BAU Scenario for the City of Helsinki's Emissions up to 2050

Report

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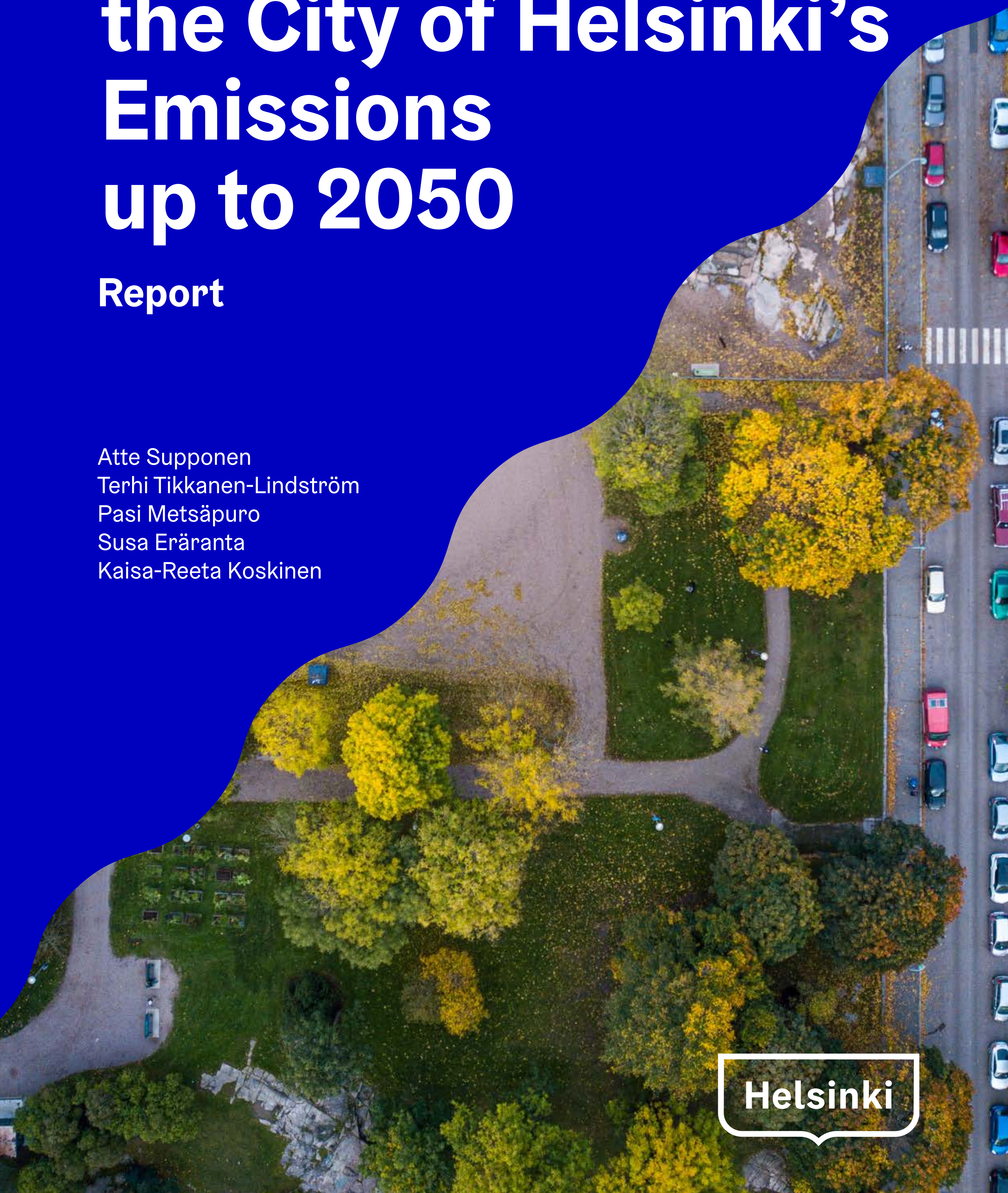

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Foreword

The Helsinki City Strategy for 2021–2025 speeds up the City's target to achieve carbon neutrality by 2030 rather than 2035. The City has also set the target of zero carbon by 2040 and becoming carbon negative after that. Unlike with the carbon neutrality target, the option of offsetting carbon emissions outside the city boundary will no longer be available for the zero-carbon target. This means that the maximum level for emissions will be determined by the city's own carbon sinks. The smaller the car-bon sinks get, the higher the emissions reduction target must be.

Work has begun to support the achievement of the above targets, with concrete boundary conditions and future scenarios for a carbon-negative city. When time and resources are limited, it is important to ensure that they can be allocated to the most effective actions for achieving the set targets. In order to concretise the necessary actions, an indicative understanding is also needed of which emission classes will be central in scale in the coming decades and what the current measures will achieve in each sector.

The aim of the work was to develop the first transparent and comparable method for implementing a snapshot analysis of emissions in a specific area, such as a city, to support climate management. The calculation model produces an overall indicative estimate on the scale of emissions, and it ena-bles area-based comparisons between the current state scope 1, 2 and 3 emissions and the estimates made for the reference years 2030, 2040 and 2050 based on the BAU scenario. Especially with regard to scope 3 emissions, the calculation results are merely indicative due to the qualitative problems with the baseline data. WSP Finland Oy was responsible for method development and the correctness of the calculations. The principles and assumptions of the calculation model have been systematically and transparently reported to enable easy updating, follow-up reviews and further development by non-city users as well.

Only emission-reducing actions support the achievement of the set targets. Only binding decisions made so far on plans and investment projects that have a significant impact on emission trends, leg-islation and other government measures affecting emission trends, and other factors with an impact on emission trends have been factored into the estimates and projections. For this reason, for exam-ple, ongoing local master plans and any changes to land use proposed therein have been excluded from the analysis; however, it is necessary to identify the importance of the decrease in the plan re-serves when interpreting the results. Similarly, the assumptions underlying the scope 3 projected emissions in principle do not include any radical changes in diet. The baseline assumptions made are presented in the report for each estimate. The calculation should be updated whenever there are any changes to the operating environment that significantly affect the baseline data.

From among the city's own actions, those most highlighted in the calculation are the preservation and strengthening of carbon sinks. The calculation model requires further development, especially with regard to carbon sinks, and it does not unequivocally take into account basal areas, as it should do for construction, for example. However, the existing analysis already provides indications of the im-portance of preserving and strengthening carbon sinks, curtailing projects that reduce carbon sinks and regulating the basal area subject to planning to save the existing green structures and soils so that the set targets can be achieved in a timely manner. The assumptions used to calculate scope 3 emissions should also be clarified.

The calculation also shows the emergence of emission classes for which the City of Helsinki has lim-ited means to manage on its own in the coming decades. From society's perspective, it is essential to identify the right methods and the appropriate level of regulation for them. Other actors will also have to take effective emission-reducing actions.

Helsinki 27 February 2023,
Susa Eräranta and **Kaisa-Reeta Koskinen**

WSP FINLAND OY

BAU SCENARIO for the CITY of HELSINKI'S EMISSIONS up to 2050

REPORT

21.2.2023

Contents

1. Background and objectives

Work has begun to formulate a vision to support the City of Helsinki's goal of becoming carbon negative and to define the boundary conditions and future scenarios of a carbon negative city. Formulating the vision also requires an understanding of the current and future division and scale of the city's total emissions.

This study aims to gain a holistic view that comprises the current state and a long-term Business-As-Usual (BAU) scenario of the greenhouse gas emissions occurring within the geographical area of the City of Helsinki and of greenhouse gas emissions occurring elsewhere as a result of activities in the city. The BAU scenario reference years are 2030, 2040 and 2050.

The report describes the emission sources and sinks for the following emission sectors:

- heating of buildings,
- electricity consumption,
- transport,
- industry,
- agriculture and forestry,
- waste management,
- other indirect emissions,
- carbon sinks associated with land use.

The report covers direct emissions occurring within the geographical area of the city and indirect emissions caused by activities taking place within the city boundary. Indirect emissions are the result of activities taking place within the city boundary, however, they occur outside the city boundary.

The work was guided by the City of Helsinki's steering group, which included Kaisa-Reeta Koskinen and Susa Eräranta. The report was compiled by WSP Finland Oy, where those participating in the work were Atte Supponen, Terhi Tikkanen-Lindström, Pasi Metsäpuro, Elli Happonen, Samuli Kyytsönen and Tuomas Seppänen.

2. Business-As-Usual (BAU) scenario

The purpose of scenarios is to illustrate how a future state develops from the present moment and what alternative ways exist to change the trajectory. The Business-As-Usual (BAU) scenario illustrates the change in emissions over the long term, where the baseline assumption is that only measures already decided and legislation already in force are considered. In addition to these measures, the city's forecasts on population and jobs as well as general market trends serve as baseline data for the scenario.

2.1. The measures and legislation in force

For the legislation in force and the climate measures decided, the main baseline data for the BAU scenario are:

- The share of the energy content of biofuels from the total energy content of petrol, diesel and biofuels supplied by the distributor must be increased to 30% in 2029 (the distribution obligation).
- The share of biofuel in light fuel oil supplied for consumption will be 10% in 2028 and beyond (the distribution obligation of biofuels).
- The use of coal as a power source for electricity or heat production by power plants and heating plants will be banned in 2029.
- Helen Ltd's development programme and any ongoing and planned projects to replace the use of coal with other fuels.
- Helsinki City Plan 2016 (City of Helsinki 2018), which promotes a densifying urban structure and infill development. No supplementary construction is expected in planning areas that are not covered by the city plan (Östersundom) or in areas where elements of the plan have been removed. The relevant pending local master plans may change the situation from the estimates of this report.
- Decisions taken on future transport network development projects: Raide-Jokeri, Crown Bridges, Vihdintie light railway, the Pasila–Kalasatama tram line and Sörnäinen tunnel.

The baseline for the scenario does not include objectives or draft resolutions. This means, for example, that the Government resolution on reducing greenhouse gas emissions from air transport (Government 2021), or the draft resolutions on the green public procurement criteria for building work (see Ministry of the Environment 2019) or the emission cap-and-trade system for maritime transport (see Honkatukia et al. 2021) have not been used as baseline data for the scenario.

2.2. Forecasts on population and jobs

Three alternative projections of the city's demographic trends have been prepared, of which the base case forecast is used as the baseline (City of Helsinki 2022a, City of Helsinki 2022b). The city currently has about 658,000 residents and, according to the population projection made based on the base case, the city population will grow to 824,000 residents (+25%) by 2050 (Figure 1).

The forecast on the number of jobs in Helsinki has been prepared as part of the Uusimaa employment projection (Laakso 2021). The projection chosen as the baseline is Ve0, in which the number of jobs continues to grow in line with the growth trend of the second half of the 2010s and business growth is focused on the Helsinki Metropolitan Area. The current number of jobs is 413,000, and it will grow to about 482,000 (+17 %) by 2050 (Figure 1).

Employment projections are prepared by sector, and these sector-specific data are used in the estimation of projected emissions for industry and services. In the employment projection, industry is growing towards knowledge-intensive production processes. As a result, growth in the industrial, business services and information technology sectors is focused on the Helsinki Metropolitan Area. The number of industry and service sector jobs in Helsinki grows from the current state (Figure 1).

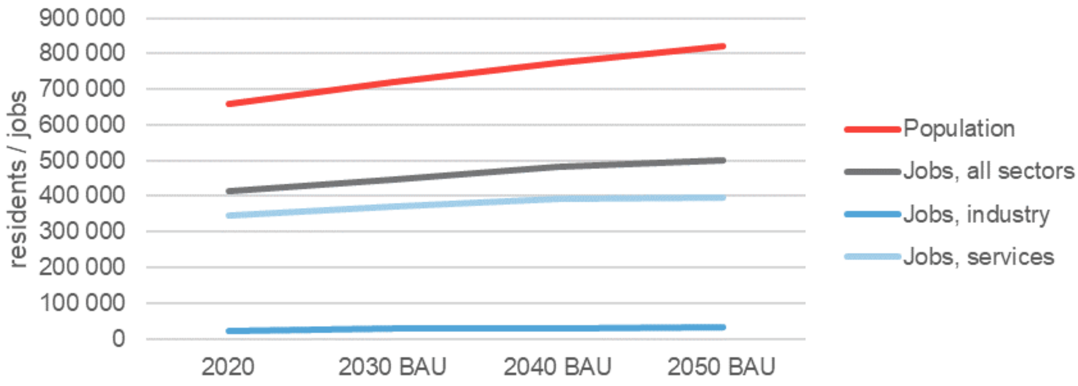

Figure 1. Projected number of residents and jobs in Helsinki (City of Helsinki 2022b).

2.3. General market trends

In addition to the development within the city, the formulation of a long-term outlook for emissions must make baseline assumptions about national and global market trends. For these assumptions, this work is primarily based on the WEM (With Existing Measures) scenario of the National Climate and Energy Strategy and its impact assessment (Koljonen et al. 2021), sector-specific climate roadmaps (Paloneva and Takamäki 2020) and, in the case of indirect emissions, also on the scenarios of measures decided by international organisations (ECAC, IEA, IMO).

3. The method

Many calculation models are used around the world to calculate the greenhouse gas emissions of cities. The calculation model used in this study combines the approaches of PAS 2070 (BIS 2014a), the U.S Community Protocol for Greenhouse Gas Emissions (ICLEI 2019) and GPC Version 1.1 (WRI 2021) for assessing city greenhouse gas emissions, which take into account both indirect emissions of a city or urban area as well as the direct regional emissions.

With regard to emissions generated within a set geographical area, the principles of the calculation model are similar to those applied in previous analyses of emission scenarios carried out in Finland (Lounasheimo 2015, Huuska et al. 2017, Karhinen and Lounasheimo 2021). The activity data and emission factors are assessed separately to implement the calculation.

The method of calculation is a simplified version of current emission inventories. Further sources of data on BAU scenario analyses and inter-city comparisons include the Hilma calculation model of Helsinki Region Environmental Services Authority (HSY 2022) and the ALas model for municipal emissions (Lounasheimo 2020) regarding geographic boundaries, and the Kulma (Liljeström et al. 2021) and ALasKulutus (Karhinen et al. 2023) calculation models for consumption-based emissions.

