TOWARDS CARBON-NEUTRAL CITIES

Effective measures for reducing unabated emissions in Lappeenranta

Lappeenranta–Lahti University of Technology LUT

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ABSTRACT

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Towards carbon-neutral cities: Effective measures for reducing unabated emissions in Lappeenranta

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The city of Lappeenranta is aiming to be carbon neutral by 2030. Carbon footprint of the city of Lappeenranta is calculated annually, but the city organization's footprint has not been studied. This thesis studies the greenhouse gas emissions caused by the city organization of Lappeenranta focusing on four emission sources, which are public transportation, district heating, non-road mobile machinery, and building-specific heating. The aim of this thesis is to calculate how much greenhouse gas emissions the city organization emits through these four emission sources and how it compares to the total greenhouse gas emissions in the city area. In addition, emission reduction solutions are presented as well as the cost-effectiveness of these solutions is examined briefly.

Emissions calculations showed that the largest source of emissions affected by the city organization is district heating. The four previously mentioned sources of emissions produced a total of approximately 33.5 kt CO2-eq emissions, of which approximately 29.5 kt CO2-eq came from district heating. Emissions for the entire city area in 2023 were slightly less than 300 kt CO2-eq. Possible emission reduction measures include phasing out fossil fuels in district heating and building-specific heating, as well as electrifying public transportation and non-road mobile machinery. The city organization can implement other emission reduction measures through land use planning, for example. In addition, monitoring and reporting, especially for non-road mobile machinery and building-specific heating, should be improved.

TIIVISTELMÄ

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Ympäristötekniikka

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Lappeenrannan kaupunki pyrkii hiilineutraaliuteen vuoteen 2030 mennessä. Lappeenrannan kaupungin hiilijalanjälki lasketaan vuosittain, mutta kaupunkiorganisaation jalanjälkeä ei ole tutkittu. Tässä diplomityössä tutkitaan Lappeenrannan kaupunkiorganisaation aiheuttamia kasvihuonekaasupäästöjä keskittyen neljään päästölähteeseen, jotka ovat joukkoliikenne, kaukolämpö, työkoneet ja rakennusten erillislämmitys. Diplomityön tavoitteena on laskea, kuinka paljon kasvihuonekaasupäästöjä nämä neljä päästölähdettä aiheuttavat kaupunkiorganisaation toimesta ja kuinka ne suhteutuvat kaupungin alueen kasvihuonekaasupäästöjen kokonaismäärään. Lisäksi esitetään päästöjen vähentämisratkaisuja ja tarkastellaan lyhyesti ratkaisujen kustannustehokkuutta.

Päästölaskelmista selvisi, että suurin päästölähde, johon kaupunkiorganisaatio vaikuttaa, on kaukolämpö. Yhteensä neljä aiemmin mainittua päästölähdettä tuottivat noin 33,5 kt CO_2-ekv päästöjä, joista noin 29,5 kt CO_2-ekv syntyi kaukolämmöstä. Koko kaupunkialueen päästöt olivat vuonna 2023 hieman alle 300 kt CO_2-ekv. Mahdollisia päästövähennyskeinoja ovat muun muassa fossiilisten polttoaineiden alasajo kaukolämmössä ja rakennusten erillislämmityksessä, sekä sähköistäminen joukkoliikenteen ja työkoneiden osalta. Muita päästövähennystoimia kaupunkiorganisaatio voi toteuttaa esimerkiksi kaavoituksen avulla. Tämän lisäksi seurantaa ja raportointia varsinkin työkoneiden ja erillislämmitysten osalta pitäisi parantaa.

KIITOKSET

Yksi elämänvaihe on tulossa päätökseen, pian on aika jättää jäähyväiset rakkaalle Skinnarilalle ja Suomen parhaalle opiskelijayhteisölle. Lähteminen Punkkerimäen paremmalta puolelta tulee olemaan haikeaa, sillä täällä kasvoin aikuiseksi ja löysin elämälleni suunnan.

Aluksi osoitan kiitokset diplomityöni tarkastajille Risto Soukalle ja Laura Lakaselle, sekä työni ohjaajalle Petri Kerolle. Kiitän myös työkavereitani tsemppauksesta ja avusta kirjoitusprosessin aikana. Suuri kiitos myös kaikille muille tahoille, jotka vastasitte kysymyksiini ja autoitte omalta osaltanne minua kirjoittamaan työni valmiiksi.

Kun astelin fuksina ensimmäistä kertaa yliopiston pääovista sisään, en tiennyt, millainen seikkailu minua odottaisi. Koronan takia opiskelijaelämä lähti hieman tahmeasti liikkeelle etäilyn sekä kampuksen sulkemisen takia, mutta pikkuhiljaa rajoituksia kuitenkin purettiin ja alettiin elää normaalia elämää. Pian sen jälkeen löysinkin itseni erinäisistä aktiivipesteistä niin omasta killasta kuin ylioppilaskunnastamme LTKY:stä. Hetkeäkään en ole yhtäkään pestiä katunut, vaikka silloin tällöin opinnot saattoivatkin jäädä taka-alalle.

Erityisen tärkeitä minulle ovat olleet ylioppilaskunnan toimistolla vietetyt hetket. Vuosien varrella toimistolla on naurettu, itketty ja paiskittu hommia rakkaan ylioppilaskunnan eteen. Ja mikä tärkeintä – siellä ei ikinä ole tarvinnut olla yksin. Tiedän, että moni ylioppilaskunnan toimistolla tapaamani ihminen on jäänyt elämääni pysyvästi, eivätkä he katoa ystäväpiiristäni, vaikka emme enää kohtaisikaan toimistolla kahvikupin äärellä. Erityisesti haluan vielä mainita hallituskaverini Suvin, Larin, Ekin, Ansun, Niilon ja Robinin, joiden kanssa vietin uskomattoman hienon hallitusvuoden ja joista tuli minulle todella rakkaita ystäviä.

Elämäni tärkeimmän ihmisen olen kuitenkin tavannut LTKY:n toimiston sijaan Pelletin kiltahuoneella. Antti – kiitos kaikesta antamastasi tuesta ja tsempistä. Odotan innolla, mihin päädymme, kun koittaa aika lähteä Skinnarilasta.

”Monesta avusta kiitollinen, sydämestäni annan nöyrän kumarruksen. On vain aikaa, arvokkaita hetkiä, iloa, naurua, toivoa & annettua arvostusta.”

Skinnarilassa, lappeen Rannoilla 31.10.2025

SYMBOLS AND ABBREVIATIONS

Roman characters

c	consumption of fuel	l/100 km, l/h, l/a, kg/h, kg/100 km
e	emission factor	t/TJ, kg/GJ
E	energy consumption	GJ
f	fuel share	%
H	heating value	GJ/t
x	distance	km

Greek characters

ρ	density	t/m^3, kg/l

Subscripts

avg	average
d	distance
ht	heating
u	usage

Abbreviations

ALas	Alueellinen Laskenta, emission calculation method
ATV	All terrain vehicle
CDP	Carbon Disclosure Project
CH_4	Methane
CHP	Combined heat and power plant

CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
ETS2	Emission Trading for Fuels
EU ETS	EU Emission Trading System sector
EU	European Union
GHG	Greenhouse gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GWP	Global warming potential
HALT	the Handprint Approach for effective actions in the Land use and Transportation sectors
HSL	Helsingin seudun liikenne
ICLEI	Local Governments for Sustainability
ISO	the International Organization for Standardization
LULUCF	Land use, land use change and forestry
N_2O	Nitrogen dioxide
NGO	Non-governmental organization
SMR	Small module reactors
WBCSD	the World Business Council for Sustainable Development
WRI	the World Resources Institute

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DECLARATIONS

Turnitin

The originality of this thesis has been reviewed with the Turnitin similarity checking service.

AI usage

The author of the thesis, Pinla Nokkanen, used the following AI-tool during the preparation of the thesis:

1. DeepL
    a. Purpose of use: Translation and grammar check
    b. Explanation of the use of the tool: DeepL was used in this thesis to check translations of words, and improve the clarity of writing

Responsibility

The author, Pinla Nokkanen, takes full responsibility for the content of this thesis and has reviewed and edited the content generated by the possible use of AI tools.

1 Introduction

The Finnish Climate act (423/2022) states that Finland must aim to be carbon neutral by the year 2035. Finnish climate policy is guided with several agreements, most important ones being Kyoto Protocol and Paris Agreement. Kyoto Protocol was the first international legally binding contract that required emission reduction actions. It was set to action in 2005, its first commitment period was from 2008 to 2012, and second one from 2013 to 2020. (OSF 2025a.) In 2015, Paris Agreement was concluded, and it was set to action in 2016. The agreement aims to limit the global average temperature increase to less than 1.5 degrees Celsius above pre-industrial levels. (Ministry of the Environment 2025.)

In order to achieve the carbon neutrality goal on time, the efforts of municipalities and regions must be stressed. Municipalities oversee, for example, statutory land use planning, land use, traffic planning, and public procurement. All of these are potential channels for influencing one's own greenhouse gas emissions. Out of 309 municipalities in Finland, 163 have set out a climate target for themselves. Most of these municipalities have a goal to reduce emissions by 80 % before 2030, and some try to achieve carbon neutrality before 2035. (Ministry of the Environment 2024; Ministry of the Environment 2022.)

The city of Lappeenranta is aiming to be carbon neutral and reduce its emissions at least 80 % from the 1990 levels by 2030. Over the years, the city has gotten quite a lot of recognition from their climate work. For example, Lappeenranta has been a WWF (World Wide Fund for Nature) Climate Capital of Finland in 2014 and 2016, they got a Green Leaf award from the European commission in 2021, and in 2025 they received an award from Covenant of Mayors for measures to reduce carbon emissions from heating. (Greenreality Lappeenranta 2025a; Greenreality Lappeenranta 2025b.) In Lappeenranta's climate programme for the years 2021–2030 (2020) the city has listed several actions to reduce emissions from different sectors, as well as actions to adapt to climate change.

This thesis is done as a part of a project called HALT (the Handprint Approach for effective actions in the Land use and Transportation sectors) implemented by the city of Lappeenranta and LUT University. The aim of this project is to look into the city's greenhouse gas emissions that are unabated and find cost-effective emission reduction solutions to compensate these emissions. As a part of HALT, the city of Lappeenranta will launch pilot

projects focusing on land use, land use change and forestry, and transportation sectors. These pilot projects will implement carbon handprint methodology, and the goal is to find effective ways to reduce emissions and replicate those to other cities, as well. (Greenreality Lappeenranta 2025c.)

The aim of this thesis is to calculate how much greenhouse gas emissions the city organization emits through four selected emission sources and how it compares to the total greenhouse gas emissions in the city area. In addition, emission reduction solutions are presented as well as the cost-effectiveness of these solutions is examined briefly. The need for this works comes from the fact that the carbon footprint of the Lappeenranta city organization has not been examined yet. Carbon footprint is calculated for the whole city area annually, but as it consists of the residents' carbon footprint as well, it does not give out a clear picture of the organization's footprint. However, the knowledge of the city organization's carbon footprint is crucial when making plans to achieve carbon neutrality as the city is fully responsible of its own greenhouse gas emissions and actions to reduce them. Based on this need, this thesis aims to answer the following questions:

- How do the city organization's unabated emissions compare to the total greenhouse gas emissions in Lappeenranta?
- What options are there to reduce said emissions and how cost-efficient it would be if the goal is to reduce them before 2030?

