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ENVIRONMENTAL IMPACT ASSESSMENT OF A HOUSING COMPANY

Lappeenranta–Lahti University of Technology LUT

Master's Programme in Sustainability Science and Solutions, Master's thesis

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ABSTRACT

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59 pages, 14 figures and 11 tables

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Keywords: carbon footprint, housing company.

This Master's thesis defines an operational carbon footprint for a housing company. Aim of the study is to identify relevant emission sources of a housing company, calculate carbon emission on an annual basis and provide potential improvement measures to decrease the annual emissions. The theoretical part of the study introduces the concept of a Finnish housing company and its operational environment. Also, relevant standards and guidance to perform the calculation are explained.

To carry out the study, two real-life case assets were assessed in detail with focus on scope 3 emissions according to the Greenhouse Gas Protocol. Both assets represent an apartment building located in Helsinki.

Findings of the study reveal that energy related emissions cover 73 % and 94 % of the carbon footprint and most significant contributors are space heating, hot domestic water and electricity consumption. Carbon footprint of an asset utilizing ground source heat pump is 10,7 kg CO_2e/n-m²/year while carbon footprint of an asset with district heating energy system is 24,8 kg CO_2e/n-m²/year. Minor contributors are waste management, water treatment in addition to maintenance and cleaning.

Improvement potential can be found from the source of heating energy. Study focuses on minor improvements and points out that annual carbon footprint could be decreased around 20 % by water and energy efficiency measures in addition to waste segregation improvement.

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Tämä diplomityö määrittelee taloyhtiön toiminnallisen hiilijalanjäljen. Tutkimuksen tavoitteena on tunnistaa taloyhtiön olennaiset päästölähteet, laskea hiilidioksidipäästöt vuositasolla ja esitellä mahdollisia parannustoimenpiteitä vuosittaisten päästöjen vähentämiseksi. Työn teoriaosassa esitellään suomalaisen taloyhtiön toimintaympäristö. Lisäksi avataan sovellettavat standardit ja ohjeet, jotka ovat olennaisia laskennan suorittamiseksi.

Tutkimuksessa paneudutaan yksityiskohtaisesti kahden olemassa olevan taloyhtiön päästöjen muodostumiseen. Selvityksessä keskitytään kasvihuonekaasuprotokollan soveltamisalan 3 päästöihin. Molemmat case-kohteet ovat Helsingissä sijaitsevia kerrostaloja.

Tutkimuksessa saavutettujen tulosten perusteella energiaan liittyvät päästöt kattavat 73 % ja 94 % hiilijalanjäljestä, ja merkittävimmät päästölähteet ovat tilojen lämmitys, käyttöveden lämmitys ja sähkönkulutus. Maalämpöpumppua lämmityksessä hyödyntävän kohteen hiilijalanjälki on 10,7 kg CO2e/n-m²/vuosi ja kaukolämpöä hyödyntävän kohteen hiilijalanjälki on 24,8 kg CO2e/n-m²/vuosi. Pienempinä vaikuttajina tuloksissa ovat jätehuolto, vedenkäsittely, kiinteistöhuolto ja siivous.

Tutkimus keskittyy esittelemään matalan kynnyksen parannustoimenpiteitä, joiden avulla vuotuista hiilijalanjälkeä voidaan arvion mukaan pienentää noin 20 % vesi- ja energiatehokkuustoimenpiteillä sekä jätteiden lajittelun tehostamisella.

SYMBOLS AND ABBREVIATIONS

CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
kWh	kilowatt-hour
n-m^2	net internal area in square meters
TWh	terawatt-hour

Abbreviations

CM	Carbon metric
EU	European Union
GHG	Greenhouse gas
HSY	Helsinki Region Environmental Services
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute

Table of contents

1 Introduction

Climate change requires remedial actions to ensure continuation of appropriate living, and use of sustainable energy sources is the key when aiming to reset the carbon emissions to zero globally. As operational stage act as the most significant emission source during building life-cycle, emission sources and reduction possibilities are essential to examine thoroughly. Finland is committed to become carbon neutral by 2035 (Valtioneuvosto 2019, p. 34) which, as a national target, leads to the necessary remedial actions to take place in over the next decade.

This thesis aims to define an operational carbon footprint for a Finnish housing company covering scopes 1-3 according to Greenhouse Gas (GHG) Protocol in an annual basis. Calculation is provided in an annual basis and presents more the operations in the housing company than the building itself. Calculation of scope 1-2 emissions according to GHG Protocol are well covered while scope 3 emissions not what comes to evaluation excluding financial perspective. Databases provide emission factors per monetary unit. At the same time, it is identified that the amount money spent -basis does not provide truthful information about the emissions produced but rather a directional estimate. More precise emission examination is needed to discover the whole potential to control the emissions.

The main research question is comprised around scope 3 emissions, to identify relevant emission sources of a housing company and how to calculate emissions by excluding the financial perspective. Research is focused on emissions that are the under the responsibility of the housing company. The areas covered are property management and maintenance activities in addition to energy consumption, water consumption and waste management which are considered including property’s proportion.

Research is driven by consumer demand as housing companies have become interested in the emissions they create in their own activities, is there a possibility to control emissions and how. This demand can only be responded by defining the emissions. Reporting the current state enables to identify operations which cause the emissions and where the potential for emission reduction is. When consciousness of the current state is obtained it is possible to set emission reduction targets and strive or low-carbon solutions. In addition to emission reductions, usually energy efficient and less carbon intensive solutions generate cost savings for example through reduction of energy consumption. This is advantageous not only to the housing company itself but also in a larger perspective.

First, relevant emission sources of a housing company are defined in cooperation with two existing housing companies. These case assets are both located in the city of Helsinki which directs the point of view of thesis to the Helsinki metropolitan area. Essential scope 3 emissions sources are clarified and the emissions generated quantified based on actual activity and consumption. As a result, a comprehensive carbon footprint including scope 1, scope 2 and scope 3 emissions for a housing company can be calculated.

Second, possibilities to a decrease the environmental impact is assessed. Assessment is focused on finding the most efficient ways for housing companies to decrease the amount of annual emissions generated through utilizing solutions to increase energy efficiency and to utilize less carbon intensive alternatives. In addition, minor actions in which also the residents can be encouraged are suggested.

Finally, a comprehensive carbon footprint representing the level of emissions for the reporting year in addition to a potential carbon footprint for a housing company is presented. Research is focused on Finnish housing companies but results can be applied to other housing and real estate; for buildings in operational stages.

2 Housing company

Housing company as a concept stands for a form of residential housing in Finland. Housing company is a limited liability company which owns and controls the building or part of the building. At the same time most of the residential apartment area in such building is possessed by shareholders. Liabilities are defined in Finnish law of Limited Liability Housing Companies Act 1599/2009. This chapters presents the operational environment, different forms of housing companies in Finland in addition to emission sources in housing companies identified.

2.1 Operational environment

Shareholder possesses a proportion of a housing company, usually an apartment, a storage or a parking lot, via the shares the shareholder owns. Role of a shareholder seems like ownership but is more a proprietary right to one's properties through holding the shares. In an administrative way each apartment, storage, parking lot etc. is formed of a number of shares which usually varies according to the area in squares. (Limited Liability Housing Companies Act 1599/2009, Rakennustieto Oy 2019.) Housing company can be simplified to a company which owns and controls a building with no financial profit as an interest. The main ambition is to upkeep the property.

Shareholders usually either holds the shares of their own home and lives in the apartment in question. One other common way is to utilize the shares and the apartment as an investment and give the apartment for rental. As an example, this can be done by an individual for a personal interest and investment regarding one apartment or several apartments. On the other hand, this can be done professionally example through real estate investment companies which one main focus is to own, control, upkeep and rent properties to generate profit usually within several and more properties through property portfolios.

It is also common for a municipality to own and control residential apartments in Finland. Municipality usually owns a company which acts as a real estate investment company with the difference that there is no interest to generate profit and no dividends are provided for the shareholders. Either way, an individual can rent a home to live in.

Decisions related to the management of the building are made in a shareholders' meeting which is to be held at least annually. Each shareholder has the possibility to participate to the meeting and vote, and usually one share equals one vote. Usually decisions in a shareholder' meeting are made according to a simple majority. The most ordinary decisions are related to selection of a board, selection of a house manager, confirming the financial statement, approve management charge, confirm the operator to carry out property maintenance and cleaning in addition to approval the articles of association. (Limited Liability Housing Companies Act 1599/2009, Rakennustieto Oy 2019.) Relations are demonstrated in Figure 1 below.

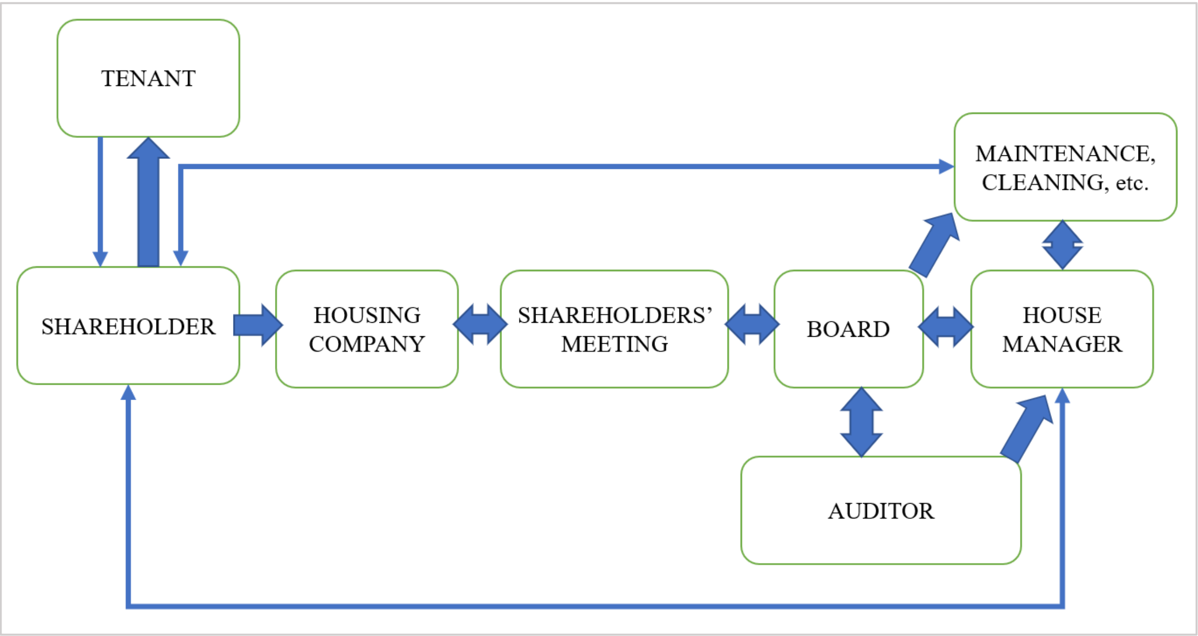

Figure 1. Operators in a housing company (adapted from: Rakennustieto Oy 2019)

Housing companies usually procure the most important services from third party specialists. Relevant areas to be covered are usually:

- house manager,
- maintenance company,
- interior cleaning,
- auditor/accountant.