3.1. Scope categorisation

Defining geographic boundaries for emissions has a significant impact on emission calculation results because activities taking place within a city can generate emissions that occur inside the city boundary as well as outside the city boundary. To distinguish among them, emissions are grouped in this report according to BIS 2014a, ICLEI 2019 and WRI 2021 into scopes based on where the emissions occur. Scope 1, 2 and 3 emissions are defined as follows:

- Scope 1 emissions are GHG emissions from sources located within the city boundary.
- Scope 2 emissions are GHG emissions occurring as a consequence of the use of grid-supplied energy (electricity, heat, cooling) within the city boundary.
- Scope 3 emissions include all other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary.

Scope 1 emissions may also be termed “territorial” emissions as they occur solely within the territory defined by the geographic boundary of the city. Scope 2 and 3 emissions, on the other hand, also take into account the emissions caused by the city’s activities outside the city’s geographic boundaries. Some industry sectors (e.g. transport) may fall under more than one scope of emissions, in which case a more detailed definition of the emissions will be required to differentiate and categorise them.

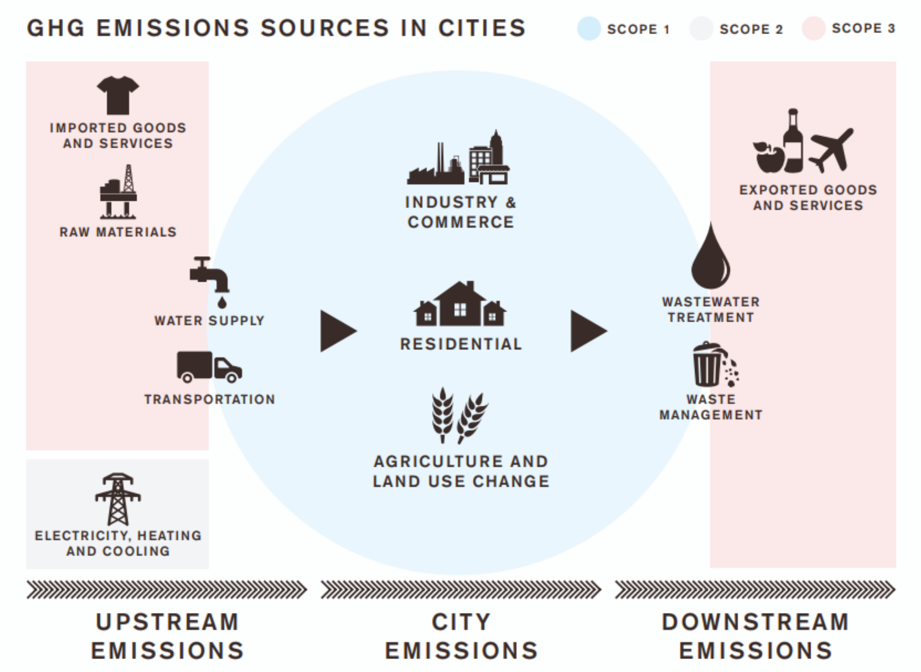

Figure 2. Scope 1, 2 and 3 emissions according to PAS 2070 (BIS 2014a).

3.2. The calculation model

The starting point for the calculation model is the establishment of geographic boundaries as described above. The calculation of GHG emissions for each cross-section year is based on an assessment of the development of the activity data and the emission factors associated with the activity measured:

$$GHG\ emissions\ =\ Activity\ data\ x\ Emission\ factor$$

The amount of GHG emissions is reported in carbon dioxide equivalents (CO2e), a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), which describes the relative potency of a greenhouse gas, taking account of how long it remains active in the atmosphere.

Activity data are a quantitative measure of a level of activity that results in GHG emissions (e.g., energy used in buildings or kilometres driven). The activity is assessed on the basis of statistical data and other sources, based on the measures of a BAU scenario and the city's general population and employment projections. Demographic development and the related construction, transportation and consumption have the greatest impact on the quantity of activity data.

The emission factor converts the activity into carbon dioxide equivalents (CO2e) expressed in weight (e.g., emissions per vehicle-kilometres travelled). Emission factors may be activity-based or life cycle-based (WRI 2013, WRI 2021):

– Activity-based emission factors describe the amount of greenhouse gases (GHG) emitted during a specific activity (e.g., fuel combustion during use). Activity-based emission factors are used to calculate scope 1 and scope 2 emissions.

- Life cycle-based emission factors include all the emissions that occur in the life cycle of a material or fuel (production, transport, combustion). Life cycle-based emission factors are used to calculate scope 3 emissions.

With regard to carbon dioxide, bio-based fuels have zero emissions in the calculations. Almost the same amount of CO_2 is considered to be captured by plants through photosynthesis while growing as is released during biomass combustion, which can make biomass a carbon-neutral source of energy. The production of biofuels and non-carbon emissions are nonetheless taken into account as a source of emissions.

3.3. Emissions sectors

In this report, emissions are broken down into sectors (Table 1) in a manner that largely corresponds to the city's previous emission reports (Huuska et al. 2017, HSY 2022). Unlike in the previous reports, however, the heating of buildings, electricity consumption and other stationary emission sources are described as sub-sectors of a common energy use sector for fuels in the manner described in the GPC and PAS 2070 (WRI 2021, BIS 2014a).

The calculation model also has a sector for other indirect emissions, which contains items that were not included in the previous calculation. Other indirect emissions are emissions that mostly occur outside the city boundary as a result of activities taking place within the city.

Table 1. Breakdown by sector of the emission sources included in the report. The items shown in brackets are not covered by the calculation model, typically due to the sub-sectors being accounted for elsewhere.

Sector	Sub-sector	Content	Scope
Energy use of fuels	**Heating of buildings**	Emissions from district heating of buildings	1
		Fuels used for separate heating of buildings	1
	Electricity consumption	Electric heating	2
		Other electricity consumption	2
	Other stationary sources of emissions	Fuel combustion in construction	1
		Fuel combustion in manufacturing industries	1
	Indirect emissions from fuels	Emissions from fuel production	3
Transportation	**Road transport**	Direct emissions from road traffic within the city	1
		(Electricity consumption by road and railway transport is described under “Electricity consumption”)	*(2)*
		Emissions from road traffic outside the city resulting from cross-border journeys	3
	Aviation and water transport	Emissions from journeys departing from the airport, with a sub-sector for journeys starting inside the city boundaries	3
		Emissions from journeys departing from harbours, with a sub-sector for journeys starting inside the city boundaries	3
		(Freight transport by air and water is described under “Other indirect emissions”)	*(3)*
Manufacturing industries	**Industrial processes**	Emissions from product use in industrial processes (solvents, propellants, coolants)	1
Agriculture and land use	**Agriculture**	Agricultural emissions from enteric fermentation, cropland and manure treatment	1
	Carbon sinks	Carbon stock changes and carbon sinks as a result of land use changes	1
		Changes in carbon stock resulting from using biomass as a source of energy	*(3)*
Waste	**Waste**	Emissions from wastewater treatment	1
		Emissions from landfill waste	2
		Composting of biowaste and sewage sludge	2
Other indirect emissions	**Food consumption**	Emissions from food consumed in the city	3
	Building materials	Emissions from building materials used in the construction of buildings and infrastructure	3
	Other consumption	Emissions from other services and goods consumed in the city	3

4. Energy use of fuels

4.1. Heating of buildings

Emissions from the heating of buildings refer to the energy used for space heating, cooling and water heating and the resulting emissions. The sources of energy are district heating, electricity, heat pump energy, fossil fuels and biomass. Of these, the emissions of electricity used for heating are reported as part of electricity consumption. Cooling energy has been omitted due to its minor importance in Helsinki.

The heating of buildings with district heat and fuel-powered heating plants is included in scope 1 emissions as the district heat transferred across city borders via a district heat network is of minor importance in the city.

Scenario baseline assumptions

The calculation model for the use of energy for the heating of buildings is based on building stock development (floor area, heat sources), energy consumption for the heating of buildings and the specific CO_2 emissions of building heat sources (Table 2). The specific CO_2 emissions of district heating are especially important as most of the energy used to heat buildings in Helsinki is generated and distributed through the district heat network.

Table 2. Variables of the projected emissions of heating energy in the BAU scenario.

Energy consumption	2020	BAU 2030	BAU 2050
Building stock	Building and Dwelling Register statistics	Helsinki City Plan 2016	
Heat sources of buildings		Geothermal heat becomes more common. Elimination of oil heating and direct electric heating by 2050	
Consumption of heating energy	Consumption data on city-owned buildings	The impact of renovation construction on the existing building stock, the energy efficiency of new construction and the impact of global warming	
Specific CO2 emissions			
District heating	Energy statistics (HSY 2022)	Replacing coal in heat production by 2029	Replacing the use of natural gas with heat pumps and biofuels

The building stock will grow until 2050 and at the same time increase the amount of floor area to be heated. The current state of the building stock has been estimated on the basis of the Building and Dwelling Register (City of Helsinki 2022c) and the building stock future outlook on the Helsinki City Plan 2016 (City of Helsinki 2018, City of Helsinki 2022d). Changes in the floor area have been estimated separately for one-dwelling, two-dwelling and terraced houses, blocks of flats, service buildings (commercial, office, assembly and education buildings) and other buildings.

The building stock reserves of the city plan take into account population growth. Especially the floor area of blocks of flats grows strongly, affecting the building stock energy needs. For this report, the City of Helsinki has provided access to the floor area reserves of the City Plan 2016 and its implementation programme, which illustrate the net changes in the floor areas of residential and office buildings by 2050 and a division by building type estimated using a computational method (Figure 3).

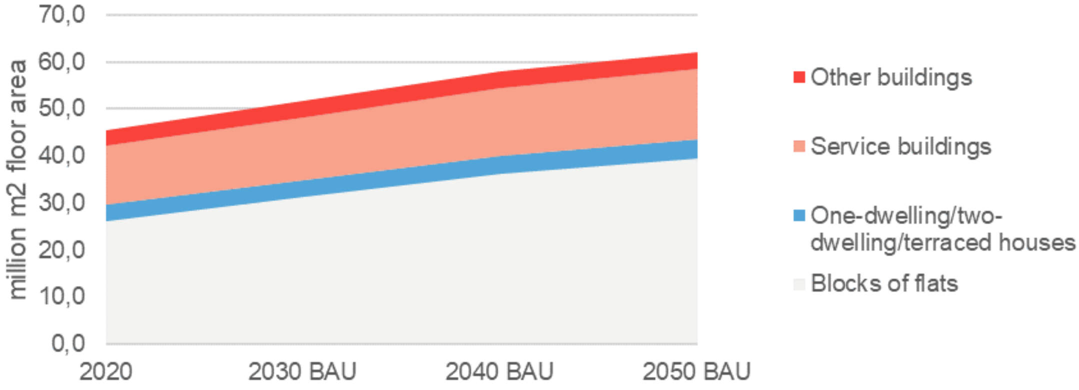

Figure 3. Growth of floor area in Helsinki according to the Helsinki City Plan 2016 (City of Helsinki 2022d). Service buildings include the floor area of retail, service and office premises.

The most important change in the scenarios for heat sources of buildings is geothermal heat becoming more common and the reduction in the proportion of oil heating (Figure 4). The growth in the proportion of geothermal heat as a heat source in the building stock of Helsinki has proliferated in recent years and is forecast to be 7–12% in 2030 (Vähäaho et al. 2022). The BAU baseline is a forecast of slower growth in which the proportion of geothermal heat from heating energy is 7% in 2030 and 15% in 2050. In the long term, the proportion of oil heating and other heating solutions is forecast to reduce to zero (Mattinen et al. 2016, Karhinen and Lounasheimo 2021).

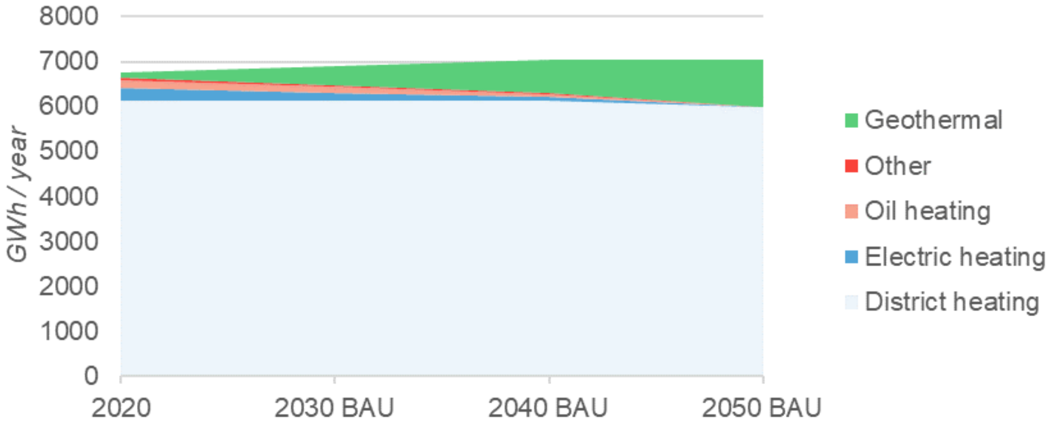

Figure 4. Projected building stock heat sources.

The heating energy consumption of the building stock decreases due to the energy efficiency of new construction, renovating the old building stock and climate change. Current heating energy consumption has been estimated separately for new and old building stock based on the city's statistics on the energy consumption of the buildings it owns (City of Helsinki 2022e). In terms of long-term changes, the consumption of heating energy by the building stock is based on the baseline scenario of the energy consumption of buildings (Mattinen et al. 2016, Karhinen and Lounasheimo 2021).

The specific CO2 emissions of energy used for heating buildings will decrease sharply in the short term due to a change in district heat production (Figure 5). Up to 2030, the specific CO2 emissions of district heat production are based on the BAU scenario of Helen Oy's development programme (Rantsi and Viholainen 2022), in which the use of coal as an energy source is reduced to zero by 2025. In the BAU scenario, coal is replaced without large investments in heat pumps, which increases the proportion of natural gas and biomass as an energy source.

