Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence

ANNEX 5 – CASE STUDY REPORT //

Finland Case Study Pilot

Quantitative Greenhouse Gas Impact Assessment Method for Spatial Planning Policy

Adjusted Annex // September 2022

This annex 5 – case study report is conducted within the framework of the ESPON 2020 Cooperation Programme, partly financed by the European Regional Development Fund.

The ESPON EGTC is the Single Beneficiary of the ESPON 2020 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States, the United Kingdom and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.

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Acknowledgements
Jukka-Antero Aaltonen (City of Tampere); Sarah-Jane Burns (NTA); Barry Colleary (NTA); Pia Hastio (City of Tampere); Joonas Hendrik Kokamägi (TalTech); Ulla Lautaoja (City of Tampere); Michael MacAree (NTA); Claire Marion (City of Edinburgh); Erno Mäkinen (City of Tampere); Sander Peterson (TalTech); Merlin Rehema (SEI Tallinn); Ville Räty (Kymenlaakson liitto) and Heikki Savikko (Ramboll).

Information on ESPON and its projects can be found at www.espon.eu.
The website provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

ISBN: 978-2-919816-19-4

Published in September 2022

Graphic design by BGRAPHIC, Denmark

Contact: info@espon.eu

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Abbreviations

BER	Building Energy Rating
CLC	CORINE Land Cover
CLMS	Copernicus Land Monitoring Service
COICOP	Classification of Individual Consumption by Purpose
CORINE	Coordinated Information on the Environment
CRF	Common Reporting Format
CSC	Carbon-Stock-Change Factors
EEA	European Environment Agency
EIO	Economic Input-Output
EPC	Energy Performance Certificate
ESDAC	European Soil Data Centre
FIPS	Forest Inventory and Planning System
FUA	Functional Urban Areas
GHG	Greenhouse Gas
GWP100	Global Warming Potential over 100 years
HBS	Household Budget Survey
ICE	Internal Combustion Engine
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LPIS	Land Parcels Information System
LULUCF	Land use, land-use change and forestry
MMR	Monitoring Mechanism Regulation
MMU	Minimum Mapping Unit
MRIO	Multi-Regional Input-Output
NEDC	New European Driving Cycle
NFI	National Forest Inventory
NIR	National Inventory Reports
NPF	National Planning Framework
p-LCA	Process-based Life Cycle Assessment
RDE	Real Driving Emissions
RGV	Renewable Gas Vehicle
RSG	Reference Soil Groups
STL	Street Tree Layer
UNFCCC	United Nations Framework Convention on Climate Change
WRB	World Reference Base for Soil Resources

1 Introduction

GHG emissions were quantified for four case studies to test the GGIA tool methodology in a variety of contexts. The service providers have committed to use a range of spatial scales for the pilot case studies, this is shown through the case study selection that vary in their urban context i.e., rural, urban and suburban, whilst also differing in population sizes and geographic contexts.

Each case study consists of a baseline analysis, the quantification of selected policies and the evaluation of results. The case study pilots have been linked to relevant policy processes and the involvement of the stakeholders has been key to ensure that the link between case study and relevant spatial planning policy is present. The pilot case studies, where possible, reflect the stakeholders' envisaged use of the GGIA tool in each territory, this includes for example local authority spatial plans, development plans and national planning frameworks. The GHG analysis of the case study plans, follow key emission sectors:

- Buildings – changes in electricity and heating demands
- Infrastructure – changes in transport
- Land Use – changes in land use.

This report provides an insight into the GHG emission inventory for Kymenlaakso as well as the data and methodologies behind the results.

2 Finland Case Study Pilot – Kymenlaakso

The region Kymenlaakso, in South-East Finland, has a population of 174,000. The largest cities are the harbour city Kotka (55,000 inhabitants), Kouvola (88,000 inhabitants) and the old bastion town Hamina (20,000 inhabitants).

Kymenlaakso is part of the Finnish *Towards Carbon Neutral Municipalities* (Hinku) network which brings together municipalities, businesses, citizens and experts to create and carry out solutions to reduce GHG emissions. The 70 municipalities involved are committed to reduce emissions at a more rapid pace than EU targets require. The network aims to create solutions that have economic and social benefits as well as environmental advantages. The GHG emission reduction target is 80% for the period 2007–2030.

The Kymenlaakso region aims to become carbon neutral by 2035. To this end, the region of Kymenlaakso has compiled a roadmap which includes detailed information on the region's GHG emissions, carbon sinks (LULUCF sector) and the main measures that need to be implemented in different sectors such as industry, forestry and traffic. According to the roadmap, the region of Kymenlaakso has to decrease GHGs mainly from transport, energy production and agriculture sectors. LULUCF sector's carbon sinks need to be increased in forests and soils. Measures in the roadmap include for example eco-innovations, cleantech, circular economy approach in all sectors, climate wise forestry, increasing the share of renewable energy, compact urban structure and environmental education and comprehensive cooperation between all sectors.

2.1 Baseline

2.1.1 Consumption-based approach

The demand vector representing the average household was used to describe Kymenlaakso. This was to accommodate the varying urban densities present in the area. There was no data provided by the stakeholders to suggest the relative income level differed from the average picture for Finland, and so no further scaling was performed based on this factor. Additionally, no information was provided with regards to the average household occupancy level, and so the consumption picture for Kymenlaakso therefore represents the typical situation for Finland as a whole. Two small modifications were made to the emission intensity side. The values for heat energy (district heating) and aviation fuel were replaced with the Swedish values, since they led to erroneously large errors in the calculation.

To justify these changes, it should be reiterated that the consumption-based emissions do not track emissions arising from a particular geographical region. Instead, they attribute an amount of emissions to the residents of an area based on their actions. Their actions are measured through the products that they purchase. Some of these emissions will occur within Kymenlaakso, but others will occur in other places around the globe. This explains why there are emissions for aviation fuel even though Kymnelaakso has no airport. Residents in Kymenlaakso still purchase air tickets and they still take flights. They are therefore responsible for a proportion of air travel emissions occurring in other regions. Hence, in the consumption picture an emission intensity for aviation fuel is needed even in the case of Kymenlaakso. However, the value that was calculated from Exiobase was anomalously high and would bias the total results for the region. Therefore, they were replaced with the value from the most similar country to Finland, which is Sweden. This situation is also true for the district heating emissions. If the original Finnish value was used for the emission intensity (describing the amount of emissions expected for each euro spent on district heating, not the amount of district heating in the region), then the total results for Kymenlaakso would be anomalously high. To illustrate this, the following graph was produced showing the emissions for Kymenlaakso where the original emission intensity for district heating was used, and when it is replaced with the Swedish value. It can be seen that using the original Finnish value increases the emissions in Kymenlaakso by over 3 tCO_2e per capita. This value can be used if required, but would provide an unrealistic picture of emissions in the region. It should finally be noted that a different value for the emissions intensity for Finland could also be used should it be provided by the stakeholders.

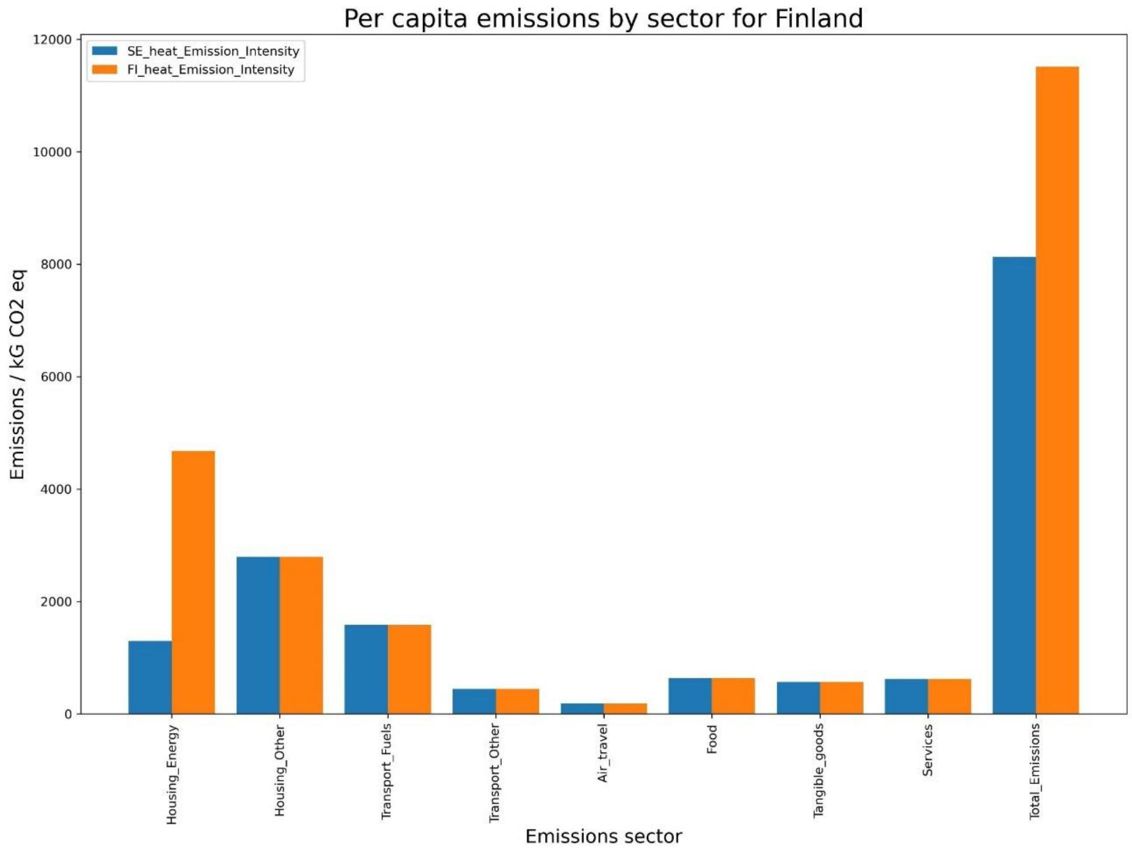

Figure 1. Comparison of per capita emissions in Kymenlaakso with and without the emissions intensity for district heating being replaced with the Swedish value.

