the goals the measures can take the regions.

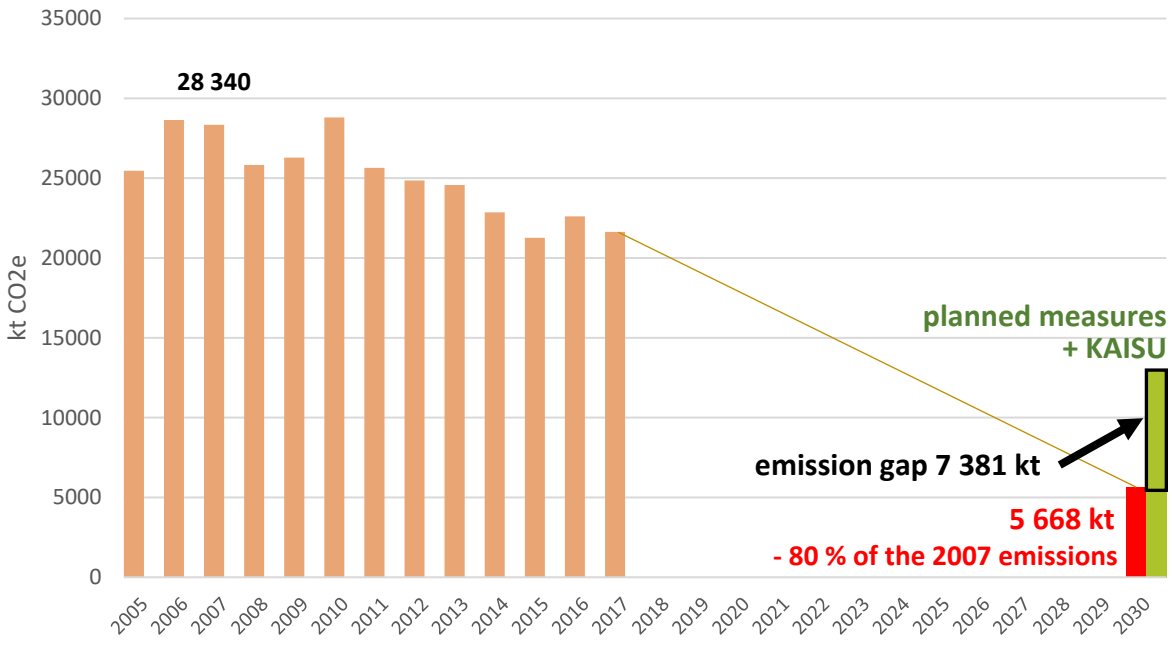


Figure 13: The emission gap of all the seven examined regions in relation to the goal of -80% from the 2007 emission level. Assessment includes emission development and reduction potential in the effort sharing sector of the regions; the emission gap is 26% of the 2007 emissions and 35% of the 2017 emissions.

Table 1. Goals according to Finland's Medium-term Climate Change Policy Plan
(assumptions of development from 2007 to 2030)

	Goal
Transport and land use	-41%
New propulsions	-20%
Energy efficiency of vehicles	-8%
Transport system	-13%
Agriculture	-7%
Separate heating of buildings	-50%
Waste management	-82%
Industry and work machines	-25%

The average emission reduction potential between 2007 and 2030 is 54%. This means that the average emission gap is 26% when aiming for emission reductions of 80% from the 2007 level (Hinku target, for example). Between 2017 and 2030, the emission reduction potential is 40% of the 2017 emissions. This is not comparable to the Hinku target and, instead, indicates how much the measures can reduce emissions after the 2017 level.

Based on the planned measures, none of the examined regions will reach the goal of 80% emission reductions from the 2007 level by 2030 (Figure 14). There is variation in the regions' emission gaps, i.e. how much emissions need to be reduced after the completion of the considered measures. The following list indicates the region-specific emission reduction need after planned and KAISU measures or, in other words, how much more reductions are needed in relation to the 2017 level to reach the goal.

- South Karelia: 49% (440 kt)
- Pirkanmaa: 25% (2 307 kt)
- North Ostrobothnia: 54% (1 475 kt)
- Päijät-Häme: 38% (841 kt)
- Satakunta: 27% (1 248 kt)
- Uusimaa: 27% (5 884 kt)
- Southwest Finland: 38% (2 070 kt).

The emissions and sinks of the land use sector were not included in the assessment, with the exception of the emissions of the agricultural sector. Alongside the measures to reduce fossil emissions, many regions are striving for carbon neutrality, in the same way as the entire country. In this context, the emissions and sinks of the LULUCF sector are also taken into account. This necessitates the inclusion of measures to increase carbon sinks in the roadmap. At present, they were largely absent in the climate roadmaps of the examined regions.

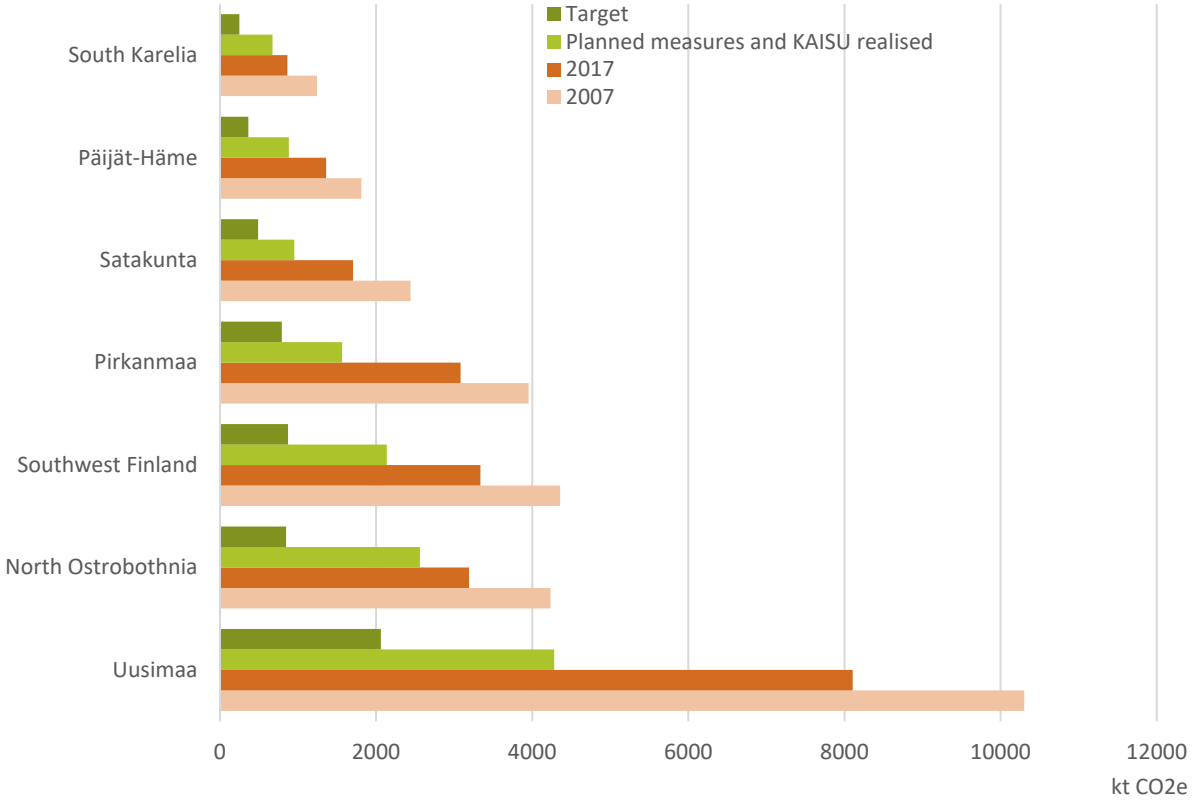


Figure 14. Realised regional emissions in 2007 and 2017 and scenario emissions (kt CO_2-eq).

4.5 The climate efforts of regions are connected to the promotion of regional vitality

The regions implement the sustainable development goals of the Finnish Government, the European Union and international agreements (incl. the EU Green Deal), which are aimed at strengthening climate measures, improving natural biodiversity and alleviate the vulnerability of people and livelihoods. Regional climate actions can create new business opportunities and jobs, expedite innovations and technological developments, and improve regional resilience to changes. It is important to carry out the regional low-carbon transition in a controlled manner, taking the varying starting points and needs of the areas into account. Each region has its own conditions and special characteristics, which is why climate roadmaps require regional customisation.

Cooperation between different actors is needed to achieve the emission reduction goals on a national, regional and municipal level. One natural cooperation level is regional. The most important role of regional actors in the mitigation of climate change is enabling and coordinating climate actions. Regional councils can steer land use, transport infrastructure and energy production requirements through development plans and city planning.

Regional councils are responsible for developing the structures of trade and industry to create and secure business activities and jobs. For this reason, it is important for the emission reduction measures to take the benefits to local economies into account. For example, investments in renewable energy yield immediate savings and earnings to local operators, but they also provide indirect and broader economic effects in the area (Karhinen 2020). The procurement and installation efforts of solar panels and ground source and air source heat pumps provide jobs. The impact on regional economy increases in proportion to the ability to procure products and services related to the energy investments from within the local area. Climate measures often gain wider acceptance when the local population takes part in their implementation. The investments can also generate new business activities, which increase the corporation and income tax earnings of municipalities. For example, the earthmoving and electrical works required for wind power investments are primarily procured from the vicinity of the construction areas, which creates jobs and local added value. Significant property tax earnings are also connected to wind power investments.

4.6 The implementation of climate efforts and climate roadmaps in the example regions

The Canemure projects involves seven regions: South Karelia, Pirkanmaa, North Ostrobothnia, Päijät-Häme, Satakunta, Uusimaa and Southwest Finland (Figure 15). In these regions, climate efforts have been promoted by a regional coordinator and supported by a regional working group. The key duties of the regional coordinators include communications, supporting the cooperation between the key actors, monitoring the efficacy of the roadmap and updating the roadmap. The communications include providing regional actors with information on the efficacy of the measures, the progress of the roadmap based on the monitoring, and the financing opportunities for climate efforts. The project has supported the preparation of regional climate roadmaps, which will be implemented in cooperation with the key actors in the field. The actual emission reduction measures are usually the responsibility of parties, such as municipalities, energy, transport and trade companies, building owners and agricultural entrepreneurs. In addition to these, business associations, the state and research organisations play a key role in achieving the results.