The first theory chapter explains three widely known and used greenhouse gas emission sectors and their greatest emission sources. The second chapter covers different concepts of carbon management. This chapter includes, for example, carbon footprint, carbon neutrality, emission offsetting and unabated emissions. On the third chapter, different standards and calculation methods guiding carbon footprint calculations are presented. In addition, the differences between carbon footprints of a city and city organization are presented briefly. The final theory chapter consists of the greenhouse gas emission trend of the city of Lappeenranta.

After the theory chapters, the greenhouse gas emissions of the city of Lappeenranta are examined, and the ones caused by the city organization itself are pinpointed and focused on. Greenhouse gas emissions from public transportation, district heating, non-road mobile

machinery, and building-specific heating are also calculated in this chapter. The calculations are based on information gathered from different Lappeenranta city departments and group companies, as well as online sources. The information contains estimations and assumptions, which might affect the results.

The results of these calculations are analysed in the following chapter. In this chapter, possible emission reduction solutions for the sectors mentioned above are presented. In addition, other solutions which municipalities have control over, and improvement solutions to the city organization's reporting methods are covered.

Finally, in conclusions the research questions are answered, and the relevance of this thesis is considered.

2 Greenhouse gas emission sectors

This chapter covers the three sectors greenhouse gas (GHG) emissions are usually divided into – EU Emission Trading System (EU ETS) sector, effort sharing sector, and land use, land use change and forestry (LULUCF) sector. In addition, the biggest emissions sources from each sector are presented.

2.1 EU Emission Trading System sector

EU has set a limited number of allowances that are either auctioned or given for free. These allowances permit the owner to emit a certain amount of carbon dioxide to the atmosphere. Over time, the number of these allowances is reduced steadily, which reduces the amount of emissions in this sector at a predictable rate. One of the advantages of this market-based system is that companies are encouraged to cut their emissions in a cost-effective way. Companies have an option to sell their allowances, when their market price is higher than the cost of reducing emissions. (Delbeke 2024.)

In 2023, the EU ETS sector covered aviation in EU, and large industrial and energy generation installations. Furthermore, starting from 2024 maritime transportation is being phased in to the emission trading system. This scheme is also being referred as General Emission Trading (ETS1). (Ministry of the Environment 2024.) Starting from 2025, a new emissions trading scheme focusing on fuels will be set up. This scheme is called Emission Trading for Fuels (ETS2). (Energy Authority 2025.)

In Finland in 2023, most of the emissions (almost 80 %) in this sector were from energy generation (Ministry of the Environment 2024).

2.2 Effort sharing sector

Effort sharing sector includes emissions that are not part of the LULUCF sector or the EU ETS sector. The largest emission sources in this sector are transportation (excluding domestic aviation), agriculture, buildings, non-road mobile machinery, waste treatment and

fluorinated gases (F-gases). Currently, effort sharing sector covers over 60 % of the EU's GHG emissions. (Ministry of the Environment 2024; Delbeke 2024.)

In Finland in 2022, the biggest emission source was transportation (9.6 Mt CO_2-eq) covering a little over third or the effort sharing sector emissions. The second biggest source was agriculture (6.0 Mt CO_2-eq) covering a little under fourth of the emissions in the effort sharing sector. (Ministry of the Environment 2024.)

2.3 Land use, land use change and forestry sector

Total emissions are usually reported excluding or separating the land use, land use change and forestry sector, which includes six land use categories (forest land, cropland, grassland, wetlands, settlements and other land as well as changes in the harvested wood product carbon pool). The excluding is done mostly because depending on data uncertainty the sector can be either a net sink or a net source. (The Finnish Climate Change Panel 2024.) According to the Ministry of the Environment (2024) 2018 was the first year in Finland when LULUCF sector transformed from carbon sink to carbon source. After 2018, the net emissions from LULUCF sector have been ranging between 1.8 and 12.0 Mt CO_2-eq. The reason behind LULUCF sector turning into carbon source is increase in deforestation, and increased decomposition due to global warming. (Natural Resources Institute Finland 2025.)

As LULUFC sector combines several categories of land use, it is possible to focus more on the net source categories in order to decrease the carbon footprint of the sector. In Finland in 2022, the largest emission sources were croplands (8.1 Mt CO_2-eq), and wetlands (2.3 Mt CO_2-eq). (Natural Resources Institute Finland 2025.)

3 Concepts for carbon management

This chapter covers the concepts of carbon management, such as carbon footprint, carbon handprint, and unabated emissions. In addition, the ideal pathway to carbon neutrality is presented as well as carbon offsetting with its limitations and challenges.

3.1 Carbon footprint

Carbon footprint is an indicator that is used to quantify the amount of carbon dioxide (CO_2) emissions or total greenhouse gas emissions (Chen et al. 2021). Emissions are commonly presented in terms of carbon dioxide equivalents (CO_2-eq), meaning that each emission is converted into an equivalent amount of carbon dioxide. This conversion is done with global warming potential (GWP) factors. (Lounasheimo et al. 2020.) Global warming potential values depend on the time horizon used, and the values may also change when calculation methods are improved. As an example, the GWP value in 100-year time horizon for methane (CH_4) is 25–27, and for nitrogen dioxide (N_2O) 265–298. (Greenhouse Gas Protocol 2024.) This means that CH_4 warms the climate 25 times more, and N_2O over 260 times more in a 100-year period than the same amount of CO_2

3.2 Carbon neutrality and ways to achieve it

Carbon neutrality is a term used to describe a situation where one's net GHG emissions are zero. Net emissions consist of emitted and absorbed GHG emissions. In some cases, the term climate neutrality is used instead of carbon neutrality even though they mean the same thing. (European Parliament 2023; Council of the European Union 2024.) The Finnish Environment Institute has proposed a new definition for carbon neutrality for municipalities and regions to ensure that it isn't achieved only with large carbon sinks or by offsetting all their GHG emissions. This new definition has two steps, which are the following:

1. "Net emissions are zero: The region's annual operational greenhouse gas emissions do not exceed the total amount of the region's own carbon sinks and any emission reduction units outside the region."

2. “Emissions reductions are significant: Operational emissions are at least 70 % below 1990 levels.”

Adding the second step highlights the importance of reducing GHG emissions in order to achieve carbon neutrality. (Saikku & Karhinen 2025.)

In figure 1, the pathway to carbon neutrality is demonstrated. The first and the most crucial step is to reduce as much GHG emissions as possible. The second step is to increase the amount of carbon sinks, and the third step is to offset the remaining emissions. (Saikku & Karhinen 2025.)

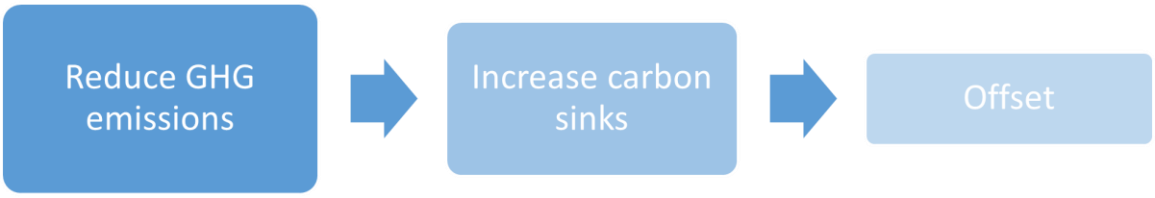

Figure 1. Ideal pathway to carbon neutrality (Saikku & Karhinen 2025).

As seen on the figure above, reducing GHG emissions is the most important and efficient way to achieve carbon neutrality. Reducing emissions is also easier to verify compared to increasing carbon sinks or emission offsetting. There are always uncertainties in calculating the true amount of carbon in a sink or the amount of offset emissions.

3.3 Carbon offsetting

When all the possible actions to reduce greenhouse gas emissions are done, the remaining GHG emissions can be offset, if needed. Offsetting is based either on regulative offset markets or voluntary markets. Regulatory markets include, for example, the EU Emission Trading System scheme. Voluntary markets are open for everyone – private person, municipality or company – to purchase carbon credits to offset one’s GHG emissions. Carbon credits can either reduce GHG emissions or increase carbon sinks. These actions can

be done anywhere in the world since the location is irrelevant from climate perspective. Possible GHG emission offsetting actions can be, for example, increasing renewable energy usage, capturing carbon dioxide from the atmosphere and either storing or utilizing it, increasing carbon sinks, and increasing energy efficiency. (Niemistö et al. 2021.)

Offsetting must pass strict quality requirements, and it can't be used as a shortcut to reach carbon neutrality. Offsetting actions must be additional, permanent, and unique, meaning that they must improve the GHG emission reduction would otherwise be in line with the basic level. This ensures that reduction actions that are already in place are not used to offset for other emissions. (Saikku & Karhinen 2025; Hildén et al. 2024.)

When a municipality or an area is aiming for carbon neutrality, offsetting might result in problems in emission calculations as there is a chance for double counting. Double counting means that an offset action is calculated twice, which can happen, for example, when an offset action for LULUCF sector is purchased in Finland resulting in increasement of carbon sinks, and both the buyer of the offset and the country of Finland take the offset in to account in their carbon inventory. (Seppälä et al. 2019; Green Carbon 2021.)

Other issues regarding offset action in the LULUCF sector, especially with forest lands, relate to permanency of the actions. Actions increasing carbon sinks in forest lands are usually either planting more trees, forest management that promotes carbon storage, or avoiding logging. Each action increases carbon sinks, however, there is no guarantee how long the forest will stand in place. Newly planted trees can be logged after they have grown enough, a well-managed forest might be logged earlier than it was originally planned, and areas that avoided logging can still be logged at some point. There are also some issues with the additionality of offset actions. In a case where energy wood can't be collected from a certain area anymore as logging has been suspended due to an offset procedure, the wood might be collected from somewhere else. This makes the offset action not additional as the same amount of logging is still done. (Seppälä et al. 2019.)

3.4 Unabated emissions

Unabated emissions are emissions that are left in the system after activities that result GHG emissions reduction. In this matter, GHG emission reduction means decrease in emissions

between two points in time. Unabated emissions can still be decreased, although it might turn out to be hard or costly. After implementing all economically and technically possible GHG emission reductions to unabated emissions, the leftover emissions are called residual emissions. (ISO 14068-1:2023:en.) In the figure below, the relations between GHG emissions, unabated emissions, and residual emissions are presented.

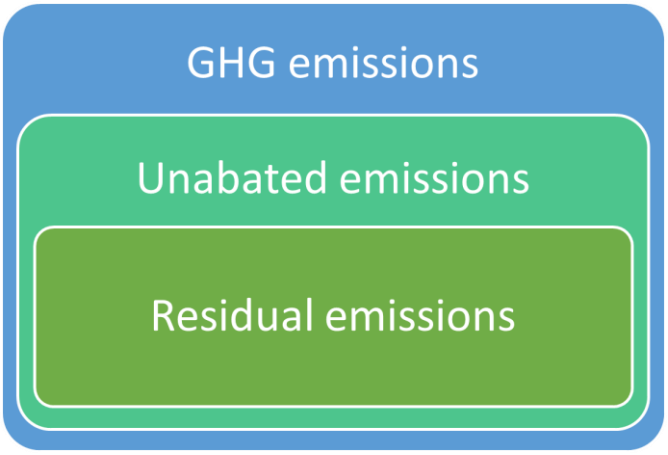

Figure 2. Relations between the presented terms (ISO 14068-1:2023:en).

As seen from the picture, all residual emissions are also unabated emissions, and all unabated emissions are greenhouse gas emissions. The focus in this thesis is on the unabated emissions, as there is not much study done about them on the level of city organization. Reducing unabated emissions might be challenging from the city organization's perspective as the solutions might be costly, and most purchases and projects must be accepted by the city council or its board depending on the size and cost (The Association of Finnish Cities and Municipalities 2025).