The data situation applied to Kymenlaakso is summarised in Table 1 below.

Table 1. Description of the data situation utilised for the consumption calculations in Kymenlaakso.

Data situation: Kymenlaakso				
Demand Vector	**Household occupancy**	**Household income level**	**Population**	**Further modifica-tions / Notes**
Finnish average	Finnish average (2.02)	Finnish average	174,167	Two sectors re-placed by Swedish values due to un-realistic values in the IO table

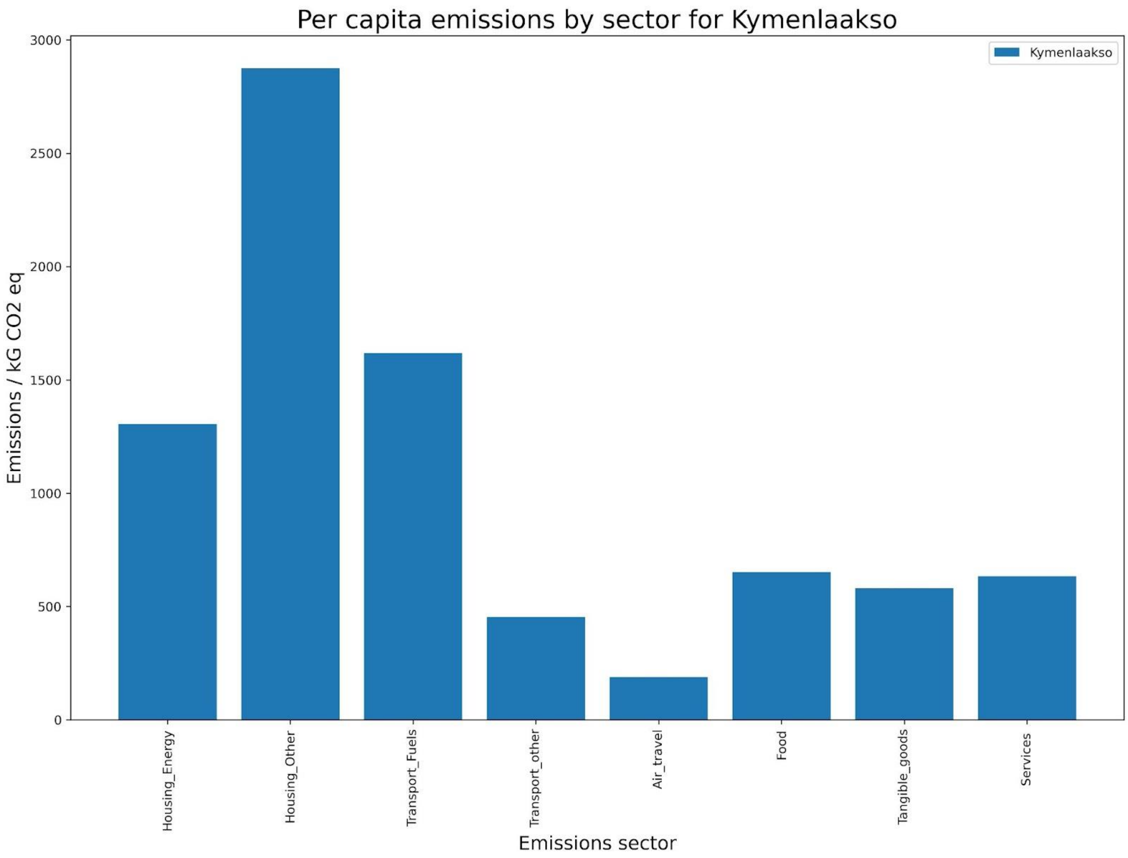

Figure 2. Annual sectoral emissions per capita for Kymenlaakso (kgCO_2e/a) (2020).

The graph above (Figure 2) displays the estimated per capita emissions for Kymenlaakso for the year 2020. Overall, the per capita emissions were 8.3 tonnes CO_2e per annum. The total consumption emissions for the region were calculated to be approximately 1.5 MtCO_2e per annum. A feature of the emissions from the region is the small contribution from the electricity sector, as well as the relatively higher contribution from electricity and renewables in household heating. This leads to a lower contribution from household energy sources in the emissions total, although the contribution from private transport is similar to County Meath and Edinburgh.

Allied to this initial finding, a relatively greater proportion of the Finnish carbon footprint arises from direct and indirect production of products, rather than the household use phase, in comparison to the other case study areas. For example, the services sector is notably higher than the other case study areas. Moreover, waste makes a large contribution to the Finnish footprint (recorded under 'household other') with significant contributions coming from landfill. Note that waste corresponds to a 'place-holder sector' in the tool, so the values are distributed in the same way for each country and region, and is also not well differentiated in the initial HBS. This means that although the waste sector may very well be different for Kymenlaakso than the average European picture, it was not considered here. This was because waste was not a sector included in this version of the tool.

Total household emissions independent of household occupation are similar between Kymenlaakso and Edinburgh. When household occupancy is considered, Edinburgh, Kymenlaakso and County Meath all have rather similar carbon footprints. Total household expenditure in 2015 was rather similar across all regions in Euro terms (higher values in Ireland are somewhat mitigated by the higher household occupancy levels). The results for Kymenlaakso are tabulated with greater sectoral detail in the following table. These results are also shown graphically along with those for the other case areas.

Table 2. Per capita sectoral emissions (including sub-divisions) for Kymenlaakso ($kgCO_2e$/(capita,a)) (2020).

Kymenlaakso	Direct Production $kgCO_2e$	Indirect Production $kgCO_2e$	Use Phase $kgCO_2e$	Total $kgCO_2e$
Shelter: Electricity, heating and fuels	601	155	550	1,305
Shelter: Actual and imputed rent	63	477	0	540
Shelter: construction	37	60	0	97
Shelter: Waste treatment, water supply and misc.	1552	686	0	2,238
Transport fuels	164	362	1,092	1,618
Vehicle purchases	102	205	0	307
Other transport services	114	33	0	147
Air travel	145	44	0	189
Food: Plant-based	49	39	0	88
Food: Animal-based	18	319	0	337
Food other	9	218	0	227
Clothing	10	67	0	77
Appliances	54	108	0	162
Furniture, household commodities and misc.	155	186	0	341
Services	139	494	0	633
Sum	3,213	3,451	1,641	**8,306**

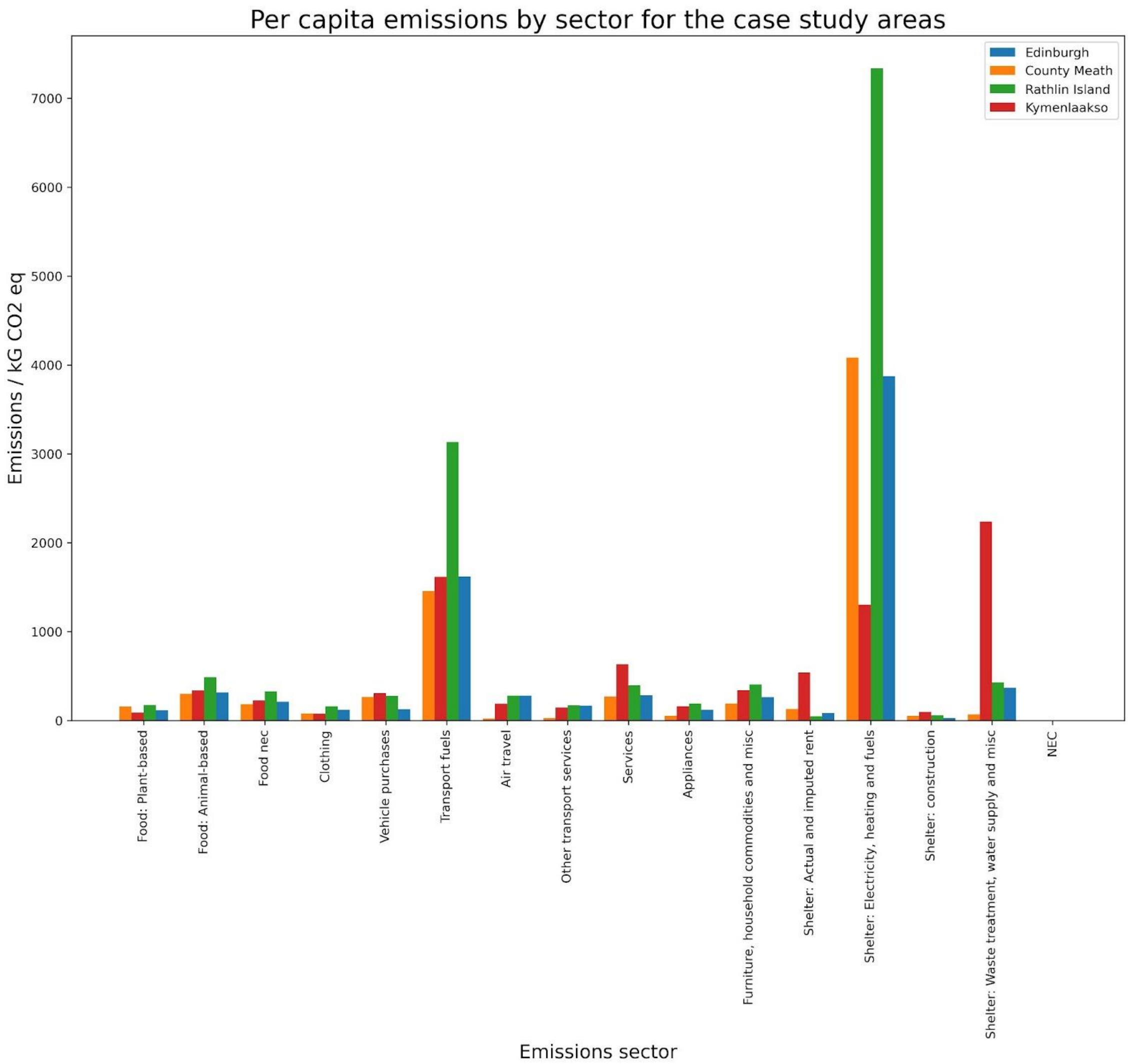

Figure 3 Per capita consumption emissions for all case areas (kgCO_2e/(capita,a)) (2020).