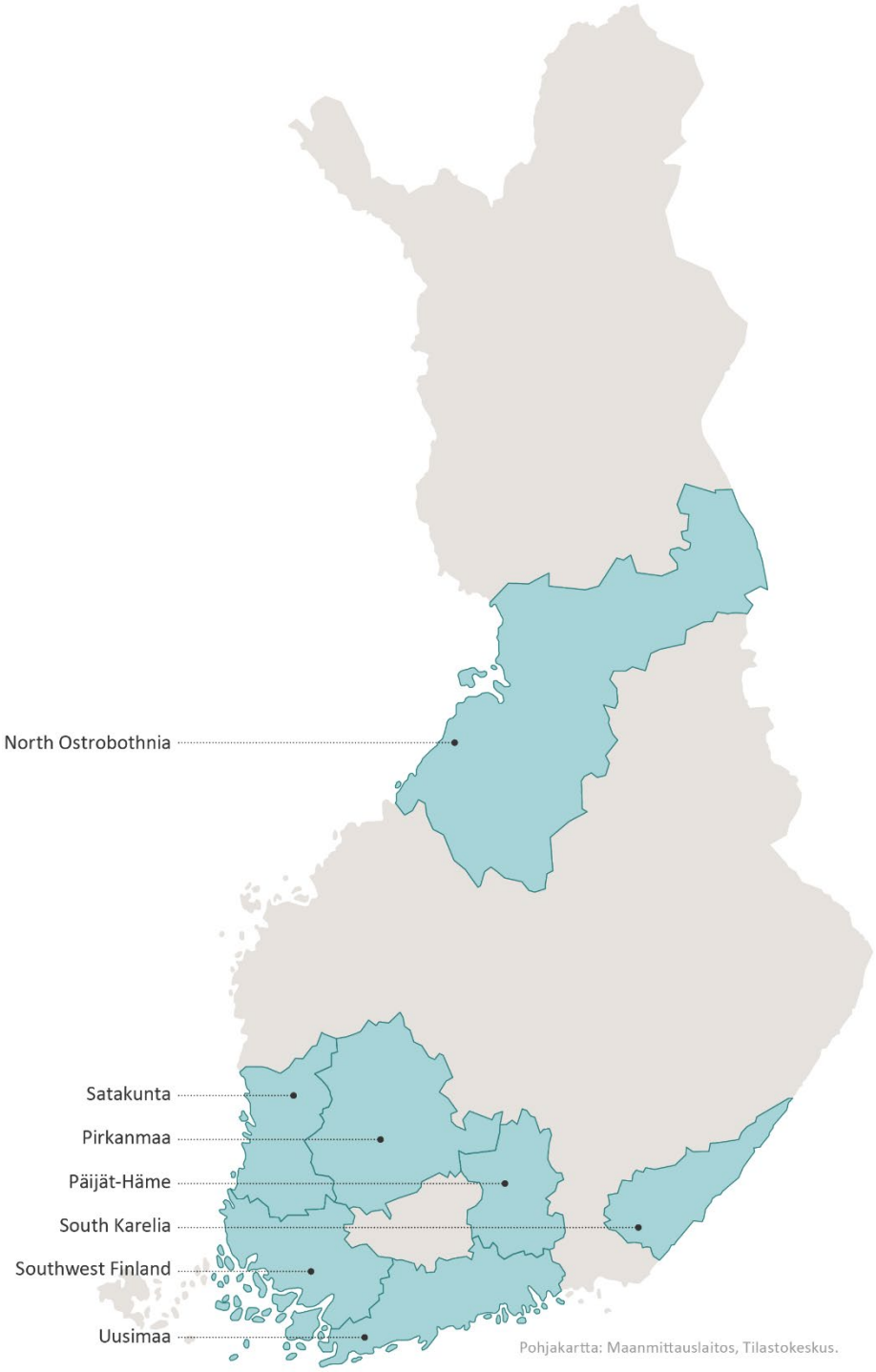


Figure 15. The examination includes the roadmaps of the Canemure project municipalities (light blue).

The roadmaps were prepared in cooperation with regional actors and SYKE experts. All of the involved regions conducted the roadmap efforts through a similar process (Table 2). However, the specific starting points of each region were taken into account in the implementation.

Table 2. Summary of the roadmap work processes.

Analysis of the initial situation: estimate of the emission gap and necessary additional measures	Roadmap preparation: setting strategic goals and emphases	Measures	Monitoring
- Determining current emissions (Syke Alas calculation). - Collecting initial data from municipalities through surveys/interviews. - Estimate of the emission reduction potential of planned and decided measures. - Estimate of the BAU development of emissions.	- Establishing a working group. - Workshops for interest groups. - Possible background analyses. - Other national and regional programmes, plans and roadmaps. - Comment/statement circulation (direct comment requests/open commenting opportunities).	- Implementing the measures/preparing a more detailed action plan. - Projectisation. - Actor engagement. - Distribution of operating models. - Communications.	Monitoring of regional emissions and indicators.

Among the strengths of the seven region's climate efforts, a few aspects stand out. The overall impression is that there is strong commitment and willingness for climate actions. For example, the Hinku status of South Karelia, Pirkanmaa and Päijät-Häme supports commitment and practical climate efforts in the regions. Both regional and national networking are seen to be in a good state, and cooperation with regional actors and networks such as the ELY Centre, regional council, energy companies and non-governmental organisations is found to be effective.

The regional coordinators find that specific weaknesses regarding climate efforts are the lack and decentralisation of resources. The practical implementation of the roadmap goals is often assigned to municipal environmental services, even though the organisation often lacks the authority or resources to ultimately carry out the measures. The justification of measures that will take years to yield benefits was also seen as a challenge.

The poor economic situation of the municipalities was thought to be a particular threat to the climate goals of the regions. As such, the practicalities of sustainability and the consideration of climate perspectives are often compromised as other aspects need to be prioritised. Some emission reduction measures were also found to be politically sensitive and polarising, such as reducing peat use and increasing wind power.

The regions generally found the EU Green Deal funding as a positive opportunity to gain more resources and expertise for climate efforts, which would also support regional economy. Substantial domestic law updates (e.g. amendments to the Land Use and Building Act, Climate Change Act and regional development legislation) are seen to support and streamline climate efforts in the future.

4.6.1 South Karelia

Petri Kero, City of Lappeenranta

The region of South Karelia is one of Finland's Hinku regions, which is committed to an 80% emission reduction by 2030 at regional level. Within the Canemure project, regional coordination is handled by the City of Lappeenranta. As a Hinku member, the entire region is committed to emission reduction, and Lappeenranta as the largest city in the region strives to profile itself as a pioneer in climate affairs.

The cooperation group formed to support the project includes members from municipalities, the University of Lappeenranta (LUT), Forest Centre, Forestry Management Association, The Central Union of Agricultural Producers and Forest Owners (MTK), ELY Centre and businesses. A representative

of the Regional Council of South Karelia serves as the chair of the cooperation group. The cooperation group convenes at least four times a year.

The roadmap for a carbon-neutral South Karelia was prepared in the spring of 2019 in a total of five workshops. Energy and energy systems, waste management, the circular economy, buildings and construction, traffic, carbon sinks and compensations, green procurements, communications and influence were selected as the main themes for the roadmap. Comments on the prepared roadmap were obtained from the regional cooperation group, interest group representatives and experts. After the comments, a little more than 100 measures in total were selected for the roadmap. In terms of practical measures and communications, the project cooperates with the regional Greenreality brand, for example.

In early 2021, the roadmap was presented in the regional employment committee and distributed to the local municipalities for comments. Based on the feedback, a decision was made to organise a separate tour of the region's municipalities for more in-depth familiarisation and engagement in 2021. The aims of the tour were to introduce municipal representatives to the content of the roadmap and action plan and determine the best and most effective measures to promote in the coming years. As one of the most significant emission reduction measures, South Karelia is seeking to increase the production of renewable energy substantially. In addition to joint projects, the main focus of driving the measures forwards is on the diffusion of operating methods between municipalities.

Estimate of the capacity to implement the roadmap

Strengths:

- LUT University, which has gained acclaim in the fields of energy, environmental technology and energy technology, is located in this region: the smooth cooperation with the university enables new innovative experiments and the rapid deployment of new technologies in the area.
- The region's energy production is already largely based on renewable sources.
- As regards district heating, the region intends to eliminate fossil fuels almost entirely within a few years.
- The regional Greenreality Network for businesses can be utilised to engage local companies in climate actions.

Weaknesses:

- Transport emission reductions in the area are a major challenge. Nearly 40% of the region's emission are attributable to traffic, and the percentage is increasing. The region is fairly large in proportion to its population, and commutes between municipalities are quite common. The region's vehicles are generally fairly old, and the charging infrastructure for EV's is somewhat deficient.
- The permit restrictions set by the Finnish Defence Forces in relation to the regional control of wind power construction have practically halted the additional construction of wind power in the area.
- The majority of South Karelia's municipalities are small and have limited resources for municipality-specific climate efforts.

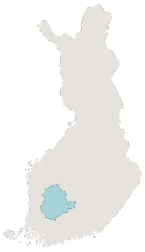
Threats (bottlenecks):

- The electrification of traffic is slow in Finland, and the methods of steering people towards low-emission vehicles are lacking. Reducing water cargo transport through Saimaa Canal would significantly increase lorry traffic in the area.
- Increasing forest felling in the area reduces carbon sinks.
- The obstacles to building more wind power cannot be dismantled, and new renewable energy production capacity will not be constructed in the region to any substantial degree.

Opportunities:

- The region's innovative and exploratory approach will help utilise the EU Green Deal funds in the area. The lessons learned from trials and pilots can be deployed quickly in the local municipalities.
- The municipality's own biogas plant and possible synthetic fuel plant can help with emission reductions in the transport sector.
- In addition to this, low-emission cargo ships of the future and lengthening the canal closures will provide an opportunity to reduce the emissions of freight transport for the industry.

4.6.2 Pirkanmaa



Liisa Hyttinen and Eero Purontaus, Council of Tampere Region

Pirkanmaa was among the first regions to join the Hinku network as a region. The region is committed to an 80% emission reduction by 2030. This commitment was made jointly by Council of Tampere Region and the ELY Centre for Pirkanmaa.

The starting points for climate efforts have been favourable in Pirkanmaa. One of the emphases of the regional strategic programme for 2018–2021 is building a sustainable region. The circular economy is one of the focuses of Pirkanmaa's smart specialisation strategy. The strategic focuses of the ELY Centre for Pirkanmaa form a solid foundation for Hinku measures within the region: climate change is mitigated, adaptation is supported, communities are developing in a sustainable manner, circular economy and bioeconomy solutions are increasing, and natural resources are being used sustainably. Pirkanmaa is also widely preparing municipality-specific and areal roadmaps and programmes aiming for carbon neutrality.

The role of the Carbon Neutral Pirkanmaa 2030 roadmap in regional climate efforts has been to bring together the carbon neutrality efforts of regional actors, municipalities and the Tampere City Region. Towards the beginning of the roadmap efforts, a workshop for representatives of the municipalities and the Tampere City Region was organised. The workshop primarily focused on the expectations and needs of the municipalities with regards to regional climate efforts and the themes and measures covered by the roadmap to be prepared. Later during the various preparation phases, the roadmap was actively presented in a variety of meetings, interest group events and forums. These have included Pirkanmaa's regional government, the meeting of municipal leaders, the environment and climate division operating under the regional government, Pirkanmaa's climate roadmap cooperation group[3], the transport system work group of the Tampere City Region, the climate work group of the Tampere City Region, and the management meetings of the Council of Tampere Region and the ELY Centre.

The policies and contents of the roadmap were coordinated with the essential national and regional programmes, plans and roadmaps aiming for carbon neutrality. In the preparation phase, the roadmap was also sent to 34 experts from different fields for comments on its main themes. In selecting the experts, the aim was to ensure a balanced group of specialists that would approach the subject matter from different perspectives and levels (for example, representatives of regional operators, municipal operators, research organisations, companies, interest organisations, etc.). A total of 27 expert comments were received. The roadmap was modified based on the expert comments. After this, the roadmap was processed by the regional government's environment and climate division, which circulated the roadmap for comments. A total of 19 statements were received, seven from municipalities and eleven from other operators. The roadmap modified based on the comments was brought to the regional government for processing and approval on 17 November 2020. The various actors in the region have also been engaged by means of communicating on the roadmap in a variety of ways. In addition to this, the roadmap has been presented widely at interest group events, forums and events in the area.

[3] The cooperation group for Pirkanmaa's climate roadmap includes representatives of local municipalities and the regional council, ELY Centre, university sector, Forestry Management Association, MTK, nature conservation district, Diocese of Tampere, Student Union of Tampere University, Ekokumppanit, Tampere City Region, Tampere Chamber of Commerce and Federation of Pirkanmaa region Enterprises.

The Carbon Neutral Pirkanmaa 2030 roadmap identified six key emission reduction themes. The main themes were formed based on the themes most commonly addressed in similar examinations. After this, the largest emission sources in the Pirkanmaa region were analysed and the instances of highest emission reduction potential were determined. Moreover, the coordination with the roadmap for the Tampere City Region, for example, affected the choice of the emission reduction themes. The themes were selected to bridge gaps in the examination in the city region, such as agriculture and forestry. The following were chosen as the main emission reduction themes on this basis: 1. Transport and mobility, 2. Energy production and energy efficiency, 3. Urban structure and construction, 4. Responsible solutions in trade and industry, 5. Agriculture and forestry, and 6. Carbon sinks and compensation.

In selecting the measures, the approach was to form an applicable toolkit. The roadmap toolkit contains concrete measures and examples that the various regional operators can implement as part of their own climate efforts. Naturally, the roadmap also includes municipal-level measures. The roadmap did not examine climate change adaptation measures, since they are specified in the carbon neutrality roadmap for the Tampere City Region, for example. In addition to this, it was agreed that the measures for individual climate-conscious residents would be addressed in the roadmap for the Tampere City Region and the municipalities in the area. The measures were also selected from the perspective that they promote the systemic change in various operating systems. The measures to expedite change were classified as follows:

1) Changes that affect structures such as various infrastructures – very significant emission reduction potential.
2) Change that impact operating models; for example, creating an enabling structure in which norms, valuations and attitudes can change –significant emission reduction potential.
3) Change that affects operating methods; for example, day-to-day solutions for individual actors/daily activities – important emission reduction potential.