Depending on the arrangements of a housing company, some of the duties can be done by the shareholders or residents. As an example, it can be decided in the shareholder's meeting to carry out different kind of renovations such as painting a fence or carry out the upkeep of external areas or planted areas by voluntary work by the shareholders and residents.

Board of a housing company is usually formed by three to five shareholders. The term of the board is the time between shareholders meetings and as such is usually a year. The board is the actual operator in charge of the management and administration of the housing company and the building. One duty is to prepare the decisions presented in the annual shareholders' meeting. (Rakennustieto Oy 2019.)

House manager is usually a third-party real estate professional but especially in smaller housing companies can also be a layperson. House manager is selected by the shareholders, eventually by the board. The role of a house manager is to carry out the daily administration of the housing company and take care of the quality of the property maintenance. House manager usually manages the shareholders' meetings according to board's order and is usually the first contact person to whom residents are in touch in their daily needs. House manager also provides house manager's certificate which is an important document for a resident and/or shareholder when selling or renting an apartment. (Rakennustieto Oy 2019.)

Each shareholder is obliged to pay management charge which usually is due monthly. Usually, the management charge is divided into maintenance fee and to capital fee. Maintenance fee exists in each housing company and covers the finances required for the daily activities and maintenance to be covered, for example, central space and water heating expenses, electricity expenses for communal areas, waste management, general maintenance in internal and external areas such as maintenance and cleaning. The capital fee covers the long-term expenses which are usually loans caused by the acquisition, construction and renovations of the asset. (Limited Liability Housing Companies Act 1599/2009, Rakennustieto Oy 2019.)

The articles of association is obligatory to be formed for each housing company and can be described as a regulation to confirm operations and responsibilities, and is applied to each party involved. The articles of association details and supplements Limited Liability Housing Companies Act 1599/2009 on a practical level. (Rakennustieto Oy 2019.)

One special occurrence in which also housing companies can be involved are related to easements. Typical cases within organisation of easements are waste management, yard areas, parking arrangements, access across neighbour site such as walkways or lanes and use of communal areas and shelters. By organisation of easement housing company’s rights and duties are defined. As an example, yard area can be used and maintained by several housing companies or can be maintained by one housing company on behalf of other housing companies involved. Usually waste management easements are related to shared waste facilities which usually ensues to combined waste amount reports for the housing companies involved.

Especially parking arrangements can vary a lot. There can be yard area parking space within the site area or all parking can take place in a parking hall under the management of the housing company. At the same time parking can take place in a joint parking hall managed by several housing companies or a separate parking company. These special but common cases related to easements need to be identified when defining system boundaries.

2.2 Forms of residential housing

This research groups Finnish housing companies into three categories; apartment buildings, terraced houses and detached houses. Apartment buildings cover typical mid and high-rise apartment blocks in addition to low-rise and garden style apartment blocks.

Generally low-rise apartment block consists buildings with two floors which both have vertically independent owners. Terraced house is typically a building with at least three apartments built together and, if with multiple floors, there is only one apartment vertically or as such vertically with only one shareholder (Sanastokeskus ry 2020). Detached houses cover both detached and semi-detached homes. As a housing company, detached house is usually a group of individual houses located on a same site and with shared responsibility as described previously. Semi-detached house is similar to terraced houses what comes to vertical ownership but is a building with two apartments.

There are altogether approximately 2,7 million permanently occupied residential apartments in Finland from which 48 % are in apartment buildings, 38 % in detached houses and 14 % in terraced houses. Finnish building stock is mainly constructed after 1940 and as such is mainly less than 80 years old. (Statistics Finland 2022.) Number of occupied residential apartments within different building types by year of construction are available in Figure 2 below.

Figure 2. Residential apartments in different building types in Finland (Statistics Finland 2022)

There were approximately 90 500 housing companies in Finland in January 2022 (PRH 2020). 75 % of all apartments within housing companies exist in apartment buildings and 25 % in terraced houses in addition to a marginal share in detached houses (HE 24/2009). Volumes of building types and number of apartments in housing companies are demonstrated in Figure 3 below.

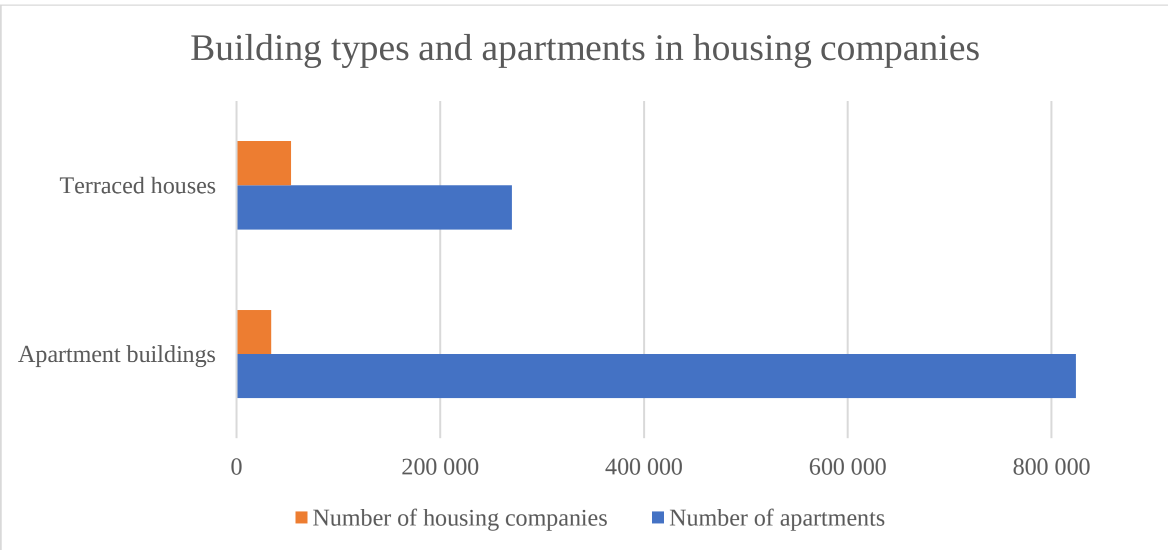

Figure 3. Number of building types and apartments in housing companies (HE 24/2009)

As such, there are more housing companies in terraced house building types than in apartment buildings. However, there are significantly more apartments in apartment buildings and as such, more shareholders and residents involved. Approximately 50 % of Finnish residents live in a housing company (Isännöintiliitto 2017).

2.3 Emission inventory

Calculation is to cover all relevant direct and indirect emissions that are generated by a housing company. Housing company is a party to own and control the building while shareholders and residents are the actual users, the boundaries need to be assessed thoroughly. Emission sources identified, estimated units and scope categories according to GHG Protocol are presented in Table 1 below and opened up verbally after that.

Table 1. Emission sources of a housing company identified

Domain	Components	Unit	Scope according to GHG Protocol
Energy use	Heating Hot water consumption Electricity	kWh/month l/month kWh/month	Scope 2
Water treatment	Drinking water production Removal and treatment of wastewater	l/month	Scope 3
Waste	Residential waste streams: - mixed waste - biowaste - paper - cardboard - plastic - glass - metal	kg/month	Scope 3
Maintenance and cleaning	Interior cleaning Yard area management Small, annual repairs Other relevant maintenance activities	m²/month m²/month NA	Scope 3
Management	Contribution of house manager	h/month	Scope 3
Transportation	Maintenance Management A common use car provided by a housing company Electric vehicle recharging stations provided by a housing company	km/month	Scope 3

For apartment buildings, the heating system is central and there typically is not sub-metering for apartment level consumption. As such heat energy consumption can not be allocated to the users. At the same time, housing company is responsible for the building to be appropriately heated and to provide hot domestic water for living. Similarly, metering of total water consumption at apartment level is variable especially in older building stock while new construction is obliged to provide apartment level water meters.

Generally, residents have electricity contracts of their own and housing company is only responsible of the electricity used in the communal areas. Consumption typically covers external and internal lighting, lifts, communal sauna areas, clubroom and laundry equipment in addition to other electricity use according to the level of services the housing company provides. Apartment level ventilation units might be attached to the property electricity or into residents own electricity. Electricity used for heating up cars during cold season is typically not allocated according to user but especially in new construction solutions for residents to pay according to use are increasing. Similarly electric vehicle charging might be included into property electricity. Nevertheless, the electricity contract of communal areas in under the responsibility of housing company and it charges shareholders according to use or by a constant sum included into the monthly management charge. At the same time, all parking might not be under the responsibility of the housing company but located in a separate company. These differences in allocating electricity use should be considered when analysing the results.

There are several services that housing companies procure and are responsible of. As described earlier, for example house manager, maintenance company, interior cleaning, and accountant are most general outsources services. In addition to these, housing company is responsible of arranging waste management as the waste regulations and municipality requires and procures the service from local service provider. Housing company itself generates usually minimal amount of waste if any but waste generated by the residents should be included in the calculation. As control of waste transportation from the asset to the waste center is not under the control of a housing company, it is excluded from the reporting.

Common use cars of housing companies seem to grow in number at the moment. These cars can be owned or rented from a third-party supplier by the housing company for residents to use. These are included in the reporting if applicable. Other sources of transportation is included according to the kilometers driven related to maintenance and management activities. As housing companies are free to choose the operator, there is a possibility to control the emission generated.

3 Status of calculating environmental impact of housing

There are innumerably different applications, service providers and guidance provided to calculate environmental impacts. In addition, standards and calculation guidance is provided to lead to transparent, coherent and truthful calculations and reporting. Relevant guidance to be followed related to this thesis and during the calculation process is introduced in the next sub-chapters. Current state of relevant calculation tools existing at the moment is also presented.

3.1 Greenhouse Gas Protocol

GHG Protocol is a worldwide group of standardized frameworks providing organizations guidance on measuring, managing and reporting GHG emission from their operations and value chains. The framework is convened by World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) in co-operation with multiple entities. (WRI & WBCSD 2011.)

The GHG Protocol Corporate Accounting and Reporting Standard and supplemental The Corporate Value Chain (Scope 3) Accounting and Reporting Standard provide comprehensive guidance on preparing GHG emission inventory. According to the standards emissions are divided into three categories due to the entity which generate the emission:

1. direct energy production used for own consumption: scope 1
2. indirect energy production ie. energy purchases used for own consumption: scope 2
3. all other indirect emissions sources: scope 3 (WRI & WBCSD 2011; WRI & WBCSD 2016.).

Scope 3 is further divided into categories of upstream and downstream emissions. Upstream activities exist before the operations of the reporting company to ensure operations, and at its simplest are related to purchasing. In turn, downstream activities exist after the operations of reporting company and are related to selling goods and services. (WRI & WBCSD 2011.) Scopes 1-3 in addition to downstream and upstream emissions are visualized in Figure 4 below.