From 2030 onwards, the projected specific CO2 emissions are not based on a plan of action but on general assumptions about the future trends of district heat production. Of the energy sources in use in 2030, the proportion of natural gas is assumed to decrease to zero according to Finnish Energy's low-carbon roadmap (Afry 2020). The energy sources to replace natural gas are assumed to be high-capacity heat pumps, in which case the use of wood-based fuels would not increase from the 2030 level. In the long-term scenario of Finnish Energy's low-carbon roadmap, geothermal energy and other new heat sources are also expected to be put into use.

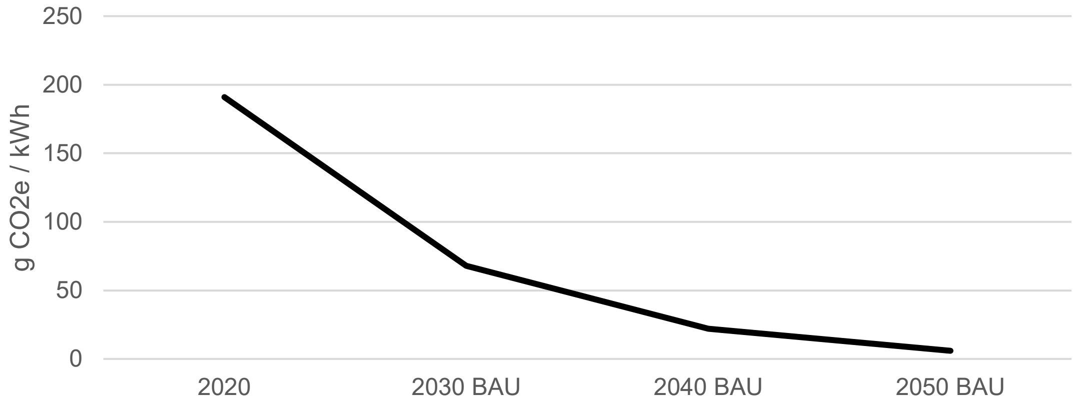

Figure 5. The projected specific CO2 emissions of district heating from the current state to 2050.

Projected emissions

In the long term, emissions from the heating of buildings will decrease significantly in relation to the current state (Figure 6). The need for purchased energy for buildings decreases in the BAU scenario despite the total floor area of the building stock growing. This is due to the increase in geothermal heat as a heat source and the decrease in the specific energy needs of buildings on account of renovation construction. However, what affects emissions the most are the specific CO2 emissions of district heating, which decrease when fossil fuels are replaced with heat pumps and biofuels.

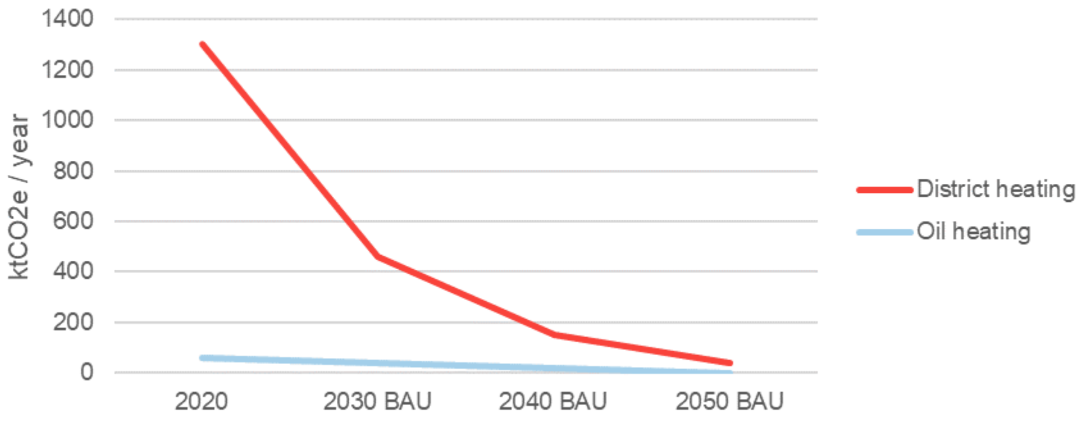

Figure 6. The BAU scenario for emissions from the heating of buildings from current state to 2050.

4.2. Electricity consumption

Electricity consumption refers to electricity used for heating (electric and geothermal heating) and electricity end-use consumption. It comprises the electricity consumption of the residential, service, industrial and public sectors in activities taking place in the city. The emissions from electricity consumed within the city boundary are wholly classified as scope 2 emissions. Due to the structure of the electricity market, in practice, the electricity consumed in the city cannot be assumed to come from its own production facilities (WRI 2021).

Scenario baseline assumptions

The BAU scenario for electricity consumption is based on changes in the consumption of the residential, industrial and service sectors and the future trends of the national specific CO2 emission factor of electricity. Residential sector electricity consumption includes forecasts on the use of electricity for heating, transport and other electricity use by households (Figure 7):

- The use of electricity for heating is estimated as part of the consumption of heating energy. The scenario takes into account the growth of the building stock floor area, geothermal heat becoming more common as a heat source in buildings and heat pumps in district heat production.
- The projected emissions of transport include an estimation of the use of electricity in transport. The scenario factors in changes in traffic volumes, the proliferation of electric cars and the expansion of the rail network.
- Other electricity use by households includes cooking, lighting and other electrical devices. Other electricity use is expected to increase in relation to population change.

The BAU scenario does not assume any future development in the energy efficiency of industry or services from the current state; it rather estimates that changes in the electricity consumption of industry and services will be relative to the change in the number of jobs in these sectors. Sector-specific forecasts on jobs in Helsinki have been estimated as part of the regional employment projection for Uusimaa (Laakso 2021).

Table 3. Variables of the projected emissions of electricity consumption in the BAU scenario.

Electricity consumption	2020	BAU 2030	BAU 2050
Electricity use for heating	Under “Heating of buildings”		
Transport	Under “Transport”		
Other use by households	Energy statistics, excluding heating	Change in the proportion of population	
Industry		Change in the proportion of jobs in industry	
Services		Change in the proportion of jobs in services	
Specific CO_2 emissions			
Electricity consumption	Energy statistics	National emission factor in the base case scenario of Finnish Energy’s low-carbon roadmap	

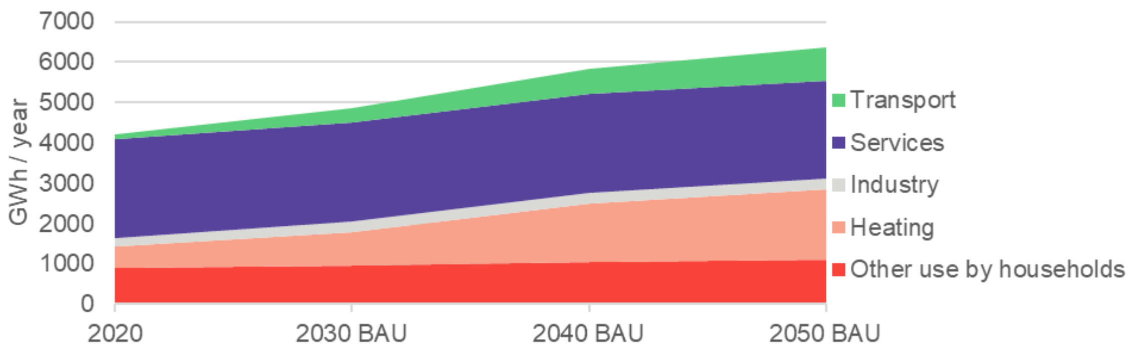

Figure 7. Projected electricity consumption in the BAU scenario from current state to 2050.

Emissions from electricity generation decrease sharply (Figure 8). The emissions from electricity consumption are calculated using a national source-specific emission factor. The current specific CO_2 emissions of electricity have been determined with Statistics Finland’s average emission factor for electricity generation (Statistics Finland 2021), and long-term development has been estimated according to the base case scenario of Finnish Energy’s low-carbon roadmap (Afry 2020, pp. 12–13). In the emission factors, the emissions from cogeneration have been distributed with a benefit sharing mechanism. The assumption is that electricity generation will change so that the use of coal will end by 2030, and the use of natural gas and peat by 2050. The same source-specific emission factor is applied in the calculation of emissions from electricity use for heating and electricity end-use consumption.

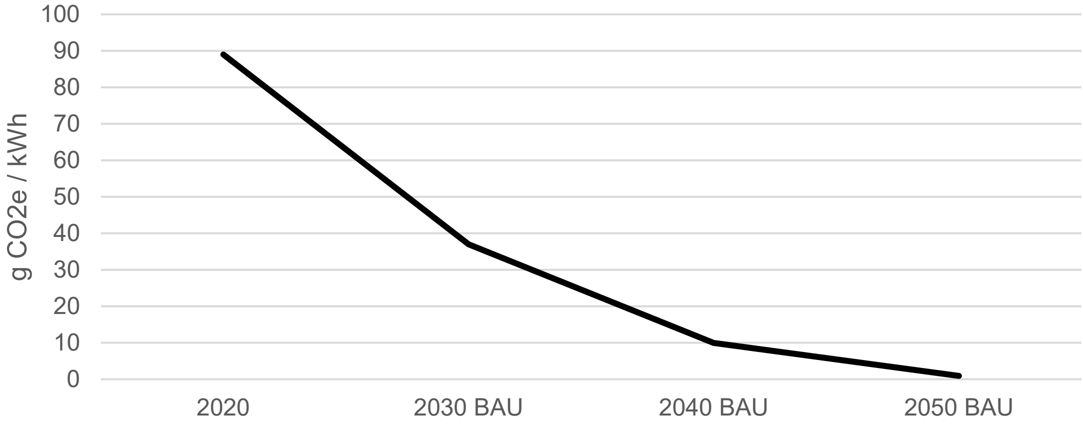

Figure 8. Specific CO2 emissions of electricity generation from current state to 2050.

Projected emissions

Emissions from electricity consumption decrease sharply from the current state due to the reduction in the specific CO2 emissions of electricity generation (Figure 9). Electricity consumption as a whole will grow by about 1% per year until 2050, mainly due to the electrification of heating and transport, as well as the electricity consumption of services. There is high uncertainty associated with electricity consumption in the services and industrial sectors, in which energy efficiency has not been assumed to improve.

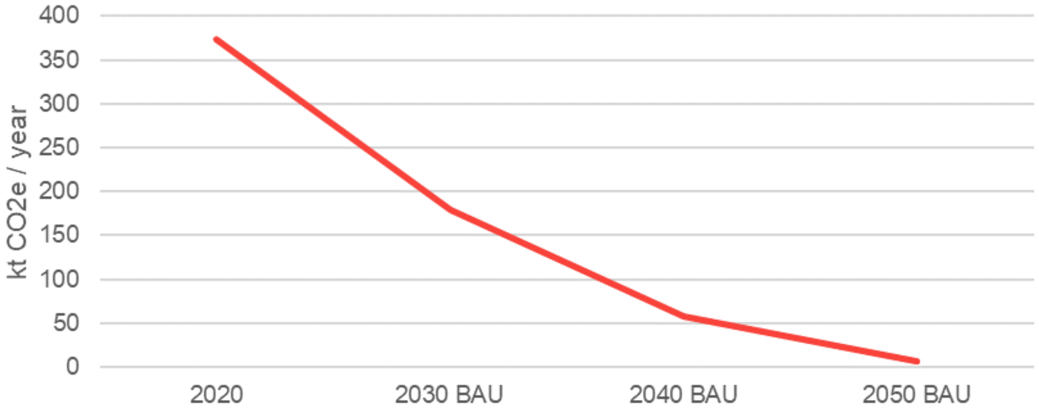

Figure 9. The BAU scenario for emissions from electricity consumption from current state to 2050.

4.3. Other stationary sources of emissions

Other stationary sources of emissions refer to the energy use of fuels in the industrial and construction sectors, excluding the heating of buildings. In industry, fuels are used, for example, to produce energy that powers steam boilers, melting furnaces, incinerators and machinery. On construction sites, fuels are used, for example, for heating, drying and machinery.

Table 4. Variables of other stationary sources of emissions in the BAU scenario.

Fuel consumption	2020	BAU 2030	BAU 2050
Industry	HSY Hilma calculation	Change in the proportion of jobs in industry	
Construction	Estimated on the basis of construction floor area	Change in the proportion of jobs in construction	
Specific CO2 emissions			
Fuels	Fuel class	Proportion of biofuel increases to 10% by 2028	

Scenario baseline assumptions

For total emissions, the importance of other stationary fuel combustion sources is minor, so their calculation model is simply based on the projected number of jobs in the respective sectors and the fuel classification of Statistics Finland. It is also taken into account that the proportion of biofuel from light fuel oil will increase to 10% by 2028.

Projected emissions

Emissions from the energy use of other solid fuels increase in the city due to the increase in construction and industry. The distribution obligation of biofuels will only compensate for the change slightly. The importance of the sector's projected emissions to total emissions is minor.

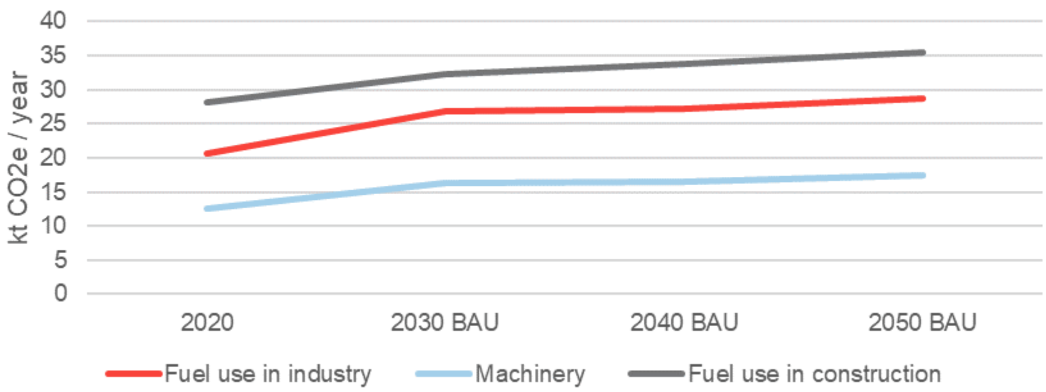

Figure 10. The BAU scenario for other stationary emission sources from current state to 2050.