At the moment, two methods have been selected for the promotion of the roadmap measures: generating projects for the region and peer support workshops.

The project generation means the coordination of financial instruments, i.e. information distribution, communications and bringing the right project operators together (cooperation through networks). Projects are sought through concrete collaboration with the municipalities and various operators in the area. This means finding the right partners to meet the shared needs and challenges, locating the right financial instruments, and creating ideas for new projects and bringing them to fruition.

The peer support workshops are facilitated events for municipalities and other municipal actors in which they can learn from experts and each other about the possibilities of implementing a specific roadmap measure in practice. The basic idea is that the representatives of a municipality talk about one of their own successful measures so that other municipalities can learn from this and apply the lessons learned in their own areas. The events can also address the bottlenecks of climate efforts and consider how to overcome them. In order to develop a shared range of measures, possible roadmap measures are considered in advance and municipal representatives are heard on their thoughts and needs. Based on this, the range of measures to push forwards is developed together.

Estimate of the capacity to implement the roadmap

Strengths:

- Wide regional cooperation networks focused on climate issues.
- Presence of climate efforts in regional strategies, the regional land use plan and spearhead projects for smart specialisation.
- Strong education and research organisations.
- Increasing interests in practical climate measures among municipalities.

Weaknesses:

- The current project funding does not suit concrete investments and measures that would support the implementation of the climate roadmap.

Threats (bottlenecks):

- The resources and expertise of the organisations are insufficient for managing projects supporting climate efforts.
- Difficult financial situation of the municipalities.
- Environmental matters are being siloed and set aside in decision-making.
- The culture and attitudes are not changing fast enough.
- Regional disparities in the implementation of climate efforts.

Opportunities:

- An increasing percentage of EU funding will support climate efforts in the upcoming programme period.
- EU and national laws require an increasing number of measures to reduce emissions.
- Climate efforts will be incorporated in the municipalities' budgets and other key operations.

4.6.3 North Ostrobothnia

Ritva Imppola, Oulu University of Applied Sciences

Oulu University of Applied Sciences has served as a regional coordinator in the national Canemure project coordinated by the Finnish Environment Institute since November 2018. The Council of Oulu Region, in turn, initiated the North Ostrobothnia Climate Roadmap project in 2019. The aim was to collaborate in drawing up a climate roadmap for North Ostrobothnia and get local decision-makers to commit to climate goals.

The roadmap efforts were guided and regularly commented on by two cooperation groups: the local climate work advisory committee appointed by the regional government of North Ostrobothnia and the regional cooperation network of the Canemure project, both of which included representatives of the most important regional partners in terms of climate efforts.

The initial data for the roadmap was collected through a survey sent to the municipalities, calculations of the Finnish Environment Institute on the greenhouse gas emissions of the region's effort sharing sector, and the specification of the operating environment. In order to determine the key themes, three public workshops were organised, the first of which involved considering the current state of the region, the second covered the goals of the climate efforts and the last one addressed the key themes identified and the solutions. In addition to this, a separate expert workshop was held around agriculture, as the theme is of regional importance.

Alongside agriculture, the key themes of climate work identified in North Ostrobothnia are smart bioeconomy and circular economy, energy, traffic, land use, forests and wetlands, and cooperation. Adaptation to climate change is related to all the key themes. In order to support the roadmap efforts, events were organised in which climate issues were discussed with local residents in person. The tour began in the IlmastoAreena climate event held in the municipality of Ii in August 2019. Afterwards, the climate discussion was continued in the context of many other events. These events reached an approximate total of 850 people interested in climate issues from preschool children to adults. At the events, each one of them voted for their own personal climate promise, for example. The events showed that people are willing to change their own habits to expedite climate change mitigation, especially to reduce food wastage and sort waste.

The climate roadmap efforts involved commissioning additional analyses related to the most prominent emission sectors. The efforts were guided by separate expert groups. The analyses were as follows:

1) Low-emission traffic – propulsion-based calculation model for road traffic and the potential of propulsion changes.
2) Sustainable utilisation of agricultural biowaste fractions and side streams and the impacts of measures in North Ostrobothnia.
3) Development of the energy use of peat in North Ostrobothnia, and impacts on the timber procurement chain and greenhouse gas emission.

In addition to this, the roadmap efforts utilised previous analysis and regional programmes, such as the regional traffic system plan and forest programme for North Ostrobothnia.

The arrangements for organising workshops and events were changed due to the coronavirus restrictions, and the majority of events were held remotely after March 2020. Towards the end of 2020, the roadmap efforts had progressed to a phase in which the materials, analyses, expert and workshop outputs, and key themes were complete. This led to the synthesis phase in which the jointly collected materials were formed into a climate roadmap for North Ostrobothnia. The approach of finding solutions instead of culprits has been fruitful, and the region is committed to the roadmap created as a result of the efforts.

The long-term work and experience of the parties involved, as well as the relevant opportunities to influence operations, have been utilised in setting the regional climate goals and measures. The climate roadmap created based on the latest data and interaction includes a description of the current state, the key themes and related measures, and an operating model for monitoring and promotion.

The climate roadmap for North Ostrobothnia extends to 2030. Climate goals are a key element in regional development and spatial planning. In addition to climate goals, it is important to pay attention to livelihoods in the region and also encourage new regional business opportunities enabled by climate change mitigation. Sustainable and energy-efficient decisions support well-being widely from the perspectives of residents, trade and industry, and the environment.

The cooperation network created through the roadmap efforts will continue its activities to support diverse climate efforts in the area. As a regional development authority, the Council of Oulu Region coordinates meetings of the cooperation network in cooperation with the Canemure project. The regional actors engaged in active climate efforts will convene two to three times a year.

Estimate of the capacity to implement the roadmap

Strengths:

- The municipalities show genuine interests towards climate efforts.
- The region has significant opportunities and willingness to produce renewable energy.
- The parties involved have committed to the goals set through wide-ranging cooperation.
- Climate goals are a key element in regional development and spatial planning.

Weaknesses:

- The implementation of transport arrangements is challenging in sparsely populated areas.
- The municipalities do not have enough resources for climate work and applying for related funding, for example.
- Peatlands and the use of peat are a sensitive subject in the area.

Threats (bottlenecks):

- The slow pace of changes.
- Resources allocation to areas other than climate efforts due to the possible prolongation of the pandemic.

Opportunities:

- The region's climate goals support not only climate change mitigation, adaptation and the retainment of biodiversity, but also the regional economy.
- National funding and the EU's Green Deal programme and other programmes focusing on regional and structural policies provide substantial resources for climate efforts.

4.6.4 Päijät-Häme

Maarit Virtanen, The Regional Council of Päijät-Häme

In Päijät-Häme, regional climate efforts are coordinated by the Regional Council of Päijät-Häme and the region's climate work group. The group includes representatives of all ten regional municipalities, LAB University of Applied Sciences, LUT University, ELY Centre for Häme and Lahti Energia. The ELY Centre for Uusimaa has also been invited to participate with regard to traffic-related themes. The climate work group convenes four times a year. The themes of the meetings have included the climate roadmap for Päijät-Häme, promotion of biogas, funding the green transition and adaptation to climate change. However, the most important thing about the meetings is the opportunity to exchange information about topical themes and agree upon cooperation.

The process of preparing the climate roadmap for Päijät-Häme began in early 2019 and included a total of five interest group workshops on various themes and information collection, especially from municipalities. Päijät-Häme gained Hinku status in late 2019, which clarified the goals of the climate work and increased shared commitment. The climate work group and other regional operators and partners were asked to provide comments on the draft roadmap, which was prepared based on the workshops and other information. In addition to the direct comment requests, the climate roadmap draft was available for open commenting through the website of the Regional Council of Päijät-Häme. The regional government approved the roadmap in October 2020.

The themes of the climate roadmap are related to sectors where emission reductions are vital and themes that are otherwise important for reaching the goals and increasing carbon sequestration. The themes of the roadmap are energy, traffic, the circular economy, agriculture, forests and land use, decision-making and climate-based management. The themes have been used to collect known measures and assess their effectiveness. As regards the circular economy, the climate efforts are directly linked to the implementation of the region's circular economy roadmap. In terms of traffic, the focus is particularly on the efforts relating to the region's transport system and the measures determined in this context.

Project activities are important for promoting climate and sustainability goals. The institutes of higher education in the area actively utilise a variety of funding sources, and the goals is for companies, too, to seize opportunities provided by the green transition funding on a broader scale. As a new initiative in business collaboration, regionwide climate partnership activities have been started between businesses and municipalities. The aim of this operating model is to encourage companies towards climate efforts and to better highlight the needs of the business sector.

Estimates of the capacity to implement the roadmap

Strengths:

- Wide commitment to shared goals – the commitment is supported by the region's Hinku status.
- Cooperation within the region and national networking.
- The regional actors conduct a wide range of measures that support the reaching of these goals.

Weaknesses:

- The measures listed in the climate roadmap are not enough to reach the climate goals.
- The challenge is achieving systemic change and making decisions that support sustainability goals even when their benefits will only materialise over the long term.

- In many municipalities, climate efforts are still too often assigned exclusively to the environmental sector, which means that there are shortcomings in the relevant authorities and resources.
- Lacking resources especially in smaller municipalities, and therefore goals may not necessarily lead to actual concrete measures.

Threats (bottlenecks):

- Short-sightedness in decision-making.
- Climate and sustainability aspects are not considered sufficiently, especially if the municipalities do not have enough finances.
- The measures are insufficient to effect wider change.
- The increasing atmosphere of confrontation impedes political decision-making on a national and local level.

Opportunities:

- Utilisation of green transition funding in companies and project activities.
- Stronger cooperation between municipalities and companies through climate partnership activities.
- The increasing appreciation and valuation of local nature has a wider impact on resolving the sustainability crisis.

4.6.5 Satakunta

Meri Olenius, Satakunta University of Applied Sciences

In the region of Satakunta, the roadmap work was steered towards updating the climate and energy strategy until 2020 for the region, prepared in 2012. The starting point for the updating efforts was the application of the national energy and climate strategy and medium-term climate policy on the regional level and extending the coverage of the strategy to 2030. The preparation of the strategy was steered by a regional cooperation group, which included representatives of many local interest groups and municipalities. The regional cooperation group included Satakuntaliitto, the region's Hinku municipalities (Pori, Rauma, Eurajoki and Harjavalta), The Central Union of Agricultural Producers and Forest Owners (MTK), Pyhäjärvi Institute, Satakunta Central Hospital, Prizztech, the environmental office for southern Satakunta, Kankaanpää, ELY Centre for Southwest Finland, Satakunta Chamber of Commerce, Pro Agria Western Finland and the Satakunta district of the Finnish Association for Nature Conservation. Approval from the regional cooperation group was obtained in the various stages of preparing the strategy.

The phases of the preparation process included determining the climate efforts of the municipalities, interest group workshops, strategic goals, operational emphases and suggestions on measures, comments from relevant parties, impact assessment, and approval of the strategy.

As many different parties as possible were included in the preparation process by a variety of means. In the first phase, a municipal survey was conducted and the representatives of as many local municipalities were met and interviewed. The purpose of this was to map out completed and ongoing climate measures and views on the strategic themes prepared in 2012.

After the meetings with the municipal representatives, work proceeded with an electronic survey and workshops. The survey aimed to determine how the themes of the strategy prepared in 2012 were seen today. The suggested measures to be included in the themes of the strategy were processed in the workshops where participants presented their views on the measures with which the goals could be achieved. The strategy draft was provided to the Canemure project's regional cooperation group, interest groups and municipalities for comments and statements.

The process of formulating the strategic themes was approached by means of a top-down method. The starting points were the climate and energy policies of the EU and Finland. After this, regional policies and the special characteristics of the municipalities were addressed. In 2018, Satakunta was the largest producer of electricity in Finland, with nuclear energy accounting for more than 80% of the electricity produced by the region. In addition to high energy production, the industrial sector of Satakunta consumes a great deal of energy (Finnish Energy 2021). The substantial emission reduction potentials and Satakunta's profile as a diverse producer and consumer of energy are the basis for the goal named 'Satakunta of Sustainable Energy Solutions.' The carbon neutrality goal in Satakunta's 2030 climate and energy strategy stems from Finland's national goal of becoming carbon neutral by 2035. Satakunta has set the year 2030 as its goal. The key starting point for the 'Climate-Smart Satakunta' goal is the Finnish Government's report on the medium-term climate policy plan for 2030 and its theme 'Towards Climate-Smart Day-to-Day Living.' Suggested measures created with interest groups were also included in each goal.