2.1.2 Territorial approach

2.1.2.1 Buildings

This section looks at the emissions arising from the building sector in Kymenlaakso, it includes both residential and commercial buildings and also analysis results from the baseline, which gives insight into the current building stock for Kymenlaakso. This baseline information is then used to compare with emissions resulting from spatial planning policy changes.

<u>Residential Sector</u>

This methodology is mainly based on the figures and datasets sourced from Statistics Finland, which gave a detailed breakdown of the floor areas for different residential dwellings, along with information on period built and heating sources for the different properties based on their floor area.

Residential units were broken down into:

- Detached
- Terraced
- Apartments

It should be noted that the Finnish statistics gather semi-detached houses as part of the detached dwellings, therefore, the residential units analysed were broken down to reflect this. Terraced houses in Finland can be defined as row houses and other attached houses.

In 2019, the largest share of residential units were detached houses; they made up 91% of the total residential housing stock in Kymenlaakso. This was followed by terraced houses (5%) and apartments (4%).

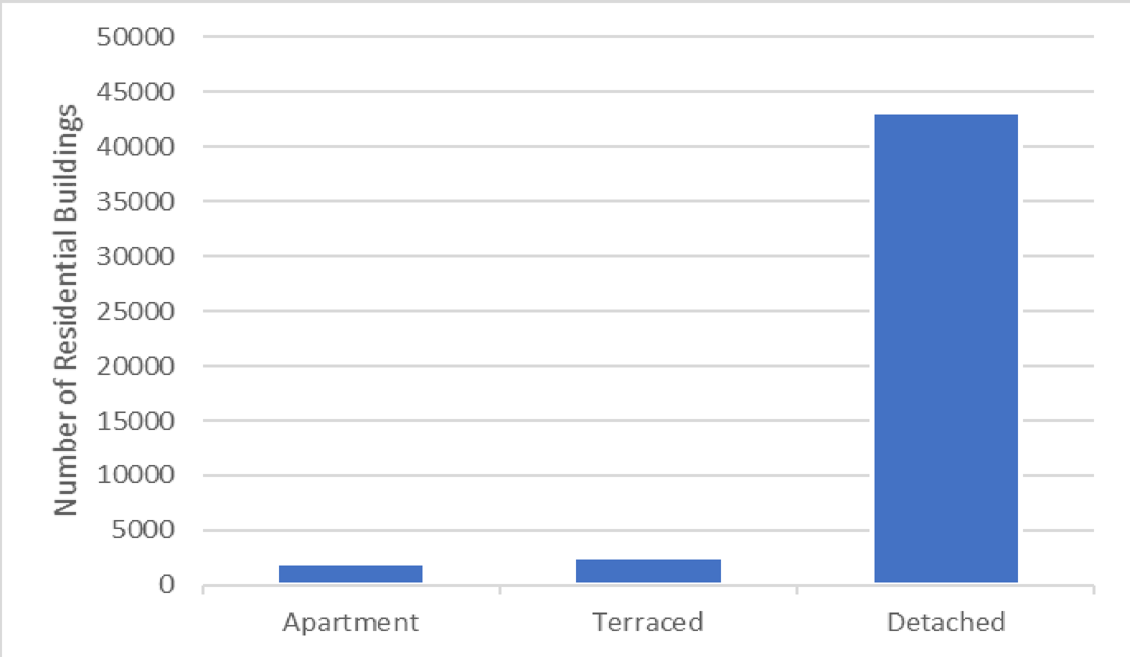

Figure 4. Total number of residential units in Kymenlaakso (2019).

Total energy use in the residential sector was 2,729 GWh. The residential fuel split mainly comes from electricity, which makes up 54% of the total energy use in this region. It should be noted that households that are heated by electricity generally tend to make use of air source heat pumps, which have become quite common in Finnish households. District heating contributes 16% to the total energy demand, followed by wood (biomass) at 15% and ground source heat pump (8%).

Figure 5 shows the total final energy use broken down into the different energy demand areas. Most of the energy used was for space heating. Space heating had by far the highest energy demand, accounting for 67% of the total. This was followed by water heating at 20%. Heating overall in the residential sector has the highest energy demand by far and creates potential for heat recovery from waste heat. It should be noted that compared to the other case study pilot areas, Kymenlaakso has colder winters, thus a higher need for space and water heating. Lighting and appliances are the least energy intensive, making up just 13%.

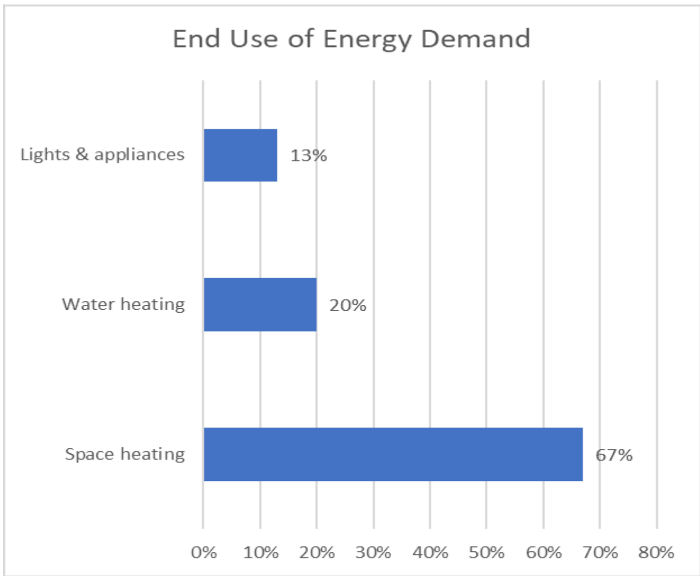

Figure 5. Share of residential energy demand in Kymenlaakso (2019).

Total emissions from the residential sector in Kymenlaakso amounted to 507,640 tonnes of CO_2. Figure 6 depicts the total emissions grouped by fuel and dwelling type. Detached houses had the highest emissions, accounting for 440,000 tonnes of CO_2. This was followed by apartments and terraced houses, all of which accounted for 49,623, and 18,017 tonnes of CO_2 respectively, of the total emissions in the residential sector.

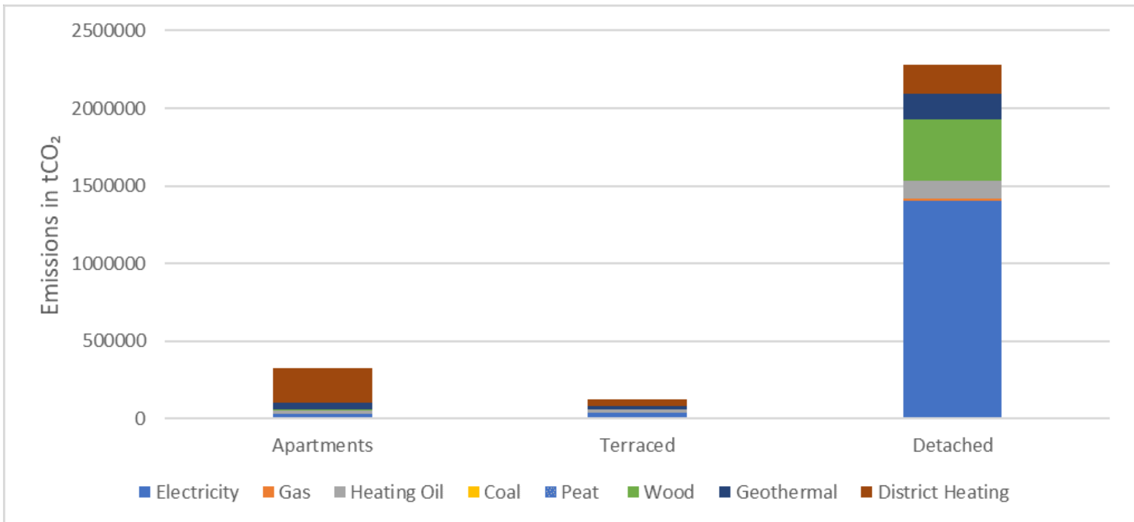

Figure 6. Total emissions in the residential sector by fuel mix and dwelling Type (tCO_2e/a) (2019).

The highest emissions in the residential sector come from electricity, biomass and district heating, which contribute 45%, 32% and 14% respectively. Heating oil, gas, coal and peat contributed to 9% of total emissions.