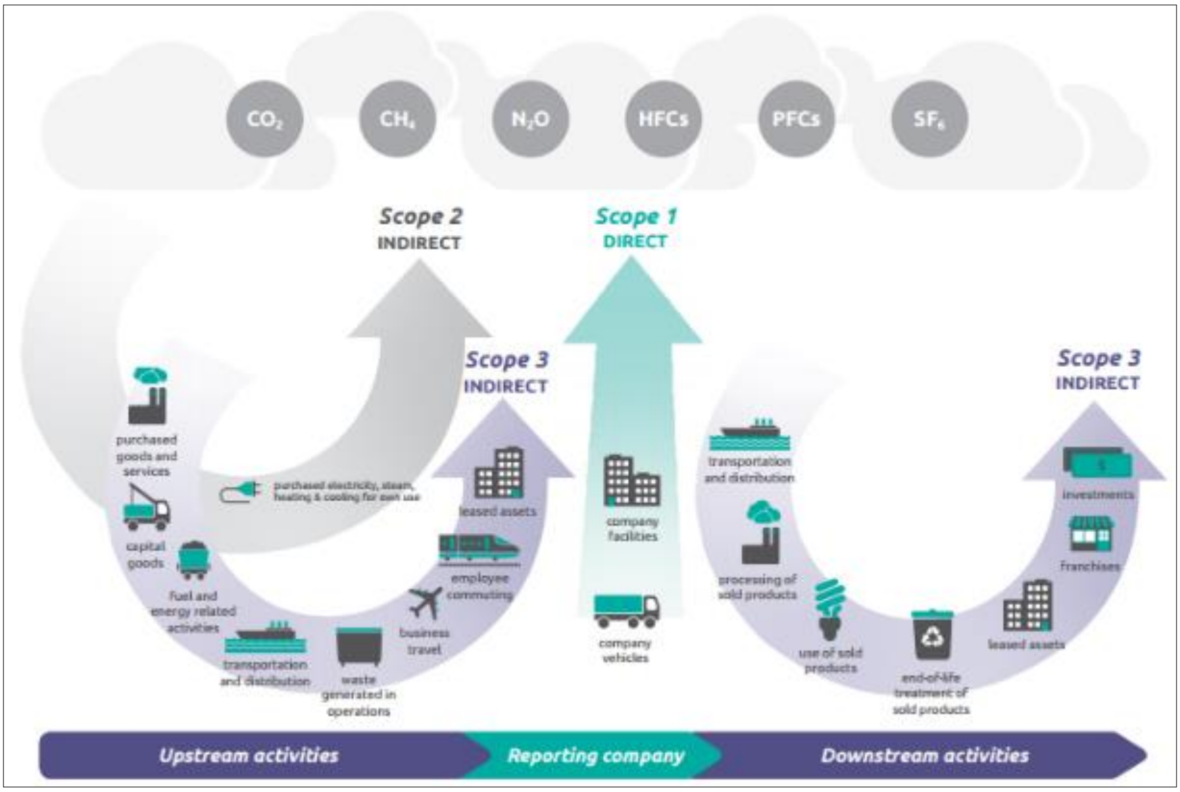

Figure 4. Scopes according to GHG Protocol (WRI & WBCSD 2011 p. 5)

Emission reporting according to the GHG Protocol Corporate Accounting and Reporting Standard is to cover scope 1 and scope 2 emissions while scope 3 emissions can be excluded or voluntarily be reported as widely as the company chooses. If reporting is done in conformance with both the GHG Protocol Corporate and The Corporate Value Chain (Scope 3) accounting and reporting standards also the scope 3 emissions are to be included.

Standard divides scope 3 emissions into 15 categories which are also visible in Figure 4 above. Relevant scope 3 activities to be reported can be outlined followingly:

- activity have significant contribution to the emissions,
- there is potential to contribute to the emission reductions,
- activity contributes to the company’s risk exposure,
- activity is deemed critical by key stakeholders,
- relevant outsourced activities,
- activity is identified as significant by sector-specific guidance,
- other (WRI & WBCSD 2011 p. 61).

Each category needs to be assessed within emission inventory including all upstream and downstream activities and if any exclusions are made, they need to be justified. Information on each excluded category as zero emissions or “not applicable” should be provided. 15 categories in question together with assessment to housing companies are provided in Table 2 below. Numbers 1-9 represents upstream activities, and 10-15 downstream activities.

Table 2. Scope 3 categories (WRI & WBCSD 2011 p. 32) in relation to a general housing company

Scope 3 category	Adapted to a housing company	Applicability
1. Purchased goods and services	Maintenance services Cleaning services Contractors of renovations Management Accountant Material related to renovation and maintenance	Yes
2. Capital goods		Not applicable
3. Fuel- and energy-related activities (not included in scope 1 or scope 2)		Not applicable
4. Upstream transportation and distribution	Kilometers driven by: - Maintenance services - Cleaning services - Contractors of renovations	Yes
5. Waste generated in operations	- Waste generated by the housing company - Waste generated by the residents - Waste water treatment	Yes
6. Business travel		Not applicable
7. Employee commuting		Not applicable
8. Upstream leased assets		Not applicable
9. Downstream transportation and distribution		Not applicable
10. Processing of sold products		Not applicable
11. Use of sold products		Not applicable
12. End-of-life treatment of sold products		Not applicable
13. Downstream leased assets		Not applicable
14. Franchises		Not applicable
15. Investments		Not applicable

One of the key steps according to the standards is to define organizational boundaries. Consistent consolidation approach should be used across the emission inventory of scopes 1-3. Consolidation approach is divided into equity and control approach and control approach further to financial and operational control approaches. Selected approach has an effect to how indirect and direct emissions are related and categorised into which scope. (WRI & WBCSD 2011.)

Equity approach is to account for missions from operations according to reporting company’s share of equity in the operation with economic interest. Operational control approach simply accounts for emissions in which reporting company has an operational control whereas financial control approach accounts for emissions in which the reporting company has financial control. (WRI & WBCSD 2011; WRI & WBCSD 2004.)

3.2 Standards

Sustainability of construction works – assessment of environmental performance of buildings (SFS-EN 15978) guides environmental assessment calculation of new and existing buildings in addition to refurbishments over the life cycle of the building. Life cycle stages identified are product stage, construction process stage, use stage and end of life.

Use stage is defined to cover the period between completion of construction process to deconstruction or demolition and includes the following scenarios:

- use of products,
- maintenance,
- repair,
- replacement,
- refurbishment,
- operational energy use,
- operational water use (SFS-EN 15978, p. 21, 48).

The standard guides to consider all relevant environmental impacts arising from the building including building-integrated technical systems and building-related furniture, fixtures and fitting. Maintenance is to cover all components used for maintenance activities including production and transportation, all cleaning in internal areas and exterior of the building in addition to all other relevant activities to maintain the building and its technical condition. Energy use is to cover heating, hot domestic water, air conditioning, ventilation, lighting and auxiliary energy used for pumps, control and automation which are all related to operational energy demand of the building. Water use includes all building-related water use and also water input and output flows for waste water treatment. (SFS-EN 15978.)

In addition to that, standard ISO 16745-1:2017 “Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage” forms more specified baseline what comes to calculating and reporting housing company’s operational emissions. Standard presents three types of carbon metrics (CM) which all are a sum of calculated annual GHG-emissions as CO2 equivalents.

- CM1 measures and quantifies all building-related energy use: energy for space heating, space cooling, air movement, domestic hot water, lighting, indoor transportation and other building auxiliary devices.
- CM^2 measures and quantifies building- and user-related energy use. User-related energy use includes energy for cooking, refrigeration, devices in data centres, supplementary lighting installed by building user and other appliances and functional devices.
- CM3 measures and quantifies CM^2 and other building related sources of GHG emissions and removals such as water consumption, waste management, property management and, administration/management.

CM1 and CM^2 includes all energy delivered to the building and on-site energy generated and used in the building. Calculating as a process to achieve a CM is multiplying energy use by GHG coefficient. Standard directs to obtain coefficients first from nationally agreed data, second from independently provided information and from internationally agreed data as the last option. (SFS-EN ISO 16745.)

3.3 Applications for assessing environmental impact

Finnish Environment Institute (2013) has developed a tool named Y-HIILARI for companies to calculate and report their carbon footprint. Calculation covers scopes 1 and 2 according to GHG Protocol in addition to scope 3 emissions covering waste, business travel, transportation and emissions related to producing fuels used for transportation demand.

Guidance for calculating environmental impact of a building at national level is created by Ministry of the Environment. Method is in accordance with EU-level standards but employed to Finland and describes calculation for the whole life carbon assessment of building based on life cycle analysis within scope from cradle to grave. Method is applied to new buildings and buildings undergoing extensive repairs. Use phase is also covered and concluded to generate most of the emissions during building life-cycle. According to the calculation method, use phase is to include energy consumed during the whole expected time in use in addition to estimation about maintenance and repairs with part changes needed. (Kuittinen 2019.)

ENVIMAT (environmentally extended input-output) -model generated by the Finnish Environment Institute is widely used in Finland to define carbon footprint for household consumption. Model is used to calculate life-cycle greenhouse gas emissions and the result obtained is based on how much money is spend. (Seppälä et al. 2009, p. 89, 130-131.) Also an individual is able to calculate carbon footprint for oneself in a Finnish Climate diet -calculator which is based on ENVIMAT-model. The result is based on euros used what comes to renovations, cleaning and goods and services (Finnish Environment Institute (SYKE) 2019).

There are uncountable amount of different calculation models and tools for assessing carbon footprint or environmental impact. Predominantly models are focused on assessment of a product and energy consumption. Ability to assess these is well-known and calculation itself relatively simple. If services are included, the calculation method turns into economical input-output model which stands for monetary expenses. Results are not comparable when the amount of emission is based on the money spent.

3.4 Remarks from literature

Onat, N. C. et al. (2014) have carried out scope-based analysis according to GHG Protocol for commercial and residential buildings in the U.S. According to the study, use phase of a residential building cover 89 % of the total life cycle emissions. Scope 3, the indirect emissions, are found to cover 34 % of the overall emissions of a residential building, scope 1 with 22% share and scope 2 with 44% share. Maintenance and repair within the scope 3 emissions are based on monetary unit. Study highlights that the residential buildings in the nation consume electricity provided by fossil fuels as the primary energy source and as such is the reason for use phase emission domination. Results reveal that residential and commercial building perform very similarly what comes to the emission distribution within the three scopes in addition to emission distribution between building life cycle phases. Research method represents hybrid economic input-output life cycle analysis.

According to Fenner, A. E. et al (2018) indirect emissions during operational stage of a building are usually ignored by the literature. Nature of energy source used is the most significant contributor to guide the calculations. It is suggested that commuting should be included into the system boundaries to speed up carbon neutrality for its part; to include commuting into suburban planning from emission perspective. While comparing different calculation methods for both residential and non-residential buildings, Fenner et al. concluded the total emissions being significantly similar between residential and commercial building types.