4.4. Indirect emissions from fuels

Indirect emissions from the energy use of fuels consist of indirect emissions caused by the production, processing and transport of fuel that is used in the city. Emissions from the combustion of fuels during operation have been reported in other sub-sectors.

Emissions from the production, processing and transport of fuels occur outside the city as part of the production of the consumed fuel. The calculation model includes fuel used in the heating of buildings, which mainly comprises consumption through district heat production. Emissions from the production of fuels have been calculated using the source-specific emission factors established in accordance with the database of the Department for Business, Energy & Industrial Strategy (2021). Emissions from the production of fuels also include emissions caused by the collection and transport of biomass.

Like emissions from district heating, indirect emissions from fuels also decrease steadily as the proportion of heat pumps and biofuels among energy sources rises (Figure 11). Emissions from biofuel production are lower than emissions from fossil fuels when their use has been assumed to focus on forest chips and forest industry side streams in the future.

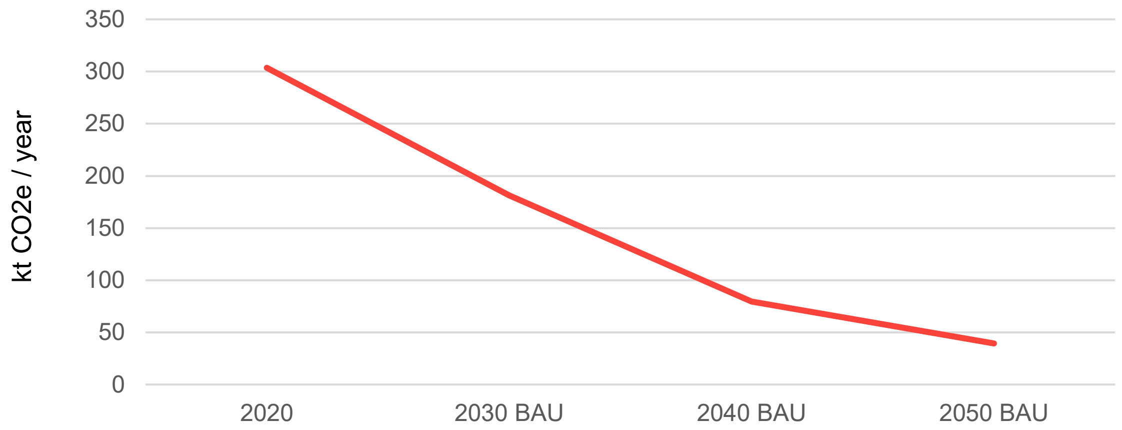

Figure 11. The BAU scenario for indirect emissions caused by the use of fuels to 2050.

5. Transport

5.1. Road transport

Road transport emissions mean emissions resulting from the consumption of fuels by cars and vans, heavy-duty vehicles and buses. Emissions are generated as direct emissions through the exhaust pipe and in the production of fuels. Electricity consumption in transport mainly takes place in connection with housing and is thus included in the emission sector of electricity consumption.

There is road transport both inside and outside the city boundary as the result of activities in the city. The classification of emissions into emissions occurring inside the city boundary and indirect emissions from activities has been done using the derived demand method presented by the GPC standard (Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, WRI 2021).

In road transport, scope 1 emissions include direct emissions from transport within the city (origin and destination in Helsinki) and half of the kilometres travelled of journeys that cross the city border (origin or destination in Helsinki). Scope 3 emissions include half of the kilometres travelled of journeys that cross the city border. In addition, scope 3 emissions include emissions from the production of fuels consumed in road transport.

<u>Scenario baseline assumptions</u>

The BAU scenario for road transport is based on projections of traffic performance measured in kilometres travelled, change in the power source of vehicles, the distribution obligation of biofuels and specific CO2 emissions of fuels. The baseline assumptions are presented below (Table 5).

The kilometres travelled have been estimated by mode of transport on the basis of the data produced using the Helsinki Region Transport forecast model (Supponen and Kyytsönen 2022). The traffic volume trends take into account new land use as suggested in the city plan and any transport development projects approved for implementation at the time of making the calculations.

In road transport, traffic performance mainly consists of passenger car journeys, for which the number of kilometres travelled grows in line with population growth. This means that there are no significant changes in the breakdown by mode of transport of journeys made within the city and to the city in the reference years of the scenario. Intensified land use and new construction along good public transport connections in accordance with the city plan increases the use of sustainable modes of transport, however, at the same time, the relatively lower operating costs of electric cars have an increasing effect on the use of passenger cars. (Supponen and Kyytsönen 2022.)

Table 5. Variables of the projected emissions of road transport in the BAU scenario.

Kilometres travelled	2020	BAU 2030	BAU 2050
Passenger cars	A separate scenario prepared on the basis of the Helsinki Region Transport forecast model: • Changes in the number of residents and jobs by region (intensification of land use under the city plan) • Decided and ongoing transport projects • Car operating costs (rise of electric cars)		
Heavy-duty vehicles			
Buses			
Specific CO2 emissions			
Fleet of cars	LIISA calculation	The rise of electric cars according to a national base case forecast	
Fuels	LIISA calculation	Distribution obligation of biofuels 30%	
Electricity consumption	LIISA and RAILI calculations		

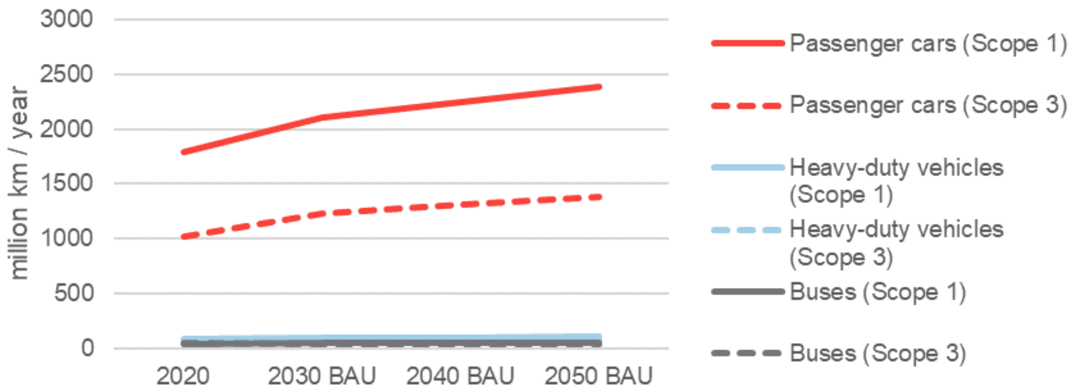

Figure 12. Road transport change in kilometres travelled in the BAU scenario.

Road transport's specific CO2 emissions reduce with the proliferation of electric cars (Figure 13). The power source data on passenger cars and heavy-duty vehicles are based on the base case forecast of greenhouse gas emissions in domestic traffic (VTT 2021), but for buses, the baseline assumption is faster electrification of transport than in the abovementioned forecast. In the long term, electricity will be the main source of energy for passenger cars and buses, while the pace of introducing electricity to heavy-duty vehicles is slower.

The specific CO2 emissions of road transport also take into account the distribution obligation of biofuels, which requires that the proportion of the energy content of biofuels from the total energy content of petrol, diesel and biofuels supplied by the distributor be increased to 30% in 2029. More precise assumptions have not been made on the division between fuels. The emission factors used in the work mainly correspond to the previous forecasts on the specific CO2 emissions of Helsinki's car fleet (Kaartinen 2021).

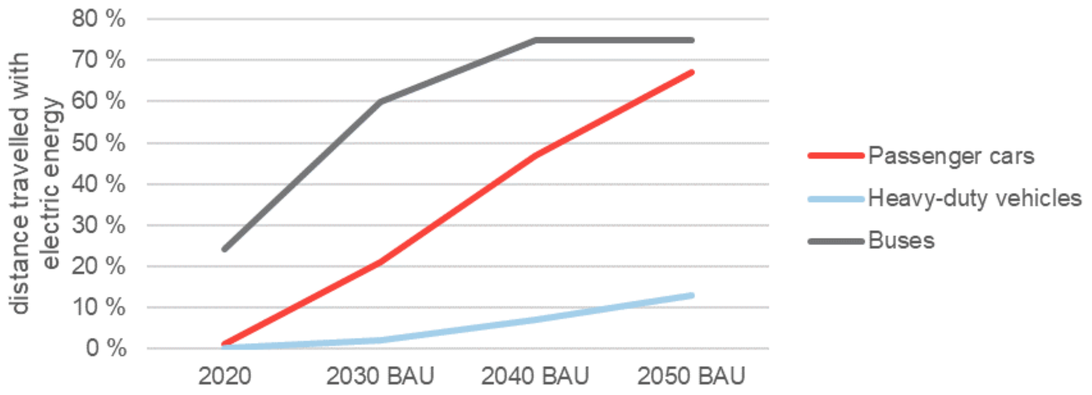

Figure 13. The proportion of distance travelled with electric energy from total kilometres travelled in the BAU scenario.

Projected emissions

Emissions from road transport decrease due to a strong reduction in specific CO2 emissions although the number of kilometres travelled increases (Figure 14). The reduction in the specific CO2 emissions of road transport is especially due to the electrification of transport and the impact of the distribution obligation of biofuels.

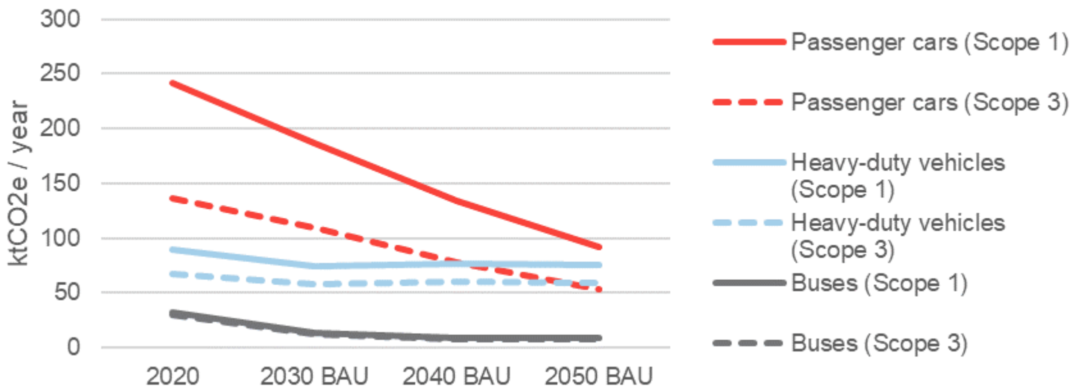

Figure 14. The BAU scenario for emissions from road transport from current state to 2050.

5.2. Air and water transport

Air and water transport means the passenger traffic at Helsinki Airport and ports located in Helsinki. Emissions from the transport of goods included in the other indirect emissions sector as part of the life cycle emissions of the consumption of food, goods and services are excluded from the subsector.

Airport and port terminals serve a wider area than the city, so emissions are recommended to be quantified with an area-based approach in proportion to the amount of travel departing from the area (WRI 2021). In the report, emissions have been calculated for completed journeys and are included in the scope 3 category. Only the emissions of departing journeys are considered to be emissions caused by activities in the city.

For air and water transport, the reference year used for comparisons between the current state and the scenario is 2019, because in 2020, the demand for air and water transport was exceptionally low due to the COVID-19 pandemic.

Scenario baseline assumptions

In the BAU scenario for air transport, future emissions and kilometres travelled are estimated on the basis of passenger volumes, travel destinations and the emissions factors of flights. The current state is based on passenger statistics and the long-term development trends on a Europe-wide scenario analysis.

According to air transport passenger statistics, the total number of journeys departing from Helsinki Airport was 15.1 million in 2019 (Finavia 2021a) and the average distance travelled about 2,400 kilometres (Finavia 2021b, Finavia 2021c) when the flight distance is assumed to be from Helsinki Airport to the capital city of each destination country. Approximately 15% of the passengers who responded to the Helsinki Airport passenger survey departed from Helsinki (Finavia 2006).

The current emissions associated with flights have been calculated using the CO2 Connect Calculator (IATA 2020) while taking into account the travel destinations. The weighting of the destination countries and cities is relative to the amount of travel. The specific CO2 emissions are calculated by dividing the amount of total emissions with the number of passenger-kilometres.

The long-term scenario for passenger volumes and emissions in air transport is based on the baseline scenario of the European Civil Aviation Conference (ECAC) (Traficom 2022), the preparation of which has taken into account the impact of the COVID-19 pandemic on air transport. According to the forecast, the pre-pandemic level of air travel will be reached by 2028 and the number of air transport passengers will increase by about 5% by 2030 and by 35% by 2050.

With regard to long-term trends in specific CO2 emissions, the starting point is a scenario that takes into account the technological development of aircrafts and improved fuel efficiency after 2019 (Traficom 2022). In the scenario, air transport emissions per passenger-kilometre are reduced from the 2019 level by 12% by 2030 and by 23% by 2050.

Table 6. Variables of the projected emissions of air transport in the BAU scenario.

Completed journeys	2020	BAU 2030	BAU 2050
Number of journeys	Passenger statistics	Growth according to the ECAC Baseline scenario, taking into account the impact of the COVID-19 pandemic	
Travel destinations	Travel statistics by destination country		
Proportion of journeys departing from Helsinki	Helsinki Airport passenger survey		
Specific CO2 emissions			
Emission factor for flights	IATA emissions calculator	ECAC Aircraft Technology scenario that takes into account the impact of technological development	

In the BAU scenario of water transport, the future number of completed journeys and amount of emissions are estimated based on passenger volumes, travel destinations and emission factors of flights. The passenger statistics and the long-term development, which serve as a source of information on the current state, are estimated on the basis of Europe-wide aviation scenarios.