The strategy is being implemented in cooperation between a variety of parties. The cooperation centres around a variety of projectisation measures through which Satakunta can pilot solutions and use them to establish permanent good examples, taking the special characteristics of the region into account. The implementation primarily focuses on the effort sharing sector, which encompasses domestic traffic, separate building heating, work machinery and other energy use outside the emissions trade sector, waste management and agriculture.

Estimate of the capacity to implement the roadmap

Strengths:

- Commitment to climate goals and shared motivation across the region.
- The continuous visibility of the matter.
- Climate change is a Priority value and overarching theme in the regional strategy.

Weaknesses:

- Lack of human and financial resources for implementing the measures.

Threats (bottlenecks):

- Confrontation in decision-making.
- Insufficient impact of the measures.
- Lack of commitment to the measures.

Opportunities:

- Utilisation of funding.
- Cooperation between municipalities and regions (sharing best practices).
- Ensuring that the willingness to mitigate climate change becomes ordinary.
- Support for the measures from municipal residents.

4.6.6 Southwest Finland

Merja Haliseva-Soila, ELY Centre for Southwest Finland

In Southwest Finland, the Canemure regional coordination project is managed by the ELY Centre for Southwest Finland. The project group includes experts from the ELY Centre, the Regional Council of Southwest Finland and Valonia. Since 2019, the region's climate efforts have been promoted by the climate responsibility division, which operates under the Regional Management Committee and also serves as the cooperation group for the Canemure project.

The climate responsibility division (31 members) includes representatives of the municipalities, energy companies, economic development centres, waste management companies, trade unions, institutes

of higher education, research bodies and regional administration. The division is tasked with preparing and developing regional climate policies, engaging operators in different fields in the development and implementation of climate-positive solutions and operating models, promoting the implementation of the regional programme in matters related to climate change, monitoring the discussion, research and especially decision-making around climate change, and making suggestions on operating policies suitable for Southwest Finland. Other aims include promoting the interaction between trade and industry, public administration, and education and research related to climate change, and fitting together and coordinating project activities related to the relevant themes.

The setup is highly representative and has provided an opportunity to delve deeply into the issues faced by the various sectors. The division's meetings have involved expert presentations, based on which the processes of specifying the change goals and measures for each theme have been initiated. After the groundwork laid by the division, each theme has been addressed through webinars, roundtable discussions and other forms of contact. Participation has been active.

The first phase of the roadmap involved setting a goal of making Southwest Finland carbon-neutral by 2035. The roadmap process was set to be cyclical, since the rate of change is increasing and it is difficult to anticipate new technologies, for example. Three sectors that are essential in terms of emission were selected as the themes of the first phase: energy, transport and agriculture. After the varied discussions, an online survey on the change goals and measures of the roadmap was made available for the duration November. The survey yielded 256 responses and generated active social media and e-mail discussions. Based on the results of the survey, the roadmap draft was updated and specified. The roadmap was published on 1 February 2021.

The themes to address in 2021 were land use, urban structure, construction and carbon sinks. The second phase will be published in 2022. The parties involved will also take this opportunity to assess the development of emission reductions and revise the selected change goals and measures.

Achieving systemic change requires, on the one hand, activities with sufficiently broad focuses and, on the other, eventually engaging every relevant party and individual in some way. Alongside the aforementioned themes, the roadmap can be supplemented at least with themes related to public procurement, consumer behaviour and biodiversity as well as links to adaption to climate change.

In order to increase awareness of the roadmap and speed up its implementation, efforts have been made in communications, especially through websites (ymparistonyt.fi) and newsletters. There is a desire to make the regional climate measures visible to everyone and help interest groups to distribute information on events and successes. Communications on financial instruments and application periods are released actively.

The implementation is focused on diverse cooperation with municipalities. Climate meetings for municipalities are organised multiple times a year. Through surveys, municipalities have been requested to provide statements on the measures that they will take to contribute to the implementation of the roadmap. Discussion and workshop events are also organised for other operators to speed up the measures. Efforts are being made to resolve any bottlenecks for development. As regards implementation, the aim is to utilise existing cooperation forums, which include regional strategy preparation groups, the cooperation group for land use, working groups for the traffic system and LHT, and groups related to funding programmes.

Estimate of the capacity to implement the roadmap

Strengths:

- The cooperation group that represents multiple fields and has a great deal of influence, and the good cooperation within the key organisations, such as the ELY Centre, Regional Council, Valonia and the largest cities.
- Matters related to the climate are constantly represented in the media.
- Pioneering activities of large organisations.

Weaknesses:

- The low resources of the Canemure project in relation to the roadmap's goals for change and the necessary measures.
- Emission calculations on emission development that are lagging behind causes frustration among the operators involved.

Threats (bottlenecks):

- The poor state of the economy in municipalities.
- The municipalities' lack of resources and thereby expertise.
- Political opposition
- The continuation/recurrence of the pandemic.

Opportunities:

- The EU's Green Deal funding and recovery funding.
- Goals of the government programme.
- Major legislative amendments (Land Use and Building Act, Climate Change Act, Regional Development Act).
- Nature positivity strengthened by the pandemic.

4.6.7 Uusimaa

Simo Haanpää and Pia Tynys, Helsinki-Uusimaa Regional Council

In Uusimaa, the decision on preparing the Carbon Neutral Uusimaa 2035 roadmap was made by the Regional Assembly in December 2018. The roadmap efforts supported by the Canemure project were initiated in late spring 2019 with the preparation of a situational picture on climate efforts, i.e. a municipal analysis. The round of interviews that covered nearly all municipalities in the region examined the initial state and challenges of municipal climate efforts, measures already completed, and the municipalities' wishes regarding the Council's climate efforts. At the same time, good collaborative relationships were formed with the key persons in municipal climate work.

The Helsinki-Uusimaa Regional Council, ELY Centre for Uusimaa, Helsinki Regional Transport Authority (HSL) and Helsinki Region Environmental Services (HSY) established a joint working group to steer and support the roadmap efforts. The wider regional climate cooperation group that was already in operation was also engaged in the efforts to steer climate work. At the same time, this group serves as a regional coordination and steering group for the Canemure project.

The most important focus points of the region's climate efforts were identified by the Council's experts during the 2019–2020 winter, based on factors such as the feedback received in the roadmap presentation events and the policies laid down in relation to the EU's funding instruments. The focus points were used to identify and categorise key operating policies for reducing emissions within the region. These were presented and discussed at multiple events and cooperation meetings. The aim was to prepare a broad pool of measures from which all interest groups could identify operating models that are essential to their own climate efforts.

Due to the coronavirus pandemic, the extensive interest group workshops planned for the spring of 2020 had to be cancelled, and operating policies were prepared in late spring by the aforementioned more limited working group. The policies were presented to the region's municipalities in virtual workshops in May. The participants had the opportunity to comment on and develop the policies in the workshops and through an electronic platform. Through joint streamlined SWOT analysis, the workshops also outlined the strengths and weaknesses of the region's climate efforts to support further measures. In Uusimaa, the regional approach was seen as a good basis for cross-municipal climate work, even though shared challenges and opportunities can also be identified even on a wider scale.

The focus points and operating policies of the climate roadmap were addressed by the Regional Board and Regional Management Committee (MYR) in June 2020. In order to ensure sufficient interaction, they were sent to municipalities and key regional actors for statements during the period 17 June–4 September 2020. The materials were also presented on the Council's website to ensure that the views of local residents were heard. The final roadmap highlighted six focus points under which 42 collections of measures were identified.

The climate roadmap was edited based on the feedback during the autumn, and the process was revised in relation to the Council's various programmes. At the same time, preliminary efforts were made to identify the network of different actors, interest groups and monitoring indicators. The effectiveness of the operating policies was assessed from the emission reduction perspective with regional group of climate and sector-specific experts, with support from special experts from SYKE. The roadmap policies were also assessed from the viewpoints of social fairness and equitable transition with support from the Climate-KIC partnership programme's Pioneers into Practice programme.

The Regional Assembly approved the roadmap in December 2020. The preparation of the roadmap action plan was initiated in 2021. The aim was to identify primary measures in the work to be conducted in the various focus areas. The focus points of the Council's own climate efforts will be sought based on the measures identified through internal work around the programme and outlined measures. The climate efforts carried out by the interest groups will be incorporated into the roadmap on a sector-specific basis through bilateral cooperation and collaboration through a variety of networks.

Estimate of the capacity to implement the roadmap

Strengths:

- The roadmap enables a variety of measures and implementation paths.
- The municipal field of Uusimaa is diverse and enables network-based cooperation.
- Cities and energy companies in the Helsinki Metropolitan Area are strongly motivated to take climate action; these operators have a significant impact on the development of the region's emissions.
- Uusimaa has strong RDI networks, which can be leveraged to look for mitigation solutions.

Weaknesses:

- There is significant variation in the availability of resources for climate work.
- The success of climate efforts is dependent on the aims and motivation of many separate actors; it is difficult to steer the actions of individuals, even if the framework for climate-positive ways of life is in order.
- The carbon sinks in the region are scant in proportion to the population and consumption.

Threats (bottlenecks):

- In some sectors, the success of mitigation measures is dependent on national solutions (energy production, traffic) and on the achievement of national goals.
- Climate efforts are not seen as essential to the purview of municipalities and they often take the form of separate measures.
- Funding for climate work cannot be secured for the long term.

Opportunities:

- The EU's support policy (Green Deal funding) enables the better integration of climate efforts more into development policies.
- Uusimaa has excellent preconditions for sustainable mobility solutions and the financial capabilities for a sustainable energy transition.

5 Model roadmaps for implementing effective climate measures

The model roadmaps include themed collections of measures required to be carried out to achieve carbon neutrality and significant emission reductions. Many climate change mitigation measures also promote adaptation to and preparation for weather extremes and other detrimental effects, such as heatwaves and insect damage, that are worsening due to global warming.

Utilising individual model roadmap measures and efforts in regional and municipal climate plans and roadmaps always requires considering the characteristics of the area in question. Climate change mitigation efforts can only be planned if current emission volumes in individual sectors as well as potential for emission reductions in the area are known.

The measures in the model roadmap are based on emission reduction studies and example measures selected from the roadmaps of the seven regions.

The regional climate roadmaps and the abbreviations used in the model roadmap tables are as follows:

- South Karelia (SK) (verbal communication Petri Kero 17 March 2021)
- Pirkanmaa (PI) (Council of Tampere Region 2020)
- Päijät-Häme (P-H) (Regional Council of Päijät-Häme 2020a); Traffic action plan (Regional Council of Päijät-Häme 2020b)
- North Ostrobothnia (NO) (Council of Oulu Region 2021)
- Satakunta (S) (Satakunta University of Applied Sciences 2021)
- Uusimaa (UM) (Helsinki-Uusimaa Regional Council 2020)
- Southwest Finland (SF) (Ympäristö Nyt 2021).

The climate roadmap measures of the regions are based on carbon neutrality goals and policies on how emission reductions should be implemented in various sectors. As regards energy production, the roadmaps have stated that, in order to reduce emissions, it is essential to abolish fossil energy sources in heat and electricity production and to improve energy efficiency. The use of peat will be discontinued, with due consideration to security of supply and a fair transition. The roadmaps list policies and schedules regarding the elimination of oil in the heating of buildings. The roadmaps also include information related to the energy levels and emissions related new constructions and independent construction, for example. In terms of traffic, the roadmaps contain policies on increasing the shares of sustainable modes of transport and reducing the use of fossil fuels in transport. As regards agricultural emissions, the roadmaps generally indicate that the goal is to promote the sustainability of the food system. All roadmaps also emphasise the importance of carbon sequestration, the role of energy use and production, and communications throughout the entire food supply chain. None of the roadmaps set any numerical targets for reducing agricultural emissions. On the topic of the sustainable use of forests, the roadmaps refer to the national forest strategy, for example.

Measures that have no essential impact on emission or that may even increase emissions by 2050 have been excluded from the model roadmaps. These measures include the burning of stemwood and stumps for energy (see for Liski et al. 2011, for example).