Also Fenner, A. E. et al (2018) concluded that the operational phase emissions of all building life-cycle phases is ub the most significant role in the total building GHG emissions, covering approximately 70 % of all life-cycle emission. Majority of the emissions are due to energy use during operation and as such calculations in literature are focused in energy consumption. (Fenner, A. E. et al. 2018; Ozawa-Meida, L. et al. 2013.)

Study provided by Nissinen & Savolainen (2019) state the carbon footprint in 2016 of an average Finn being 10,9 t CO_2e/person/year in which living and energy cover 29% of the total carbon footprint. At the same time study provided by Sitra (2019) presents that average carbon footprint of a Finn in 2018 was 10,3 t CO_2e/person/year from which housing cover 20%. Distribution of emissions according to Sitra (2019) between sectors are visible below in Figure 5.

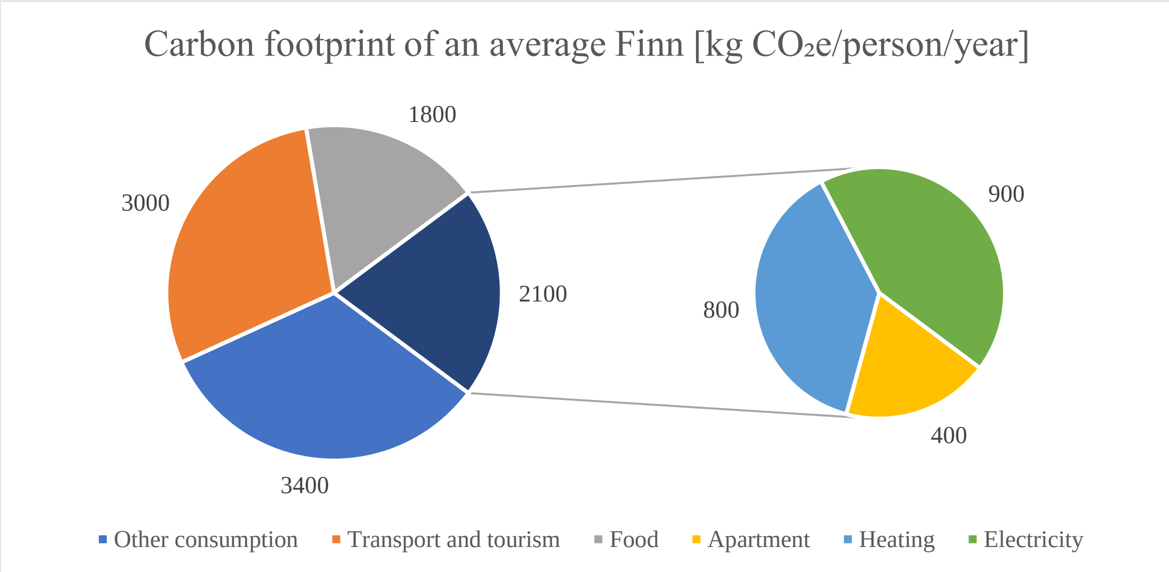

Figure 5. Carbon footprint of an average Finn (Sitra 2019)

Akenji et. al (2019) have analyzed lifestyle carbon footprints within five countries, including Finland. Lifestyle carbon footprint of an average Finn was discovered to 10 400 kg (CO_2e/cap/yr) from which 24 % is due to housing. Housing emissions were defined by energy and water consumption in addition to construction and maintenance activities.

Calculation of construction and maintenance was based on internal area of an apartment as housing space (m^2) multiplied by a known GHG intensity factor ($kgCO_2e/m^2$). Calculation is based on previously reviewed ENVIMAT model (Finnish Environment Institute (SYKE) 2019).

Studies are unanimous about the use phase being the most significant contributor to the life cycle emissions, mostly due to energy consumption. It can also be concluded that from one fifth to nearly one third of the emissions produced by a Finn is comprised around housing and more closely to energy used for heating and electricity. In addition, scope 3 emissions are defined by a constant, based on monetary value or mainly excluded from the system boundary.

3.5 Background information to carry out the calculation

Energy consumption, water treatment, waste management in addition to property maintenance are the most relevant and identified emission sources for a housing company. Next chapters present the relevant background information related to emission coefficients and the existing state of each topic in Finland in question.

3.5.1 Energy consumption

District heating is the most common way to produce space heating and hot domestic water for apartment buildings in Finland. Environmental impact of the heating system varies between different geographical areas around the country as local district heating operators produce heat from different sources. Renewable fuel sources covered 60 % of the heating produced in district heating plants in Finland in 2021 and the use of renewable heating sources are expected to increase. Emission coefficient on the average was 0,102 kg CO2e/kWh in 2021. (Energiateollisuus 2023.) Local emission coefficients are well reported at annual level and as an example is 0,1693 kg CO2e/kWh for assets located in Helsinki (Local power 2021) being one of the highest at national level.

Emissions which are generated due to district heating system is practically out of the control of housing company as district heating operator can not be chosen. There might be a zero-emission district heat or some kind of green heating alternative provided depending on the district heating operator. This is usually provided at an additional cost for housing companies choose freely. (Helen 2022a; Alva 2023.)

Competitive alternative to the dominative district heating system for new construction and during heating system renovations can be seen different heat pump systems. Geothermal heating system or ground source heat pump is seen as a potential alternative to produce space heating and hot domestic water locally. The actual heat source is renewable, but system consumes electricity in producing the heat.

It is unusual for residential buildings to sub-meter energy consumed for space heating and energy consumed for hot domestic water separately. Energy consumed to heat up cold water can be calculated with Formula 1:

$$Q_{dhw} = 58 \times V_{dhw} \quad (1)$$

where Q_{dhw} is the energy consumed for hot domestic water [kWh/year], V_{dhw} is the amount of hot water consumed [m^3/year], 58 is the energy needed to heat up water (temperature change 50 °C) [kWh/m^3] (Motiva 2022a).

According to a survey carried out by TTS the water consumption is 65 % cold and 35 % hot water in Finnish households. Approximately 45 % of the water usage is related to hygiene: showering and washing face and hands. At the same time the study concluded that Finnish residents consume approximately 113 litres of water per 24 hours per person. (TTS 2020 p. 18, 20.)

Contrary to the central and usually stable way of procuring heat, the contract related to electricity supplier is available for housing companies to choose freely. As such, emission coefficient on a national level is seen as the most reliable for the calculation. Electricity production mission coefficient as an average value of last 5 years is 0,125 kg CO2/kWh (Statistics Finland 2020). Utilizing average value of 5 years instead of using coefficient from a certain year compensates the yearly fluctuation. As well as district heating can be chosen from less GHG intensive production, also electricity is available from renewable sources (Fingrid 2023).

Typical energy consumption in Finnish households is related to space heating, hot domestic water and electricity use for different purposes. Distribution of energy consumption in Finnish households according to end-use can be seen in Figure 6 below. Household appliances include lighting 1,5 TWh, cooking 0,8 TWh and other electrical equipment 6,9 TWh.

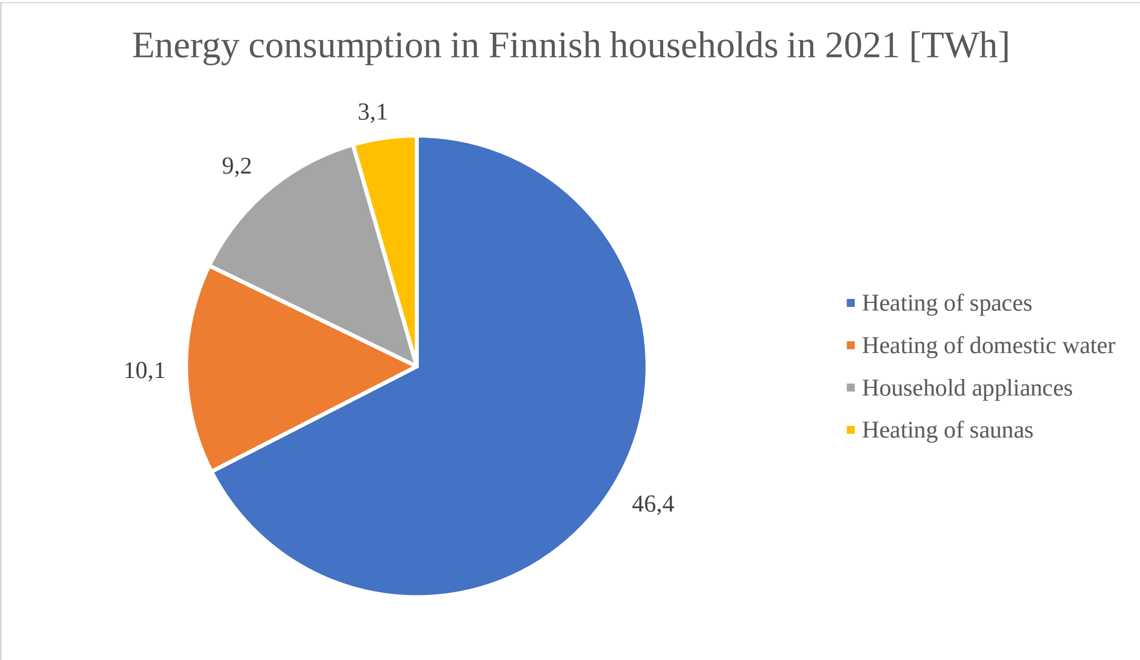

Figure 6. Energy consumption in Finnish households (Tilastokeskus 2022)

From the overall energy consumption of 68,8 TWh, 67% of the energy is used for heating of premises, 15% for heating of hot domestic water and 18 % for household appliances heating of saunas (Tilastokeskus 2022). As such, from the heat energy demand 82 % is used for space heating and 18 % for hot domestic water.

3.5.2 Water treatment

Energy consumed to heat up hot domestic water is considered in the previous chapter. In addition to energy consumption, it is essential to consider emissions generated in cleaning the raw water to safe drinking water and in removal and treatment of wastewater. Emission coefficients for the Helsinki metropolitan area are defined by Helsinki Region Environmental Services HSY (2018) and are 449 g CO2e/m3 for wastewater treatment and 7 g CO2e/m3 for cleaning raw water and distribution for year 2021. As such, emission coefficient for water and wastewater treatment is 0,456 kg CO2/m3.

3.5.3 Waste management

Waste management is regulated through European Union (EU) legislation. The minimum requirements related to residential waste at national level are provided in Waste Act 646/2011 and in Government Decree on Waste 978/2021. Municipalities are responsible of arranging waste collection for residential waste (Waste Act 646/2011 § 32) and separate collection for biowaste, glass, metal, plastic, paper and cardboard is to be arranged for properties with five or more dwellings (Government Decree on Waste 978/2021 § 17,18).