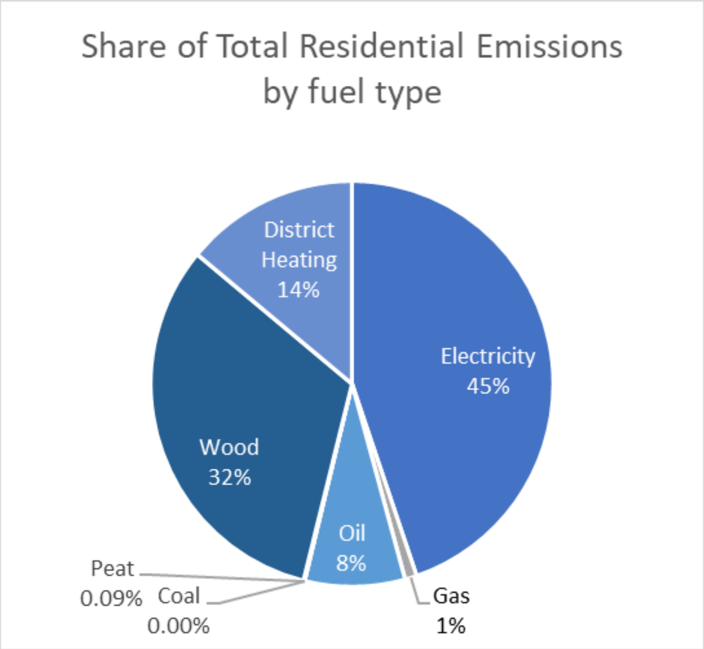

Figure 7. Share of total emissions in the residential sector by fuel type.

Table 3. Total residential emissions in the City of Edinburgh (tCO_2e/a) (2019).

Residential sector	Fuels						District heating	Total
	Electric-ity	Gas	Oil	Coal	Peat	Wood		
Apartments	4,379	517	6,292	1	8	2,935	35,492	49,623
Terraced	5,695	393	4,985	0	2	681	6,261	18,017
Detached	217,341	3,902	29,555	22	444	159,541	29,195	440,000
Total tCO_2e/a	**227,415**	**4,813**	**40,831**	**23**	**454**	**163,157**	**70,948**	**507,640**

Commercial

This methodology is mainly based on the figures and datasets sourced from Statistics Finland, which gave a detailed breakdown of the floor areas for different commercial properties, along with information on heating sources for the different properties.

The majority of commercial properties can be categorised as industrial uses, warehouses, retail, offices, education and health with only 7%, accounting for the remaining commercial properties.

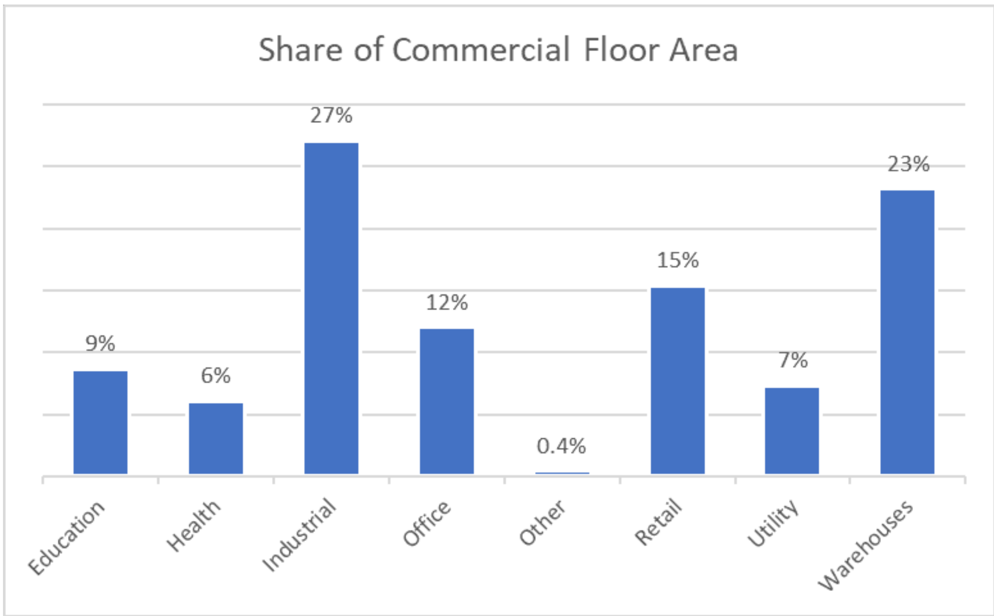

Figure 8. Share of commercial floor area in Kymenlaakso.

The total energy used in the commercial sector was 971,441 GWh. District heating (595 GWh) and electricity (152 GWh) accounted for the main share of this energy use. The commercial sector had a high use of heating oil, 147 GWh, meanwhile gas, ground source heat pump and biomass (wood) all together made a total of 77 GWh.

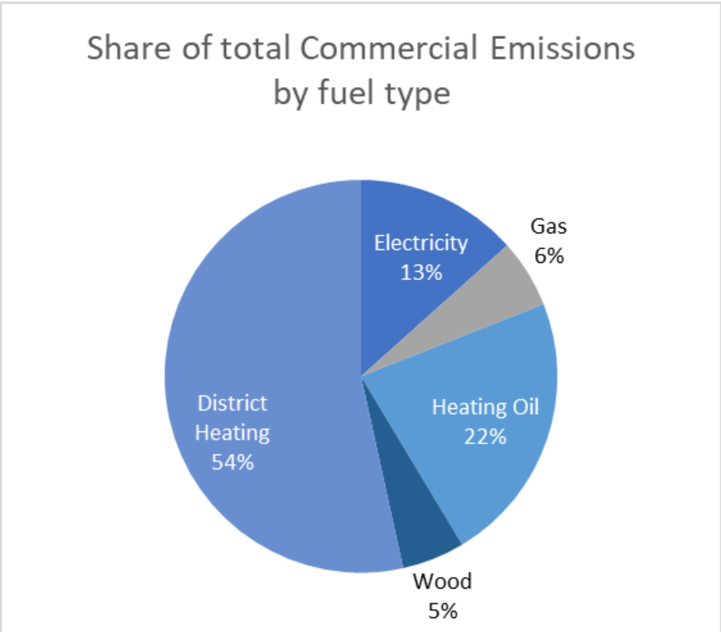

Figure 9. Share of total emissions in the commercial sector by fuel type.

Total emissions from the commercial sector amounted to 175,898 tonnes of CO_2. Of the total emissions emitted by the commercial sector, district heating accounts for the largest share of the total emissions (54%), followed by heating oil at 22%. Electricity also produced significant emissions, contributing 13% to the total.

Table 4. Total commercial emissions in Kymenlaakso (tCO_2e/a) (2019).

Commercial sector	Fuel						District heating	Total
	Electric-ity	Gas	Oil	Coal	Peat	Wood		
Total tCO_2e/a	23,530	9,923	39,349	0	0	9,087	94,010	175,898

Total emissions

Total emissions from both the residential and commercial sectors in Kymenlaakso accounted for 683,540 tonnes of CO_2 in 2019. The residential sector contributed 74% and the commercial sector 26% to the total emissions. The main source of emissions come from electricity (37%), followed by wood (25%) and district heating (24%). The rest of emissions were made up mainly from heating oil (12%) and gas (2%).

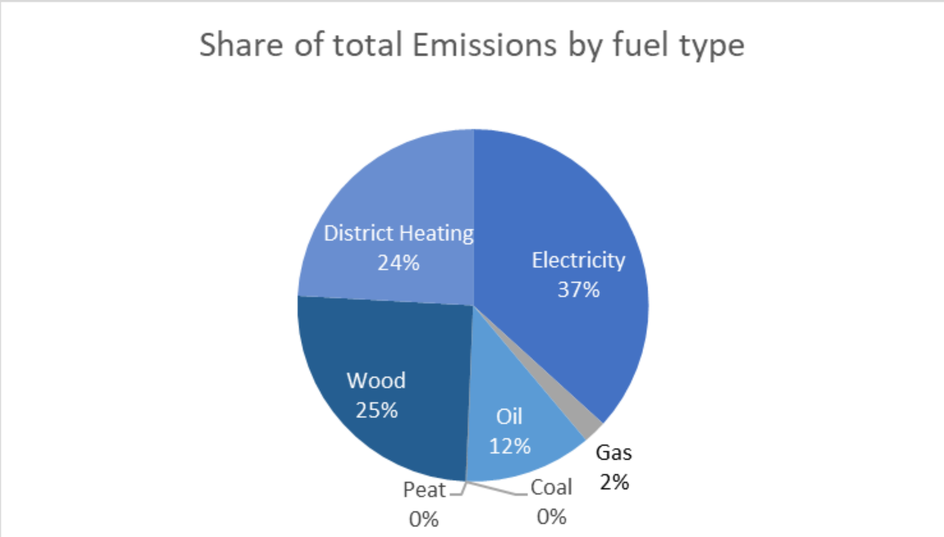

Figure 10. Share of total emissions in the building sector by fuel type.

Table 5. Total emissions from the building sector in Kymenlaakso (tCO_2e/a) (2019).

Building sector	Elec-tricity	Gas	Oil	Coal	Peat	Wood	District heating	Total
Residential	227,415	4,813	40,831	23	454	163,157	70,948	507,640
Commercial	23,530	9,923	39,349	0	0	9,087	94,010	175,898
Total tCO_2e/a	**250,944**	**14,736**	**80,180**	**23**	**454**	**172,244**	**164,958**	**683,538**

2.1.2.2 Transport

Kymenlaakso region is characterised by high share of transit transport and relatively high car-dependency in passenger transport. According to the Kymenlaakso carbon neutrality roadmap, the changes in transport are expected to bring about appr. 6% of the total GHG reductions which are needed in addition to the base-line scenario by 2040. The key actions include changes in transport activity, vehicle fleet and fuels.

The territorial study quantifies all traffic activity within the Kymenlaakso territorial boundary. One specific feature of Kymenlaakso is the transport on water and the harbour activities, which cannot be analysed in detail in this study.