In the model roadmaps, emission reduction measures are defined as actions that lead to direct emission reductions when taken. Tasks that support and enable direct emission reductions have been listed under these measures. The impact of the model roadmap measures on emission reductions or carbon sinks have been evaluated on a scale of one to five stars, with five stars indicating the strongest impact. The bases of the assessment have been presented on theme-specific basis. Measures that support resilience have been marked in the tables with the # symbol.

5.1 Clean energy production for electrical, heating and gas networks

Karoliina Auvinen, SYKE

The effectiveness of emission reduction measures related to energy production have been assessed in relation to national emission reduction scenarios, which have been used to determine the technologies that can be used to reach the carbon neutrality goals in Finland (Table 3 & 4). Measures with very low or no emission reduction impacts have been excluded from the model roadmap.

The most important emission reduction measures are as follows:

- Replacing fossil fuels with clean energy production capacity, such as wind power and heat pumps.
- Reducing the need for primary energy through energy efficiency measures, such as investments in the utilisation of waste heat.
- Replacing fossil fuels by improving the nutrient and material circulation of organic materials and, especially, through biogas investments based on agricultural side streams.

Examples of concrete emission reduction measures:

- Helsinki, Jyväskylä, Lahti, Lappeenranta, Pori, Tampere, Turku and Vantaa will be increasing the amount of wind power through the jointly owned Suomen Hyötytuuli Oy. The company has a 186 MW wind power capacity and is in the process of constructing two new wind farms and planning numerous investments throughout Finland.[4]
- In Espoo, St1 and Vantaan Energia are constructing geothermal heating plants for the Fortum and Vantaa district heating networks.[5]
- The district heating networks of Helen Oy, which is owned by the City of Helsinki, utilise environmental and waste heat from wastewater, the Paulig coffee roastery, Lidl outlets, the Ilmarinen property and seawater. A large heat store is also under construction.[6]
- Biogas plants have been constructed in Jyväskylä, Kouvola, Lahti and Nokia. They are owned by the respective municipalities through the regional water and waste management companies of the municipalities.[7]

[4] Additional information: hyotytuuli.fi
[5] Additional information in Finnish: Vantaan Energia rakentaa geotermisen maalämpölaitoksen and st1.fi/geolampo
[6] Additional information in Finnish:Helteet pudottavat kaukolämmön tarpeen, mutta silti Helsingin piiput hönkivät ilmastoa lämmittäviä päästöjä – kesällä 2023 tähän tulee stoppi, Lidlin myymälän jäähdytys tuottaa myös kaukolämpöä, Kahvipaahtimon hukkalämpö hyötykäyttöön, Huima suunnitelma Helsingissä: Kruunuvuoren alla oleva jättimäinen luolasto täytetään merivedellä – vedestä otettavalla energialla lämmitetään tuhansia koteja, Uusi kiertotalousratkaisu on kiinteistön omistajalle ikiliikkuja: lämmittää, viilentää ja tuottaa lämpöä kaukolämpöverkkoon hiilineutraalisti
[7] Additional information: labio.fi, kymenlaaksonjate.fi, mustankorkea.fi and pjhoy.fi

Table 3. Emission reduction measures and tasks related to specific to forms of energy production
The effectiveness of the measures has been assessed on a five-tier scale. The assessment is based on whether or not the measure supports the deployment of a technology or solution that provides national emission reduction and growth potential. The effectiveness of measures is graded as very significant (*****), significant (****), good (***), advisable despite the fairly low impact (**) or very low (*). # = strengthens resilience of the society. The effectiveness of enabling tasks has not been evaluated.

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties / schedule
Increasing wind power production (SK, PI, P-H, NO, UM, SF)		*****	Wind power capacity (MW) or production (MWh)	
	Recruiting a wind power coordinator to promote the deployment of wind power in the area. (P-H, SF)			ELY Centre, 2021
	Indicating wind power areas and 110 kV and 400 kV power lines with regional plan notations, and promoting their realisation. (PI)			Regional council
	Bolstering the main grid capacity and regional power grids. (PI, UM)	#		Fingrid, network companies, regional council
	Influencing to eliminate obstacles for constructing wind power (SK), promoting the resolving of the radar interference issue. (UM)			Regional council, LUT and municipalities
	Increasing services and awareness related to wind power permits and guidance. (PI, SF)			ELY Centre
	Working at the national level to increase the production of offshore wind power. (UM)			
Utilisation of waste heat and ground source, water and air heat in district heating networks (PI, UM, SF, SK, NO)		***** #	Heat pump capacity (MW) or production (MWh)	Energy companies, property owners, ICT operators, municipalities and joint municipal authorities, waste water companies
	Implementing ambient and waste heat in-vestments: varying sizes of investments in heat pump solutions utilising ground source and bedrock heat (SF). Using industrial heat pump solutions for waste heat solutions, for example. (SK)	#		Municipalities, energy companies
	Enabling local heat energy networks based on heat pump solutions and the utilisation of regional waste heat. (SF)	#		
	Developing official practices and guidelines and legislation especially as regards geothermal energy, regarding aspects such as the positioning of energy wells of varying depths and permit provision for deep heat wells, with due consideration to groundwater, noise and vibration detriments. (UM)			
	Determining the economic potential of waste heat sources (data centres, industrial facilities, etc.) and their utilisation. (PI, P-H, UM)			Energy companies, municipalities, universities of applied sciences
	Optimising data centre and server locations in city planning. (UM)			Municipalities
	Promoting the use of geothermal heat (kilometre-deep wells) through city planning and enabling their connection to the district heating network. (SK)	#		

Emission reduction measures	Emission reduction tasks	Effectiveness	Indicator	Responsible parties / schedule
Increasing the production of solar power (SK, NO, S, UM, SF)		*** #	Solar power capacity (MW) or production (MWh)	
	Constructing industrial-scale solar power plants. (SK, UM)			Regional council, municipalities, companies, land owners
	Implementing and promoting solar power projects in the areas indicated in the regional land use plan. (SF)	#		Cooperation between municipalities, companies and land owners
	Identifying potential solar panel locations by means of location data analysis, for example. (UM)	#		
Increasing biogas production (PI, P-H, UM, SF, NO)		*** #	Biogas plant capacity (MW) or production (MWh)	ELY Centre, municipalities, state, agricultural operators
	Building local biogas plants to produce heat, power and biogas for transport purposes, especially by means of utilising agricultural side streams. (SF)	#		State, municipalities, ELY Centre, agricultural producers, energy companies
	Preparing a regional biogas roadmap. (PI)			Regional council and ELY Centre, 0–2 years
	Analysis on the possibilities of utilising biogas. (P-H)	#		University of applied sciences
	Promoting grass-based biogas production in agriculture. (UM)	#		
	Developing agroecological symbioses of farms and other operators for the production of biofuels. (UM)	#		Waste management and circular economy operators, farms
	Promoting sustainable energy solutions in agriculture. Utilising side streams in energy production. (S)	#		
Sustainable utilisation of bioenergy		*-** #	Biogas plant capacity (MW) or production (MWh)	
	Ensuring the availability of sustainable biofuel and biogas in the transition phase, without compromising carbon sinks. (UM)	#		

Table 4. Emission reduction measures and tasks that increase clean energy production and the efficiency of energy production.
The effectiveness of the measures was assessed on a five-tier scale. The assessment is based on whether or not the measure supports the deployment of a technology or solution that provides national emission reduction and growth potential. This effectiveness of the measures is graded as very significant (*****), significant (****), good (***), advisable despite the fairly low impact (**) or very low (*).
= strengthens resilience of the society. The effectiveness of enabling tasks has not been evaluated.

Emission reduction	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties / schedule
Improving resource efficiency in production and reducing transfer losses (SK, PI, SF)		****#	Consumption of primary energy (MWh)	
	Improving the energy efficiency of district heating networks: determining the heat losses of district heating networks and rectifying any observed heat losses. (SK)			Energy companies
	Analysis on the capabilities of utilising lower temperatures in district heating systems. (PI)			
	Leveraging heat storage to minimise the use of fossil fuels in the centralised power and heat production of urban areas. (SF)	#		Energy companies
Increasing clean energy production (SK, PI, P-H, S, UM, SF, NO)		*-***** #	Clean capacity (MW) / production (MWh) in total	
	Improving the attractiveness of investments: supporting the profitability of renewable energy sources, removing obstacles for decentralised energy production through e.g. new distribution innovations and legislative amendments, streamlining the permit processes (UM), developing bidirectional electricity and district heating network. (SF, UM)			
	Accelerating investments: active influencing efforts on a national level (PI), expediting clean power and district heat production through the ownership steering of energy companies. (PI)			Municipalities, regional council
	Improving the energy system's flexibility and failure resistance: promoting energy storage and demand flexibility solutions (PI, NO, SF), piloting (PI, UM) and increasing decentralised production domestically. (PI)	#		Municipalities, regional council, energy companies, owners of wind farms, compa-nies, RDI organisa-tions, consumers, educational institutes
	Concrete implementation of strategies and programmes: Implementing the action plan on sustainable energy and climate change (P-H), promoting and implementing the energy theme of the regional Hinku emission reduction path (PI), encouraging operators to prepare low-carbon strategies, and promoting new and sustainable low-carbon solutions for the industry. (S, UM)	#		Regional councils, municipalities
	Enabling the growth of green energy production through city planning (S) on a large scale (SK): Zoning more renewable energy production areas (SK, P-H), securing the requisite space for electricity transfer and district heating networks and energy storage (UM), and identifying the challenges in city	#		Municipalities, regional council, ELY Centre

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties / schedule
	planning processes and developing methods for official cooperation. (UM)			
	Promoting the scaling of measures by improving networks (NO, S), cooperation between sectors and information sharing: establishing a cooperation forum involving network owners, producers, property owners, industrial customers, etc. (UM)	#		Regional council
	Increasing investments by conducting analyses such as energy system analyses to support the preparation of a regional energy strategy (PI), municipal analyses on renewable energy (P-H) and analyses on the possibilities of utilising smart energy networks. (S)			Regional council and ELY Centre, 0–3 years
	Public bodies procure only renewable and certified electricity (PI, UM), heating and cooling. (SF)			Property owners, public bodies
	Investments in the research, development and piloting of new energy technology and circular economy solutions to accelerate the shift in the energy sector (PI, P-H, UM): developing renewable and emission-free energy production solutions that do not involve combustion (UM), and developing business-oriented operating environments. (P-H)	#		RDI operators, public sector, universities of applied sciences
	Promoting the hydrogen economy (NO, UM) and the production, distribution and use of synthetic fuels based on renewable energy. Producing synthetic fuels in Lappeenranta, including a CO_2 collection system, utilisation of excess hydrogen or hydrogen production, and the production of synthetic fuel. (SK)	#		Business Finland, RDI operators, energy companies, municipalities, GRN, LUT University, businesses
	Increasing energy-related and environmental knowledge: producing new research data to improve business and technical understanding in the energy sector (PI), informing operators of the possibilities of using local renewable energy sources (UM), developing educational activities on a wider scale, and training the workforce. (S)	#		Universities, universities of applied sciences, regional council, advisory organisations

5.2 Decentralised energy production and energy efficiency of buildings

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Effectiveness has been estimated in relation to national emission reduction scenarios that model the measures needed to increase energy efficiency and clean energy production so that Finland can achieve its carbon neutrality goals (Table 5). Measures with very low or no emission reduction impacts have been excluded from the model roadmap. The effectiveness of enabling measures has not been evaluated. The most important emission reduction measures are as follows:

- Replacing fossil fuels with clean energy production capacity, such as heat pump and solar energy investments.
- Reducing the energy demands of the building stock through measures that improve energy efficiency (making the reduction of energy consumption a key element in all repairs).
- Promoting spatial efficiency by modifying existing buildings to serve multiple purposes, constructing multi-purpose spaces or demolishing unused buildings.

Examples of measures:

- Huovila School in Muhos switching from oil to geothermal heat.[8] Project implemented using the ESCO energy saving model, with investments costs standing at 162 000 €. Energy savings of 179 MWh/y were achieved. The estimated emission reduction is 60 t CO_2-eq/y.
- Kiilto's hybrid system utilises waste heat as well as ground source heating and cooling.[9] The investment cost was 320 000 €, the payback period was 4 years, the energy savings stood at 1,800 MWh/y, and the estimated emission reduction was 310 t CO_2-eq/y.
- The first housing company that sells district heating provides residents with savings.[10] The investment cost was 754 150 €. The payback period was calculated to be 18 years, and the emission reduction was estimated to be 140 t CO_2-eq/y.