More detailed arrangements are provided in local waste management regulations. In practise, while municipalities are responsible of municipal waste generated the actual waste management takes place in regional companies which organize the waste collection in a certain area which can cover multiple municipalities (Ministry of the Environment 2019). For example, in Helsinki metropolitan area covering municipalities Helsinki, Espoo, Kauniainen, Vantaa and Kirkkonummi also mixed waste collection is required to be arranged within each property according to waste management regulations provided by the Helsinki Region Environmental Services HSY (HSY 2022).

Municipal waste is the waste generated in households and waste comparable to household waste generated in the consumption of final products. Nearly 3,4 million tons of municipal waste was generated in Finland in 2021. Mixed waste is the largest waste stream with share of 51 %. Other relevant household waste fractions are paper and cardboard with the share of 14,1 %, biowaste 13,8 %, plastic 3 %, glass 2,3 % and metal 1,2 %. (Statistics Finland 2021.) Amounts of these waste fractions in tons in addition to other waste fractions identified are presented in Table 3 below.

Table 3. Municipal waste amounts in Finland in 2021 (Statistics Finland 2021)

Waste fraction	Total [ton]	Total [%]
Mixed waste	1720691	51,0
Separately collected paper and cardboard waste	476093	14,1
Separately collected biodegradable waste	465178	13,8
Other and unspecified waste	205377	6,1
Separately collected wood waste	144883	4,3
Separately collected plastic waste	99802	3,0
Separately collected electrical and electronic waste	78868	2,3
Separately collected glass waste	78092	2,3
Other separately collected fractions	65021	1,9
Separately collected metal waste	42160	1,2
Total waste	3376165	100,0

Helsinki Region Environmental Services have studied the composition of household mixed waste in the Helsinki metropolitan area in 2021. The study revealed that the amount of mixed waste generated was 119 kg/capita in apartment buildings in which there are 19 or more apartments within the building. Largest waste streams identified were biowaste with amount of 46 kilograms, plastic 16 kilograms and paper 10 kilograms. (HSY 2021a, p. 17-18.) Total composition of mixed waste according to the main division between waste fractions is presented in Figure 7 below.

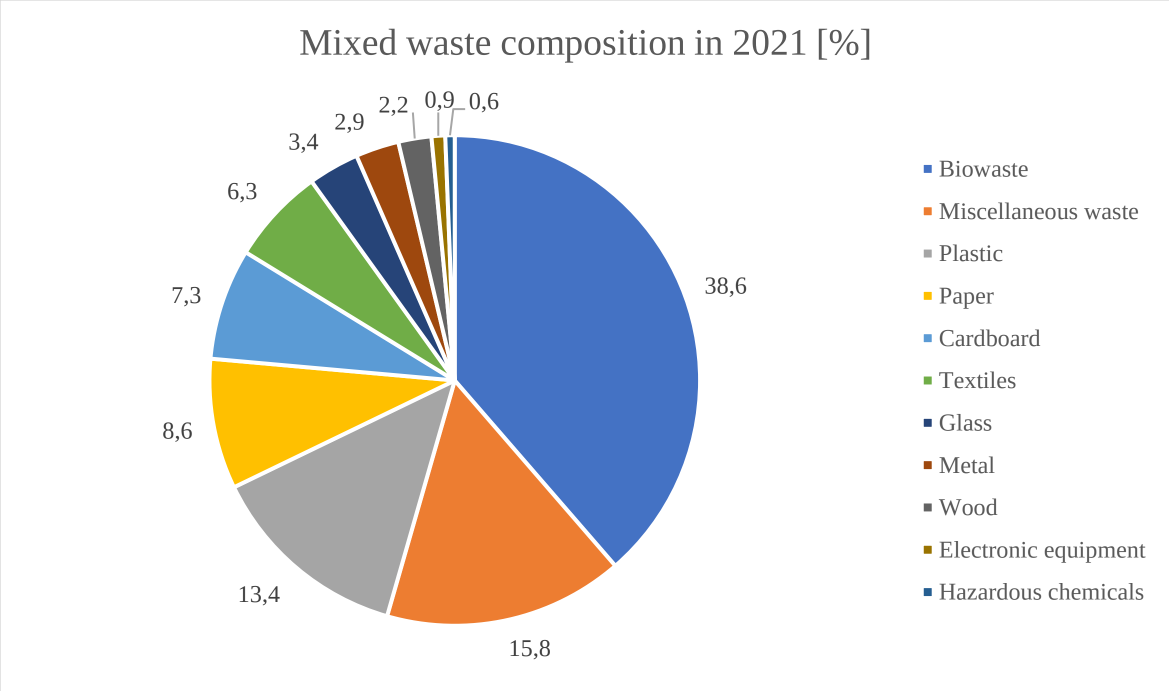

Figure 7. Mixed waste composition according to Helsinki Region Environmental Services Authority (HSY 2021b)

The study divides main waste fractions also into sub-categories. 15,7 % so 18,7 kg of the total amount of mixed waste produced by a capita per year was estimated to edible food waste which simply is food which was uneaten while 17,4 % of mixed waste so 20,7 kg was actual biowaste. 5,0 % so 6 kg of mixed waste was soft tissues which could have been segregated as biowaste and approximately 3,5 % so 4,1 kg was other forms of paper which could have been segregated as paper. 10,1 % so 12 kg of mixed waste was plastic packaging which could have been segregated as plastic. Share of cardboard packaging such as milk, juice and take away food cartons, egg packaging etc. covered 4,9 % so 5,8 kg. (HSY 2021b.)

At national level, Programme of Prime Minister Sanna Marin's Government 2019 has identified and committed to decrease the amount of food loss and food waste for the coming years. Amount of food loss and food waste is to be halved by 2030. (Valtioneuvosto 2019.) Linked to that, national ambition is also to achieve recycling rate of 57 % by 2027 to the municipal waste generated (Ympäristöministeriö 2022 p. 9).

Waste amount reporting for residential apartment buildings vary according to the organization managing the waste collection. For some cases there are exact waste volumes in tonnes or kilograms available, for some cases there is an estimation of mass provided by the waste company and in some cases the initial data is based on waste bill or waste contract in which the size and number of waste containers and collection frequency is provided.

Helsinki Region Environmental Services has provided guide for waste amount calculations. The guide presents average weights of certain waste containers during container pick-up based on measurements made by Helsinki Region Environmental Services. These numbers are provided in the Table 4 below. Information provided is usable to achieve directional masses of the waste generated based on averages when exact waste volumes are not available.

Table 4. Average weight of waste containers (HSY 2021c)

Waste container	Size of the container [l]	Average weight of the container [kg]
Mixed waste	200-290	16 (collection frequency once a week)
Mixed waste	200-290	22 (collection frequency once every two weeks or rarely)
Mixed waste	600-690	34
Biowaste	140	14
Biowaste	240	24
Paper	120	24 (weight of full container) 16,8 (weight with 70% fill rate)
Paper	240	48 (weight of full container) 33,6 (weight with 70% fill rate)
Paper	370	72 (weight of full container) 50,4 (weight with 70% fill rate)
Paper	660	132 (weight of full container) 92,4 (weight with 70% fill rate)
Cardboard	660	17 (weight of full container) 11,9 (weight with 70% fill rate)
Plastic	140	3
Plastic	240	4
Plastic	660	10
Plastic	800	12
Glass	240	32
Glass	600	200
Metal	240	11
Energy waste	660	15

Mass of paper and cardboard containers are provided according to mass of full container instead of average mass of container when collected. To manage the uncertainty related to the containers always being full an additional calculation is needed. It is assumed that the containers have fill rate of an average 70 %. These calculated masses are also provided in the Table 4 above.

Reliable waste related emission coefficients to carry out calculation further are developed by Finnish Environment Institute (2013) and are available in a calculator called Carbon

Footprint Tool for companies Y-HIILARI. Relevant emission coefficients are presented in Table 5 below.

Table 5. Emission coefficients for waste management (Finnish Environment Institute (SYKE) 2013)

Waste fraction	Emission coefficient [CO2e (kg/t)]
Recycled	
Biowaste (anaerobic digestion)	119,3
Biowaste (composting)	56,7
Carton and cardboard	53,43
Glass packages	13,17
Metal	24,64
Plastic packages	365,87
Paper	72,55
Incinerated	
Mixed waste	400,0

Also in Helsinki metropolitan area most of the segregated waste fractions are recycled as material, mixed waste is incinerated and 50% of the biowaste is directed to anaerobic digestion and 50% to composting (HSY 2023).

3.5.4 Property maintenance

Emissions generated during property maintenance activities can not be found from the literature as such and requires more detailed processing. Most of the emissions generated can be said to relate to the kilometres driven to enter to the asset in addition to the actual work carried out in the asset. It is assumed that mowing the lawn, snow plowing and other activities which require a fuel machine to perform in addition to internal cleaning are the most frequent, usual and emission generative tasks on site.

Emission coefficients for passenger car powered by petrol, van powered by diesel, lawn mower powered by petrol and a snow plowing vehicle powered by diesel are essential and provided in Table 6 below. Numbers provided is literature are related to the emissions generated, kilometres driven and fuel consumption of vehicles and machines in question. Coefficients are calculated from the information provided on a yearly basis for 2020.

Table 6. Emission coefficients for property maintenance activities

Vehicle	Emission coefficient	Source
Passenger car (petrol)	0,148 kg CO2e/km	VTT 2020a
Passenger car (electric)	0 kg CO2e/km	VTT 2020a
Van (diesel)	0,147 kg CO2e/km	VTT 2020a
Van (electric)	0 kg CO2e/km	VTT 2020a
Lawn mower (petrol)	2,057 kg CO2/litre	VTT 2020b
Large diesel vehicle which can be driven	2,635 kg CO2/litre	VTT 2020b

The fuel consumption is unclear and needs to be processed more deeply in cooperation with maintenance companies.

4 Case study

Calculation is carried out with two existing assets provided by a cooperative house managing company. Introduction to the case assets, activity data, calculation methods, results of the calculation and improvement potential identified are presented in the next sub-chapters.

4.1 Introduction to the case assets

Two case assets were received for a detailed calculation from a house managing agency. Priority aims while choosing the case assets were to have two housing companies with apartment buildings from different decades, with different heating systems and which operate with cooperative maintenance companies. General information about the case assets is compiled to Table 7 below.

Table 7. Basic information about the case assets

	Asset 1	Asset 2
Building type	Apartment building	Apartment building
Year of construction	1961	2005
Location	Helsinki	Helsinki
Net internal area (n-m²)	1477	2080
Number of apartments	25	27
Number of residents	30	47
Heating system	Ground-source heat pump	District heating
Ventilation system	Natural	Mechanical ventilation
Waste data provided	Waste bill	Waste report
Major renovations	Facade renovation 2003 Large HVAC and electricity renovation 2015	-
Parking arrangements	Car parking within the site area; 4 parking garages in the asset in addition to 6 yard area park spaces	Car parking in a separate parking hall managed by different company – excluded from the calculation

Initial data was delivered by the house managers and relevant information was found from:

- house manager’s certificate,
- balance sheet book,
- waste report or waste bill,
- maintenance activities during 2021.