According to the passenger statistics on shipping, there were approximately 11.6 million outbound boat trips in 2019 (Port of Helsinki 2020). The number of passenger-kilometres is based on international maritime transport statistics (Statistics Finland 2022a) and, for domestic journeys, on data from the Port of Helsinki. Based on these data, the average distance travelled is 145 kilometres. According to the destination survey of ports by Helsinki Regional Transport Agency HSL (Tuominen and Kiiskilä 2016), the share of passengers departing from Helsinki is 40%.

The current specific CO2 emissions of shipping are from the LIPASTO emissions database for the year 2016 (VTT 2016). In the emissions database, area-based allocation has been used to allocate 80% of the emissions from a car ferry to passengers and 20% to cargo. This allocation produces results similar in size to those of the MERIMA emission calculation models of Finnish ship traffic (Salanne et al. 2022). The speed of the car ferry has been assumed to be 25–27 knots for traffic to Estonia and 18 knots elsewhere. Half of the traffic between Estonia and Finland is gas-powered. Emissions from shipping do not include the electricity consumption of ports, but the fuel consumption of a ship in the port is included.

In terms of passenger volumes, the long-term scenario for shipping is based on a scenario analysis by the Port of Helsinki (Port of Helsinki 2020). The analysis has assumed that passenger transport will increase by about 30% from 2019 to 2040, with the port operations continuing in their current locations. The passenger volumes for 2030 and 2050 have been estimated on this basis, with the assumption that growth will continue at a steady pace before and after 2040.

The emission factor for shipping is expected to decrease in the long run as a result of taking various measures. The new measures to be introduced in the long run include, for example, lower speed limits, utilisation of waste heat, wind rotors, reduction of hull resistance and alternative fuels. (IMO 2020.)

According to a report by the International Maritime Organization (IMO 2020), carbon dioxide emissions from maritime transport have decreased in relation to the reference year

2008 and have diverged from the growth trend in the number of completed journeys in maritime transport. In the report's long-term BAU scenario the emissions efficiency of shipping as a whole improves by an average of 25% and for passenger vessels by 20% by 2050.

The BAU scenario for the specific CO2 emissions of shipping is based on the above long-term scenario by IMO. The emissions trading under preparation has not been taken into account in the scenario, however, the starting points are improving the energy efficiency of ships and redesigning them with a market-driven approach in accordance with the Energy Efficiency Design Index (EEDI).

Table 7. Variables of the projected emissions of shipping in the BAU scenario.

Completed journeys	2020	BAU 2030	BAU 2050
Number of journeys	Passenger statistics for Port of Helsinki	Scenario analysis for Port of Helsinki	
Travel destinations	Travel statistics by destination country		
Proportion of journeys departing from Helsinki	Passenger surveys at ports		
Specific CO2 emissions			
Emission factor for boat trips	LIPASTO unit-specific emissions	Emission reductions through improved efficiency of passenger ships in the International Maritime Organisation's (IMO) BAU scenario	

Projected emissions

In the BAU scenario for air and water transport, emissions will increase from the current state to 2050, mainly due to an increase in demand. Emissions from air transport will first decrease to 2030, partly due to the long-term effects of the COVID-19 pandemic on passenger volumes. However, in the long run, emissions will increase slightly, by about 4% by 2050.

In water transport, the BAU scenario does not include a corresponding decrease in passenger demand due to the COVID-19 pandemic as in air transport. In the long term, passenger volumes will increase by 30–40% and emissions by 10–15% from the current state.

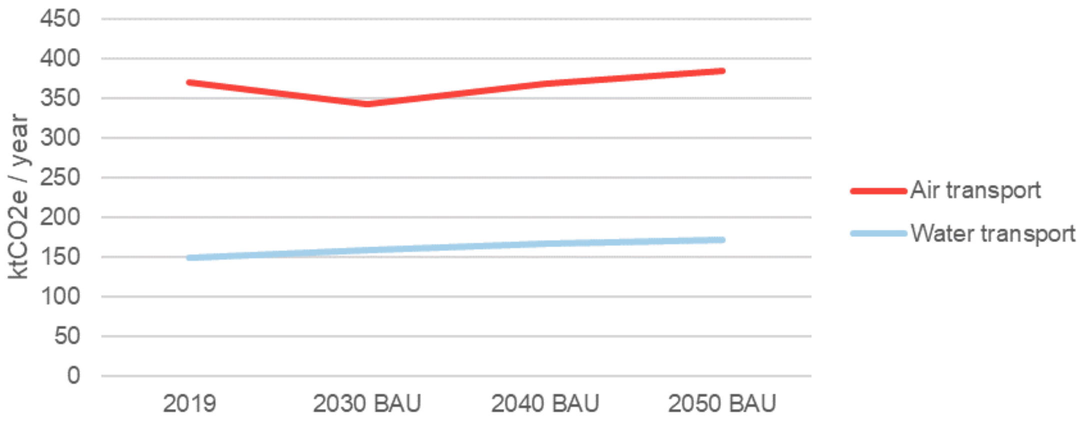

Figure 15. Emissions from air and water transport in the BAU scenario from the current state to 2050. The base year for the current state is 2019, when the COVID-19 pandemic did not reduce the passenger volumes.

6. Industry

Emissions from industry mean the emissions generated through industrial processes and product use, which are mainly caused by the chemical treatment and physical processing of raw materials. Emissions from the energy use of fuels in industry are calculated as part of the energy use of fuels.

Emissions from industrial processes and product use are unimportant in Helsinki as a whole, so their future development is not estimated separately. Emissions from industrial processes are less than a kilotonne per year (HSY 2022).

7. Waste

Waste management comprises landfill disposal of waste, composting of bio-waste, composting of sewage sludge and wastewater treatment. The management of waste disposed in landfills and bio-based waste in Helsinki takes place outside the city (scope 3) and wastewater is treated at the Viikinmäki wastewater treatment plant (scope 1). Emissions from composting by properties have been excluded from the analysis because they have been discarded as an important source of emissions.

Scenario baseline assumptions

The current state of emissions from waste management can be established on the basis of the Hilma calculation of HSY (HSY 2022). Future trends in projected emissions are estimated on the basis of historical trends. Emissions from the processing of waste disposed in landfills have decreased by 5% annually since 1990, and this trend is expected to continue into the future. With regard to biowaste and wastewater, emissions have grown moderately, so their development is expected to follow the demographic trend.

Projected emissions

Emissions from waste management as a whole decrease slightly due to the decrease in the emissions from waste disposed in landfills (Figure 16). Emissions from waste management are of minor importance at the city level.

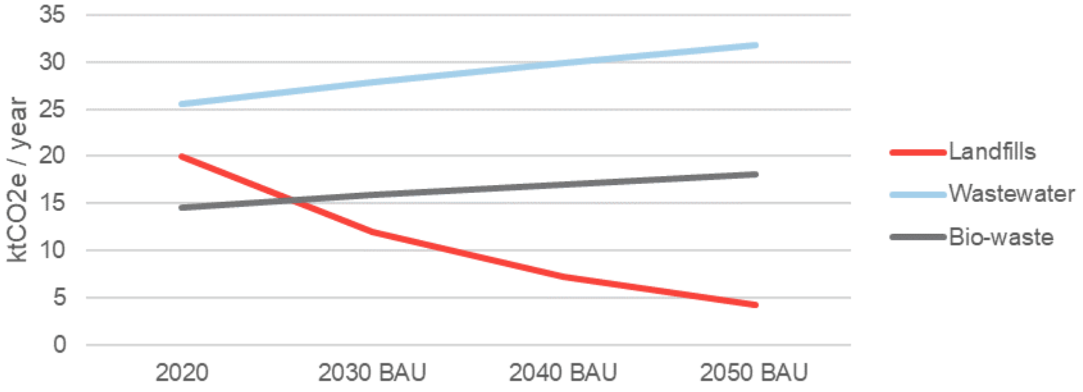

Figure 16. Emissions from waste management in the BAU scenario from the current state to 2050.

8. Agriculture, forestry and land use

8.1. Agriculture

Emissions from agriculture cover emissions from domestic animals and in-field soil emissions within the city, which are mainly caused by animal digestion and handling of manure. These emission sources are classified as scope 1.

Scenario baseline assumptions

The current state of emissions from agriculture can be established on the basis of the results of the Hilma calculation by HSY (HSY 2022). Future trends in projected emissions are estimated on the basis of historical trends. From 1990 to 2020, emissions from agriculture in Helsinki have decreased by about 50% (HSY 2022), and this trend is expected to continue.

Projected emissions

Emissions from agriculture as a whole are decreasing, however, their importance is minor at the city level.

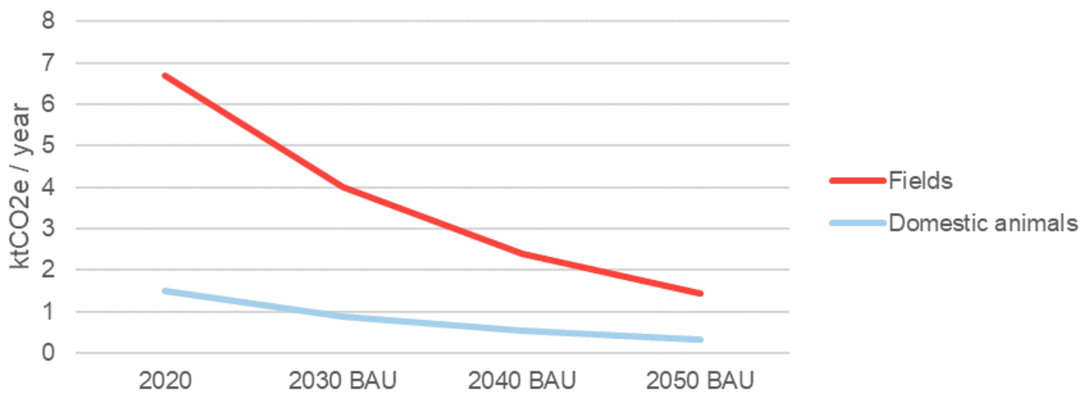

Figure 17. Emissions from agriculture in the BAU scenario from the current state to 2050.

8.2. Carbon sinks

A carbon sink is a mechanism that absorbs carbon dioxide from the atmosphere. The calculation of carbon sinks uses a method for reporting annual changes in the carbon stock in biomass. An area acts as a carbon sink when the total carbon stock sequestered by vegetation and soils increases. Carbon stock refers to the amount of carbon dioxide stored in vegetation and soils in green areas. The stock increases when more carbon is sequestered than released annually (including harvesting).

Scenario baseline assumptions

The existing carbon stocks currently located within the Helsinki city boundary have been assessed in the Carbon Sink Mapping of Helsinki Metropolitan Area carried out by HSY (HSY 2021). The mapping work included measuring the carbon stocks and their annual changes in vegetation and soil for various management categories:

- urban green spaces (A),
- open-space areas reserved for green spaces (B),
- urban forests (C),
- protected areas (S), and
- other areas (E, O, R).

The most important future development path in the city of Helsinki regarding the change in carbon stocks is new construction and a land-use approach that reserves areas designated as green spaces for urban blocks and street areas (Appendix 1). These changes have two ways of affecting the carbon stocks:

1. Carbon sequestration by vegetation and soils decreases during construction, which is considered an emission source.
2. A permanent change in land use affects the ability to annually increase the carbon stocks as well as the amount of carbon sequestered.

The annual change in carbon stocks for the long-term BAU scenario is calculated based on changes in the land areas chosen for a land-use category, for all subdivisions of land area. Carbon stocks and carbon fluxes are quantified per ground area for each subdivision of land area, land-use category and management category in the current state. This data is accompanied by information on changes in the land areas chosen for a land-use category, for all subdivisions of land area (Appendix 1). The carbon stocks of each management category are assumed to change in relation to their current carbon stocks, with the exception of protected areas (S), in which the stocks remain unchanged.

When calculating the annual change in carbon stocks, the method used takes into account that the change in land-use category from green space to built environment does not directly indicate a complete removal of the carbon stock; urban blocks and street areas will have areas in which carbon stocks (green spaces, trees) are preserved. Quantifying the carbon stocks is done for all subdivisions of land area so that the differences in the method of construction between city districts can be taken into consideration in the amount of carbon stocks to be preserved within the urban blocks.

Projections of future trends in carbon sinks

Carbon sequestration by vegetation and soils in carbon stocks located within Helsinki city limits decrease from the current state as the result of construction (Figure 17). The current carbon stock is about 5,610 kt CO2 (HSY 2021), and it will decrease by 8% by 2050 due to changes in the land-use categories. In the calculation model, this decrease has a trajectory of annual values of removals; in other words, it is deducted from the amount of carbon sequestered by growing vegetation.

The change in the carbon stock of vegetation and soils currently stands at -95 kt CO2 per year. In the BAU scenario, the annual change in carbon stocks is about 7% lower than the current state and, in the long term, the change will be about -89 kt CO2 in 2050. Carbon sequestration by vegetation or soils in carbon stocks thus acts as a carbon sink in all the reference years, although changes in the land-use categories reduce the amount of carbon sequestered by vegetation annually.

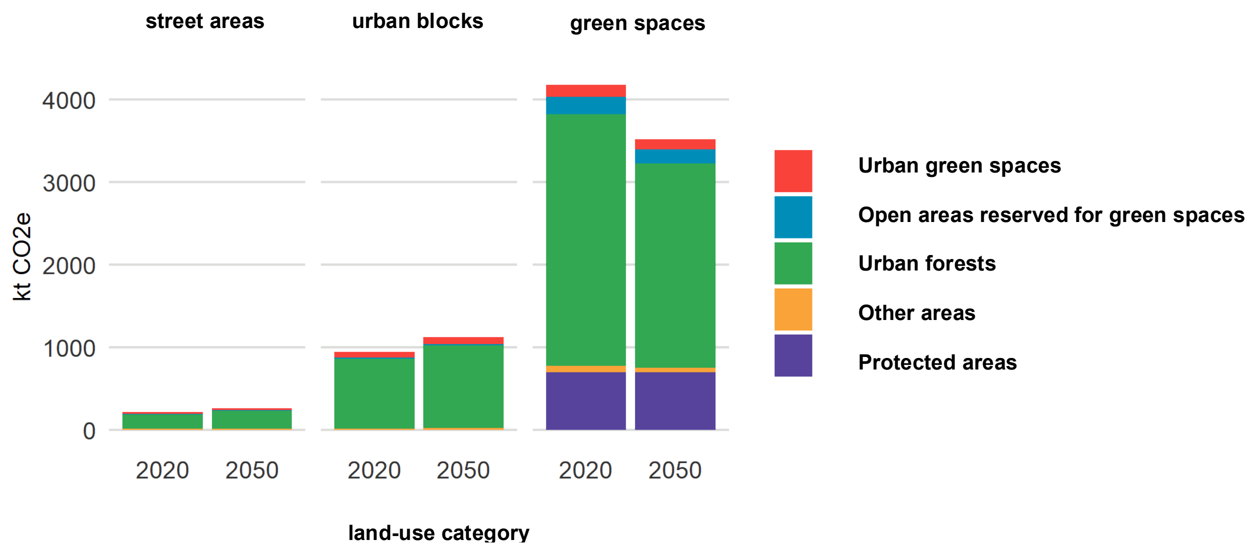

Figure 18. Carbon stocks of areas designated in various land-use categories and management categories in the current state and in the BAU scenario to 2050.