Table 5. Emission reduction measures and tasks that increase the decentralised energy production and energy efficiency of buildings

The effectiveness of the measures was assessed on a five-tier scale. The assessment is based on whether or not the measure supports the deployment of a technology or solution that provides national emission reduction and growth potential. Effectiveness is graded as very significant (*****), significant (****), good (***), advisable despite the fairly low impact (**) or very low (*). # = strengthens resilience in the society. The effectiveness of enabling tasks has not been evaluated.

Emission reduction measures	Emission reduction tasks	Effectiveness	Indicator	Responsible parties/schedule
Replacing oil and other fossil fuels in heating		***** #	Floor area and energy consumption (MWh) of oil-heated buildings (m^2), number of installed geothermal heat pumps and air-to-water heat pumps (pcs), district heating network's number of customers (pcs)	Schedule according to the carbon neutrality goals.
	Renovating the energy systems of properties to abolish oil heating (SF) by adding heat pumps (environmental and waste heat). (PI, NO, P-H)	#		Municipalities, other public and private property owners, ELY Centre, ARA, Motiva
	Developing official practices and instructions on heat pump permits, considering e.g. groundwater, noise and vibration detriments. (UM)			Municipalities, ELY Centre
	Promoting the cooperation between various parties in order to achieve carbon neutrality goals through hybrid solutions, for example. (UM)			Municipalities, other public and private property owners, and developers/ constructors
	Developing incentives for and guidance on energy renovations (UM) and charting the opportunities for supporting building stock improvements in areas where securing funding on market terms is challenging. (PI)			Municipalities, Energy Authority, Motiva, Ministry of the Environment
	In relation to renovation projects, determining ways to rectify competence deficits and labour shortages (e.g. increasing education).			Educational institutes, institutes of higher education, municipalities

[8] Muhoksen Huovilan koulu öljystä maalämpöön (in Finnish)
[9] Kiilto's hybrid system utilises waste heat as well as geothermal heat and cooling – Sustainability Leap (ymparisto.fi)
[10] The first housing company to sell district heating creates savings for the residents – Sustainability Leap (ymparisto.fi)

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties/schedule
Improving the energy efficiency of buildings		*** #	Energy consumption of buildings (kWh/m^2), numbers of buildings in various energy classes (pcs)	Schedule 0–10 years.
	Energy renovations of properties (improving insulation, adding roof insulation, heat insulation for roof structures and suspended floors, additional heat insulation in the context of cladding replacements, modernising external ground frost insulation, sealing penetrations, replacing windows and doors, replacing fireplaces with energy-efficient ones, building automation solutions). (PI, NO) Also included in basic renovations in the design phase. (SF)			Municipalities, other public property owners, owners of private properties, ELY Centre for Pirkanmaa (incl. customer service centre for environmental matters) ARA, Motiva
	Implementing the measures specified in the energy efficiency agreements of the municipalities and the state (KETS) to improve the energy efficiency of the organisations' own buildings. (PI, P-H, SF)			Municipalities, joint municipal authorities
	Implementing the cost-efficiency investments and repair measures presented in the energy analyses of buildings. (SF)			Municipalities, companies
	Improving the energy efficiency of rental buildings (P-H)			Rental housing companies, municipalities
	selecting energy-efficient appliances, other devices (e.g. heat recovery, water fixtures and flat-specific measurement) and lighting fixtures to replace the current ones when they reach the end of their technical life span. (PI)			Property owners
	Making energy efficiency more of a focus in city planning. (UM)			Municipalities
	Utilising waste heat of buildings. (PI, NO, SF)	#		Property owners
	Supporting and implementing ESCO projects during the energy efficiency agreement period (2017–2025). (PI)			Municipal operators and service providers
	Developing and deploying demand-flexible solutions for energy: equipping buildings with smart control systems that prevent the unnecessary heating of homes, reduce electricity consumption and balance out consumption peaks. (PI, SF)	#		Energy companies, organisations in the field, property owners
	Improving the competence and training of labour by increasing the open and digital offering of education on renovation and energy efficiency to support continuous learning. (PI, UM)			Educational institutes, research organisations, Finnish National Agency for Education, project clients, competitive bidding organisers, municipalities, Ekokumppanit

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties/schedule
	Developing advisory services and communications related to modifying old buildings to be highly energy-efficient and low in carbon in a cost-efficient way. (PI, SF, NO)			Public operators, businesses, municipalities, housing companies
	Developing and piloting energy storage. (PI)	#		Research bodies, energy companies, regional councils
Improving the spatial efficiency of buildings (UM)		**** #	Building stock size (m^2), size of per-resident building stock (m^2/resident)	Schedule 0–10 years
	Utilising the existing building stock as long as possible by modifying purposes of use and utilising circular economy methods, for example. (UM)	#		Property owners, municipalities
	Promoting the efficient use of the existing building stock, changing the purpose of use of buildings and using spaces for multiple purposes to extend the life spans of buildings. (UM)	#		Municipalities, property owners
Increasing solar power in properties (PI, UM, SF)		** #	Installed solar panel capacity (MW)	Schedule 3–10 years.
	Installing solar panels on building roofs or offering holdings in solar parks. (PI, SF)	#		Property owners, businesses, municipalities
	Promoting the use of PPAs in the public sectors. (UM)			State, ELY Centre, regional state administrative agency, municipalities
	Transitioning to net power measurement as quickly as possible. (PI)	#		Network companies, legislators
Constructing new buildings as zero-energy buildings (PI)		** #	E value of new buildings (kWh/m^2/year)	Schedule 3–10 years.
	Equipping new buildings with low-emission energy solutions (geothermal heat, solar energy and air or air-to-water heat pumps). (PI)	#		Construction companies, other public developers, property owners, state/legislators
	Productising new methods and technical solutions to reduce the carbon footprint of construction. (P-H)			Companies, research bodies
	Application of energy efficiency criteria in city planning and land provision terms. (PI)	#		Municipalities, ELY Centre
	Developing and deploying planning regulations and construction method guidelines that mitigate climate change. (PI)	#		Municipalities, ELY Centre
	Organising guidance for zero-energy and plus-energy construction. (PI)			Municipalities, Motiva, Ekokumppanit, ELY Centre

5.3 Transport

Johanna Mäkinen & Heikki Liimatainen, Transport Research Centre Verne, Tampere University)

The measures to reduce transport emissions have been assessed in relation to the effectiveness of the measures (Table 6). The most important emission reduction measures are as follows:

- Significantly improving the service level of public transport
- Ensuring a dense urban structure and enabling public transport corridors
- Electrifying the equipment used by municipalities and purchased transport services

Examples of measures in the transport sector:

- Shared-use bicycles. The modal share of cycling can be increased by providing shared-use bicycles. For example, Helsinki, Espoo, Kuopio and Oulu have had good experiences with shared use city bikes. In Helsinki and Espoo, city bikes were used more than 3.7 million times in the 2019 season (City of Helsinki 2019). In Kuopio, the popularity of electric city bikes exceeded the predictions in the first year 2019, and more than 7 000 people registered as users. In Kuopio, the profits of the city bikes exceeded the expenses, meaning that city did not incur any costs from them. (Yle 2019)
- Free public transport for primary school pupils: Pieksämäki and Mikkeli have gained positive results by providing primary school pupils with free public transport. In Pieksämäki, passenger numbers have doubled and even the volume of paying customers has increased. The increased ticket proceeds have covered the costs caused by the free public transport.
- Electrifying the transport equipment owned by municipalities: The municipalities of Ii and Lappeenranta, for example, have purchased EVs for their employees' work-related travel, but both municipalities also rent them out to local residents in the evenings and on weekends. (Municipality of Ii 2021, City of Lappeenranta 2021)
- Updating parking norms and market-rate parking: The City of Helsinki has begun to use a market-rate parking arrangement in some residential areas (City of Helsinki Urban Environment Committee 2019). In market-rate parking, the city does not specify the number of parking spaces to be built. Instead, developers can build as many parking spaces as it believes the residents will buy. Market-rate parking can be used to assign parking costs to the user, reduce excess parking space due to inflexible norms and enable a tighter urban structure.
- Assessing the climate impacts of the urban structure in the planning phase: The City of Tampere has prepared a tool that can be used to assess the greenhouse gas emissions of transport, heating, cooling, electricity consumption and renovations in the urban structure. For example, the tool can be used to compare the climate impacts of the urban structure's future scenarios. (City of Tampere 2020)

Table 6. Emission reduction measures and tasks that promote emission reduction.
The effectiveness of the measures was assessed on a five-tier scale where the emission reduction is very significant (*****); significant (****); moderate (***); recommended, even though the emission reduction impact or growth potential is minor (**); very low (*, excluded from the examination). # = bolsters social resilience. Notes: [1]The emission reduction potential is very significant in urban areas if the use of passenger cars is steered by means of pricing (for example, congestion charges).
Without pricing and outside urban areas, the emission reduction potential is moderate. [2]The emission reduction potential is small in the short term, but very significant in the long term. [3]The modernisation of the vehicle stock towards lower emissions provides very significant emission reduction potential; however, municipal and regional measures have a relatively minor impact on modernising the vehicle stock (with the exception of the vehicle fleets owned by municipalities).

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties / schedule
Increasing the modal shares of walking and cycling (SF, P-H, S, UM, PI)		*** #	Modal split	
	High-quality pedestrian and bicycle paths. (PI, SF, NO, UM, P-H, S, SK)	#		Municipalities, ELY, regional council, state
	Bicycle parking, park-and-ride (UM, PI, P-H, SK)			Municipalities, ELY, regional council
	Shared-use bicycles (city bikes) (UM, PI, P-H)	#		Municipalities, public transport operators
	Winter maintenance (UM, PI, P-H, SK)	#		Municipalities, state
	Steering, communications and campaigns related to sustainable mobility (e.g. promotion campaigns, smart mobility programmes). (PI, SF, P-H)			Municipalities, regional council, organisations
	Encouraging towards sustainable modes of transport for commutes (showers and dressing rooms, bicycle parking, limiting the free parking of cars). (UM, SK)			Employer
Increasing the modal share of public transport (UM, PI, SF, S, P-H, SK)		**** #	Modal split	
	Fast public transport links (e.g. trunk lines, public transport benefits, short intervals). (SF, PI, UM, P-H)			Public transport operators, municipalities
	Streamlining travel chains (park-and-ride solutions, development of station areas, compatible ticket and payment systems). (P-H, PI)	#		Municipalities, state, ELY, VR, regional councils, other parties ordering and providing transport services
	Developing rail traffic (trams, local trains, fast intercity transport links). (UM, SF, S, PI, P-H, SK)	#		Municipalities, state, VR, public transport operators, regional council, ELY
	Discounts and campaigns.			Public transport operators, municipalities
	Mobility services (also in sparsely populated areas), demand-responsive public transport (S, UM, PI, SF, P-H)	#		Municipalities, businesses, state, ELY, regional council
	Combining passenger and goods transport and opening up transport arrangements to private paying customers. (PI, P-H)			Municipalities, Kela, businesses, other public parties using and ordering transport services

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties / schedule
Reducing the transport performance of passenger cars (UM, PI, NO)		*** - *****[1] #	Transport performance of passenger cars	
	Use of urban space (improving the walking environment in city centres, carless streets, freeing up space reserved for cars for walking/ cycling/business). (PI, UM, P-H)	#		municipalities (town planning and traffic planning)
	Parking policies that influence users (e.g. removing the minimum requirements for parking spaces, increasing parking fees, centralised parking). (UM, SF, P-H)			municipalities (town planning and traffic planning)
	Transport pricing (e.g. congestion charges) (UM)			State, municipalities
	Encouraging the use of shared cars (e.g. municipalities can make cars available to residents in the evenings, parking fee discounts). (S, PI, P-H, UM)	#		Municipalities, companies
	Supporting carpooling. (UM)	#		Employers
	Remote work opportunities, remote services. (NO, S, PI, UM)	#		Employers, municipalities
Sustainable land use and transport plan-ning (P-P, SK, V-S, P-H)		**–*****[2] #	Average trip, accessibility of services, accessibility of public transport	
	Steering construction within the urban structure towards pedestrian and public transport zones. (V-S, NO, SK)	#		Municipalities
	Tightening and unifying the urban structure, complementary construction. (SK, NO)	#		Municipalities
	Overall examination of investment deci-sions regarding various forms of transport. (PI)			Municipalities, state
	Regional transport system planning to minimise the emission impacts of transport. (PI, P-H)	#		Regional council, municipali-ties, ELY
	National transport system planning to minimise the emission impacts of transport.	#		State, regional council, munic-ipalities
	Positioning decisions regarding the mu-nicipal service network ensure the ac-cessibility of local services through sus-tainable modes of transport. (PI)			Municipalities, ELY