4.2 Energy and water use, waste amounts

Consumption numbers related to energy and water use were provided in the balance sheet books at annual level. As energy system of Asset 1 is based on local ground source heat pump, the energy used in the asset is powered by electricity. Asset 2 utilizes combination of district heating and electricity to fulfil the energy demand. Consumption numbers are provided in Table 8 below.

Table 8. Consumption numbers of the case assets

	Asset 1	Asset 2
District heating [kWh/year]	0	261 400
Electricity [kWh/year]	91 618	32 400
Water use [m3/year] [l/person/day]	 1485 136	 1928 112

Waste bill was provided as initial data for Asset 1. Estimation of waste amounts were calculated via number and size of the waste containers in relation to collection frequency and average weights of containers provided by HSY. The calculation is provided in Table 9 below.

Table 9. Waste amount calculation of Asset 1

Waste fraction	Size of one container [l]	Number of containers [pcs]	Average weigh of one container [kg]	Collection frequency [times/ week]	Collection frequency [times/year]	Waste amount [kg/year]
Mixed waste	600	2	34	2	104	7072
Biowaste	240	1	24	0,5	26	624
Paper	NA	NA	NA	NA		
Cardboard	660	2	11,9	1	52	1238
Plastic	660	2	10	1	52	1040
Glass	NA	NA	NA	NA		
Metal	NA	NA	NA	NA		

Waste report with waste amounts in kilograms per waste fraction was provided for Asset 2. Data can be seen in Table 10 below.

Table 10. Waste amounts of Asset 2

Waste fraction	Waste amount [kg/year]
Mixed waste [kg/year]	3744
Biowaste [kg/year]	1248
Paper [kg/year]	NA
Cardboard [kg/year]	780
Plastic [kg/year]	901
Glass [kg/year]	90
Metal [kg/year]	66

Initial data of waste amounts of residential housing vary between municipalities as described in section 3.5.3 and apparently reporting varies within a municipality as well. Both case assets are located in Helsinki, but the initial data is inconsistent. In addition, according to the waste regulations paper, glass and metal is obligated to collect separately in both of the case assets. However, comprehensive data of these waste fractions is not available.

According to studies and statistics provided by Statistics Finland (2021) and Helsinki Region Environmental Services Authority (HSY 2021b) it is visible that amounts of glass and metal recycled properly as well as amounts of glass and metal which ends up to mixed waste are both quite small. In addition, emission coefficients of glass and paper are the lowest regarding all waste fractions so even if data would be available, amounts of these waste fractions would have been low and environmental impact due to low emission coefficients can be seen not relevant. Similar conclusion can be made for paper segregation. As such, lack of initial data related to glass, metal and paper segregation does not have significant impact to the results in this case but causes inaccuracy.

4.3 Property maintenance

Maintenance services were reviewed in more detail with two maintenance companies. To attain a comprehensive overview of the maintenance activities carried out during 2021, a report of all actions was asked for and provided by the maintenance companies. In addition, representatives from both companies were interviewed via phone call. According to information gained, operations and emissions generated during maintenance services can be simplified to

1. Kilometers driven to reach the asset.
2. The actual work carried out in the asset.

Kilometers driven consist of the travel between maintenance companies office, storage or pit to the asset. Generally, one maintenance company or team operates in a certain area or part of a town. As housing companies tender all their service providers, typically one residential area is operated by multiple maintenance companies and as such neighbour buildings can be operated by different service providers. According to the information gained from the maintenance companies, there is no systematic or organized way to conduct the active or daily maintenance activities in certain locations or neighbourhoods. Arrangements of the daily work are organized by the maintenance person who is in charge of the task. Nevertheless, conjunction of activities to certain areas to avoid unnecessary kilometers is recommended.

Maintenance companies of the case assets operate in certain parts of Helsinki. For both companies the distance between storage in which all the equipment is located and the asset is less than three kilometers. Also offices of the companies are located within three kilometers.

The actual maintenance activities in both companies are similar. Continual, annual main maintenance activities identified are

- mowing the lawn,
- snow plowing,
- rubbish removal from external areas,
- activities indoors: change of ventilation machine filters, routine activities (contact information updates such as name change, fact sheet and other information related papers to deliver), on call duties (forgotten keys of a resident, blocked drain etc.)
- other activities outdoors: sand removal, rake, washing of asphalt areas at spring etc.

These activities can be simplified into two categories:

1. Activity causing emissions due to fuel usage.
2. Activities carried out with manual labour or no need for any equipment.

Table 11 below presents average activity frequencies for the most common maintenance activities. In addition, time needed to carry out the activity and fuel consumption of the equipment used were provided during the interviews.

Table 11. Maintenance activities and frequencies

Activity	Number of actions/year	Time needed to carry out the activity [hour/action]	Fuel consumption [liters/hour]	Fuel consumption [liters/year]
Snow plowing	15	0,25	13	48,75
Sand removal and washing asphalt surfaces	1	0,5	13	6,5
Lawn mowing	17	0,3	3	15,3
Leaf removal	3	Only travel		
Internal cleaning	52	Only travel		
Other activities	50	Only travel		

Maintenance companies in question rely on traditional, diesel-powered machines what comes to for example snow plowing and vehicle used for travel by the maintenance person. Petrol powered machines are used for mowing the lawn.

4.4 Results

Results are formed by multiplying the activity data with the emission coefficient. Asset 1 carbon footprint is 15766 kg CO2e/year which is 10,7 kg CO2e/year/n-m². Distribution according to the origin of emission:

- energy consumption 73 %,
- waste management 21 %,
- water treatment 4 % and
- maintenance and cleaning 2 %.

Distribution is visible in Figure 8 below presented by kg CO2e/year. 73 % of the emissions belong to scope 2 category and 27 % to scope 3.

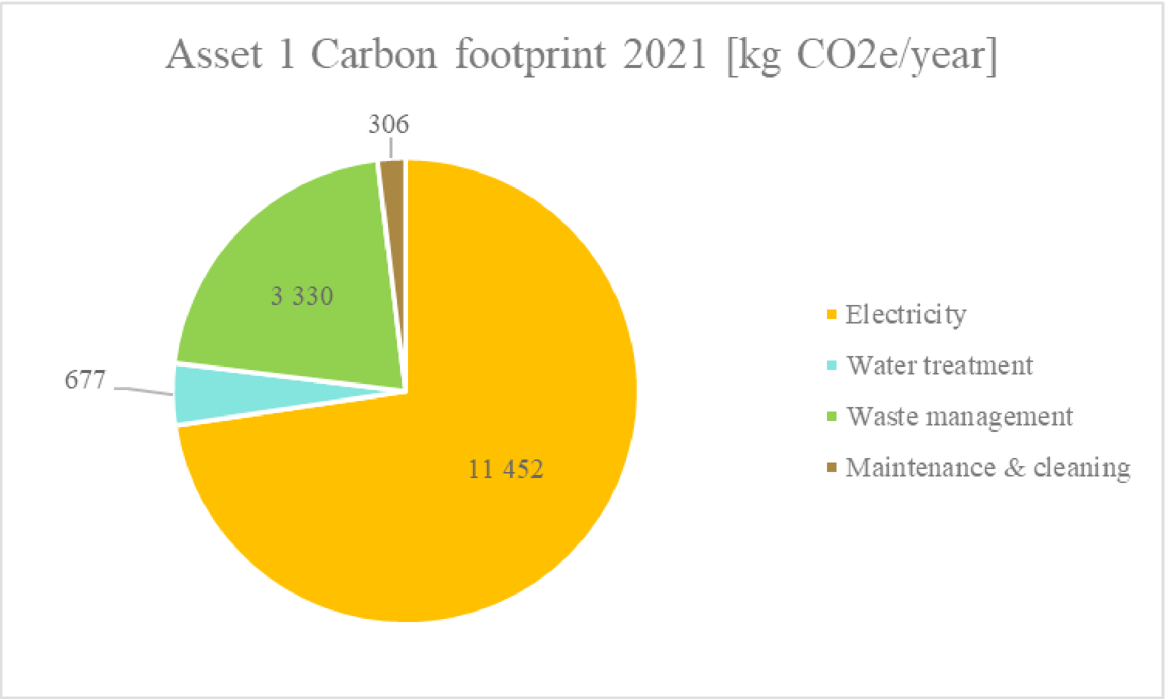

Figure 8. Carbon footprint of Asset 1

Asset 2 carbon footprint is 51 574 kg CO2e/year which is 24,8 kg CO2e/year/n-m². Distribution according to the origin of emission:

- energy consumption 94 %,
- waste management 4 %,
- water treatment 2 % and
- maintenance and cleaning 1 %.

94 % of the emissions belong to scope 2 category and 6 % to scope 3. Distribution is visible in Figure 9 below presented by kg CO2e/year.

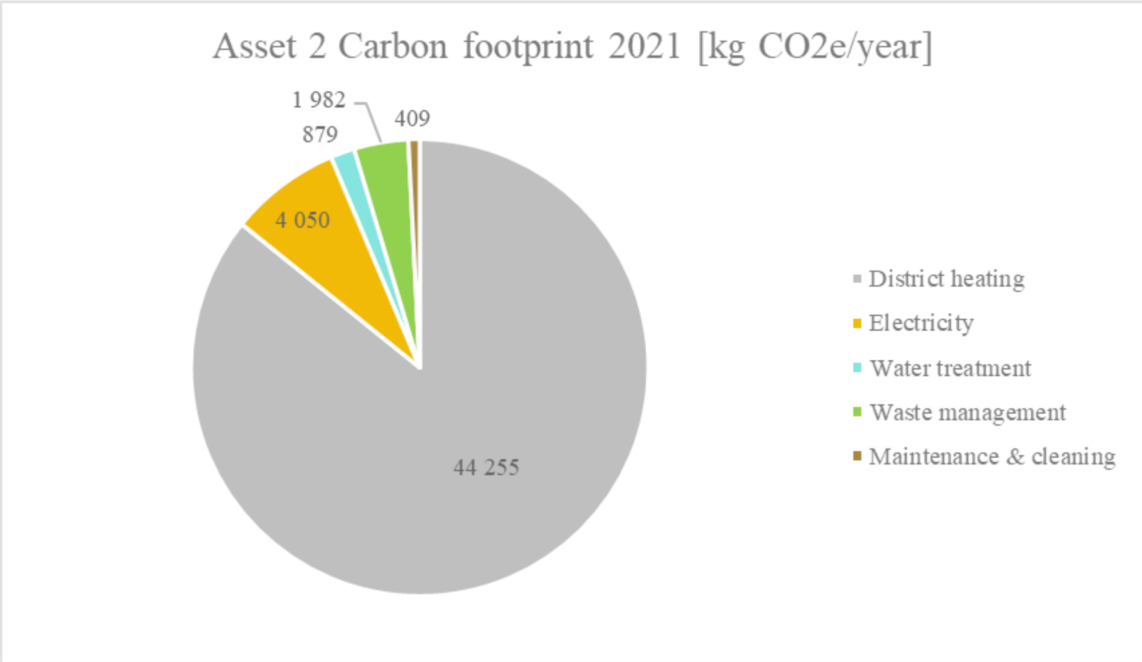

Figure 9. Carbon footprint of Asset 2

As district heating in Helsinki area has one of the highest emission coefficient at national level because of carbon intensive heat sources, results related to district heating are also calculated with the national average. Emission coefficient on the average was 0,102 kg CO2e/kWh in 2021.