3.5 Carbon handprint

Carbon handprint can be considered as an opposite indicator to carbon footprint as it is used to indicate the positive impacts to the environment. However, the principle on handprint approach is that only improving the performance of another actor is considered a handprint action. Therefore, reducing one's own carbon footprint is not a handprint action. From a city's perspective, handprint actions could be enhancing waste recycling opportunities or

reducing the carbon footprint of public transportation. (Pajula et al. 2021; Grönman et al. 2019.) Carbon handprint could be seen as a complementary measure in the pathway to carbon neutrality. As it is used to measure the positive impact on other actor's emissions, it can't be a shortcut to carbon neutrality.

4 Carbon footprint calculation for cities

In this chapter, common carbon footprint calculation standards and methods are presented. Greenhouse Gas Protocol and ISO 14064-1 are widely known calculation standards that share many similarities. Both standards and their key focuses are presented, after which some differences are pointed out. From cities' perspective, the most used GHG emission calculation methods are Kasvener and ALas (Alueellinen Laskenta), both created by the Finnish Environment Institute. These calculations methods are covered in this chapter as the city of Lappeenranta utilizes both calculations methods when reporting their GHG emissions. After the standards and calculation methods are covered, the key differences between calculating the carbon footprint of a city and its organization are also presented briefly.

4.1 Standards

GHG Protocol is a commonly used calculation standard in carbon footprint calculations. It was created by the Greenhouse Gas Protocol Initiative which is a multi-stakeholder partnership including non-governmental organizations (NGOs), governments, and businesses. The Initiative was launched in 1998 by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). (WRI & WBCSD 2004.) Over the years, the Initiative has improved their calculation standards, and they have created in collaboration with C40 Cities and Local Governments for Sustainability (ICLEI) a standard more suitable for cities and communities. This standard is called Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). GPC is the official reporting tool for the Covenant of Mayors, and it is also recommended by Carbon Disclosure Project (CDP), which is a widely used environmental disclosure system. (Lounasheimo et al. 2020; WRI, C40 Cities & ICLEI 2022.)

GHG Protocol requires dividing the emissions into three scopes. Scope 1 includes all direct GHG emissions which can be, for example, combustion, agricultural activity, and waste management happening in the area of the company or city. As an exception, emissions from biomass combustion and all GHG emissions that are not covered by the Kyoto Protocol are

reported separately. Scope 2 includes emissions from purchased electricity for own use. These emissions are indirect, as they are generated elsewhere. Scope 3 is an optional category that allows to report all other indirect GHG emissions. These emissions occur away from the area of the company or city but are still the result of the company's or city's activities. For example, emissions from the use of sold goods and services, transportation of purchased fuels, and outsourced activities are included in Scope 3. (WRI & WBCSD 2004; Lounasheimo et al. 2020.)

ISO 14064-1 is standard created by the International Organization for Standardization (ISO), which is a worldwide federation consisting of national standard bodies. ISO standards are mainly created by different technical committees. This standard was created by two technical committees ISO/TC 207 and CEN/SS S26 both focused on environmental management. (SFS-EN ISO 14064-1:2019:en.)

ISO 14064-1 states five principles for accounting GHG emissions – relevance, completeness, consistency, accuracy, and transparency. During reporting, the standard allows to define the boundaries for organizational level in two ways: either the organization accounts all GHG emissions and removals from every facility it has control either financially or operationally. Other option is to share the emissions between respective facilities. For organizations GHG emissions are divided into the following categories: direct GHG emissions and removals, and indirect GHG emissions from imported energy, transportation, products used by organization, associated with the use of products from the organization, and from other sources. (SFS-EN ISO 14064-1:2019:en.)

When comparing GHG Protocol and ISO 14064-1, many similarities can be seen, for example, in definition, quantification principles, and reporting boundaries. However, there are also differences between the two frameworks. Firstly, GHG Protocol focuses more on calculating emissions for various sectors without providing formal verification requirements. GHG Protocol also provides best practices for emission calculation, as well as different calculation methods and emission factors. Whereas ISO 14064-1 focuses more on procedures, such as outlining the steps for quantifying, reporting, and verifying greenhouse gas emissions. ISO 14064-1 allows organizations to choose emission calculation methods themselves based on their needs. (Carbonology 2025; WRI & WBCSD 2004; SFS-EN ISO 14064-1:2019:en.)

Another key difference between the two frameworks is the way they address avoided GHG emissions, and removals. GHG Protocol mentions avoided emissions, and it requires them to be reported separately. (Carbonology 2025; WRI & WBCSD 2004; SFS-EN ISO 14064-1:2019:en.) Emissions avoided are defined as a positive impact when comparing two different solutions and their GHG impact (WBCSD 2023). ISO 14064-1 doesn't mention avoided emissions at all. However, ISO 14064-1 focuses on removals for each category making them an innate part of the quantification. GHG Protocol allows the reporting of removals separately from GHG emissions but is not very clear about the methods. (Carbonology 2025; WRI & WBCSD 2004; SFS-EN ISO 14064-1:2019:en.)

In September 2025, GHG Protocol and ISO announced a partnership to create a unified standard for carbon footprint calculation and accounting (Greenhouse Gas Protocol 2025). The collaboration will be a big step towards clearer reporting.

4.2 Calculation methods

Probably the most known GHG emission calculation method in Finland is Kasvener. Its first version was created in 1997 for municipalities by the Finnish Environment Institute and The Association of Finnish Cities and Municipalities. In Kasvener emissions can be calculated either based on production or consumption. Consumption based calculation means only energy consumption in this case, which makes understanding the terms difficult as nowadays consumption-based emissions include the use of products and services, as well. In Kasvener the emissions are divided into four categories, energy, industry, agriculture and waste management. Furthermore, the energy sector is divided into electricity production, district heating, building-specific heating, industrial waste heat, other fuels, and transportation in production-based calculations. In usage-based calculations the energy sector is divided into district heating, electricity heating, building-specific heating, other electricity usage, other fuels, and transportation. The latter list of sectors is used in modern calculation methods nowadays. (Seppälä et al. 2019.)

After Kasvener had been in use for around 20 years, a new calculation method was created by the Finnish Environment Institute. The new method is called ALas. The method is use-based, and it's based on the product-based emissions of the area. In exception, some emissions can be calculated based on consumption, as well. The method follows closely the

GPC standard created by GHG Protocol, while including agriculture, through traffic, F-gases and network losses, but excluding local air traffic. (Finnish Environment Institute 2024; Lounasheimo et al. 2020.) GHG emissions are calculated for each municipality annually, and the results can be observed in the database of the Finnish Environment Institute's (Finnish Environment Institute 2022).

It can be assumed that the ALas calculation method is a modernized and improved version of Kasvener. Therefore, there are many similarities in these methods. Some differences can still be found in, for example, electricity consumption, combined heat and power (CHP) production, and non-road mobile machinery. (Lounasheimo et al. 2020; Huuhtanen 2017.) In table 1, the key differences between Kasvener and ALas calculation methods are listed.

Table 1. Key differences between Kasvener and ALas calculation methods (Lounasheimo et al. 2020; Huuhtanen 2017).

Sector	Kasvener	ALas
Electricity consumption	Electricity used in transportation is excluded from other electricy consumption.	Includes all electricity consumption, except electric heating, electricity used for geothermal heat pumps, and rail transport.
CHP production	Efficiency of heat production is fixed 90 %. The effiency resembles a situation where heat is produced separetely from electricity.	Effiency method is used to distribute fuel usage and emissions between heat and power production on a monthly basis.
Non-road mobile machinery	Not reported separetely, but it's included in the other fuel usage.	Nine proxys are developed for machinery use. One or more can be used based on the type of the machinery.
F-gases	Not included in this calculation method	F-gases are included in the calculations from over 20 different sectors.

When looking at these four examples in table 1, it can be seen clearly that the ALas calculation method is more detailed method compared to Kasvener. More detailed calculation tends to lead to more accurate results.

4.3 Differences in calculating the carbon footprint of a city and its organization

In Alas calculation method, which is also utilized in this thesis later, calculating carbon footprints for a city and its organization, different limitations must be considered. Carbon footprint of a city usually consists of all GHG emissions created inside the city borders. This includes the GHG emissions of residents, companies located in the area as well as the emissions from through traffic. (Finnish Environment Institute 2025.)

As city's carbon footprint consists of all emissions created inside its borders, the city organization's emissions are also included in it. City organization's carbon footprint consists of buildings, vehicles and other possessions, group companies and their actions and possessions, as well as emissions from own activities. From the city organization's perspective, GHG emissions from own activities can include work trips employees are making or projects the city is implementing. (WRI & WBCSD 2004.)

5 Greenhouse gas emissions in Lappeenranta

This chapter focuses on the GHG emissions in Lappeenranta city area and its recent emissions trends.

Greenhouse gas emission calculations for the city of Lappeenranta are taken from an emission database provided by the Finnish Environment Institute. The database gathers emissions calculations for each municipality in Finland as well as for each emissions source separately. The GHG emissions are calculated with ALas calculation method created by the Finnish Environment Institute. (Finnish Environment Institute 2022.)

Greenhouse gas emissions in Lappeenranta area have been decreasing constantly over the last 20 years. When comparing the years 2005 and 2023, the decrease in emissions is almost 47 %. At the same time, the population of the city of Lappeenranta has gone up from 71 400 to almost 73 000. (Finnish Environment Institute 2025.) In figure 3, the emission levels of Lappeenranta in 1990 and 2005–2023 have been presented. The total GHG emissions have been divided into six categories: energy and buildings, transportation, agriculture, waste management, non-road mobile machinery, industry, and F-gases. Emissions from LULUCF sector have been excluded from this figure as there is no accurate city-specific data available.

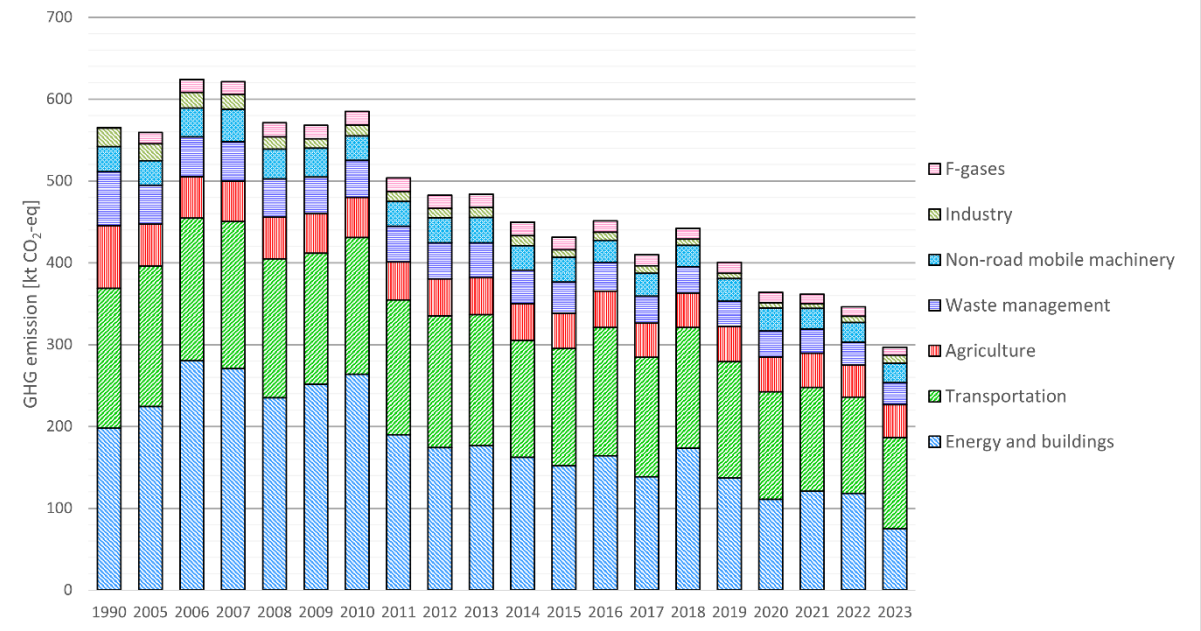

Figure 3. Lappeenranta's GHG emissions in 1990 and 2005–2023 (Finnish Environment Institute 2025).