The baseline analysis utilises the transport activity data collected for the Carbon neutral Kymenlaakso roadmap, created by Ramboll in 2019 (Kymenlaakson Liitto, 2021) and the LIPASTO database by VTT (LIPASTO, 2021). LIPASTO provides the road transport activity and the respective CO_2e emissions by municipality. The rail transport activity figures are from the Carbon neutrality roadmap baseline data. The road transport was divided into driving on streets (in an urban environment) and roads (rural environment) utilising the information from the Kymenlaakso carbon neutrality roadmap. This will later help to allocate the impacts of planning policies, which are likely to have a higher impact on the residents than transit transport. It is also important to note that maritime transport and the harbour activities were not analysed in this study.

Total emissions

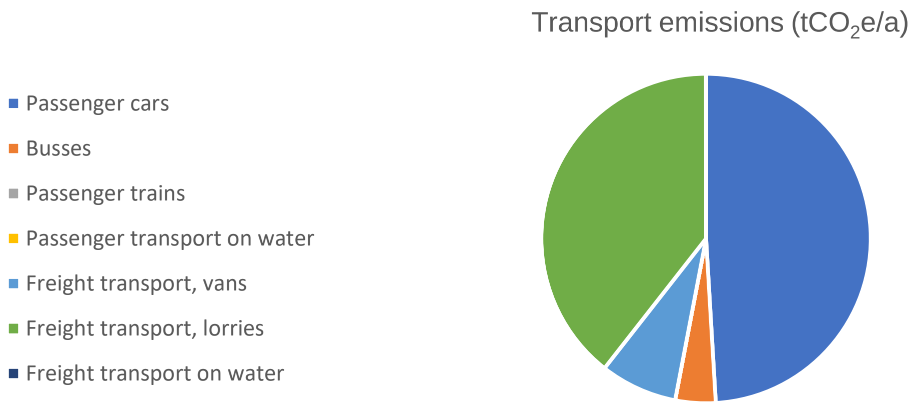

Figure 11. The baseline emissions for transport in Kymenlaakso (tCO_2e/a) (2019).

Table 6. The baseline emissions for transport in Kymenlaakso (tCO_2e/a) (2019).

Mode of transport	million vehicle-km/a	tCO_2e/a	%
Passenger car	1,142	163,242	49.1
Bus	16	13,168	4.0
Passenger train		2	0.0
Passenger transport on water		1	0.0
LGV (vans)	162	25,159	7.6
HGV (lorries)	114	131,148	39.4
Freight on rails			
Freight transport on water		32	0.0
Total		**332,751**	**100.0**

2.1.2.3 Land use

The distribution of Kymenlaakso land cover classes and soil types are shown in Figure 12 and Figure 13.

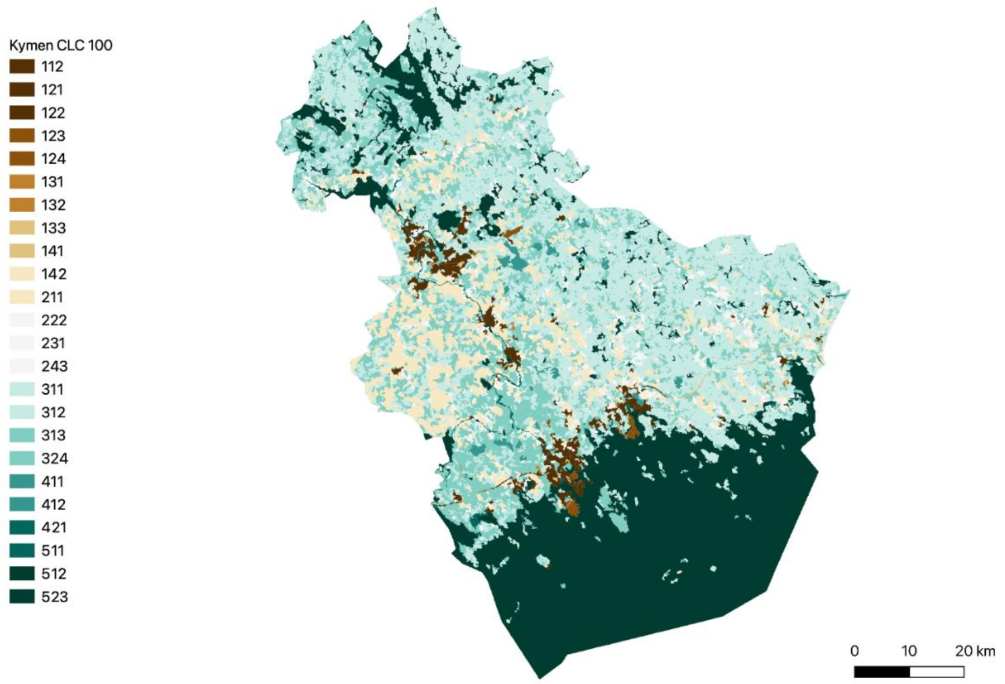

Figure 12. CORINE land cover classes in Kymenlaakso.[1]

Figure 13. Soil types in Kymenlaakso (European Soil Database).[2]

[1] CORINE classes: artificial areas (112–142); agricultural areas (211–243); forest and semi-natural areas (311–324); wetlands (411–421); water bodies (511–523).

[2] WRB soil classes: CM - Cambisol; HS - Histosol; LP - Leptosol; PZ - Podzol.

The dominant land cover is forest and semi-natural areas (CORINE class 3 ≈ IPCC forest land) that constitute 65% of total Kymenlaakso area (Table 7). This is in very good agreement with the overall land use distribution in Finland – forest land represents 65% of total Finland area (Finland's National Inventory Report 2021)). Agricultural areas account for 20% (CORINE class 2 ≈ IPCC cropland, grassland) while grasslands account less than 0,1% of Kymenlaakso area. It's also described in NIR that there are no large grazing land areas or permanent grasslands in Finland. Water bodies have a share of 11% (CORINE class 5 ≈ IPCC unmanaged land). Artificial areas (CORINE class 1 ≈ IPCC settlements) constitute 3%, followed by Wetlands 1% (CORINE class 4 ≈ IPCC peat extraction sites, unmanaged wetlands).

Table 7. Kymenlaakso land use and soil types.

CORINE land class		IPCC land-use category	mineral	organic	Total area (ha)
Class 1: Artificial areas	112	Settlements	6,988	38	7,026
	121		1,478	87	1,565
	122		45	0	45
	124		224	153	377
	131		166	0	166
	132		161	0	161
	133		102	0	102
	141		216	0	216
	142		305	0	305
Class 2: Agricultural areas	211	Cropland	54,717	711	55,427
	222		37	0	37
	231	Grassland	8	0	8
	243	Cropland	15,589	187	15,775
Class 3: Forest and semi-natural areas	311	Forest land	2,172	13	2,185
	312		129,083	5 910	134,993
	313		68,548	1 006	69,555
	324		23,889	737	24,626
Class 4: Wetlands	411	Unmanaged wetlands	362	0	362
	412	Unmanaged wetlands & peat extraction sites	2,794	337	3,131
					(2,020 peat extraction)
Class 5: Water bodies	511	Unmanaged land	1,405	0	1,405
	512		38,641	187	38,829
Total			**346,930**	**9,365**	**356,295**

According to the information provided by the case study stakeholder (Regional Council of Kymenlaakso) there were 2,020 hectares of peat production areas that have environmental permits in Kymenlaakso in 2018. According to the European Soil Database, Histosols (IPCC organic soils) constitute 3% and mineral soils 97% of total area.

The several environmental parameters (e.g., forest land litter production, annual increment etc) are estimated separately for Southern and Northern Finland. Carbon stock changes and emissions, however, are reported at country level in the CRF tables, thus the average Finland CSC factors (Table 8) were used (except for peat extraction sites) in the baseline calculation in Kymenlaakso case study.

Finland applies the following IPCC Tier 1 simplifications for grasslands remaining grasslands: it is assumed that no changes occur in mineral soil C stocks since no changes are anticipated in the carbon input or quality. The net carbon stock change in dead organic matter is considered insignificant (no emissions assumed).

Off-site CO_2 emissions from peat removed for horticultural use are reported combined with the on-site CO_2 emissions under Peat Extraction Remaining Peat Extraction in Finland. In the current study only on-site emissions from peatland management are considered, therefore the on-site emission factor for peat extraction sites of South boreal regions in Finland was used. Carbon stock change in dead organic matter of peat extraction sites is considered insignificant or included elsewhere.

In the settlements category Finland assumes according to the IPCC Tier 1 method no changes in biomass, dead organic matter and soil carbon pools.

Table 8. Finland's land use carbon-stock-change factors (Submission 2021, inventory year 2019).

Carbon-stock-change factors	Biomass		Dead organic matter		Soil	
tC/(ha, a)	above-ground	below-ground	dead wood	litter	mineral	organic
Forest land remaining forest land	0.27	IE	IE	IE[5]	0.14	-0.18
Cropland remaining cropland	0.0005	IE[4]	IE	IE[6]	-0.08	-6.50
Grassland remaining grassland	0.31	IE[4]	NO	NO	NO	-3.50
Peat extraction remaining peat extraction	-0.01	IE[4]	NA/NO	NA/NO	NO	-4.15
Settlements remaining settlements	NO	NO	NO	NO	NO	NO

NO – not occurring/no emissions.

IE – included elsewhere.

NA – not applicable/reporting not required.

Negative CSC factors denote decrease and positive increase in the C pool.

The land use sector in Kymenlaakso is estimated to be currently a net sink of -259 593 tCO_2 mainly due to the large share of carbon sequestering forest land (Table 9). The emissions from forest organic soils might be overestimated here because emissions from forest organic soils are assessed only in the drained organic soils, while the carbon stock changes of soils in undrained peatlands is assumed to be in a steady state (equal to zero) in Finland. In the current analysis all managed organic soils were considered drained, which is a conservative approach according to the IPCC the guidelines and common assumption among countries reporting under the UNFCCC. Major emissions result from peat extraction sites and cultivation of cropland organic soils.