Theoretical result for Asset 2 is total annual emission 33 982 kg CO2e and 16,3 kg CO2e/year/n-m². Even though figures seem quite similar, the theoretical emission is 35% less than the actual emission of 2021. As such, the local district heating production can be seen determinant. Recalculated, theoretical carbon footprint of Asset 2 is visible in Figure 10 below.

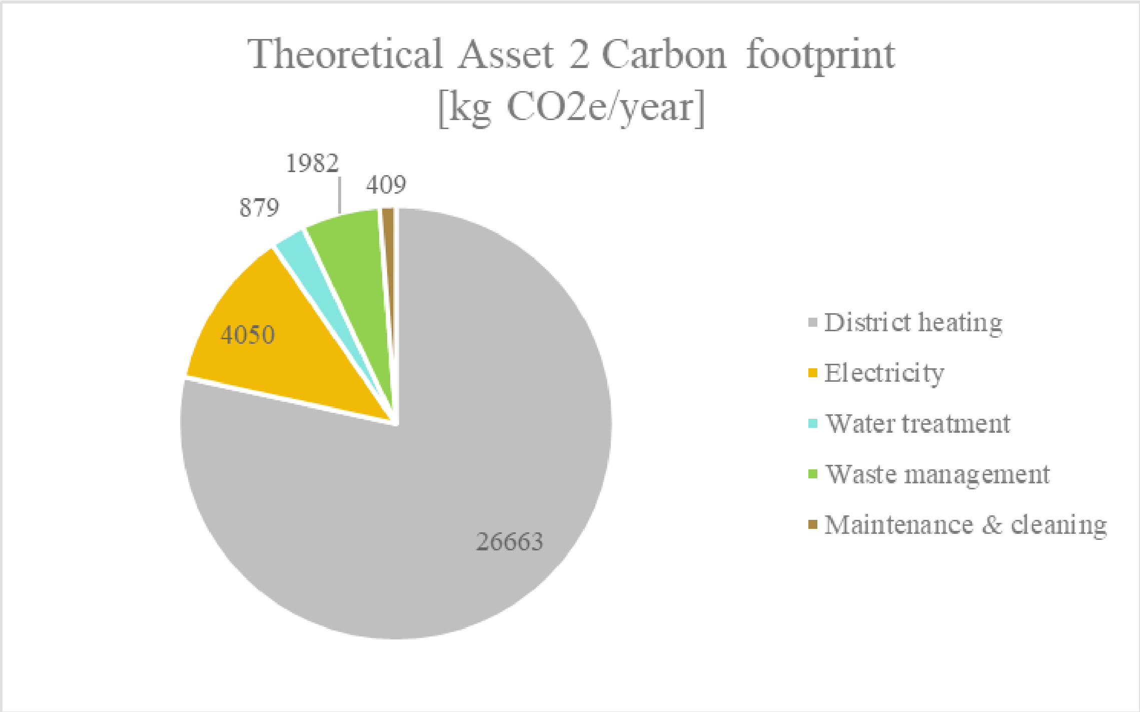

Figure 10. Theoretical carbon footprint of Asset 2

Energy used for space heating, hot domestic water production and electrical equipment and appliances within the communal areas of Asset 1 is all visible in category of electricity. Whereas energy used for space heating and production of hot domestic water is visible in category of district heating for Asset 2 and category of electricity covers all electricity used within the communal areas. The greatest difference and the most significant impact to the results between the case assets is related to heating energy systems and can be seen from Figure 11 below.

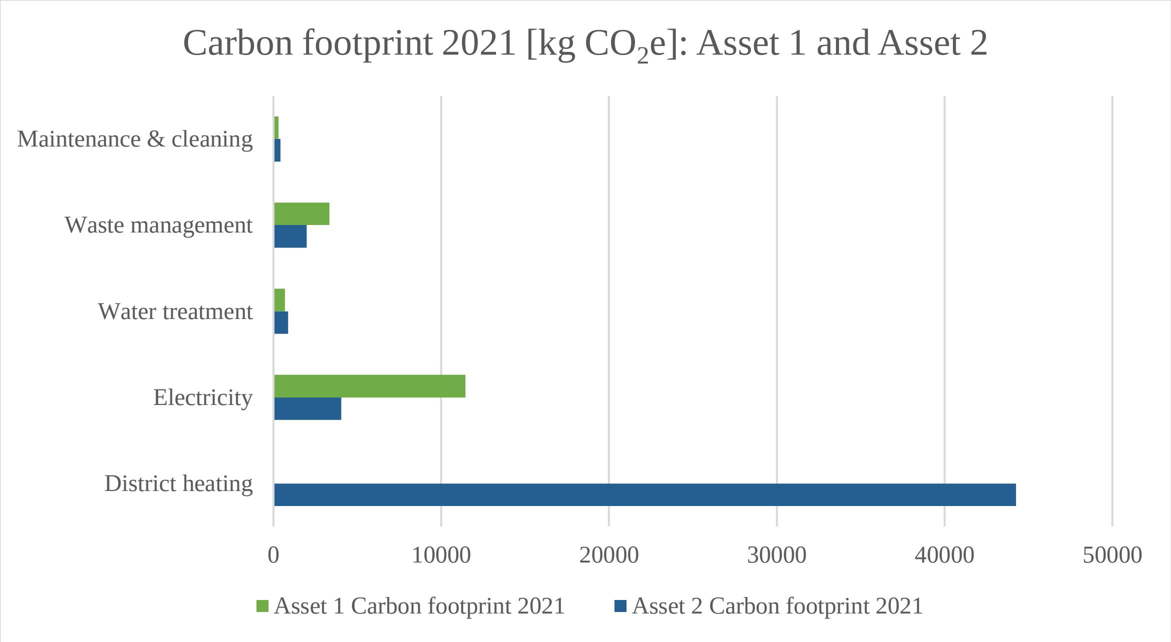

Figure 11. Comparison of carbon footprints between categories in kg CO2e

Whereas Asset 1 energy and scope 2 related total emission is 11 452 kg CO2e/year, the same emission of Asset 2 is 48 305 kg CO2e/year. As such, energy and scope 2 related emissions are more than four times higher for Asset 2 and is due to different heating systems. As ground source heat pump utilizes electricity to provide space heating and hot domestic water, the electricity usage and emission caused is nearly three times more than electricity emission for Asset 2. At the same time, Asset 2 district heating related emission is approximately 44 000 kg CO2e/year which is entirely avoided in Asset 1.

The overall results provide data for comparing the assets by the total emission generated within one year and could be turned into more practical description such as how many times could be travelled around the Globe with such amount of emission. Results which might be more comparable are obtained through emission generated per net square meter (n-m^2). These results are provided in Figure 12 below.

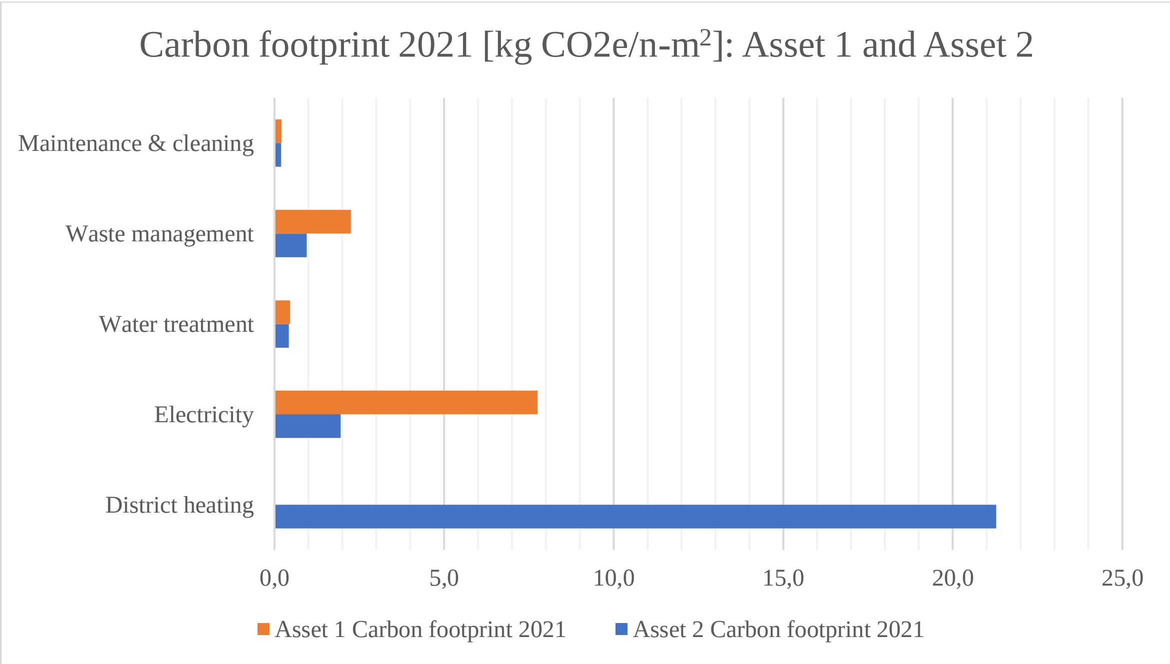

Figure 12. Comparison of carbon footprints between categories in kg CO2e/n-m²

Results per net square meter are 10,7 kg CO2e for Asset 1 and 24,8 kg CO2e for Asset 2. Whereas Asset 1 energy and scope 2 related emission is 7,8 kg CO2e/n-m², the same emission of Asset 2 is 23,2 kg CO_2e/n-m². Still, energy and scope 2 related emissions are significantly higher for Asset 2 being more than three times higher than in Asset 1. As water consumption is higher per resident in Asset 1 also water treatment emissions are higher when analysing by net area. Within other categories the weightings are quite similar whether the emissions are compared by the total results of by the result per n-m².

4.5 Potential to decrease the emissions

Greatest potential to reduce emissions can be found from the sources which causes most of the emissions. Actions to increase energy efficiency to decrease energy demand are the prior suggestions. As can be recognized from the initial of the two case assets, the energy use of purchased energy is significantly higher for the asset utilizing district heating than the asset utilizing geothermal heat source. Consumption numbers in 2021 were:

- Asset 1: electricity 91 618 kWh/year,
- Asset 2: electricity 32 400 kWh/year and district heating 261 400 kWh/year.