Emission reduction measures	Emission reduction tasks	Effec-tiveness	Indicator	Responsible parties / schedule
Expediting the modernisation of the vehicle stock and low-carbon powertrains (P-H, NO, S, UM, PI, SF, SK)		*****3 #	Powertrain distribution of the vehicle stock, average age of vehicles, average Co2g/km$_2$g/km of vehicles	
	Public transport equipment, vehicle fleet of municipalities and the state, and purchasing clean transport services (at least) as specified in the EU legislation on clean vehicles. (SF, PI, UM, P-H, S, NO, SK)			Municipalities, other public procurement units, public transport providers
	Businesses purchase vehicles with alternative powertrains for their own use and as company cars. (V-S, NO, S)			Businesses
	Charging network for EVs (SF, PI, UM, NO, S, SK, P-H)	#		Municipalities, state, businesses
	Quick-charging stations for EVs (SF, PI, UM, P- P)			Municipalities, state, businesses
	Biogas fuelling network and production. (SF, PI, S, NO, SK)	#		Municipalities, regional councils, state, businesses
	Distribution network for other alternative fuels. (S, NO)	#		Municipalities, regional councils, state, businesses
Low-emission transport and logistics (SF, UM, S, PI, SK)		**** **#**	Powertrain distribution of vehicles, transport performance, driving empty (% of transport performance)	
	HCT transport (UM, SF, P-H, SK)			State
	Renewable fuels in transport, development of the distribution network. (SF, S)	#		Businesses, state, municipalities, regional councils
	Electrifying roads.			State
	Electric delivery transport and urban logistics. (SF, S, UM)			Municipalities, businesses
	Improving the efficiency of logistics (optimising routes, combining deliveries). (SF, UM, PI)			Businesses
	Replacing the road transport of goods with rail transport arrangements. (UM, S)			Businesses, state, rail transport operators
	Replacing the road transport of goods with water transport arrangements. (SK)			Regional council, municipalities, businesses
	Electrifying ferries. (SK)			Municipalities, regional council, Finnish Transport Infrastructure Agency

5.4 Agriculture

Kristiina Lång, Luke

The effectiveness of emission reduction measures in agriculture was assessed on a five-tier scale (Table 7). The most important emission reduction measures are as follows:

- The priority is to stop the increase in the area of cultivated peat soils, which is why measures to reduce clearing are highly justified.
- The environmental impacts of land use in agriculture are more significant than in other land use categories, which is why afforestation and other measures to reduce field area are important.
- Measures on cultivated peat soils are effective in proportion to the area, so their prioritisation is important.

Examples of good practices among regional operators:

- Pirkanmaa's plans are impactful as regards cultivated peat soils, as it intends to discontinue clearing activities within seven years. Other roadmaps do not include such plans or are only aiming to reduce clearing activities. However, Pirkanmaa's roadmap does not specify the ways of ensuring a sufficient number of the requisite measures such as land consolidation, exchanges of fields or developments of manure handling. That said, these are practices that the region can develop if it so desires.
- Pirkanmaa's roadmap includes several mentions of investments in RDI activities, which is a good way of promoting lesser-known emission reduction opportunities, in particular. Among the good practices highlighted by the roadmap, Carbon Action carbon farms, the holistic grazing model and distributing excess food to those of lesser means are examples of practices that can be reproduced in other parts of the country.
- The online courses of regenerative cultivation, which were mentioned in Päijät-Häme's roadmap, are an example of a concrete and viable measure for which an implementing party can be clearly specified. On the other hand, the impacts of such measures only materialise over time as the operators begin to utilise the lessons learned in practice.
- Another concrete measure is continuing the operations of a cooperation network that develops the refining of manure and biomasses, as mentioned in Pirkanmaa's roadmap. In this case, too, a party with experience in activities that support the roadmap goals is already defined.

Table 7. Measures and tasks that promote emission reductions in agriculture.
The effectiveness of the measures was assessed on a five-tier scale where the emission reduction is very significant (*****), significant (****), moderate (***); recommended, even though the emission reduction impact or growth potential is minor (**), very low (*). # = bolsters social resilience.

Emission reduction measures	Emission reduction tasks	Effective-ness	Indicator	Responsible parties / schedule
Reducing energy use and promoting bioenergy production			MWh	
	Strengthening the use and production of renewable energy, energy self-sufficiency and energy efficiency on farms. (SF, UM, NO, S, PI)	*** #		NO: Agricultural entrepreneurs, ProAgria, MTK, research, ELY Centre, Council of Oulu Region PI: 3–7 yrs.
	Promoting the use and production of biogas. (S, NO, SF, PI)	*** #		PI: 3–7 yrs.
	Developing the use of biomasses; e.g. sustainable collection and further processing of straw. (P-H)	* #		City of Heinola, LAB University of Applied Sciences, LUT University
	Promoting the use and production of biochar. (P-H, PI)	* #		University of applied sciences, research, land owners/3–7 yrs.

Emission reduction measures	Emission reduction tasks	Effective-ness	Indicator	Responsible parties / schedule
Maintaining and increasing soil carbon stores			Emission reduction t CO_2-eq	
	Promoting the prevalence of grass and other year-round plant coverage. (SF, PI, S, NO)	*** #		Agricultural entrepreneurs, organisations and businesses NO: Agricultural entrepreneurs, ProAgria, MTK, research
	Diversifying field use by means of crop rotation and new crop species. (V-S, NO, SK)	** #		
	Improving the growth conditions and water management of agricultural lands. (SF, PI, NO)	*** #		NO: Agricultural entrepreneurs, ProAgria, MTK, research PI: 0–7 yrs.
	Reducing soil tillage and increasing no-till farming. (NO)	* #		NO: Agricultural entrepreneurs, ProAgria, MTK, research
	Measures that reduce peat decomposition. (S)	*** #		
	Agroforestry. (NO)	* #		
	Adding organic matter to the soil (NO, PI, SK), optimising soil tillage. (S)	** #		NO: Agricultural entrepreneurs, ProAgria, MTK, research
	Controlled drainage in peat fields. (NO)	*** #		
Carbon-smart changes to land use			Emission reduction t CO_2-eq	
	Discontinuing or reducing the clearing of peat fields. (PI, S, NO, SK)	***** #		Agricultural entrepreneurs, parties responsible for developing manure handling PI: 0–7 yrs.
	Field afforestation. (S, NO)	**** #		
	Removal of peat fields in poor condition from cultivation use. (PI, S)	***** #		PI: State, municipalities, EU; 0–7 yrs.
Measures to curb nitrous oxide and methane emissions			Emission reduction t CO_2-eq	
	Prevention of N_2O emissions: crop rotations, optimised fertilisation, precision fertilisation. (PI, S)	**		Agricultural entrepreneurs, organisations, communities and associations. PI: 3–7 yrs.
	Prevention of CH_4 and N_2O emissions in manure management, fractioning of manure and further processing of nutrients. (PI, S, NO, SF)	*		Agricultural entrepreneurs, organisations, communities PI: 0–3 yrs.
	Reducing methane emissions through the optimisation of animal feeding (SA), animal breeding and fodder feeding. (PI)	*		PI: 3–7 yrs.
Information-based steering				
	Reducing food wastage. (UM, NO)	*	t	Municipality
	Increasing the share of plant-based food. (UM, NO, PI)	#	%	Municipality PI: 3–7 yrs.

Emission reduction measures	Emission reduction tasks	Effective-ness	Indicator	Responsible parties / schedule
	Improving protein self-sufficiency (plants, mushrooms, insects). (NO)	*	%	
	Increasing research and testing activities on farms. (SF)	#		
	Online courses on regenerative farming for local farmers and other interested parties. (P-H)	** #	Number of participants	Municipality
	Developing the effectiveness, visibility and flexibility of advisory activities. (SF)	** #		
	Cooperation between farms to promote resource efficiency. (NO)	*** #		
	Bolstering the preconditions for the profitability of sustainable food production through regional coop-eration. (SF, UM)	* #		
	Increasing awareness throughout the food supply chain. (SF, UM, P-H)	* #		Farmers, regional council, ELY Centre, MTK, ProAgria, municipalities, institutes of higher education
	Analysis on reducing agricultural emissions and increasing carbon sequestration (P-H, UM); increasing awareness of peat fields (NO); research and innovations (PI)	* #		PI: 3–10 yrs.

5.5 Forests

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As regards measures that reduce emissions and strengthen the carbon sinks of forests, effectiveness was assessed subjectively on a five-tier scale based on strengthening carbon sinks, reducing emissions and maintaining carbon stores (Table 8). The time frame of the impacts was assessed by roughly dividing the measures into two categories. The most important measures for reducing emissions and strengthening carbon sinks are as follows:

- Measures such as extending rotation times, protecting forests and growing denser forests reduce emissions and strengthen local carbon sinks effectively, but only for a few decades before the stand biomass C stock saturates. In analysing such aspects, it is also important to consider how synergies with conservation benefits are realised, how felling activities are affected in other locations, and how the structures of the forests can be changed sustainably to maintain forests' sink C capacity over the long term.
- Measures related to drained peatland forests: Avoiding excessive drainage and providing related guidance and advice; increasing ash fertilisation and continuous cover forestry, if the hydrological conditions permit a rise in water level and, by extension, a reduction in the rate of peat loss.
- Preventing forest loss; especially avoiding the clearing of peatland forests for fields; related regional solutions, instructions and advice.

Examples of regional measures:

- Pirkanmaa: 3 hectares of forest was planted in Hämeenkyrö (6 000 spruce saplings in total). The planting was conducted by the municipality of Hämeenkyrö in accordance with the Taimiteko

operating model of 4H Finland. This was Hämeekyrö's way of compensating for the trees cleared to make way for the construction of a bypass road. Since the beginning of 2020, the municipality's goal has been to find new areas where saplings can be planted.

- Satakunta: Fully implementing the voluntary conservation programmes for landowners (Metso, Helmi) in Satakunta by identifying the locations that meet the conservation criteria.

Table 8. Measures for reducing emissions and strengthening carbon sinks:
The effectiveness of the measures was assessed on a five-tier scale. The assessment is based grading the impact on strengthening carbon sinks, reducing emissions and retaining carbon stores, considering the implementation area, as very significant (*****), significant (****), moderate (***), recommended, even though the impact is relatively minor (**), low impact (*). # = promotes adaptation to climate change, & = significant positive impacts on diversity. N = the area-specific impact of the measure is significant in the short term, by about 2035, H = significant impact will materialise over decades (per area unit). The impact of measures conducted in forests is measured based on the change in the forest ecosystem's carbon store capacity ΔC, but the life-cycle emissions and substitution effects of products must be considered to assess the total impacts. The progress of the measures can also be monitored based on area (A).
Notes: As regards the management of peatland forests, the long-term impacts on the carbon stores of the soil are not known very well at this time.