Table 9. Baseline land use emission estimates in Kymenlaakso (tCO_2/a) (2019).

IPCC Land use category	Biomass		Dead organic matter		Soil		Total
	above-ground	below-ground	dead wood	litter	mineral	organic	
Forest land	-226,347	IE	IE	IE	-111,911	5,138	-333,121
Cropland	-120	IE	IE	IE	21,492	21,393	42,764
Grassland	-9	IE	0	0	0	0	-9
Peat extraction sites (wetlands)	51	IE	0	0	0	30,722	30,773
Settlements	0	0	0	0	0	0	0
Total	**-226,426**	**0**	**0**	**0**	**-90,420**	**57,252**	**-259,593**

Emissions have positive and removals negative signs.

IE – included elsewhere.

NE – not estimated.

2.2 Spatial planning policies

The Region of Kymenlaakso aims to be carbon neutral by 2035. The Carbon Neutral Kymenlaakso Region 2040 roadmap includes the most important measures that need to be implemented for the region to meet this goal. Some of the measures outlined in this roadmap include, for example, circular economy, land use and the increase in forestry, compact urban developments and the increase in share of renewable energy. According to the Carbon Neutral Kymenlaakso 2040 roadmap, the most important GHG emission reduction potentials are in industry, energy use and transport.

2.2.1 Policies to be quantified

2.2.1.1 Buildings

Actions from the roadmap that the tool has quantified for the building sector relate to the use of low carbon fuels and energy efficient technologies in buildings. While no numerical proposals are highlighted, nevertheless, the following measures from the roadmap can be quantified:

- Replacing fossil fuels with renewables
- The phasing out of peat as an energy source.

The tool developed is able to quantify the impacts on emissions from:

1) Construction of new buildings, both residential and commercial buildings
2) Retrofits of the building sector – which will also allow for changes in the current buildings' space and water heating to account for changes in technologies such as changing from boilers to heat pumps or alternatively to account for connections to low carbon heat
3) Changes in urban densification
4) Change in building use (from commercial to residential or vice versa).
5) Increase in renewable energy generation from retrofits and new buildings.

2.2.1.2 Transport

The study has quantified some impacts of

- Transport 12, the national transport system plan 2021–32 (Vayla, 2021)
- Kymenlaakso transport system plan (Kymenlaakson Liitto, 2021).

Kymenlaakso transport system plan implements the national transport plan on a territorial level. The transport system plan of Kymenlaakso aims to also implement the Carbon neutrality roadmap. The actions are specified by cross-examining the transport-related actions in the roadmap and the regional transport system plan. They include:

- Developing a distribution network for biogas vehicles; quantification by adjusting the shares of alternative fuels (%) in 2025–35
- Improvements of main rail connections in 2025–40
- Improvements of Road 15 (Kouvola–Kotka) 2022–2029; upgrade to a highway.

2.2.1.3 Land use

The stakeholder of Kymenlaakso did not request quantifying any spatial planning policy actions in the land use sector. However, given the data provided in Finland's NIR the following actions can be quantified:

- afforestation: cropland/grassland/wetlands/settlements conversion to forest land
- deforestation: forest land conversion to cropland/grassland/settlements
- land conversion to peat extraction
- grassland/wetlands/settlements conversion to cropland
- cropland/wetlands conversion to grassland.

2.2.2 Quantification results

2.2.2.1 Building related policies

Retrofits

There are no indicative numerical proposals in the Carbon Neutral Kymenlaakso Region 2040 roadmap, however it was assumed that over the lifetime of the roadmap, the use of coal and peat would be eliminated from buildings and 20% of electricity generation for buildings, will be sourced from renewable energy.

Territorial Emissions

If retrofit buildings were to eliminate the use of coal and peat, and also make use of renewable energy generation for 20% of electricity usage in Kymenlaakso, this would result in a reduction of 50,510 tonnes of CO_2. A total of 45,804 tCO_2 would be reduced from the residential sector and 4,706 tCO_2 from the commercial sector.

Consumption-based Emissions

The policy was quantified in 2026. It was assumed that the retrofitting lead to a reduction in energy use for heating of 20% and that solid fuels were eliminated (at the expense of electricity). This led to per capita emissions of 7.3 tCO_2e in 2026 (in comparison to 7.3 tCO_2e in the baseline scenario for the same year – to an extra significant figure, savings are on the order of 50 kgCO_2e). This would reduce emissions over the whole of Kymenlaakso 8 ktCO_2e in the same year. These changes are low as most solid fuels are already distributed to wood, and both wood and electricity have low emission factors for Finland within the tool.

Renewable energy generation

Territorial Emissions

If retrofit buildings were to make use of renewable energy generation for 20% of electricity usage in Kymenlaakso buildings, this would result in an increase of 324,049 MWh of renewable energy generation, of which 91% is from the residential sector and 9% from the commercial sector. The reason behind these findings is that electricity demand is much higher in the residential sector as most of the buildings would make use of air source heat pumps which would need electricity to heat their homes.

Consumption-based Emissions

This policy was quantified in 2026. If 20% of the local electricity demand was produced locally (in this case by wind power) it would lead to per capita emissions of 7.3 tCO_2e in 2026. The total savings against the baseline would be 0.12 $MtCO_2e$. Note that for both this policy and the baseline scenario, the rather low share of fossil fuels for electricity production is already considered. So these savings are on top of that.

2.2.2.2 Transport related policies

Biogas station network

Territorial Emissions

The policy to be quantified is to enhance the share of biogas (biomethane) vehicles in the car fleet by building up a network of biogas stations in Kymenlaakso. To differentiate them from natural gas vehicles (NGV) with rather high emission factor, biomethane-fuelled vehicles are referred to as RGVs (renewable gas vehicles).

A report by The International Renewable Energy Agency (IRENA) provides various emission factors for RGVs depending on the raw material and ranging from 66 gCO_2/vehicle-km (maize) to 33 gCO_2/vehicle-km (liquid manure). The emission factor 48 $kgCO_2$/vehicle-km (organic waste) was applied in this calculation. (IRENA, 2018).

The average emission factors for street and road driving with the Finnish average car fleet were calibrated to match with the municipality-level data from the LIISA database by adjusting the emission factors for petrol and diesel engines. In the baseline situation, these emission factors are:

- Street driving, passenger car in average: 178 gCO_2/vehicle-km
- Road driving, passenger car in average: 124 gCO_2/vehicle-km.

Based on these two factors, four driving profiles (city, town, suburban, rural) were defined for the baseline situation (Table 10).

Table 10. The driving profiles for the six municipalities of Kymenlaakso.

streets	gCO_2e/vkm LIISA	GGIA driving profile	$kgCO_2e$/vkm applied
Hamina	178	city	178
Kotka	178	city	178
Kouvola	178	city	178
Miehikkälä	135	town	136
Pyhtää	135	town	136
Virolahti	135	town	136
roads	**gCO_2e/vkm LIISA**	**GGIA driving profile**	**$kgCO_2e$/vkm applied**
Hamina	131	suburban	131
Kotka	132	suburban	131
Kouvola	129	suburban	131
Miehikkälä	124	rural	124
Pyhtää	141	town	136
Virolahti	137	town	136

The share of biomethane fuelled cars was adjusted in the average car fleet to calculate the impact on the emission factor for an average passenger car (Table 11). The share of “alternative energy” in the Finnish car fleet is today 0.5 % (Eurostat). Biomethane was assumed “alternative energy” and the results were calculated with the RGV shares of 1, 2, 5, 10 and 20 percent. The shares of diesel and petrol were reduced accordingly.

Table 11. Increasing share of biomethane-fuelled cars (RGVs) reduces the average emission factor for the car fleet.

Share of biomethane cars (%)	Average emission factor gCO_2e/km of the car fleet		
	Average driving	Road driving	Street driving
0.5 (baseline)	141	124	185
1.0	140	124	185
2.0	137	121	180
5.0	130	115	171
10.0	118	104	156
20.0	109	96	143

Table 12. The shares of internal transport and transit transport according to the Carbon neutrality roadmap data applied on transport activity data 2020 (LIISA).

Municipality	Internal	Transit	Internal	Transit
	Million vkm/a	Million vkm/a	%	%
Hamina	10.715	5.462	66.2	33.8
Kotka	13.726	2.883	82.6	17.4
Kouvola	42.345	9.017	82.4	17.6
Miehikkälä	0.832	0.175	82.6	17.4
Pyhtää	1.996	6.030	24.9	75.1
Virolahti	0.706	6.805	9.4	90.6

The results are presented in Table 13. The share of biomethane-fuelled passenger cars is assumed to increase in internal transport only. Transit transport continues to operate with a vehicle fleet equal to the Finnish average car fleet in the baseline situation.

Table 13. The impact of the promotion of biomethane-fuelled cars on the total passenger car transport emissions in Kymenlaakso.

Share of biomethane %	City gCO_2e/vkm	Town gCO_2e/vkm	Suburban gCO_2e/vkm	Rural gCO_2e/vkm	Total CO_2e emissions tCO_2e/a	Reduction in car emissions %
0.54	178	136	132	124	163,880	baseline
1.0	177	136	131	124	163,502	0.2
2.0	173	133	128	121	160,522	2.0
5.0	164	126	121	115	154,623	5.6
10.0	149	115	110	104	144,791	11.6
20.0	138	105	102	96	136,780	16.5

In the total transport sector GHG emissions, the policy would reduce 6,569 tonnes CO_2e/a (2.0%).