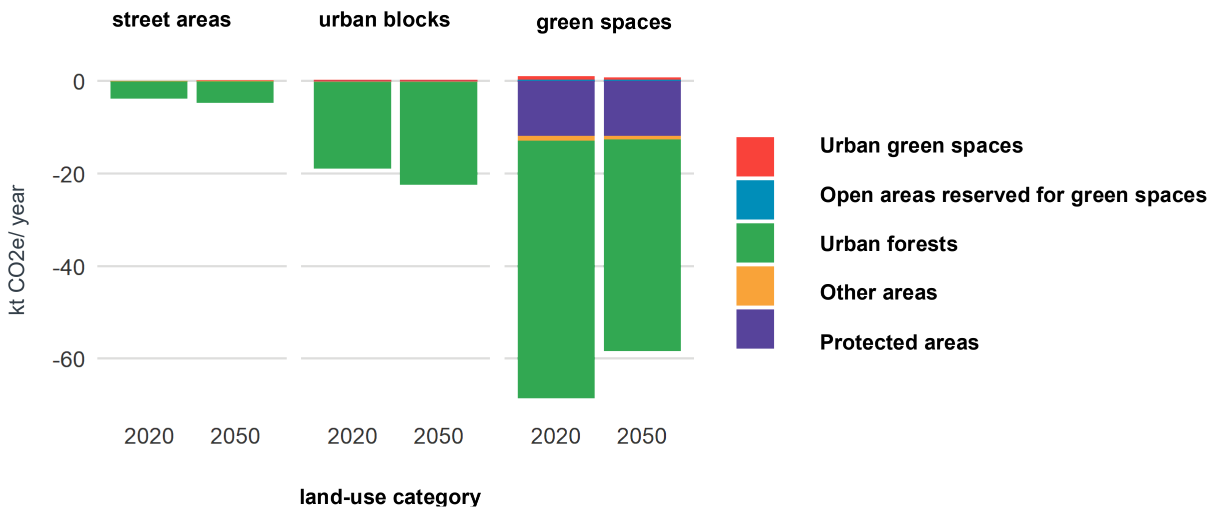

Figure 19. Annual change in the carbon stocks of areas designated in various land-use categories and management categories in the current state and in the BAU scenario to 2050.

Changes in carbon stocks resulting from the use of biomass

Bio-based fuels have zero carbon emissions in the calculation in the energy use of fuels sector. Carbon emissions from the use of biomass are not calculated in the energy use sector, as they are included in the carbon stock changes of the land use sector. For example, according to the GPC standard (WRI 2021), emissions from the burning of wood pellets or forest chips must be reported as a change in the forest carbon stock in the forest growth area instead of the area of use.

Based on the calculation principles, the emissions caused by the use of biomass correspond to other indirect emissions caused by activities in the city (e.g. indirect emissions from the use of fuels). In the BAU scenario, increasing the use of biomass will replace fossil fuels and the increasing use of biomass may at the same time weaken the carbon balance of forests outside the city boundary.

The biomass used in district heat production is currently focused on forest chips (Finnish Energy 2022). In addition, increasing the use of forests seems to significantly reduce carbon sinks in relation to the reduction of emissions achieved through the replacement of fossil fuels (Soimakallio et al. 2022).

However, the impact of the city’s increased use of wood energy on carbon stocks has not been taken into account in the calculation model of this analysis. A computational presentation would require baseline data on how much of an impact the use of biomass in the city’s energy production has on the harvesting of wood, and how well the forest chips generated as side streams of other forestry activities meet the energy use needs.

9. Other indirect emissions

Other indirect emissions mean emissions from the consumption of food, goods and services that occur outside the city. Consumption-based emissions are generally not included in calculation models in which emissions are broken down by geographical area (ICLEI 2019, WRI 2021), however, they are partially included in the “Direct Plus Supply Chain” (DPSC) assessment method of PAS 2070 (BIS 2014a). Other indirect emissions are included in scope 3 emissions.

Consumption-based emissions can be calculated using two methods (Heinonen et al. 2022):

1. Area-based calculation takes into account all consumption in a given area, regardless of where the consumer is from.
2. Residence-based calculation takes into account the consumption of the residents of the area, regardless of where the consumption takes place.

The scope 3 definition “emissions occurring outside the city boundary resulting from activities that take place inside the city” is more in line with area-based calculation. However, due to the available data sources, the data on emissions from consumption are mainly based on the consumption of residents.

Emissions from consumption include emissions from the entire life cycle of goods or a service, and they partly overlap with other sectors. For example, a large part of the emissions from the production of services are caused by the heating of buildings, electricity consumption and transport, which are calculated in other sectors. The calculation models therefore usually calculate emissions from consumption separately from emissions broken down by geographical area (BIS 2014a, ICLEI 2019).

In this report, however, consumption-based emissions have been placed in the same calculation model in which emissions are broken down by geographical area with the other emission sectors. The calculation model has been applied with the aim of separating emissions generated within the city boundary from emissions embedded in imports.

9.1. Food consumption

Emissions from food consumption mean the emissions caused by food consumed by city residents. Emissions from food production are mainly generated in primary production and agriculture, so emissions from the food consumption of city residents in Helsinki are mainly generated outside the city.

Scenario baseline assumptions

Emissions from food consumption per capita in Helsinki are currently 1.83 tonnes of CO2-eq per year. About 84% of the annual emissions are generated outside of the geographical area of Helsinki. (Karhinen et al. 2023.) A similar size estimate of the emissions caused by the consumption of food by residents has also been made with the Kulma calculation model, which is based on actual consumption (Liljeström et al. 2021).

The baseline data of the long-term BAU scenario is based on demographic trends and the national With-Existing-Measures (WEM) scenario for the projected emissions of agriculture up to 2050. The city’s demographic trend follows the population projections for the city, and food consumption per capita is expected to remain at the current level until 2050. This assumption is similar to the national WEM scenario, in which food consumption per capita was generally assumed to remain at the 2019 level from 2019 to 2050 (Miettinen et al. 2022).

In the national WEM scenario, emissions from agriculture are expected to decrease moderately by about 4% by 2040 (Koljonen et al. 2022). In the WEM scenario of the Climate Roadmap for Agriculture, emissions decrease by about 7% by 2050, while the production level remains unchanged (Lehtonen et al. 2020). These serve as the BAU scenario's baseline assumption for the change in emissions associated with food.

Table 8. Variables of the projected emissions of food consumption in the BAU scenario.

Food consumption	2020	BAU 2030	BAU 2050
Number of residents	Demographic statistics	Helsinki population forecast	
Consumption expenditure	Food consumption per capita at the current level		
Consumption structure	No assumptions about dietary changes or deductions based on consumer choice		
Specific CO2 emissions			
Emission factor per consumption unit	Emission factor per resident	Moderate decrease in emissions from agricultural production according to the national WEM scenario	

<u>Projected emissions</u>

Consumed food is of high importance in the indirect emissions caused by activities in the city now and in all the reference years of the BAU scenario (Figure 20). Emissions from food consumption will increase by about 15% from the current state when changes in the consumption structure are not used as the baseline for the scenario. Population growth increases consumption, and from the point of view of emissions, the development of efficiency is moderate in agricultural production.

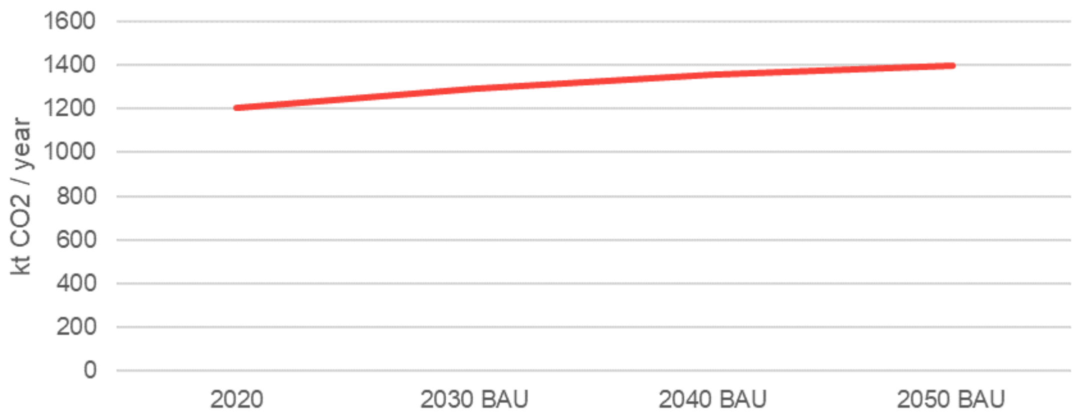

Figure 20. Projected indirect emissions caused by the use of fuels in the BAU scenario to 2050.

9.2. Consumption of construction materials

Emissions from construction materials refer to the building materials used in buildings and infrastructure and the materials used to repair them. Currently, the most important ones are concrete, steel, wood, asphalt and stone aggregates. Emissions associated with materials account for the majority of emissions generated during the life cycle of construction. Other emissions from construction (construction sites, transport) are calculated as part of other sectors.

Scenario baseline assumptions

Construction materials are consumed in two ways: in housing construction and infrastructure construction. Emissions from these activities have been estimated separately. The emission calculation model for both is based on estimating the volumes of construction taking place within the city boundary and estimating the specific CO2 emissions of various construction materials.

The annual floor area of new housing construction has been calculated on the basis of the floor area of buildings completed in 2020 (City of Helsinki 2022c), and the long-term scenario is based on the city plan's net floor area during the previous decade (City of Helsinki 2022d).

The amount of construction per year decreases in the scenario for the reference years 2030 and 2050 (Figure 21). This is explained by the exceptionally high volume of construction of residential and office buildings in 2020. In the scenario, the amount of construction per year decreases after 2040, however, the long-term estimate of the amount of construction may need to be updated to a higher level due to new local master plans or city plans.

The current specific CO2 emissions of materials used in construction and renovation construction are based on studies of various building types (Bionova 2021, Laine et al. 2020). Specific CO2 emissions have been determined by building type (one-dwelling, two-dwelling and terraced houses, blocks of flats, service buildings, other buildings), the current and future net floor areas of which can be obtained from construction statistics and the city plan.

The strongest impact on the specific CO2 emissions of construction materials in the future will be caused by:

- Material choices for the building stock: The carbon footprint of wooden structures is about 20–25% smaller than the carbon footprint of concrete structures (Bionova 2018).
- Projected emissions from the manufacturing of construction materials: Making the right choices in the manufacture of materials is a way of affecting the generation of emissions during the life cycle of the manufacturing process, for example, by choosing low-carbon concrete products. In addition, the manufacturing of cement is covered by the emissions trading system, which affects the emissions generated by concrete (Klimscheffskij et al. 2020).

The control of low-carbon buildings is based on the entire building life cycle, including the construction activities, heating energy, construction materials and demolition, so the future development of the above factors cannot be estimated separately from the control of the entire life cycle. Simply put, the future emissions of construction materials are assumed to reduce by 20% by 2030 and 40% by 2050 based on the estimates made in the low-carbon roadmap of the Confederation of Finnish Construction Industries RT on the impact of emissions trading on concrete and steel production (Klimscheffskij et al. 2020).

Table 9. Variables in the projected emissions of construction materials in the BAU scenario.

Floor area (m2)	2020	BAU 2030	BAU 2050
New construction of buildings	Building and Dwelling Register	Helsinki City Plan 2016 floor area (m2)	
New construction of infrastructure	Construction of street areas in line with the increase/decrease in the surface area of urban blocks (Appendix 1) Separate large infrastructure projects under the City of Helsinki Investment Programme		
Specific CO2 emissions			
New construction of buildings	Emission factors of building types	The impact of emissions trading on concrete and steel production	
New construction of infrastructure	Multiple sources	The impact of emissions trading on the specific emissions of asphalt and stone aggregates	

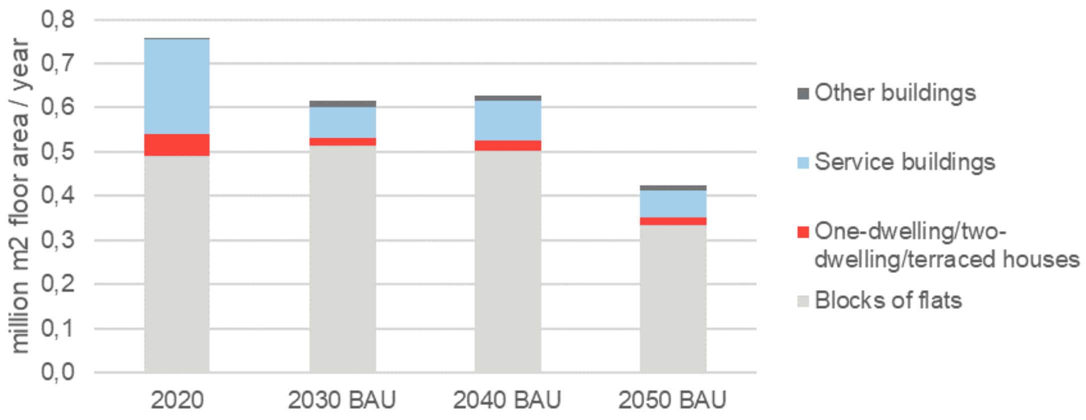

Figure 21. Increase in the floor area of the building stock in the reference years by building type.