As seen from the figure above, the GHG emissions were around 620 kt CO_2-eq in 2006, and a little under 300 kt CO_2-eq in 2023. Energy and buildings have been causing the most emissions throughout the years until 2017, after which the transportation sector has been around the same level as energy and buildings. The category of energy and buildings consists of used electricity and heating of the buildings (electric, oil, district, and other heating methods). The emissions from energy and buildings have decreased over 200 kt CO_2-eq from the peak year 2006. In figure 4, emissions from energy and buildings are presented more thoroughly.

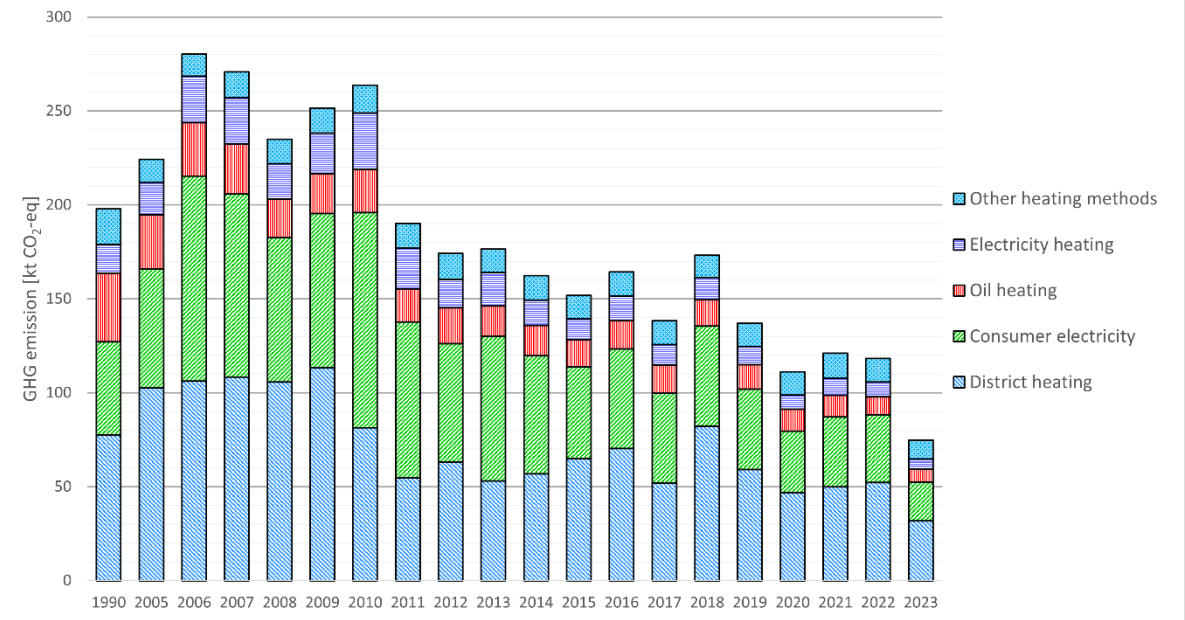

Figure 4. GHG emission distribution in the energy and buildings sector in 1990 and 2005–2023 (Finnish Environment Institute 2025).

After energy and buildings, transportation causes most emissions. transportation includes road, rail, and water transport. Rail and water transport causes only about 6 % of the whole transport sector emissions combined. Road transport includes all cars, buses, and trucks driving in Lappeenranta area, as well as through traffic. However, the emissions from transportation sector might not be precise as the motive powers of different vehicles are only reported from 2014 onward in the dataset, and there isn't any driven distance nor emission factors reported for the year 1990. (Finnish Environment Institute 2025.) To get a clear picture of the biggest emission sources in Lappeenranta, they are listed in table 2 from the largest source to the smallest one. In addition, the share of the total GHG emissions of each source is reported in the table.

Table 2. GHG emission distribution in Lappeenranta in 2023 (Finnish Environment Institute 2025).

	GHG emissions m_{CO2} [kt CO_2-eq]	Share
Road transport	106	36 %
Agriculture	40	14 %
District heating	32	11 %
Waste management	27	9 %
Non-road mobile machinery	24	8 %
Electricity usage	21	7 %
Other heating methods	10	3 %
F-gases	10	3 %
Industry	10	3 %
Oil heating	7	2 %
Electric heating	5	2 %
Water transport	3	1 %
Rail transport	3	1 %
Total	297	100 %

As seen from the table above, the biggest greenhouse gas emission source in Lappeenranta in 2023 was road transport causing over a third of the total GHG emissions. Next two sources (agriculture and district heating) caused a fourth of the total GHG emissions combined.

6 City organization's unabated greenhouse gas emissions

When observing the table 2 from the city organization's perspective, the largest sources of emissions that the city organization can influence are road transport as the city owns vehicles and is in charge of the public transportation, district heating as it is operated by the city's group company, non-road mobile machinery as the city own quite a lot of machinery, and finally, building-specific heating (other heating methods and oil heating) as the city owns buildings that are heated with fossil fuels. Waste management is also operated by the city's group company, but it's not included in these calculations as there is a lot of uncertainty with the available GHG emission data, and it is challenging to limit emissions data to only cover emissions caused by the city owned group company.

6.1 Public transportation

The public transportation system in Lappeenranta is operated by Lappeenrannan seudun joukkoliikenne. They are responsible for operating the public transportation both in Lappeenranta and Imatra, as well as between these cities. (Lappeenranta 2025a.) The information about the public transportation systems, such as annual driven distances, was gathered via request of information from Lappeenrannan seudun joukkoliikenne.

The public transportation system is divided into four categories: local transportation around the city of Lappeenranta, suburban transportation that includes journeys from Joutseno, Nuijamaa, Vainikkala and Ylämaa to the Lappeenranta city centre, school transportation, and regional transportation that covers the driving between Lappeenranta and Imatra. (Lappeenranta 2025a.) In table 3, the driven distances in 2024 are listed for each of these categories. In addition, the number of buses used, and their motive powers are listed in the table.

Table 3. Public transportation driven distances in 2024 in Lappeenranta and the number of buses used (Koski 2025).

Transportation category	Driven distance in 2024 [km]	The number of buses used and their motive powers
Local transportation	1 424 877	Diesel 10 pcs, biogas 2 pcs, electricity 6 pcs.
Suburban transportation	556 798	Diesel 18 pcs.
School transportation	775 575	Diesel 3 pcs, renewable diesel 31 pcs.
Regional transportation	394 603	Diesel 4 pcs.
Total	3 151 853	74 pcs.

With the following equations (1 & 2), the total amount of emissions from public transportation can be calculated. Equation 1 is used for diesel and other liquid fuels, and equation 2 is used for biogas and other gas fuels.

$$m_{\mathrm{CO2}} = e \cdot H \cdot \rho \cdot \frac{c_{\mathrm{avg}}}{1000} \cdot \frac{x_d}{100} \quad (1)$$

, where e is the emission factor of the fuel (kg/GJ), H is the heating value of the fuel (GJ/t), ρ is the density of the fuel (kg/l), c_{avg} is the average consumption of fuel (l/100 km or kg/100 km), and x_d is the annual driven distance (km/a).

The amount of emissions for biogas and other gas fuels are calculated in a similar way to liquid fuels, except fuel density isn't considered as the amount of used fuel is reported already in kilograms or tonnes.

$$m_{\mathrm{CO2}} = e \cdot H \cdot \frac{c_{\mathrm{avg}}}{1000} \cdot \frac{x_d}{100} \quad (2)$$

In the table below, the amount of emissions for the public transportation system in 2024 is presented. Emissions for each fuel type (diesel, renewable diesel, and biogas) is calculated separately, and the summed up together. The average fuel consumption in diesel buses is estimated to be around 35–50 l/100 km (Pihlatie et al. 2021; Kuljetusala 2025). In the calculations, the value is set to 42.5 l/100 km which is in the middle of the estimate. For biogas buses the average consumption is set to an estimate of 41 kg/100 km (Motiva 2018). It can also be assumed that electric buses don't emit GHG emissions during driving (OSF 2025b).

Table 4. Characteristics for the used fuels, and emissions calculations (OSF 2025b).

Fuel type	Emission factor e [kg_{CO2}/GJ]	Heating value H [GJ/t_{fuel}]	Fuel density ρ [kg/l]	Driven distance x_d [km]	Annual GHG emissions m_{CO2} [t CO_2-eq/a]
Diesel	73.4	42.8	0.807	1 811 432	1952
Renewable diesel	71.6	43.6	0.780	707 142	732
Biogas	54.6	23.0	-	158 320	82
Electricity	0	0	-	474 959	0
				Total	2765

As seen in the table 4, the public transportation system emissions in 2024 were around 2.8 kt CO_2-eq.

6.2 District heating

Emissions from district heating are calculated based on the amount of district heating used by the municipality. Usage of district heating includes all production done in the area of the municipality, purchased heat from energy installations and neighbouring municipalities, as well as sold heat. Heat distribution losses are allocated to the end-user and are therefore not included in the calculation. (Lounasheimo et al. 2020.) The data of district heat use in Lappeenranta was gathered from several online sources.

In Lappeenranta, district heating is operated by Lappeenrannan Energia – group company owned by the City of Lappeenranta. Lappeenrannan Energia is responsible for energy and water transmission and maintaining the energy and water networks in the city, as well as the operation and maintenance of thermal and steam plants, waterworks and waste water treatments. (Lappeenrannan Energia 2025a.) In 2023, over 80 % of residents in Lappeenranta were within the district heating network. Lappeenrannan Energia purchases all the energy it uses for district heating from six different producers. The biggest energy producer is Kaukaan Voima that operates a bioenergy plant in Lappeenranta. Energy bought from Kaukaan Voima covers around 73 % of the district heat demand in the city. Other energy producers Lappeenrannan Energia uses are Lappeenrannan Lämpövoima (21 %), Adven (4

%), Finnsementti (1 %), Imatran Lämpö (0.9 %), and UPM-Kymmene (0.05 %). (Finnish Energy 2025a.)

Kaukaan Voima is a combined heat and power plant (CHP) owned by Pohjolan Voima and Lappeenrannan Energia. The CHP plant produced around 90 % of the total energy with bio-based fuels (wood products), around 9 % of the energy with peat, and the rest with natural gas in 2023. (Finnish Energy 2025a; Pohjolan Voima 2025.)

Lappeenrannan Lämpövoima is a subsidiary company of Lappeenrannan Energia. It operates two power plants in Lappeenranta – Mertaniemi and Ihalainen. Mertaniemi powerplant has five district heat boilers that use natural gas as fuel, except for one that uses electrity. Two of the natural gas boilers also use light fuel oil as a reserve fuel. The combined power of these boilers is 150 MW. Ihalainen thermal plant has four district heat boilers with a combined power of 60 MW. Until fall 2023, all four boilers were fuelled with natural gas and used light fuel oil as a reserve fuel, after which two of these boilers were converted into wood pellet boilers. (Lappeenrannan Energia 2017; Lappeenrannan Energia 2022.) In 2023, Lappeenrannan Lämpövoima produced 60 % of the energy with electricity, 28 % with natural gas, 7 % with wood pellet (pellet use started during the fall 2023), and 5 % with light fuel oil. (Finnish Energy 2025a).