<u>Consumption-based emissions</u>

This policy was quantified in 2030. It was assumed that a doubling of biofuels use also led to a doubling of biofuel purchases by residents. In principle, these may not be exactly equivalent if residents of the area make a significant number of fuel purchases outside of the region. That being said, introduction of this policy would lead to biofuel use in private transport of around 40%. In turn, this leads to per capita emissions of 6.5 tCO_2e in 2030. The equivalent emission in the baseline scenario would be 6.7 tCO_2e. In turn, the emissions savings were 38 $ktCO_2e$ in 2030.

Improvement of main rail connection

As with the biofuel network, no quantitative information detailing the expected modal shift changes were provided for this policy, and so the results should be seen as indicative.

<u>Territorial emissions</u>

The improved rail transport is estimated to reduce the passenger car transport in Kouvola: 5% in vehicle-kilometres on streets and 10% in vehicle-kilometres on roads. The latter is based on the assumption that more fluent rail connection reduces transit transport. For the municipalities around Kouvola, the passenger car transport activity is assumed to remain on the same level, as the trip to the Kouvola railway station would most likely utilize passenger car. This impact would equal to 22 million passenger-kilometres per year. The reduction in passenger car transport is 2,807 tCO_2e/a. When the respective number of passenger-kilometres is added in rail transport activity, the estimated increase is 342 tCO_2e/a. The total reduction in passenger transport emissions is 2,465 tCO_2e/a.

If the freight transport on roads decreases by 5% in Kouvola, by 3% in Pyhtää and by 2% in Hamina and Virolahti, the total reduction in GHG emissions is 3,595 tCO_2e/a. Assuming that one new freight train with a diesel engine drives twice per week through the Kymenlaakso area in East-West direction (2x60 km/week), the annual GHG emissions increase 84 tCO_2e/a. The total reduction in freight transport emissions is 3,512 tCO_2e/a.

Altogether, these developments would reduce the baseline transport emissions of Kymenlaakso by 1.8% (appr. 6,000 tCO_2e/a).

<u>Consumption-based emissions</u>

This policy was quantified in 2030. It was assumed that this policy led to a 20 % reduction in private transport fuel purchases, and an equivalent percentage increase in public transport expenditure by households. Moreover, expenditure on the purchase and maintenance of vehicles was also reduced by 10%. Finally, the percentage of public transport on rail travel was increased to 50 % from a starting value of 35% at the expense of bus travel. These changes would lead to per capita emissions in 2030 of 6.5 tCO_2e, and total savings across the whole region of 34 $ktCO_2e$.

Improvement of Road 15, Kouvola–Kotka

Territorial emissions

The transport activity on Road 15 was first estimated with the help on traffic count data of Väylävirasto (Liikennemääräkartat - Väylävirasto (vayla.fi)). The road length for Kouvola and Kotka were estimated by measuring in Google Maps. The estimates are presented in Table 14 and Table 15.

Table 14. Road 15 lengths and an estimate on the total volume of road transport on Road 15 (Kouvola-Kotka).

	Road length	Nr vehicles / day	Vehicle-km / a
Road 15 in Kouvola	28.1	5,800	59,487,700
Road 15 in Kotka	10.5	5,800	22,228,500

Table 15. Estimated division of car passenger transport on all roads and on Road 15 by vehicle type.

Kouvola and Kotka	Total		Road 15, Kouvola	Road 15, Kotka
Kouvola and Kotka	million vkm/a	%	vkm/a	vkm/a
Passenger car	585	76.6	45,573,582	17,029,274
Van	82	10.8	6,421,377	2,399,447
Bus	7	0.9	537,610	200,886
Lorry	68	8.9	5,305,079	1,982,325
Motorcycles	21	2.8	1,650,052	616,567
Total	**763**	**100.0**	**59,487,700**	**22,228,500**

GGIA tool cannot directly calculate the impact of congestion. Therefore the impact was quantified with driving profiles and their emission factors. The emission factors were assumed as follows:

- Urban driving 178 gCO_2e/km
- Rural driving 124 gCO_2e/km
- Highway driving 140 gCO_2e/km
- Highway driving with congestion (+30%) 177 gCO_2e/km.

The GHG emissions calculation was disaggregated to define the share of Road 15 so that the average emissions for one vehicle-kilometre match with the municipal values in the LIISA database (Table 16). According to the LIISA data, the weighted average of internal and transit car transport on roads is 131.3 gCO_2e/vehicle-km in both Kotka and Kouvola.

Table 16. Passenger car transport activity on Road 15 and baseline GHG emissions.

With congestion on Road 15			Total / LIISA	Conversion factors	Average	Baseline
		million vkm/a	million vkm/a	gCO_2e/vkm	gCO_2e/vkm	tCO2e/a
Kotka	Road 15	22.2	170.8	177.1	131.3	3,937
	Other	148.6		124.5		18,490
Kouvola	Road 15	59.6	414.1	177.1	131.3	10,535
	Other	354.6		123.6		43,845
Total						**76,807**

Table 17. Passenger car transport activity on Road 15 and policy impact on the road transport GHG emissions.

Without congestion on Road 15			Total / LIISA	Conversion factors	Average	Baseline
		million vkm/a	million vkm/a	gCO_2e/vkm	gCO_2e/vkm	tCO2e/a
Kotka	Road 15	22.2	170.8	139.9	126.5	3,110
	Other	148.6		124.5		18,490
Kouvola	Road 15	59.6	414.1	139.9	126.0	8,322
	Other	354.6		123.6		43,845
Total						**73,767**

When the emission factor for Road 15 is adjusted from 177.1 gCO_2e/km to 139.9 gCO_2e/km, the calculation shows a reduction of 3,040 tonnes CO_2e/a in passenger car transport. The policy has an impact only on the road transport in Kotka and Kouvola. In the total Kymenlaakso passenger car transport emissions the reduction is 1.3%.

Table 18. The policy impact on the total passenger car emissions in Kymenlaakso.

streets	Total / LIISA million vkm/a	baseline tCO_2e/a	policy tCO_2e/a
Hamina	36.541	6,517.2	6,517.2
Kotka	94.712	16,892.1	16,892.1
Kouvola	149.197	26,609.7	26,609.7
Miehikkälä	3.419	462.3	462.3
Pyhtää	9.465	1,279.5	1,279.5
Virolahti	5.725	773.9	773.9
roads	**million vkm/a**	**tCO_2e/a**	**tCO_2e/a**
Hamina	116.840	15,359.1	15,359.1
Kotka	170.781	22,470.2	21,600.1
Kouvola	414.105	53,461.8	52,167.0
Miehikkälä	13.295	1,652.9	1,652.9
Pyhtää	73.451	10,321.5	10,321.5
Virolahti	54.337	7,441.9	7,441.9
Total		**163,242.0**	**161,077.1**

With the assumptions described above, this policy reduces the average passenger car emission factor for road driving in Kotka 3.7% and Kouvola 4.1%. The same impact was applied on the emission factors of bus and road freight transport. The total impact of the policy is presented in the Table 19 below.

Table 19. The policy impact on the total transport emissions in Kymenlaakso.

Road 15 improvement / impact on transport emissions Hamina, Kotka, Kouvola, Miehikkälä, Pyhtää, Virolahti	Without policy tCO_2e/a	With policy tCO_2e/a
Passenger car	163,242	160,238
Bus	13,168	12,974
Passenger train	2	2
Passenger transport on water	1	1
Freight transport, vans	25,159	24,693
Freight transport, lorries	131,148	128,244
Freight transport on water	32	32
Total	**332,751**	**326,182**

The total emission reduction in the Kymenlaakso transport emissions is 2%. However, it is important to notice that the fluent highway connection may also attract more road transport. Increase in transport volume would have an opposite impact on the road transport emissions.

Consumption-based emissions

This policy was quantified in 2030. It was assumed to lead to a 20% increase in expenditure on private transport fuels, an increase in private car purchases of 10%, and a 20% reduction in public transport expenditure. The percentage of total public transport expenditure on bus travel was increased to 60% from a starting value of 50%. This would lead to per capita emissions in 2030 of 7.0 tCO_2e and would increase total emissions in the region by 53 $ktCO_2e$.

2.2.3 Results

The results of the policy quantification are summarised in Table 20 below. In general, there was a lack of quantitative numbers linked to specific policies in the reference document, meaning assumptions were required to perform the calculations.

Table 20. Quantifying spatial planning policies for Kymenlaakso.

policy	impact	module	quantification in the tool	CO_2e increase /decrease (tCO_2)	Emissions per capita (tCO_2/capita)
1. Biogas station network	2025-35	transport	share of biogas fuel engines in passenger cars increases; petrol and diesel reduced respectively	-6,569	-0.04
		consumption-based	part of the car transport expenditure moves from petrol to biogas	48,000	6.5 (in 2030)
2. Improvement of main rail connections	2025-40	transport	shares of passenger and freight transport on rails increase; road transport reduced respectively	-5,977	
		consumption-based	part of the transport expenditure moves from passenger cars to railroad passenger transport	45,000	6.5 (in 2030)
3. Improvement of Road 15 from Kouvola to Kotka	2022-29	transport	adjusting driving profiles to quantify the impact of less congestion on Road 15	-3,040	-0.02

policy	impact	module	quantification in the tool	CO_2e increase /decrease	Emissions per capita
		consumption-based	increase in private transport, de-crease in public transport but in-creas in bus share	-45,000	7.0 (in 2030)
4. Retrofitting	2022-26	energy use in buildings	change in energy consumption pro-file of existing buildings	-51,000	
		consumption-based	change in ex-penditure on en-ergy	27,000	7.1 (in 2026)
5. Increase in re-newable energy generation	2022-26	energy use in buildings	change in energy consumption pro-file of existing buildings	324,049 MWh	
		consumption-based	increase in the share of locally produced and used renewable energy	12,000	7.2 (in 2026)

3 Conclusions

This section identifies the key findings from the different carbon emitting sectors for both the consumption and territorial-based approaches, and also discusses the actions from the quantified spatial planning policies that can contribute the most to emission reductions in Kymenlaakso.