Emission reduction measures	Emission reduction tasks	Impact/ time frame	Indicators (examples)	Responsible body
Forest management that mitigates climate change (S, P, NO, SK)			ΔC, A, (tree density, rotted trees)	Forest and land owners, SMK, Tapio Oy, advisory organisations, nurseries, research bodies
	Fast regeneration after final felling. (H, SK).	****#		
	Extending rotation times. (N) (PI, S) and management of high-density forests.	*****&		
	Afforestation of fields and wasteland areas. (H)	****(#&)		
	Utilising refined sapling material in forest cultivation. (H) (S, SK)	****#		
	Postponing thinnings, no excessively aggressive intermediate felling. (N)	****		
	Increasing the amount of dead wood. (H)	***&		
	Fertilisation. (N) (IP, S, SK)	***		
Special measures for the climate-sustainable management of peatland forests (S, NO)		#	ΔC, A	SMK, forest owners, advisory organisations, timber buyers
	Promoting continuous cover forestry. (N) (S)	***		
	Reducing drainage efficiency (shallower ditches) in rotation forestry. (N)	***		
	Controlled damming of ditches in excessively drained areas. (N)	***		
	Trials/pilots of new methods for managing the water balance. (NO)	***		
	Ash fertilisation of nutrient-rich peatland forests. (N)	****		

Emission reduction measures	Emission reduction tasks	Impact/ time frame	Indicators (examples)	Responsible body
	Excluding the low-productive drained peatland sites from active forestry. (N) (S)	**&		
Carbon-smart changes to land use with regard to forests		#	ΔC, A, density of town planning and change in unbuilt area	Municipality, region, land owners, ELY Centres, ProAgria
	Discontinuing the clearing of peatland forests for fields. (N) (PI, S)	*****		
	Reducing deforestation through the planning and design of the urban structure. (N) (PI, UM, S, NO, SK)	****&		
	Increasing the forest area (i.e. afforestation), old peat production and wasteland areas. (H) (PI, S, NO, SK)	***(&)		
	Restoration of suitable peatland forest locations (where forestry is unprofitable; especially areas with low nutrient levels). (H) (S, NO)	****(&)		
	Establishing green areas and carbon sink parks in urban areas. (H) (SK)	***&		
Reducing the negative climate impacts of forest damage (S)			ΔC, A, n	SMK, advisory organisations, land owners, fire authorities, municipal operators
	Favouring more diverse forest structures and landscapes, mixed trees. (H) (S)	***#&		
	Preventing forest fires (N) and maintaining preparedness to fight them. (H)	***#		
	Advancing thinning in areas that are susceptible to damaged caused by snow. (H)	**		
	Preventing the formation of sharp forest edges in the context of clearing due to the increased risk of damage caused by wind and bark beetles. (H)	***#		
Climate-friendly products and services, analyses (NO)		(#&)	ΔC, average life span and substitution effect of products.	Industry, Metsähallitus, private entrepreneurs, travel entrepreneurs, municipalities, regional council, ELY
	Updating the value chain of timber production and refinement: developing and manufacturing long-lived wood products (UM, S, NO, SK) (H/N)			
Regional forest programmes, certification, advice (P-H, PI, NO)		(#&)	Visibility of climate goals in the programme Number of town planning choices or their impact	Regional council, SMK, regional forest councils, Tapio Oy, forest management associations

Emission reduction measures	Emission reduction tasks	Impact/ time frame	Indicators (examples)	Responsible body
			on the carbon balance, substitutive measures ELY Centres, RDI companies	
	Including measures and tasks based on the climate roadmap into the region's updated forest programme for future terms. (PI, P-H)			
	Promoting the use of climate-smart forest management practices through communications and guidance and increasing competence among forest owners, professionals and young people based on new research data. (S, NO, P-H)			
	Developing possible new forest management services. (P)			
	Determining the distribution of the region's carbon sinks and stores and the climate impacts of land use. (S, P-H)			
	The possibilities provided by new technology to strengthen the carbon sinks of forests. (NO)			
	Considering and monitoring climate goals in the municipalities' own forests and planning efforts.			
	Examining and developing carbon emission and carbon sink compensation schemes; market-based mechanisms and identifying relevant locations and methods. (SK, S)			

5.6 Adaptation

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The adaptation efforts related to the regional roadmaps were highlighted and synergies of adaptation measures were assessed in relation to the mitigation efforts. Examples and good practices on regional adaptation efforts and plans were highlighted (Table 9). Measures supporting resilience by sectors were analysed separately and presented in Tables 3-8.

Table 9. Examples and good practices of regional adaptation efforts.

Sector/ description	Measures	Regions	Mitigation synergies/need to develop adaptation in relation mitigation measures
General/ strategy/ business activity	• Regional/municipal risk analyses of the impacts of climate change and measures to prepare for and/or adapt to them. • Preparing recommendations on measures. • Promoting business opportunities related to adaptation. • Developing communications related to climate change adaptation, forming adaptation networks. • Developing sustainable nature and local tourism as well as nature-related products. • Promoting the realisation of the Sustainable Development Goals (Agenda 2030) and engagement.	(P-H, S, PI, NO)	Synergy/simultaneous implementation may increase the cost-efficiency and diverse benefits of both measures.

Sector/ description	Measures	Regions	Mitigation synergies/need to develop adaptation in relation mitigation measures
	• Monitoring and taking part in national and international adaptation efforts.		
Water resources and water management.	• Improving the management of floods and stormwater, protecting water resources by changing mixed sewers to separate sewers, wetland areas. • Flood protection measures related to water bodies. • Updating the stormwater plan. • Reducing impenetrable surfaces/urban planning.	(SK, UM, S, NO)	Possible conflict with the increasingly dense urban structure. Updated through stormwater work under the Land Use and Building Act.
Energy	• Preparing for power outages, underground cabling. • Improving the preparedness of critical infrastructures/sectors (energy, water) against weather extremes • Developing energy storage solutions, demand flexibility and domestic decentralised production. • Shift to domestic renewable energy sources reduces dependence on import energy and price fluctuations. • Enabling local heat energy networks, biogas plants, heat pump solutions and the utilisation of regional excess heat. • Promoting community energy.	(S, NO, PI, SF, SK, UM)	Synergy/through energy self-sufficiency, flexibility, energy security and risk management.
Natural resource sector	• Supporting the adaptation of the food sector and promoting the self-sufficiency and sustainability of the food system. • Developing the irrigation systems and water management of fields, increasing year-round plant cover and improving the growth conditions of the soil. • Supporting biodiversity in the context of agriculture and forestry. • Using crop plants which adapt to the changing climate. • Preventing forest fires and developing effective extinguishing measures. • Preventing plant and animal diseases. • Considering the impacts and risks of climate change in forestry (e.g. tree species, prioritising mixed forests, selecting suitable growth areas). • Maintaining the health and diversity of commercial and conservation forests. • Reducing and ending the clearing of peatlands for fields. • Increasing advice to private forest owners on sustainable forestry; for example, assessing the need to renew ditches in peatland areas. • Afforesting unproductive land areas, establishing carbon sink parks. • Promoting research and trial activities on farms in cooperation with research institutes and farmers.	(S, NO, SF, P-H, SK, UM)	Synergy/carbon sequestration through supporting and maintaining the health and condition of ecosystems (e.g. soil, forests and water bodies). Promoting Nature-Based Solutions provides diverse benefits; for example, wetland solutions in forests and field areas, and continuous cover especially in peatland forests.
Built environment	• Preparing for increasing weather extremes and climate risks in land use planning and construction. • Steering land use in a sustainable manner, retaining natural and green areas and taking into account climate change impacts. • Ensuring the retainment of ecological links in urban planning. • Limiting new construction outside flood risk areas and/or ensuring the management of flood risks. • Utilising the 'Green Factor' in municipal plans. • Regional analysis on green structures and ecosystem services. • Taking adaptation to climate change into account in urban and construction planning (e.g. moisture stress), e.g. Nature-Based Solutions.	(UM, P-H, NO, S)	Possible conflict with increasingly dense land use and construction. Considering Nature-Based Solutions on various planning levels in the Land Use and Building Act update.

Sector/ description	• Measures	Regions	Mitigation synergies/need to develop adaptation in relation mitigation measures
Transport	• Increasing the share and operating capabilities of sustainable modes of transport in urban planning and ensuring social sustainability in the pricing of public transport. • Considering the year-round functionality of the urban structure and transport corridors. • Preparing for floods caused by heavy rainfall in road management. • Developing the accessibility of fuelling and charging stations for alternative motive powers.	(UM, NO, S, SF, PI, SK)	Synergy/ reducing emissions with special attention to sustainable modes of transport, safety, social fairness and regional equality.
Biodiversity	• Considering climate goals and biodiversity as part of municipal land policies; promoting cooperation on a regional and municipal level. • Considering biodiversity in municipal project planning. • Promoting the implementation of conservation programmes (Metso, Helmi) in cooperation with landowners. • Green network analysis, i.e. determining the core biodiversity areas and ecological link areas. • In land use planning, promoting the retention of areas and ecological links that are valuable to natural biodiversity. • Increasing the amount of urban green in urban areas and municipal centres. • Limiting the spread of harmful invasive species, with due consideration to possible new ones. • Afforesting wasteland areas and diversifying the range of tree species. • Restoring unused peatlands to wetland areas.	(S, SK, P-H, NO)	Synergy/carbon sequestration, preventing urban heat island effect/cooling Synergies related to promoting Nature-Based Solutions, once the concept has been defined more specifically.

6 Summary

This report gathers together effective emission reduction measures from the climate roadmaps of seven regions and experiences regarding the implementation of regional climate measures. The example regions are South Karelia, Pirkanmaa, North Ostrobothnia, Päijät-Häme, Satakunta, Uusimaa and Southwest Finland. The regional roadmaps list a variety of measures which aim towards a sustainable society in cooperation with numerous actors and sectors. Regional climate efforts provide strategic support to local actors in practical climate work.

The model roadmaps in the report were collected by picking the most impactful measures from each region's roadmap to guide the further regional efforts. The model roadmaps also include indicators that can be used to support the practical monitoring of climate work and examine the effects and progress of overall measures. The model roadmaps contain expert assessments on the relevant collections of the measures. However, the report does not analyse the effectiveness of the seven regions' roadmaps as a whole. Assessing the emission reduction impacts of the measures is challenging, as most of the roadmap measures enable the indirect implementation of the actual emission reduction measures but do not involve their actual direct implementation.

The report emphasises the role of regional actors, such as regional councils, ELY Centres and development organisations, in achieving the carbon neutrality goals. As regards clean energy production, the tasks of the regional actors include city planning, developing permit processes and promoting cooperating between key actors, competence and funding. In relation to the energy efficiency of buildings, regional operators can encourage local property owners to make energy renovations, as is the case with the construction development centre and Päijät-Häme's project that provides sustainable solutions for oil heating. City planning impacts transport emissions. In addition to this, regional actors prepare sustainable mobility programmes and implement and support pilot projects.

The strengths of the seven regions' climate efforts include strong commitment of local actors in general and their willingness to take climate action. That said, some emission reduction measures were found to be politically sensitive and polarising, such as eliminating peat use and increasing the number of wind farms. Other strengths of the regional climate efforts are networking and solid regional and national cooperation. Particular weaknesses of the climate efforts are the lack and decentralisation of resources. The practical implementation of the roadmap is often assigned to a body that lacks the authority or resources to ultimately carry out the measures. The poor economic situation of the municipalities is often a specific threat to the climate goals of the regions. As such, the practicalities of sustainability and the consideration of climate perspectives is often compromised as other aspects need to be prioritised. The regions generally found the EU Green Deal funding as a positive opportunity to gain more resources and expertise for climate efforts, which would also support regional economy.

The resources for the climate efforts of regions and municipalities are limited, which is why it is important to focus them on the most impactful measures. Critical measures to curb fossil fuel emissions include reducing energy consumption and increasing its efficiency, substantially increasing the proportion of low-emission energy, and electrifying heating, traffic and industrial processes in a clean manner. In the land use sector, critical emission reduction measures include managing emissions from peatland fields and forests and preventing deforestation.

Many of the regions will continue their efforts by focusing on a few specific sectors at a time. Regional climate work is a continuing process, as new action plans and measures that impact emissions are being constantly prepared and conducted. As regards the result orientation of the climate efforts, it is important for the emission reduction measures in the roadmaps to progress to practical implementation in a fast and reliable manner. Especially now that the EU provides additional support for climate measures and investments, it would be critical to ensure that municipalities and other implementing organisations have sufficient resources to bring the roadmaps to realisation. Concrete investments

strengthen regional and municipal economies. Local improvements in municipal economy and employment rates can reduce confrontation, which makes it easier to conduct climate measures later on.

Climate change mitigation is a key element in the regional climate roadmaps. In the future, however, more attention needs to be paid to synergies between mitigation and adaptation measures. The progression of climate change causes significant risks to people, livelihoods and nature. These risks can make it more difficult to reach various sustainable development goals.

The report's model roadmaps will create a basis for result-oriented climate efforts in years to come. The model roadmaps describe the scope of climate work and the multidisciplinary questions related to carbon-neutrality efforts. In the implementation phase of the climate programmes, it is important to retain the inclusive work method based on joint development, in which regions conduct measures in cooperation with local and national experts and interest groups.

The model roadmaps can also serve the regions where roadmap efforts are just being started or where the relevant practices are being updated. Mitigation of and adaptation to climate change is vital to regional economies as well as public health and safety.

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