The rest of the power plants supply around 6 % of the total purchased energy in Lappeenranta. In Joutseno area, Adven operates a powerplant that uses hydrogen as a fuel. This powerplant covers most of the district heat demand in Joutseno. (Lappeenrannan Energia 2020.) Adven's powerplant uses light fuel oil as a reserve fuel and in 2023 less than 1 % of the total energy was produced with it (Finnish Energy 2025a). Finnsementti operates a sement plant in Lappeenranta area and its operations release quite a lot of waste heat, which is utilized for district heat by Lappeenrannan Energia. (Finnsementti 2025.) The rest of the heat is produced by Imatran Lämpö using wood products, peat and biogas as a fuel, and UPM-Kymmene using black liquor (Finnish Energy 2025a).

In the table below, the powerplants are listed as well as their used fuels and the amount of energy produced.

Table 5. Powerplants that sell energy to Lappeenrannan Energia as well as their fuel types and the amount of the total produced energy in 2023 (Finnish Energy 2025a).

Powerplant	Fuel type	Produced energy 2023 E_{ht} [GWh]	Share of the used fuel per powerplant [%]
Kaukaan Voima Oy	Wood products	733	90 %
	Peat	73	9 %
	Natural gas	7	1 %
Lappeenrannan Lämpövoima Oy (Mertaniemi and Ihalainen)	Electricity	81	60 %
	Natural gas	38	28 %
	Wood pellet	9	7 %
	Light fuel oil	7	5 %
Adven Oy	Hydrogen	24	99 %
	Light fuel oil	0.2	1 %
Finnsementti Oy	Waste heat	*	100 %
Imatran Lämpö Oy	Wood products	181	99 %
	Biogas	1	1 %
	Peat	0.3	0.2 %
UPM-Kymmene Oyj	Black liquor	0.4	100 %

* The amount of total produced waste heat is unknown; it is only reported that 6 GWh of waste heat was purchased in 2023 by Lappeenrannan Energia.

As seen from table 5, the most used fuel in district heat production is wood products, such as bark and logging residue. The second most used fuel was electricity, and the third was peat.

The amount of greenhouse gas emissions emitted from district heating can be calculated with equation 3.

$$m_{\mathrm{CO2}} = E_{ht} \cdot f \cdot e \tag{3}$$

, where E_{ht} is the purchased energy (TJ), f is the share of the used fuel per powerplant (%), and e is the emission factor of the fuel (t/TJ).

GHG emissions emitted from electricity usage are calculated in a different way. In these calculations an emission factor for average electricity produced in Finland is used. The greenhouse gas emissions for the electricity usage are calculated with equation 4.

$$m_{CO2} = E_{ht} \cdot e \quad (4)$$

, where E_{ht} is the purchased energy (GWh), and e is the emission factor of the fuel (t/GWh).

In the table below, the emissions for each fuel type in each powerplant are calculated.

Table 6. Calculated GHG emissions for district heating in 2023.

Powerplant	Amount of purchased energy 2023 E_{ht} [TJ]	Fuel type	Share of the used fuel per powerplant [%]	Emission factor e [t_{CO2}/TJ]	Annual GHG emissions m_{CO2} [t CO2-eq/a]	Source for emission factor
Kaukaan Voima Oy	1607	Wood products	90 %	0	0	(Motiva 2024)
		Peat	9 %	103.2	14819	(OSF 2025b)
		Natural gas	1 %	55.81	740	(OSF 2025b)
Lappeenrannan Lämpövoima Oy (Mertaniemi and Ihalainen)	467	Electricity	60 %	16.7	4680	(Motiva 2025a)
		Natural gas	28 %	55.81	7340	(OSF 2025b)
		Wood pellet	7 %	0	0	(Motiva 2024)
		Light fuel oil	5 %	73.0	1702	(OSF 2025b)
Adven Oy	78	Hydrogen	99 %	0	0	(Lappeenrannan Energia 2018)
		Light fuel oil	1 %	73.0	47	(OSF 2025b)
Finnsementti Oy	23	Waste heat	100 %	0	0	(Finnish Energy 2025b)
Imatran Lämpö Oy	21	Wood products	99 %	0	0	(Motiva 2024)
		Biogas	1 %	54.6	6	(OSF 2025b)
		Peat	0.2 %	103.2	3	(OSF 2025b)
UPM-Kymmene Oyj	1	Black liquor	100 %	95.3	103	(OSF 2025b)
Total	2196				29439	

As seen in table 6, the total GHG emissions from district heating in 2023 were around 29.4 kt CO_2-eq.

6.3 Non-road mobile machinery

Necessary information for this section was gathered with a questionnaire and requests for information sent to various people. The questionnaire was done as a part of the HALT project, and it was sent to every Lappeenranta city department and group company. The purpose of the questionnaire was to gather information about the vehicles owned by the city. Each department could report their vehicles (cars, non-road mobile machinery and small machinery), and their motive powers and usage via the questionnaire.

In table 7, all departments and groups companies in Lappeenranta that have non-road mobile machinery are listed as well as the amount of machinery they have.

Table 7. Vehicles reported via the questionnaire (Kero & Nokkanen 2025).

Department / Group company	The amount of reported non-road mobile machinery
Airport	12
City teather (Kaupunginteatteri)	3
Port of Lappeenranta	2
Sports department (Liikuntatoimi)	41
Street maintenance (Kadut ja ympäristö)	18
Total	76

As seen from table 7, the city owns a total of 76 non-road mobile machines. Greenhouse gas emissions from the reported non-road mobile machinery are calculated with equation 1, where e is the emission factor of the fuel (kg/GJ), H is the heating value of the fuel (GJ/t), ρ is the density of the fuel (kg/l), c_{avg} is the average consumption of fuel (l/100 km, l/h, kg/h or kWh/h), and x_u is the total annual usage (km/a or h/a).

One of the city departments did not report the annual usage of their machinery, therefore their emissions were calculated utilizing receipts from fuel purchases. The receipts are acquired from the city's financial management system. One receipt consists of about two weeks' worth of purchases as fuel purchases are billed twice every month from the department. Ten receipts were observed and with them an average for fuel usage was calculated. These results are listed in table 8.

Table 8. Receipts from fuel purchases, and calculated average.

	Amount of diesel purchased [l]
Receipt 1	1062
Receipt 2	1293
Receipt 3	1601
Receipt 4	1009
Receipt 5	1035
Receipt 6	1658
Receipt 7	988
Receipt 8	1328
Receipt 9	911
Receipt 10	1332
Average purchase twice a month	1222
Average purchase annually	29322

On average, this department purchases around 29 000 litres of diesel fuel annually for their non-road mobile machinery. This is noted on the GHG emission calculation for the city-owned non-road mobile machinery. The reported machinery is listed in table 10 based on the type as well as the total usage of each type of machinery, and their reported average fuel consumption. The used characteristics for different fuel types are listed in table 9. It can be assumed that electricity powered machines don't emit GHG emissions during use (OSF 2025b).

Table 9. Characteristics for different fuel types (OSF 2025b).

Fuel type	Emission factor e [kg_{CO2}/GJ]	Heating value H [GJ/t_{fuel}]	Fuel density ρ [kg/l]
Diesel	73.4	42.8	0.807
Fuel oil	73	43.2	0.830
Gas	55.81	38.2	-
Gasoline	70.5	41.6	0.746

Table 10. City-owned machinery, their reported fuel consumption, annual usage, and calculated GHG emissions (Kero & Nokkanen 2025).

Machine type	Used fuel	Average fuel consumption c_{avg}	Total annual usage x_u	Annual GHG emissions m_{CO2} [t CO2-eq/a]
All terrain vehicle (ATV)	Gasoline	5 l/100 km	140 km/a	0.02
Brush blower	Fuel oil	30 l/h	220 h/a	17
Bucket loader	Fuel oil	15 l/h	20 h/a	1
Conveyor belt	Fuel oil	5 l/h	25 h/a	0.3
Forklift	Electricity	Not reported	356 h/a	0
Ground power unit	Fuel oil	20 l/h	50 h/a	3
Ice resurfacer	Diesel	10 l/h	450 h/a	11
	Electricity	Not reported	600 h/a	0
	Gas	8 kg/h	250 h/a	4
Lawn mower	Gasoline	4 l/h	150 h/a	1
Reel cutter	Diesel	5 l/h	120 h/a	1
	Gasoline	5 l/h	240 h/a	3
Ski trail machine	Diesel	13 l/h	1800 h/a	59
Snow blower	Fuel oil	100 l/h	100 h/a	26
Snow mobile	Gasoline	18 l/h	635 h/a	25
Tractor	Diesel	3 l/h	40 h/a	0.3
	Gasoline	8.7 l/h	5450 h/a	120
Wheeled loader	Diesel	10 l/h	40 h/a	1
Work platform/ferry	Diesel	12 l/h	100 h/a	3
Machinery of one department based on receipts	Diesel	29322 l/a		74
			Total	348

Based on the reported fuel consumptions and usage hours, the city-owned non-road mobile machinery caused around 0.4 kt CO_2-eq GHG emissions in 2024.

6.4 Building-specific heating

The information about the building-specific heating, such as different heating methods and annual energy consumptions, was gathered via request of information to the Facility services of Lappeenranta (Lappeenrannan Toimitilat Oy). The buildings with building specific

heating are divided into seven main categories that include several building types. The building categories are listed in table 11.

Table 11. Categories for buildings with building-specific heating.

Building category	Building types included in the category
Education and Schools	General education buildings, vocational education buildings, and daycare centers
Healthcare and Social Services	Health centers, specialized healthcare facilities, and care homes
Commercial and Office Buildings	Department stores and shopping centers, hotels, restaurants, and office buildings
Industry, Storage and Agriculture	Industrial halls, storage buildings, barns, and grain drying and storage buildings
Culture, Leisure and Sports	Multipurpose and sports halls, ice rinks, swimming halls, club and association buildings, theatres, opera and concert halls, and museums and art galleries,
Public and Technical Buildings	Fire stations, vehicle maintenance and storage buildings, utility infrastructure buildings, and libraries and archives
Other / Miscellaneous	Other buildings, such as saunas

In total, there are 51 city-owned buildings that are heated with building-specific heating methods, such as natural gas and light fuel oil (Pietinen 2025). The different heating methods are listed in table 12 as well as their emission factors and the number of buildings utilizing each heating method.

Table 12. Distribution among different heating methods and their emission factors (Pietinen 2025).

Heating method	Number of buildings	Emission factor *e* [kg_{CO2}/GJ]	Source for emission factor
Geothermal heat	2	0	(Motiva 2025b)
Light fuel oil and geothermal heat	1	73; 0	(OSF 2025b; Motiva 2025b)
Light fuel oil	8	73	(OSF 2025b)
Natural gas	5	55.81	(OSF 2025b)
Direct electric heating	7	0	(Greenreality Lappeenranta 2025d)
Not reported	28	-	-

It can be assumed that both geothermal heat and direct electric heating methods are carbon neutral in Lappeenranta. Geothermal heat pumps utilize the heat stored in soil, rock or water, and in some cases heat from warm groundwater currents, and fission energy from the Earth's core. The only emissions from geothermal heat pumps during the usage period comes from the electricity used to power the pumps. (Motiva 2025b; Rototec Oy 2020.) The electricity used in all city-owned buildings is carbon neutral, as well. The city of Lappeenranta is the first city in the world to get EKOenergy ecolabel, which is an internationally recognised mark of renewable energy. (Greenreality Lappeenranta 2025d; EKOenergy 2025.)