3.1 Key Findings from the baseline

3.1.1 Consumption-based approach

- The per capita emissions were 7.9 tonnes CO_2e per annum.
- The total consumption emissions for the region were calculated to be approximately 1.4 $MtCO_2e$ per annum. A feature of the emissions from the region is the small contribution from the electricity sector, as well as the relatively higher contribution from electricity and renewables in household heating. This leads to a lower contribution from household energy sources in the emissions total.
- A relatively greater proportion of the Finnish carbon footprint arises from direct and indirect production of products, rather than the household use phase.

3.1.2 Territorial approach

3.1.2.1 Buildings

- Total emissions from both the residential and commercial sectors in Kymenlaakso accounted for 683,540 tonnes of CO_2 in 2019.
- The residential sector contributed 74% and the commercial sector 26% to the total emissions.
- The main source of emissions come from electricity (37%), followed by wood (25%) and district heating (24%).

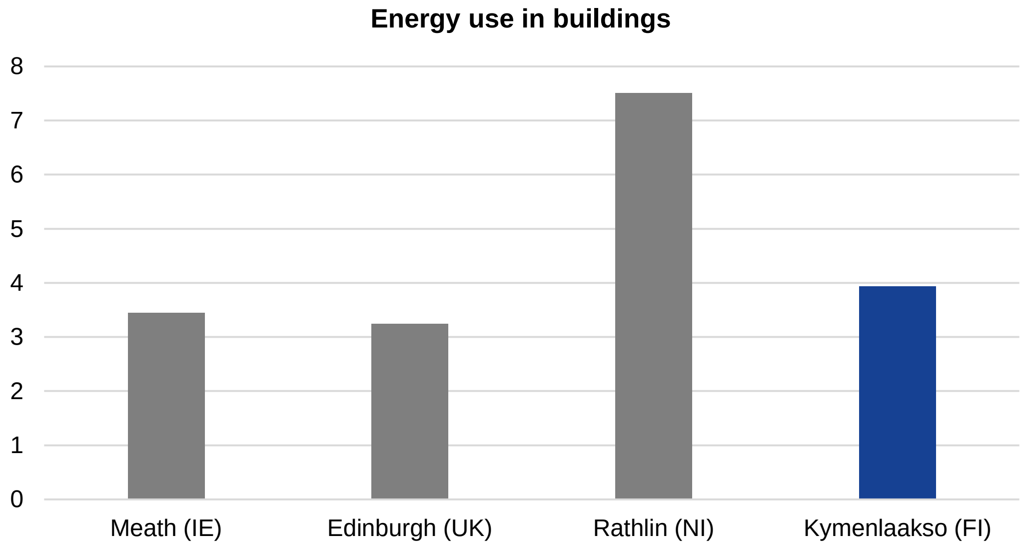

Figure 14. Annual buildings baseline emissions per capita ($tCO_2e/(capita,a)$) (2019).

3.1.2.2 Transport

- Kymenlaakso area is characterised by high share of transit transport and relatively high car-dependency in passenger transport.
- Transport emissions in Kymenlaakso come from:

  Passenger cars 49.1%

  Freight transport, lorries 39.4%

  Vans 7.6%

  Busses 4%.

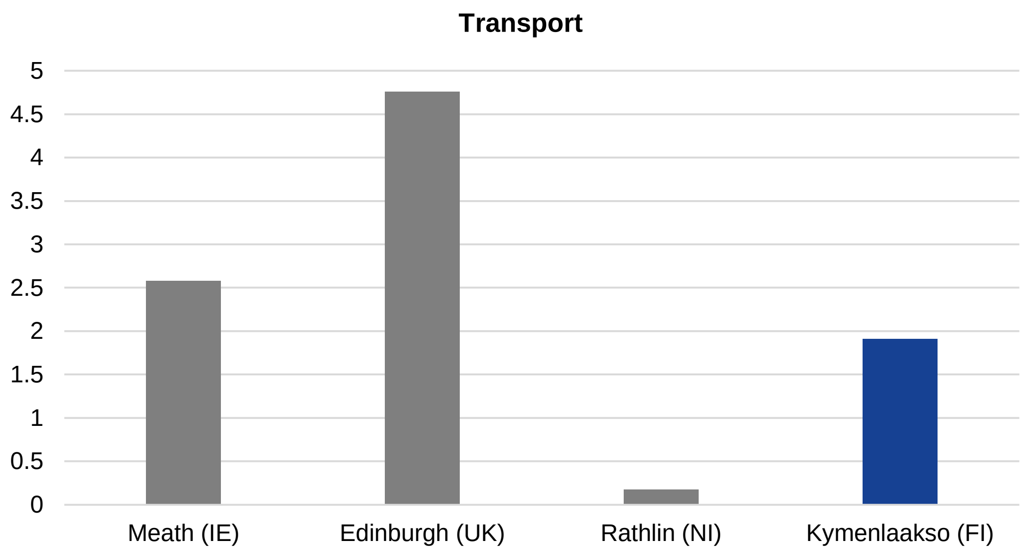

Figure 15. Annual Transport baseline emissions per capita (tCO_2e/(capita,a)) (2019).

3.1.2.3 Land use

- The land use sector in Kymenlaakso is estimated to be currently a net sink of -259.593 tCO_2 mainly due to the large share of carbon sequestering forest land.
- The emissions from forest organic soils might be overestimated here because emissions from forest organic soils are assessed only in the drained organic soils, while the carbon stock changes of soils in undrained peatlands is assumed to be in a steady state (equal to zero) in Finland
- Major emissions result from peat extraction sites and cultivation of cropland organic soils.

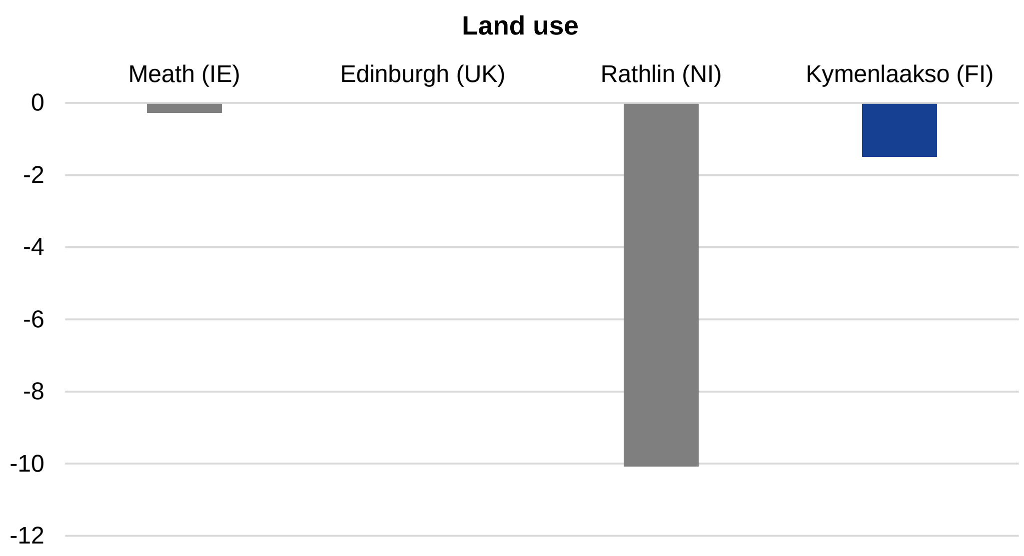

Figure 16. Annual land use baseline emissions per capita (tCO_2e/(capita,a)) (2019).

3.2 Key findings from the action quantification of spatial planning policies

From the actions that were quantified for the Carbon Neutral Kymenlaakso 2040 roadmap, transport related actions had the greatest potential to reduce emissions.

The improved rail transport is estimated to reduce the passenger car transport in Kouvola: 5% in vehicle-kilometres on streets and 10% in vehicle-kilometres on roads. This impact would equal to 22 million passenger-kilometres per year. The reduction in passenger car transport is 2,807 tCO_2e/a. When the respective number of passenger-kilometres is added in rail transport activity, the estimated increase is 342 tCO_2e/a. The total reduction in passenger transport emissions is 2,465 tCO_2e/a.

If the freight transport on roads decreases by 5% in Kouvola, by 3% in Pyhtää and by 2% in Hamina and Virolahti, the total reduction in GHG emissions is 3,595 tCO_2e/a. The total reduction in freight transport emissions is 3,512 tCO_2e/a.

Altogether, these developments would reduce the baseline transport emissions of Kymenlaakso by 1.8% (approximately 6,000 tCO_2e/a).

Furthermore, if the biogas station network were to be enhanced and the share of biogas (biomethane) vehicles in the car fleet were to be increased in Kymenlaakso, this could also potentially decrease emissions by a further 6,569 tCO_2e/a.

When considering energy use in buildings, if retrofit buildings were to eliminate the use of coal and peat, and also make use of renewable energy generation for 20% of electricity usage in Kymenlaakso, this would result in a reduction of 50,510 tonnes of CO_2. A total of 45,804 tCO_2 would be reduced from the residential sector and 4,706 tCO_2 from the commercial sector. This would also result in an increase of 324,049 MWh of renewable energy generation, of which 91% is from the residential sector and 9% from the commercial sector. The reason behind these findings is that electricity demand is much higher in the residential sector as most of the buildings would make use of air source heat pumps which would need electricity to heat their homes.

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The ESPON EGTC is the Single Beneficiary of the ESPON 2020 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States, the United Kingdom and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.