In the calculation model, infrastructure construction includes the emissions from the construction and repair materials of street areas and large infrastructure projects (motorways, main streets, rail projects). In addition to street areas and the main transport network, the construction infrastructure also includes the construction of public green spaces and urban technology (district heating, water supply, electricity networks), however, their importance as a whole is minimal.

The increase/decrease in the construction of new street areas if the city plan is implemented have been estimated with a separate model (Annex 1). The increase/ decrease in the surface area of street areas does not directly follow the increase/ decrease in the floor area of buildings. The decisive variable for the street areas is the surface area of the urban block. The surface area of urban blocks increases more slowly in connection with infill development and high-density construction compared to new construction associated with civil engineering projects.

For the main transport network (motorways, main streets, rail projects), increases/ decreases are assumed to be based on separate projects. The projects assumed for the transport network in the BAU scenario include Raide-Jokeri, Crown Bridges, Vihdintie light railway, the Pasila–Kalasatama tram line and Sörnäinen tunnel. The project schedules only extend to 2030, so after that year, they are not taken into account as a source of emissions from construction or in the reduction of emissions from transport.

The specific CO2 emissions of infrastructure construction in its current state have been estimated using multiple data sources. For street areas, the emission factors are based on the emission factors of the KEKO calculation method (2016). For large infrastructure projects, the amount of emissions is proportional to the investment costs, and the factor used is based on the cost and emissions data collected on tramway projects.

The future trends in specific CO2 emissions of infrastructure construction are mainly affected by the same variables as are the specific CO2 emissions of housing construction. Material choices are a way of achieving major emission reductions in infrastructure construction, although the results vary depending on the sites (Dettenborn et al. 2022). Specific CO2 emissions are assumed to reduce by 15% by 2030 and by 30% by 2050, based on the reduction in the specific CO2 emissions of asphalt and stone aggregates presented in the low-carbon roadmap of the Confederation of Finnish Construction Industries RT (Klimscheffskij et al. 2020).

Projected emissions

The annual emissions driving climate change generated by the materials used in housing construction and infrastructure construction reduce in all the reference years of the BAU scenario (Figure 22). Annual construction volumes increase from the current state to 2030 and 2040, however, the reduction in specific CO2 emissions will be stronger in proportion to the increased volume. The volume of new construction in the city plan decreases up to 2050, which also leads to a stronger reduction in emissions.

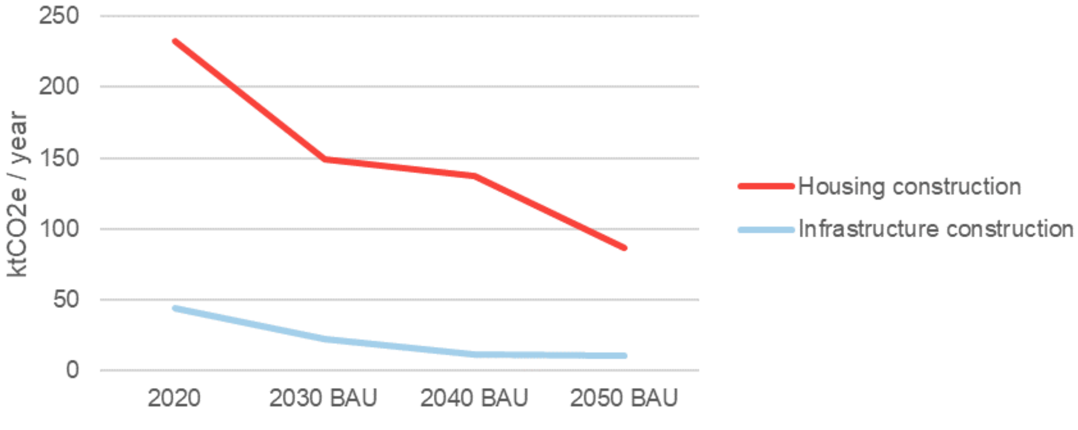

Figure 22. Emissions from construction materials in the current state and in the BAU scenario to 2050.

9.3. Other consumption

Other consumption means the consumption of goods and private and public services in sectors other than those described above. The calculation model for private services and goods is based on the consumption of residents, as data on regional consumption is not available. The calculation of public services, on the other hand, is based on the area-based consumption of the city organisation.

Scenario baseline assumptions

The projected emissions from current state of other consumption are based on the results of two calculation models. Calculated using the ALasKulutus model of the Finnish Environment Institute (SYKE), Helsinki's per capita emissions from goods and services total about 2.33 CO2-eq per year. The emissions from services are 0.96 tonnes of CO2-eq per year, and the emissions from goods 1.37 tonnes of CO2-eq per year. Roughly 83% of the emissions from services and 88% of the emissions from goods are generated outside the city boundary. (Karhinen et al. 2023.)

In the calculations of the Finnish Environment Institute, the emissions from public procurement and investments in Helsinki are about 0.66 tonnes of CO2-eq per year after the following items belonging to other sectors have been deducted: construction investments, electricity and gas, heating, foodstuffs, construction materials, construction services, and accommodation and catering services. (Karhinen et al. 2023.)

According to the results of the Kulma calculation model of Sitowise and the Natural Resources Institute Finland (Luke), the total emissions of goods and services per capita amount to 2.35 tonnes CO2-eq per year. Of these, private consumption accounts for about 1.88 tonnes of CO2-eq per year and the public sector for 0.47 tonnes CO2 per year. (Liljeström et al. 2021.)

The figures for the current state are presented with the following limitations:

- Catering services are counted as food consumption (above), and are not included in services.
- Construction and maintenance are counted through the energy consumption of construction materials and construction, and are thus deducted from consumption.
- Emissions from the production of services do not include emission items belonging to other sectors: construction, heating, electricity, foodstuffs, construction materials and maintenance.

Long-term emissions are influenced by population growth, household consumption expenditure, changes in the consumption structure and the emission factors for consumer goods, which are affected by technological developments. Emissions from Finnish consumption have decreased over the past 15 years (Nissinen et al. 2019). Population growth and the growth of consumption expenditure have caused emissions to rise, however, changes in the consumption structure and technological developments have had a stronger, reducing effect on total emissions. As a result of technological developments, The baseline assumption of this report's BAU scenario is that these trends will continue. The city's population will rise by about 25% by 2050, while the emissions generated per consumption unit will continue to fall due to technological developments. In the Stated Policies Scenario of the International Energy Agency (IEA 2020), the overall energy efficiency of production improves by 2.2% per year and the energy emission factor decreases by 0.8% per year to 2050, compensating for the projected increase in energy consumption.

This means a reduction of about 27% in emissions per consumption unit in 2030, and a 58% reduction by 2050.

In the national WEM scenario, household consumption expenditure has been estimated to increase though the population does not increase significantly (Honkatukia et al. 2021). However, changes in consumption expenditure and consumption structure have not been used as baseline data in the scenario, as the long-term changes in the consumption structure could not be estimated.

Table 10. Variables in the projected emissions of other consumption in the BAU scenario.

Other consumption	2020	BAU 2030	BAU 2050
Number of residents	Demographic statistics	Helsinki population forecast	
Consumption expenditure	No changes in consumption expenditure and consumption structure		
Consumption structure			
Specific CO2 emissions			
Emission factor per consumption unit	Emission factor per resident	Energy efficiency during the review period 2.2% per year, and emission intensity 0.8% per year	

Projected emissions

Emissions from other goods and services reduce from the current state to the reference years of the scenario (Figure 23) on account of lower emission factors. The consumption of services and goods increases due to population growth, however, there is more technological development and energy efficiency improvements in relation to consumption.

Previously, the Finnish Climate Panel (Seppälä et al. 2022) has estimated that, by 2030, emissions from other domestic consumption will reduce by about 43% in the effort sharing sector and by 60% in the emissions trading sector compared to the 2015 level. Emissions abroad are estimated to reduce by 2030 by 40% from the 2015 level. The emission reductions are based on the greenhouse gas emission reduction plans of Finland and the EU in a scenario in which the consumption level remains the same throughout the review period.

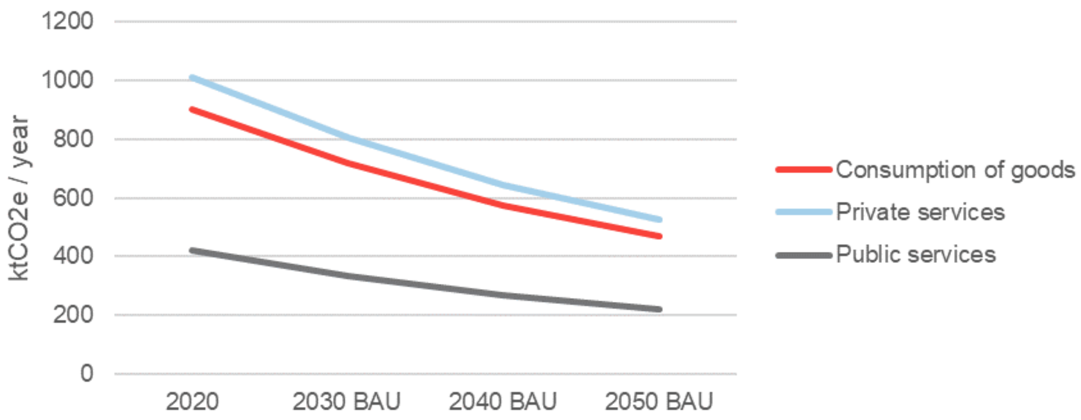

Figure 23. Projected other indirect emissions in the BAU scenario to 2050.

10. Summary

This report contains the BAU scenario for the emissions of the City of Helsinki from the current state to 2050. The emissions have been divided into categories describing where the emissions occur and what is the relationship between the source and the area under review. Scope 1 category includes emissions generated within the city's geographical area, whereas scope 2 and scope 3 categories take into account emissions from activities taking place outside the city.

In the BAU scenario, greenhouse gas emissions generated within the city's geographical area reduce to about half the current level by 2030 and to one quarter by 2050 (Figure 24). Currently, the emissions generated within the city boundary are about 2,300 kt CO2-eq. In the current state, emissions per capita are 3.2 tonnes of CO2-eq per year, and in the long term with the baseline assumptions of the BAU scenario, about 0.3 tonnes per year in 2050.

The main sources of emissions in the current state are heating of buildings, transport and electricity consumption (Figure 24). Emissions from the heating of buildings reduce rapidly in the BAU scenario due to abandoning the use of coal in district heat production. By 2050, the use of natural gas will also be replaced by heat pumps and biofuels. The energy consumption of the building stock remains close to the current level, as the improved energy efficiency of buildings compensates for the floor area growth of the building stock.

In the BAU scenario for transport, the number of vehicle-kilometres travelled increases from the current state due to population growth as the distribution of travel by mode of transport remains the same. The strongest influence on the emissions from transport are thus caused by the rise of electric cars among the city's car fleet. With passenger cars in particular, the share of electric driving is expected to rise to half of the vehicle-kilometres travelled in 2040, and then continue to grow steadily from there.

Emissions caused by electricity use will decrease despite growing consumption in the BAU scenario for the reference years 2030 and 2050 (Figure 24). Growing electricity consumption is due to the growing number of residents, the spread of geothermal heat, the use of heat pumps in the production of district heat and the electrification of transport.

The reduction in emissions from electricity consumption is a result of major changes taking place in the national production structure already by 2030. Electricity generation based on fossil fuels and peat will be phased out and the share of renewable energy will grow. The strong change will make the specific CO2 emissions of electricity consumption reduce close to zero in the long term.

The importance of the change in the city's carbon stocks and of carbon sinks net emissions will be minor. In the BAU scenario, reserving more and more land for the use of urban blocks and street areas reduces the carbon stocks and annual carbon sinks of urban forests and other green spaces, however, in the big picture, the change is small.

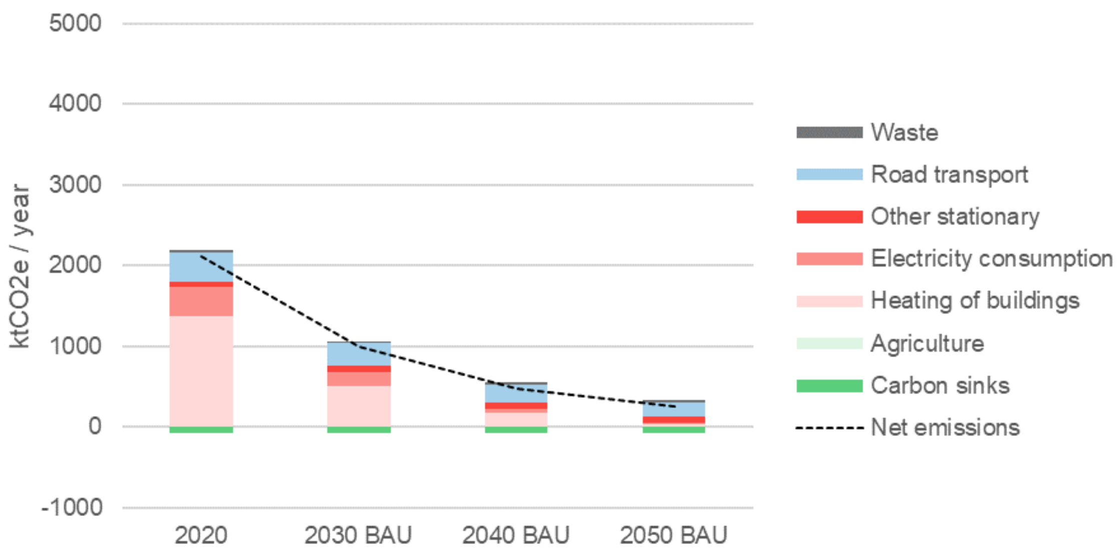

Figure 24. The BAU scenario for net emission in the geographical area of Helsinki from current state to 2050.