The amount of greenhouse gas emissions emitted from building-specific heating can be calculated with equation 5.

$$m_{\mathrm{CO2}} = E_{ht} \cdot e \tag{5}$$

, where E_{ht} is the energy consumption (GJ), and e is the emission factor of the fuel (kg/GJ).

There are some deficiencies in the reporting, not all heating methods are reported, and some buildings are missing energy consumptions. The complete list of all 51 buildings with reported information can be found from appendix 1. As there are 28 buildings without a reported heating method, accurate calculations are not possible. Therefore, calculating emissions for two different scenarios is a useful approach in order to determine a range for the total GHG emissions. In scenario 1, the emissions are calculated only for the buildings with reported heating methods, and in scenario 2, the emissions are calculated for every

reported building assuming that the heating method is light fuel oil if the method has not been reported.

The buildings, their heating methods, energy consumptions, and calculated emissions in scenario 1 are listed in table 13. The GHG emissions are calculated with equation 5.

Table 13. Scenario 1: calculated emissions.

Building	Heating method	Energy consumption 2024 E_{ht} [GJ]	Annual GHG emissions m_{CO2} [t CO_2-eq/a]
Education and Schools 1	Natural gas	2294	128
Healthcare and Social Services 2	Light fuel oil	1203	88
Education and Schools 2	Light fuel oil	1039	76
Commercial and Office Buildings 3	Natural gas	893	50
Education and Schools 3	Light fuel oil	716	52
Education and Schools 4	Natural gas	502	28
Education and Schools 5	Light fuel oil	414	30
Education and Schools 6	Light fuel oil	351	26
Education and Schools 7	Natural gas	285	16
Education and Schools 8	Light fuel oil	267	19
Education and Schools 9	Light fuel oil, Geothermal heat	241	4
Other / Miscellaneous 1	Natural gas	231	13
Education and Schools 10	Light fuel oil	193	14
Culture, Leisure and Sports 4	Light fuel oil	Not reported	-
		Total	544

One of the buildings (Education and Schools 9) was reported to have both light fuel oil and geothermal heat as a heat source. The total emissions for this building were calculated assuming that geothermal heat produces 80 % of the needed heat, and light fuel oil the rest 20 %. This assumption was based on Proheat Oy's (2025) article about heating with both light fuel oil and geothermal heat. Moreover, the last building in the table (Culture, Leisure and Sports 4) had no energy consumption reported, therefore, it was excluded from the

calculations. After these assumptions, the total emissions in scenario 1 are around 0.5 kt CO_2-eq.

The buildings, their heating methods, energy consumptions, and calculated emissions in scenario 2 are listed in table 14. The GHG emissions are calculated with equation 5.

Table 14. Scenario 2: calculated emissions.

Building	Heating method	Energy consumption 2024 E_{ht} [GJ]	Annual GHG emissions m_{CO2} [t CO_2-eq/a]
Education and Schools 1	Natural gas	2294	128
Public and Technical Buildings 1	Assumption: light fuel oil	2226	163
Healthcare and Social Services 2	Light fuel oil	1203	88
Commercial and Office Buildings 1	Assumption: light fuel oil	1084	79
Commercial and Office Buildings 2	Assumption: light fuel oil	1068	78
Education and Schools 2	Light fuel oil	1039	76
Commercial and Office Buildings 3	Natural gas	893	50
Commercial and Office Buildings 4	Assumption: light fuel oil	753	55
Education and Schools 3	Light fuel oil	716	52
Culture, Leisure and Sports 1	Assumption: light fuel oil	703	51
Commercial and Office Buildings 5	Assumption: light fuel oil	645	47
Culture, Leisure and Sports 2	Assumption: light fuel oil	507	37
Education and Schools 4	Natural gas	502	28
Commercial and Office Buildings 6	Assumption: light fuel oil	496	36
Healthcare and Social Services 3	Assumption: light fuel oil	468	34
Education and Schools 5	Light fuel oil	414	30
Commercial and Office Buildings 7	Assumption: light fuel oil	392	29
Education and Schools 6	Light fuel oil	351	26
Education and Schools 7	Natural gas	285	16
Education and Schools 8	Light fuel oil	267	19
Industry, Storage and Agriculture 1	Assumption: light fuel oil	259	19
Education and Schools 9	Light fuel oil, Geothermal heat	241	4
Healthcare and Social Services 4	Assumption: light fuel oil	238	17
Other / Miscellaneous 1	Natural gas	231	13
Education and Schools 10	Light fuel oil	193	14
Industry, Storage and Agriculture 2	Assumption: light fuel oil	64	5
Healthcare and Social Services 5	Assumption: light fuel oil	53	4
Culture, Leisure and Sports 4	Light fuel oil	Not reported	-
		Total	1197

In scenario 2, the same assumption for building Education and Schools 9 was made as in scenario 1. Building Culture, Leisure and Sports 4 was excluded from this scenario, as well.

The total emissions in scenario 2 are almost 1.2 kt CO_2-eq. Therefore, the emission range for building-specific heating in 2024 is 0.5–1.2 kt CO_2-eq.

7 Results and analysis

In this chapter the results from the previous chapter are analysed. Following the analysis, possible emission reduction solutions for the four emission sources are presented. In addition, other solutions which municipalities have control over, and improvement solutions to the city organization's reporting methods are covered. In the final sub chapter, the cost-effectiveness of these actions is considered.

7.1 Analysis of the results

Based on the calculations, in 2024 the GHG emissions caused by public transportation system in Lappeenranta were 2.8 kt CO_2-eq which is a little over 2.5 % of the total greenhouse gas emissions in road transport sector (105.5 kt CO_2-eq in 2023). The error margin in these calculations is low, as the driven distances were reported as well as the number of buses and their motive powers. The exact values for fuel consumptions were not available, but they were based on several sources and estimations making them as accurate as possible. It should also be noted that the regional transportation operates between Lappeenranta and Imatra, so part of the driven distance in regional transportation should not be included in the GHG emissions of Lappeenranta as they are part of Imatra's GHG emissions.

According to the GHG emissions database the Finnish Environment Institute provides, total GHG emissions caused by district heating in Lappeenranta are 31.8 kt CO_2-eq. Finnish Energy provides a database for district heat emissions, and according to the database the GHG emissions in Lappeenranta were 30.6 kt CO_2-eq (Finnish Energy 2025c). Based on the calculations the GHG emissions are 29.4 kt CO_2-eq. The difference in these results can be explained with the fact that most likely Finnish Energy and Finnish Environment Institute include all district heat produced in the area and also the sold heat. Another option is that there are some differences in calculation methods and assumptions on the initial data. It is also possible that different emission factors have been used for the different fuels. It should also be noted that it is common to consider using wood products as fuel to be carbon neutral, as was done in these calculations, too. However, using wood as a fuel affects LULUCF

sector as it reduces carbon sinks. Therefore, even if the use of wood-based fuel wouldn't affect the carbon footprint of the municipality, it still affects the national carbon footprint.

Non-road mobile machinery causes around 9 % of the total GHG emissions in effort sharing sector in Finland. Regionally, the amount of GHG emissions varies a lot as it can be anything from 1.4 to 38.5 %. The biggest factor affecting the amount of emissions is the amount of industry in the area as especially mining requires a lot of non-road mobile machinery. (Auvinen et al. 2025.) Based on the calculations, the city-owned non-road mobile machinery caused around 0.4 kt CO_2-eq GHG emissions in 2024, which is only 1.5 % of the total GHG emissions caused (23.7 kt CO_2-eq in 2023) by non-road mobile machinery in the city area. Therefore, the impact of reducing the emissions from the city-owned non-road mobile machinery is not very significant when reaching the goal of carbon neutrality by 2030.

However, the error margin in the calculations can be quite high as they were based on estimations made by multiple people. Estimations of machinery's usage time and fuel consumptions might not be accurate, and even if the estimations are only slightly off, many small miscalculations quickly add up. Moreover, the GHG calculation based on receipts from fuel purchases is not an accurate method. Even though there were several receipts from different times of the year, they don't give out a clear image of total fuel consumption. The result calculated based on the receipts is only a rough estimation of the total fuel consumption.

Based on the calculations, the GHG emissions for building-specific heating in 2024 were 0.5–1.2 kt CO_2-eq. This is around 3–7 % of the total GHG emissions caused by building-specific heating in the city area. Over half of the buildings with building-specific heating didn't have a heating method or energy consumption reported. The number of buildings without reported heating method or energy consumption could be explained with the fact that several buildings are connected to the same energy meter, meaning that the energy consumption marked for one building could include several others. As there were several buildings without reported heating methods, the GHG emission calculations were done in two scenarios giving a range for the GHG emissions. In the first scenario, only the buildings with reported heating methods were included in the calculations giving the possible minimum amount of GHG emissions. In the second scenario, all buildings without a reported heating method were assumed to have light fuel oil as the used heating method. This was done to get the hypothetical maximum amount of GHG emissions, as light fuel oil had the

biggest emission factor out of the reported heating methods. It can be assumed that the actual amount of GHG emissions fall into the calculated range, as the other factors (energy consumptions and emission factors) were exact values, and there were no other assumptions done in the calculations.

In the table below, the city organization's unabated emissions are listed as well as how they compare to the total emissions in each sector as well as to the total GHG emissions.

Table 15. Share of the unabated emissions compared to the total emissions.

Emission category, sector	Calculated unabated emissions m_{CO2} [kt CO_2-eq/a]	Share of the sectors' GHG emissions [%]	Share of the total GHG emissions [%]
Public transportation (road transport)	2.8	3 %	0.9 %
District heating (district heating)	29.4	92 %	10 %
Non-road mobile machinery (non-road mobile machinery)	0.4	1 %	0.1 %
Building-specific heating (other heating methods & oil heating)	0.5–1.2	3–7 %	0.2–0.4 %
Total GHG emissions	33.1–33.7		11.1–11.4 %

As seen in the table 15, the share of the calculated unabated emissions caused by Lappeenranta city organization is quite marginal – around 11 % of the total GHG emissions in Lappeenranta area. Overall, the error margin in the calculations is small, and the results can be assumed to be accurate.

7.2 Potential GHG emission reduction solutions

This subchapter presents GHG emission reduction solutions for each of the unabated sector studied in the previous chapters. The solutions are gathered mostly from literature and articles related to the topics. The calculation results from the previous chapter are also

utilized in this section. In addition, other potential ways for the city organization to reduce the GHG emissions are presented. The main focus is on solutions that municipalities have control over.

7.2.1 Solutions for public transportation

Good practices for reducing emissions in public transportation sector can be derived from Helsingin seudun liikenne (HSL) which operates in Helsinki and nearby municipalities. HSL has set a goal to have carbon neutral public transportation system by 2035. The most effective way to reduce emissions has been electrification of the transportation system. In 2024, 547 buses out of 1363 (40 %) were electric. Electric buses are considered carbon neutral, as driving them won't emit GHG emissions, and HSL requires that the buses must be charged with fossil-free electricity produced in the Nordic countries. (Ahonen & Kotikangas 2025.)

HSL also considers the life-cycle emissions of buses, not just the direct emissions from driving. They have recognized that manufacturing electric buses causes more emissions than diesel bus manufacturing. It is also problematic that most electric buses and their batteries are manufactured in China, and their sustainability reports are not as trustworthy as European reports are. Even though the manufacturing emissions are greater for electric buses, their life-cycle emissions can be over 90 % lower than the emissions of diesel buses. (Ahonen & Kotikangas 2025.)

Other methods HSL uses to reach the carbon neutrality goal are for example, paying an environmental bonus to contract-carriers for making measures to reduce emissions. Environmental bonus is used to compensate for the cost of using biofuels instead of fossil fuels that can be cheaper but cause more emissions. In addition, HSL has developed their tendering criteria to encourage bidders to offer emission-free vehicles, which futher supports HSL's emission reduction targets. (Ahonen & Kotikangas 2025; HSL 2025.)

Motivating and informing people to use public transportation is a great way to decrease the carbon footprint in the transportation sector. The more people use public transportation, the less cars are used, which lowers the amount of GHG emissions in the area. This could also be interpreted as a carbon handprint action (Pajula et al. 2021). By increasing the number of

bus lines and the buses operating them the quality of public transportation increases, as well. The price of public transportation must also be affordable for everyone, even making it free is a viable option. (Seppälä et al. 2024.) The city of Rauma decided to trial free public transportation during June and July in 2025, and the usage rate multiplied during the trial (City of Rauma 2025). Moreover, HSL has implemented features to their route guide that inform passengers about sustainability. The route guide informs, for example, the amount of GHG emissions of the planned route. The guide also provides up-to-date information about the traffic and possible delays, which makes planning the route as smooth as possible. Streamlined traffic reduces unnecessary energy consumption and emissions, as well. (HSL 2025.)

7.2.2 Solutions for district heating

Solutions to reduce GHG emissions from district heat production rely heavily on renewable energy sources. Replacing peat, natural gas, and light fuel as fuels reduces the emissions significantly. For example, replacing district heat boilers using natural gas as fuel to ones using wood pellets. This was already trialled in Ihalainen thermal plant in 2023, where two boilers were converted into using wood pellets as a fuel (Lappeenrannan Energia 2022). This method could be exploited further, starting with replacing the other two district heat boilers in Ihalainen. Another option could be district heat production with electric boilers. Electric boilers are designed to produce steam or hot water, which can be used for heating purposes. Electric boilers are beneficial in Finland as the electricity price is lower than the average price in Europe, and the boilers are also resilient in cold temperatures. (Säämäki et al. 2025.)

Another viable option could be the utilization of waste heat from industry with heat pumps. This is already done in Lappeenranta, however, in a very small scale as only 1 % of the total purchased heat is waste heat from Finnsementti. Waste heat could be utilized from different industries, such as metal and steel industry, food industry, or technology industry (Motiva 2021). Especially, technology industry has a massive potential as a waste heat source as data centres are built more and more across Finland. In 2025, it was reported that there are 45 ongoing construction projects for new data centres in Finland. (Yle 2025.)

Small module reactors (SMR) are also a potential option for energy production in the near future. SMRs can be used to generate electricity as well as heat, which could be further used

in district heating. It is estimated that SMRs designed for district heating purposes could be in commercial use already in 2030. Even though there are many positive aspects in small module reactors, such as clean energy production, the social barriers can be quite high. SMRs utilized in district heating should be located in the city area near its residents, which may raise concerns about the safety of these reactors amongst these people. The disposal of nuclear waste is also one of the issues regarding the use of SMRs. (Energiforsk & Think Atom 2023; Vainio & Kojo 2024.)

Heat storage systems can support the district heat production by enabling excess production when it's economically profitable. When energy production gets less profitable, for example, when fuel costs are increased suddenly, or when there are malfunctions or issues with the production, heat from the storage can be used. In Lappeenranta, first trial runs of district heat storage have been done during the summer 2025. For one hour, the whole district heating grid used only heat from a Mertaniemi heat storage that holds 10 000 m^3 of hot water. (Finnish Energy 2025d; Lappeenrannan Energia 2025b.)

7.2.3 Solutions for non-road mobile machinery

Technological solutions to reduce the GHG emissions caused by non-road mobile machinery are, for example, improving energy efficiency of the machinery, electrification of the machinery, and switching to fossil-free fuels. (Auvinen et al. 2025.)

Improving energy efficiency of the machinery is a concrete way to reduce the use of resources and therefore, reduce GHG emissions, as well. Efficiency can be improved even without updating the machinery – optimizing the working schedules and routes, minimizing idle running, and maintaining the machinery regularly have a big effect on energy efficiency. Updating the machinery to newer models might offer better options to monitor the fuel consumption and usage hours in real time. This aspect can encourage users to work more energy efficiently with the machinery. (Auvinen et al. 2025.)

Electrification of non-road mobile machinery is a very effective way to reduce emissions, even though it requires big investments. Machinery can be electrified in two different ways, either using cable-powered of battery-powered machines. Cable-powering suits well for machines that have limited movement requirements, as well as for machines with great

power demand. Powering machines through cables is an effective way to reduce GHG emissions compared to fossil fuel usage. (Auvinen et al. 2025.) If cable-powering is not possible, using batteries is also an option. Battery-powered machinery has a longer range of movement, but the machinery might require charging during the working hours. (Oslo 2025.) Even though, using battery-powered machinery doesn't cause any GHG emissions, if the battery is charged with carbon neutral electricity, manufacturing batteries uses a lot of natural resources. When comparing the GHG emissions throughout the whole life cycle of a battery-powered machine to a machine running on fossil fuels, the emissions are still significantly lower. (Auvinen et al. 2025.)

When operating with electrified machinery, the power demand must be considered and calculated carefully. If the work site is somewhere remote, there might not be an option to charge batteries or operate cable-powered machinery due to the available grid capacity. (Oslo 2025.) One option is to deliver a portable battery to the site, but it might not be cost-effective as the investment cost of the battery is high. In some cases, where the power demand is not high, and the portable battery is big enough to power all the required machinery with one charge, the use of portable battery could be cost-effective enough. If the machinery requires charging from the power grid, utilizing the charging stations built for public transportation or heavy traffic (such as trucks) could be considered. Using the same charging stations would create synergy advantages, as the stations would get higher utilization rate, and with careful scheduling the machinery could be charged alongside buses or trucks. (Pihlatie et al. 2022.)

7.2.4 Solutions for building-specific heating

Ways to reduce emissions from building-specific heating rely heavily on minimizing the use of fossil fuels in heating. This can be done in several different ways regarding the size and location of the building. For larger buildings in the city area, joining the district heating grid could be a reasonable option. Joining district heating grid is quite simple, it requires a technical space for the heat distribution centre, and a pipeline connection from the grid to the building. (Lappeenrannan Energia 2025c.)

In buildings located further away from the city centre and the district heat grid, switching to district heat might be impossible or at least very expensive. In these buildings switching to

heat pumps, such as geothermal or air-water pumps. It is also possible to switch the heating partially to heat pumps and keep the fossil-fuel-based heating system as a support system in the background. This option is currently active in one of the buildings owned by the city of Lappeenranta (Proheat Oy 2025). Switching to direct electricity heating is also a possibility, however it might be costly as the electricity prices can get quite high during peak consumption periods. To support the direct electricity heating, solar PV panels could be installed on the roof of the building to help generate electricity for the heating. (Motiva 2025c.) However, peak consumption periods, when prices are higher, are not usually during sunny seasons, but during colder and darker periods (Fingrid 2025).

7.2.5 Other reduction solutions

Municipalities are in charge of land use planning in their area. The goal of land use planning is to take the needs of residents, businesses and other actors in the area into account. Land use planning affects where new buildings are built, where pedestrians can walk, and which areas are left in their natural state. (Environment.fi 2025.) This means that land use planning is a powerful tool supporting GHG emission reduction in the area as it can be used to increase bicycle lanes, densify the city structure which reduces the need for a car, and protect nearby forests. Land use planning can also be used to improve the conditions for local businesses. For example, in Lappeenranta electric car charging station was added next to a taxi stand, which encourages taxi drivers to switch to electric cars as it makes charging the cars during work shifts effortless (Lappeenranta 2024). Municipalities can also entice green transition investments to the area by offering land areas to businesses. Recent example of this is from Lappeenranta as the city signed a contract with Solar Foods Oyj and reserved a land plot for the business to build their new factory in the area. (Lappeenranta 2025b.)

Municipalities also have influence on their area's LULUCF emissions. For example, they manage their own forests and how they are used, such as how much logging is done in the area. Reducing logging in forest areas have a significant effect on carbon sinks in the area. When logging is reduced, wood continues to absorb carbon from the air. It also affects the nearby soil quality as the amount of organic debris is increased. The debris acts as a carbon sink binding the GHG emissions from the soil in itself. Other possible reduction solutions in

LULUCF sector are forest fertilization and increasing the amount of deadwood in the forests. (Lehtonen et al. 2021.)

When a municipality makes public procurements, there are several guidelines that need to be considered. Public procurements can be services, goods, or projects, such as construction projects. The Finnish procurement legislation regulates competitive tendering procedures and operational obligations, which include, for example, principles of non-discrimination, equality, and transparency. (JHNY 2025a.) It is mostly up to the municipality to include environmental aspects to the tendering. This can be done by setting up criteria regarding environmental aspects, such as electricity consumption or GHG emissions, so that the lower these values are the more points the offer gets in the process. (JHNY 2025b.) Considering environmental aspects might also save money in the long run. According to Greenpeace & Ruokailo (2025) municipalities can save up to hundreds of thousands of euros if they lower the amount of meat used to 50 % in the food they offer in, for example, schools and daycares. In addition to saving money, increasing the amount of plant-based food in people's diets has many health benefits and the amount of GHG emissions is smaller as well.

Educating and supporting residents in climate issues can also have a positive effect on the municipality's climate impact. For example, in Lappeenranta educating children about climate change, renewable energy, and clean water has been part of the study program for years. This means that throughout the child's education path, all the way from day care to high school, these important topics are taught. (Uniori 2025.) Adult residents need guiding in environmental matters, as well, and there are many different options for that. For example, Motiva, which is a state-owned sustainable development company operating in Finland, offers energy advisory services for consumers. Advice can be asked from a national service, or experts operating in regions across Finland. Energy advisors helping local companies and residents in South Karelia are located in Lappeenranta. (Motiva 2025d) Another example is a project done in South Karelia region during 2020 and 2021, in which families could sign up for a trial run where their carbon footprint was calculated and advice on how to reduce it were given. The trial run lasted from one to three months, and after it the carbon footprint was calculated again. (Greenreality Lappeenranta 2020.) These kinds of advisory services and education options can be a great help for many people trying to lower their climate impact.

Finally, one way to reduce GHG emissions quite easily is to alter the calculation limitations. Not including some aspects in the calculations, for example, the group companies, city organization's GHG emissions would drop significantly. However, the emissions wouldn't be reduced, as they would be included in some other actor's carbon footprint.

7.2.6 Improvements in reporting methods

During the process of gathering data for the calculation section, it became clear that there are no given guidelines for tracking the owned machinery within the city organization. Each city department was sent the questionnaire about owned machinery, and the quality of answers depended heavily on the person filling out the questionnaire. Most of the answers in the questionnaire were estimations of the fuel usage or annual usage hours. Furthermore, in the case of one of the city departments, the questionnaire was not answered, as they didn't have the needed data available. This raises questions whether the city departments even follow the use of their machinery. Not keeping track of the usage might result in extra costs, if the machinery use is not scheduled or planned well.