The projected emissions in the report's BAU scenario largely correspond with the previous forecasts of the city's total emissions (Huuska et al. 2017) and emissions from transport (Supponen and Kyytsönen 2022). Up to 2030, the baseline scenario has remained largely unchanged, and the calculation model is well established. Significant new trends of change are the proliferation of the electrification of the car fleet and the spread of geothermal heat. As a result of these, with the current baseline assumptions the emissions are reducing faster compared to previous scenarios.

Indirect emission from activities in the city

The indirect emissions caused by activities in the city are currently – and in all the reference years of the BAU scenario – the largest source of emissions from activities in the city. Indirect emissions occurring outside the city boundary are currently around 5,000 kt CO2-eq per year and will reduce to 3,600 kt CO2-eq. per year by 2050 based on the baseline assumptions of the BAU scenario. Indirect emissions per capita are currently around 7.6 tonnes of CO2-eq per year and will reduce to around 4.3 tonnes per year.

Indirect emissions consist of the consumption of food and drink, services, construction materials and goods. The key factors in the long-term BAU scenario are:

- Air and water transport are expected to recover rapidly from the COVID-19 pandemic and the growth pace of passenger volumes is expected to exceed that of population growth in the coming decades. In terms of specific CO2 emissions, the BAU scenario is based on the development of aircraft and ship technology. Any emission-reducing measures under preparation have not been used as baseline data in the calculation.
- The production of goods and services is assumed to become more energy efficient in the future and the energy used in production processes to become more focused on renewable sources, thus reducing the amount of emissions. The baseline of the scenario does not assume changes in the consumption expenditure or consumption structure of the residents.

- Emissions caused by food consumption increase with population growth. The emission reductions achieved in production are moderate, based on the national emissions scenario for agriculture.

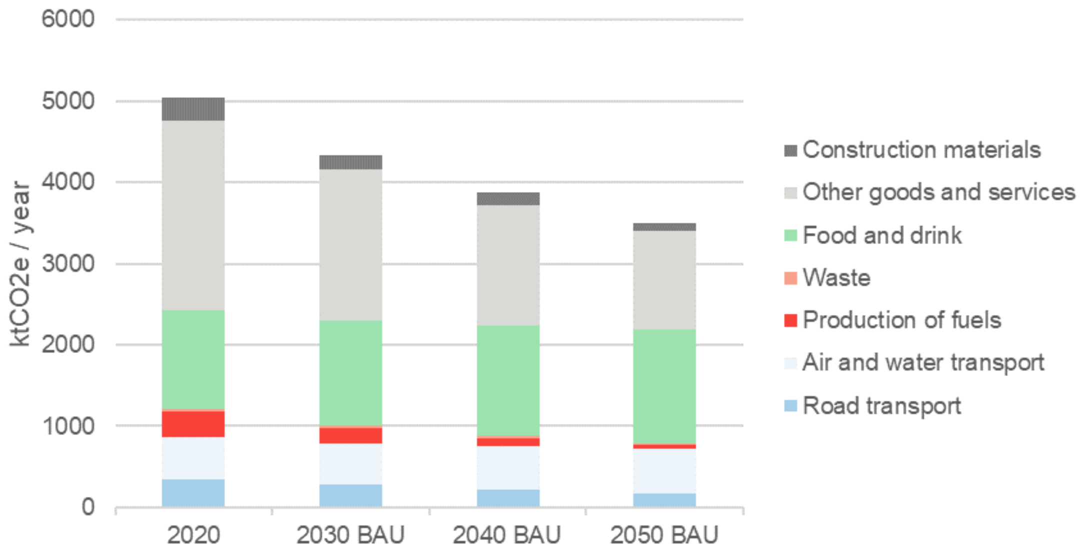

Figure 25. City of Helsinki BAU scenario for scope 3 emissions from current state to 2050. For air and water transport, the reference year for the current state is 2019.

It should be taken into consideration when interpreting the results that the calculation model and its baseline data include uncertainties and simplifications in the case of indirect emissions. For food, goods and private services, the calculation of current emissions is based on the consumption behaviour of city residents (not on geographical boundaries), which is limited to imports to the city. The greatest uncertainty is, however, associated with the estimation of projected emissions. The baseline assumptions of the scenario for future consumption trends and international regulation are uncertain and mainly fall beyond the city's decision-making

In terms of indirect emissions, the report aims to identify the scale of indirect emissions generated by activities in the city and the factors affecting them in the long run. Given the great importance of these, it will be necessary in the future to strengthen the knowledge base on the components and future trends of indirect emissions.

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Appendix 1. Projected surface areas of streets and green spaces

The following is an estimate of the impact of new construction, as suggested in the city plan, and of the increase in the ground area of urban blocks on the amount of street areas and public green spaces. Information on the changes is needed for use as baseline data in the estimation of changes in emissions and carbon stocks caused by the construction of street infrastructure. Changes in green spaces and street areas are not directly available in the city plan, so their relationship to the ground area of urban blocks has been modelled on current state data.

Street areas and green spaces relative to the area of urban blocks

The land covered by built-up urban blocks relative to the land covered by street areas and green spaces is modelled using a calculation model that is based on statistics on all subdivisions of land area. The ground area of the city – and more specifically of each subdivision of land area – is assumed to comprise the following land-use categories:

- urban blocks,
- public street areas,
- public green spaces, and
- other areas.

These land-use categories compete for the ground area within each subdivision of land area, which means that if an area designated for a certain use increases, other areas will have to decrease.

The baseline data is the distribution of the current ground area among the land-use categories, which have been summed up for the subdivisions of land area using the plan units of local detailed plans, which are the smallest unit dedicated for a particular purpose in the detailed plan (City of Helsinki 2022f). The following are exceptions to the above:

- The surface area of street areas has been excluded from the register of public areas by removing the main streets and motorways from them. The development of main streets and motorways is based on various projects that are taken into account separately.
- The plan units do not cover the entire city area, so areas not covered by the plan have been assumed to be green spaces in the current state. Areas outside the plan units are currently located in, for example, Östersundom, Kivinokka, Vartiosaari, Viikki and Santahamina.

The distribution of ground area in its current state shows that competition exists between urban blocks, the street network and green spaces (Figure 26). The surface area of the street network increases as the surface area of urban blocks increases, and correspondingly, the amount of green spaces decreases as the surface area of urban blocks (and the street network) increases. Other areas constitute a very small part of the total land area, and no clear relationship can be drawn to the land covered by urban blocks.

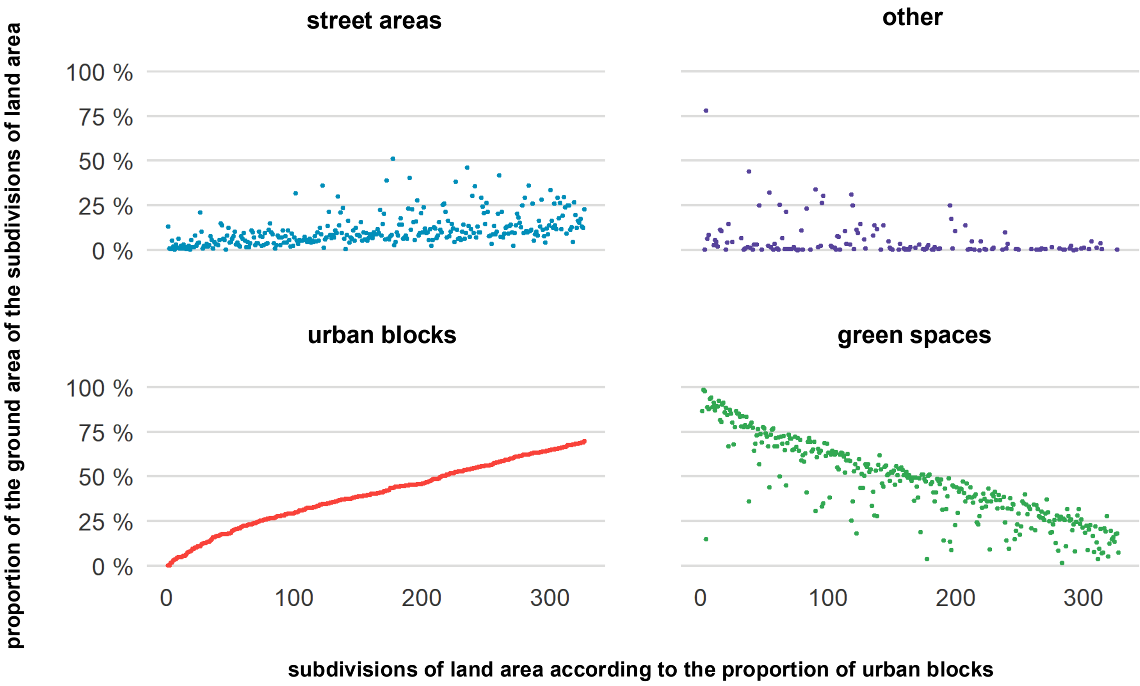

Figure 26. Distribution of the ground area of the subdivisions of land area subject to planning according to the land-use categories in the current state.

The relationship between land-use categories is estimated with linear regression modelling by using the proportion of the urban blocks from the total surface area as the explaining factor for the surface area of the street network. Regression modelling shows that an increase of 10% in the surface area of the urban block increases the surface area of the street network by about 2.4%. Since the land-use categories compete over a limited area of land, the proportion of green spaces can be determined by deducting the surface areas of the urban block and the street network from the total area. (Figure 27.)

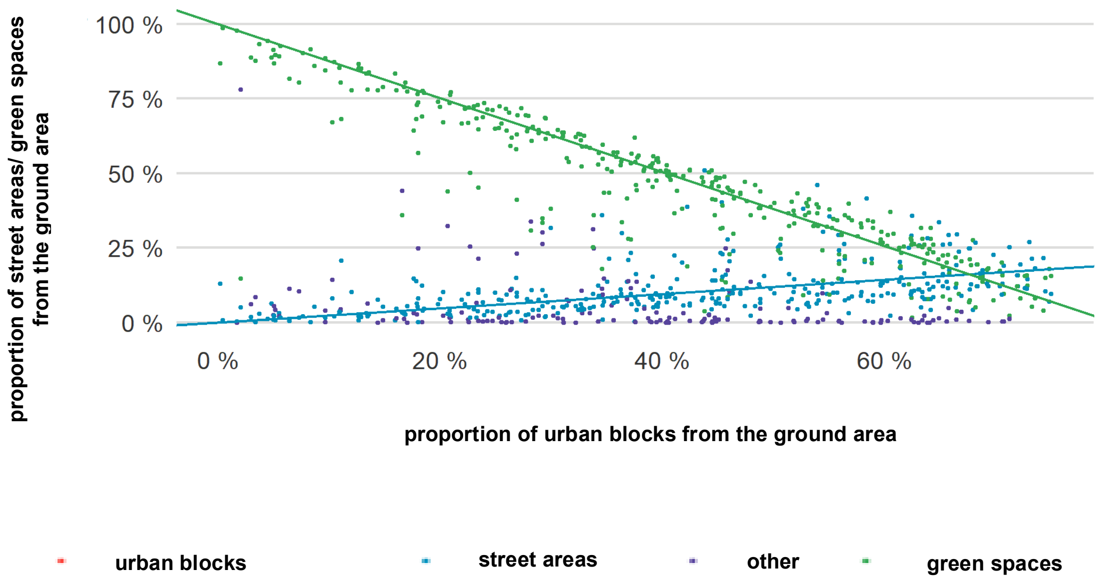

Figure 27. The proportion of public street areas and public green spaces in relation to the proportion of land covered by urban blocks from the ground area of the subdivisions of land area subject to planning.

Application to city plan dimensions

The increase/decrease in the surface area of the urban blocks in the BAU scenario for reference years 2030 and 2050 can be directly derived from the dimensions of the city plan. The dimensions are presented in the city plan in a grid pattern, and they take into account the differences in the efficiency of urban blocks and infill development. This way, they will be taken into consideration in the development of land covered by urban blocks, green spaces and street networks.

The increase in the amount of land covered by urban blocks and the above modelling are used to determine the change in the amount of street areas and green spaces for the reference years of the BAU scenario for all subdivisions of land area. A relatively larger proportion of the ground area is reserved for use by urban blocks and the amount of land covered by urban blocks will increase to about 14.4 million m2 by 2050. At the same time, the surface area of the street network increases to 3.4 million m2 and the land area reserved for public green spaces decreases to 17.8 million m2.

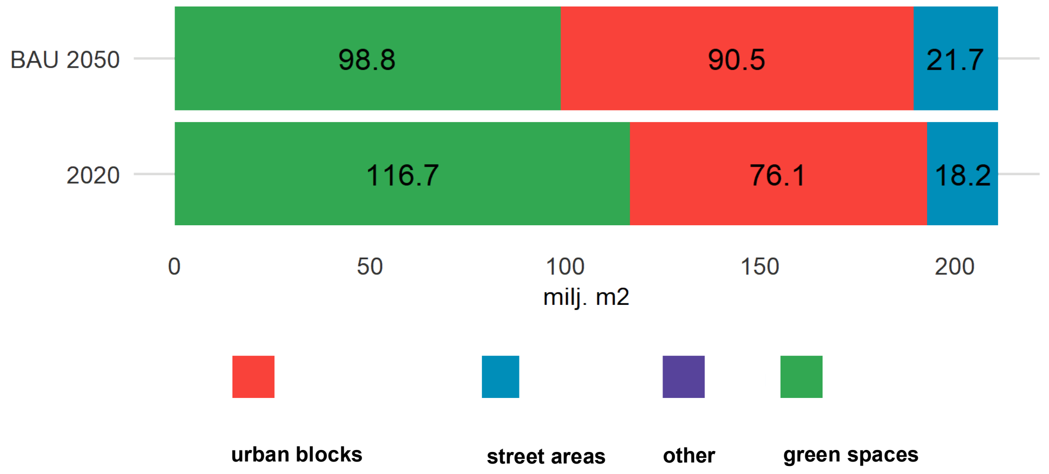

Figure 28. Distribution of the city's ground area to various land-use categories in the current state and in the BAU scenario.

Helsinki