Other concern raised from the motive powers of the machinery, especially cars. Cars were not included in the unabated GHG emission sector, even though they were reported via the same questionnaire as the non-road mobile machinery. A great share of the cars was powered by gasoline or diesel fuels. This fact is in contradictory with the city's strategy to be carbon neutral by 2030. Replacing fossil fuel powered cars with either electric or biogas cars is something the city departments should consider more. In Lappeenranta, biogas is a good fuel option as there is biogas production in the area, and its price is relatively cheap compared to gasoline (BIG 2025). The city organization should make clear instructions considering the motive powers of used machinery and a strategy for replacing the fossil fuel machinery efficiently.

There were some issues with the data regarding building-specific heating, as well. Overall, out of the 51 buildings heated with building-specific heating, 28 buildings didn't have their heating method reported. Moreover, the monitoring of energy consumption in these buildings might not be very accurate as the provided data came in the form of two Excel-files one of which had a long list of every city owned building with all kinds of information, including the heating method for some of the buildings. The other Excel-file consisted of the

consumption of energy, electricity, and water for some of the buildings. It is possible that the data can be monitored more easily directly on the used programmes but following the changes of energy consumption from these Excel-files is nearly impossible. Noticing possible leaks or other faults in the systems is very difficult if the monitoring systems are not good enough.

To sum it up, both clear instructions and strategies are needed, as well as consistent monitoring. These are quite simple yet effective ways to reduce GHG emissions as well as extra costs. Consistent monitoring also increases the chances to notice possible issues or inconsistencies in the used systems.

7.3 Cost-effectiveness of GHG reduction solutions

This subchapter studies the cost-effectiveness of GHG reduction solutions for the four emission sources studied in the previous chapter. The timeframe in this study is 2030, as the city of Lappeenranta's goal is to be carbon neutral by then.

For public transportation, the biggest GHG emission reduction solution is the replacement of diesel buses with electric ones. The city of Lappeenranta has set a goal that 20–30 diesel powered buses will be replaced with electric buses and the rest of the buses would be using either biogas or other renewable fuels. The investment is estimated to be 13–19 million euros for the electric buses and 3 million euros for the charging stops. In the longer run, money saved from the operating costs will cover the investment costs, however, this will happen after 2030. (Lappeenranta 2025c.)

The most effective GHG emissions reduction solutions for district heating are replacing fossil fuel usage, especially peat used by Kaukaan Voima Oy, and natural gas used by Lappeenrannan Lämpövoima Oy. Even though, the share of these fuels in the total district heat production is quite small the emission factor of these fuels is high, which affects the total GHG emission quite significantly. Lappeenrannan Lämpövoima Oy has been trialling with emission reduction solutions as they converted two out of four natural gas district heat boilers into wood pellet boilers. This decreased the total power of the thermal plant from 60 MW to around 45 MW. The price for this project was around 0.5 million euros per converted MW. Even though the total cost was not too high, the project won't be implemented further,

for example the other two natural gas district heat boilers won't be converted into wood pellet boilers. According to a representative of Lappeenrannan Lämpövoima Oy, the usability of the wood pellet boilers has been poorer than expected. In addition, converting the rest of the natural gas boilers into wood pellet boilers would reduce the total output of the thermal plant too much, which in turn would require the construction of a new equivalent thermal plant. (Kuiri 2025.) Therefore, other GHG emission reduction solutions should be considered, even if they turn out to be pricier.

The GHG emissions caused by non-road mobile machinery are quite simple to reduce, however costly. The simplest way would be to replace all machinery using fossil fuels to electric ones. The cost in these machines, for example, tractors is still quite high compared to ones using diesel. In addition, the battery technology is not yet at a satisfactory level. Compared to diesel tractors price of electric tractors can be 1.5 times higher, however the operational costs are usually lower as the price of electricity is cheaper than diesel, and electric vehicles require less maintenance than diesel vehicles. (Auvinen et al. 2025.) Charging stations must also be considered, and it can be assumed that the cost would be in the same price range as for the public transportation system. Therefore, the total cost of reducing the GHG emissions from non-road mobile machinery (350 t CO_2-eq) is very high. Cheaper option to reduce the emissions from the machinery would be to sell the city-owned machinery and rent the machinery when needed. This way, the emissions from caused by the non-road machinery would be shifted from the city organization to some other actor. This wouldn't reduce the GHG emissions on a national level, but it would reduce the city organization's emissions.

When considering reduction solutions for GHG emissions caused by building-specific heating, the life cycle of the buildings must be considered. Many of the city-owned buildings using building-specific heating are located away from the city centre, and it is likely that the use of these buildings ends before 2030. In 2024, the city council of Lappeenranta decided on service network reform that at least the schools in Nuijamaa, Simola and Pulp will be closed down by 2028 (Lappeenranta 2025d). This decision reduces the GHG emissions from this sector automatically. It must be noted that these buildings still continue to use energy, but if the buildings don't have any activity in them, the energy consumption decreases from the current consumption, nevertheless. In other buildings, replacing light fuel oil or natural

gas heating systems is usually economically feasible. Even if the investments are big, the decrease in operational costs usually covers the investment quite soon. (Motiva 2025c.)

To sum it up, most of the reduction solutions are doable, yet costly. Some GHG emissions are reduced on their own by 2030 as some schools are closed down etc. Reaching carbon neutrality requires quite a lot of investments from the city organization if they wish to reach their carbon neutrality goal on time.

8 Conclusions

The aim of this thesis was to examine the city organization of Lappeenranta's greenhouse gas emissions and focus on the ones that are unabated. The need for this study arose because the carbon footprint of the city organization is not calculated annually in the same way as the carbon footprint of the city area. In order to achieve its emission reduction and carbon neutrality goal by 2030, the city of Lappeenranta should be aware of the greenhouse gas emissions it causes.

Two research questions were set for the study. The first question focused on the city organization's unabated emissions and how they compare to the total greenhouse gas emissions in Lappeenranta. In this thesis, four emission sources were studied and considered unabated: public transportation, district heating, non-road mobile machinery, and building-specific heating. In total, around 33.5 kt CO_2-eq of greenhouse gas emissions were caused by these four sources. The emissions were calculated for the year 2024, except the emissions from district heating were calculated for the year 2023. Comparing the unabated emissions to the total greenhouse gas emissions of Lappeenranta area in 2023, the unabated emissions covered around 11 % of the total emissions.

The second research question was about the possible reduction solutions for the unabated emissions and their cost-effectiveness when the goal to reduce them is by 2030. Emission reduction solutions for public transportation and non-road mobile machinery rely heavily on electrification of the vehicles. Electric vehicles cost more than diesel alternatives; however, their operational cost are significantly lower meaning that the higher investment costs will be covered in time, but not before 2030. For district heating the biggest emission sources were natural gas and peat usage. Lappeenrannan Lämpövoima Oy has already trialled converting natural gas boilers to wood pellet ones, and the project cost around 0.5 million euros per converted MW, however pellet boilers have turned out to be functioning poorer than expected. Therefore, the needed investments for substituting natural gas and peat usage will most likely cost more than 0.5 million euros per converted MW. For building-specific heating the most efficient emission reduction solutions are switching fossil fuel heating to district heat or direct electric heating. In addition, some of the buildings, such as schools, will be closed down before 2030, which reduces emissions automatically. In this sector, the

costs won't be large, and the savings in operational costs will cover the investment cost easily. Overall, the cost-effectiveness calculations in this thesis are mainly estimations.

In addition, alternative greenhouse gas emission reduction solutions were presented for other sectors. The focus on these solutions was on solutions that municipalities have control over. A large emission reduction potential can be achieved with land use planning. Land use planning can affect forest usage in the area, meaning that the amount of logging could be limited. Land use planning can also be used to increase bicycle lanes, and densify the city structure, which then encourages residents to reduce the use of cars in the area.

During the study, several limitations were encountered. The first problem was that the term unabated emissions is still quite new and not widely used. Even though the exact definition of unabated emissions can be found from a standard, determining whether an emission is unabated or not remains subjective. Therefore, it is not certain that the four emission sources mentioned above are unabated. Another limitation in the study was the accuracy of the used data. The data of city-owned non-road mobile machinery was collected from city departments and group companies via a questionnaire, and most of the given answers were only estimations. Moreover, the data regarding building-specific heating in city-owned buildings was incomplete, which led to the calculation of two different scenarios. Overall, the city organization's greenhouse gas emissions are not monitored from a single location; instead, the data is scattered across different parts of the organization.

Future studies regarding this topic could focus more deeply on the total amount of the city organization's greenhouse gas emissions, and the cost-effectiveness of different emission reduction solutions. More knowledge in these topics would benefit the city organization trying to reach carbon neutrality. In addition, making sure that every city department and group company is committed to the climate neutrality goal is important as they are responsible for the city's day-to-day operations.

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Appendix 1. List of all city-owned buildings with building-specific heating

Building category	Heating method	Energy consumption (heating) 2024 [MWh]	Electricity consumption 2024 [kWh]
Commercial and Office Buildings 1		301,2	140463,2
Commercial and Office Buildings 2		296,7	
Commercial and Office Buildings 3	Natural gas	248,1	63845,2
Commercial and Office Buildings 4		209,3	48980,8
Commercial and Office Buildings 5		179,2	4655,9
Commercial and Office Buildings 6		137,7	12637,4
Commercial and Office Buildings 7		108,9	5506,1
Commercial and Office Buildings 8	Direct electric heating		1671
Culture, Leisure and Sports 1		195,3	
Culture, Leisure and Sports 2		140,8	1010241,2
Culture, Leisure and Sports 3	Direct electric heating		62337,8
Culture, Leisure and Sports 4	Light fuel oil		142977
Culture, Leisure and Sports 5			27168,3
Culture, Leisure and Sports 6			15251,9
Culture, Leisure and Sports 7			15621,4
Culture, Leisure and Sports 8			62485,6
Culture, Leisure and Sports 9			42426,3
Culture, Leisure and Sports 10	Geothermal heat		59611,3
Education and Schools 1	Natural gas	637,1	134248
Education and Schools 2	Light fuel oil	288,5	226412,1
Education and Schools 3	Light fuel oil	198,9	53219,9
Education and Schools 4	Natural gas	139,4	43979,9
Education and Schools 5	Light fuel oil	115	25417,2
Education and Schools 6	Light fuel oil	97,5	5920,6
Education and Schools 7	Natural gas	79,1	11252,6
Education and Schools 8	Light fuel oil	74,1	33176,7
Education and Schools 9	Light fuel oil, Geothermal heat	66,9	206246,6
Education and Schools 10	Light fuel oil	53,7	24024,5
Education and Schools 10	Geothermal heat		166580,7
Education and Schools 11	Direct electric heating		144640,1
Education and Schools 12			490,1
Education and Schools 13			84123,8
Healthcare and Social Services 1	Light fuel oil	334,3	124424,1
Healthcare and Social Services 2		129,9	3785,7
Healthcare and Social Services 3		66	9173,5
Healthcare and Social Services 4		14,6	4642,4
Healthcare and Social Services 5			53991,5
Industry, Storage and Agriculture 1		72	22920,3
Industry, Storage and Agriculture 2		17,7	
Industry, Storage and Agriculture 3			8717,2
Industry, Storage and Agriculture 4			2304,9
Industry, Storage and Agriculture 5			23,9
Industry, Storage and Agriculture 6	Direct electric heating		
Other / Miscellaneous 1	Natural gas	64,2	9127,7
Other / Miscellaneous 2	Direct electric heating		54674,1
Other / Miscellaneous 3			133845,8
Other / Miscellaneous 4	Direct electric heating		
Public and Technical Buildings 1		618,4	145498,1
Public and Technical Buildings 2	Direct electric heating		79820,2
Public and Technical Buildings 3			15814,4
Public and Technical Buildings 4			20174,4