It should be noted that Asset 1 total consumption of purchased energy was 277 706 kWh at an annual level before the heat source of district heating was replaced with ground source heat pump. If compared to the latest annual consumption report in which consumption of purchased energy was 91 618 kWh, the energy demand of purchased energy decreased 67 % by the heat energy system renewal. The conclusion is rough and for example excludes annual temperature differences and possible energy efficiency improvements made. Nevertheless, it is obvious that demand of purchased energy would decrease significantly and when utilizing renewable heat source, the energy related emissions for the most part would be avoided.

As one ambition of the study is to encourage all housing companies to participate to act against climate change, it is relevant to identify reduction potential also for the minor factors. In addition to large renovations, also minor improvements should be supported to decrease energy consumption. Adjustment of heating network can save up to 10-15 % of the heat energy demand (Motiva 2022b) and there is potential to save 5 % heat energy if indoor air temperature is adjusted to one degree Celsius lower than normal (Motiva 2023).

Also, residents should be involved to participate. This can especially be done via water use and waste management encouragements. Usage of hot water consumes energy and can be seen as a potential for improvement. According to the water usage studies, 113 litres/day/person is the nowadays average consumption. As such, the residents are encouraged to decrease the amount of water below the average to around 100 litres/day/person. Regarding waste composition as described in section 3.5.3, most of the mixed waste generated is recyclable and includes a potential amount of biowaste, paper, plastic, cardboard, glass and metal. According to the national targets the case assets are set a target to improve recycling by segregating recyclable materials 50 % from mixed waste.

As such, potential improvements suggested for Asset 1:

- 30 litres less water per day per resident,
- activate residents to increase recycling by segregating 50 % of recyclables from mixed waste,
- maintenance and internal cleaning services use only electric vehicles for commuting.

With these suggestions, Asset 1 could reduce its carbon footprint by 20 % from 15 766 kg CO_2e to 12 596 kg CO_2e and comparably from 10,7 kg CO_2e/ n-m² to 8,5 kg CO_2e/ n-m². Results are visible in Figure 13 below.

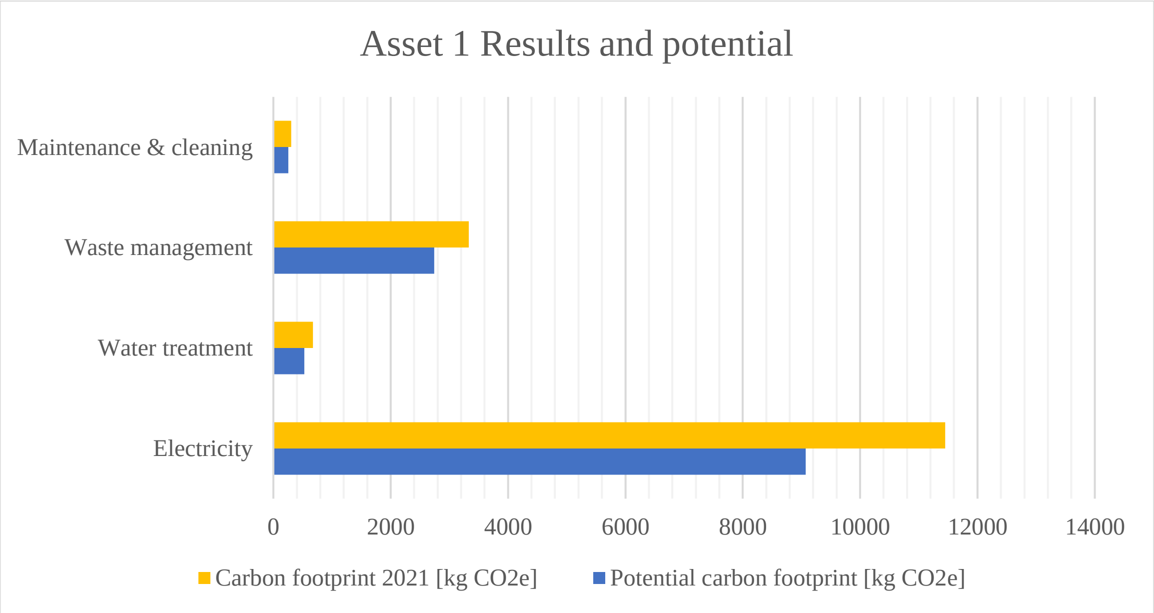

Figure 13. Asset 1 carbon footprint potential

Improvement potential suggested for Asset 2:

- adjustment of heating network which is assumed to save 10 % of the heat energy demand,
- 1 Celsius degree lower indoor air temperatures which is assumed to save 5 % of the heat energy demand,

- activation of residents to consume 10 litres less water per day,
- activate residents to increase recycling by segregating 50 % of recyclables from mixed waste,
- maintenance and internal cleaning services use only electric vehicles for commuting.

With these suggestions, Asset 2 could reduce its carbon footprint by 22 % from 51 574 kg CO_2e to 40 258 kg CO_2e and comparably from 24,8 kg CO_2e/ n-m² to 21,8 kg CO_2e/ n-m². Results are visible in Figure 14 below.

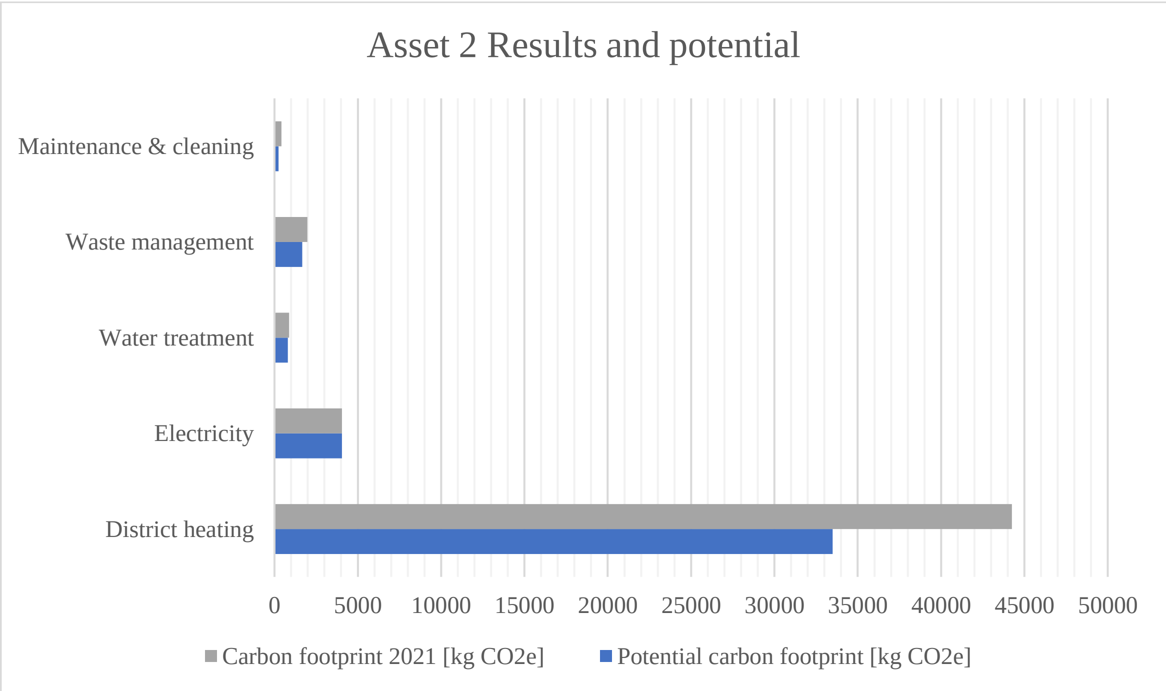

Figure 14. Asset 2 carbon footprint potential

Regarding Asset 2, district heating related emissions vary according to the location of the asset and how local district heat is produced as described in section 3.5.1. More effortless and faster way to reduce heating energy related emission or even adjust it to zero is to procure green district heat. This is usually offered at an additional cost by district heating operators. As an example, by Helen in Helsinki area and Alva operating in City of Jyväskylä in the central area of Finland offer zero emission district heat.

In any case, without improvements the emission of district heating for the case asset is most likely to decrease. The district heating operator Helen is working towards emission reductions (Helen 2022b) which will straightforwardly have an impact to the emission coefficient.

5 Conclusions

The intent of this thesis was to define an operational carbon footprint for a Finnish housing company covering scopes 1-3 according to GHG Protocol in an annual basis. In addition, aim was to provide potential improvement measures to generate an impact to decrease the emissions. One key target was to define scope 3 category emissions by excluding the financial perspective which is often used in similar cases but instead of reveal emissions based on the actual emission.

Two existing apartment buildings were received from a collaborator to carry out the study. Results of the case assets reveal that carbon footprint of these apartments buildings have the most significant impact from its heat source. Carbon footprint of an asset utilizing ground source heat pump is 15 766 kg CO_2e/year and 10,7 kg CO_2e/n-m^2/year while carbon footprint of an asset with district heating energy system is 51 574 kg CO_2e/year and 24,8 kg CO_2e/n-m^2/year. Case assets are both located in Helsinki.

Results present the emissions generated at an annual basis and are based on operational energy and water use, waste amounts in addition to maintenance and cleaning services in 2021. Correspondingly district heating emission coefficient of 2021 was used and emission coefficient of a past five-year average in Finland for electricity production was used.

It is important to recognise that district heating production in Helsinki is based on fossil fuels and has one of the highest local emission coefficient at national level. If the case asset with district heating system would have been located in some of the neighbour municipalities in which district heat is produced from less carbon intensive sources the result would have been significantly smaller. Likewise, energy related emissions would have been significantly different if the case assets would purchase their energy use, electricity and district heating when applicable, from renewable sources. If emissions from these sources would have been lower, other relevant emission sources would have stood out.

General ambition of the district heating operators is to reduce the emissions and generate heat from renewable sources. Carbon footprint of the case asset is most likely decreasing with no actions or improvements made. Nevertheless, it is relatively important to improve energy efficiency and to identify essential energy losses. Energy demand is to increase worldwide, and unnecessary use is to be avoided.

Main improvement potential is found from changing the heat source. If district heat is replaced with local heating system based on heat pumps a significant energy reduction could be achieved but not included in this assessment. Other than that, smaller scale improvements can be generated, for example, from adjustment and balancing of the heating network, reduction of hot water use for example through low water consuming taps and showers in addition to reduction of indoor air temperatures in storage areas and hallways.

It would also be important to encourage the residents to participate into the mitigation of climate change. With decreasing water use through efficient and appropriate consumption and by improving waste recycling and segregation, significant contribution to energy efficiency, water use and circular economy can be made at national level.

What comes to waste management, the data available varies between municipalities and between case assets. While some assets are able to provide exact waste amounts, most of the data is based on estimated averages of kilograms or at its most inaccurate the data is a waste bill in which waste bin sizes and collection frequencies are provided. As such the waste amounts for some cases are based only on averages.

According to the results achieved, the impact of waste management can be up to 20 % of the total result. Amount of segregated paper was missing for both of the case assets and Asset 1 could not provide information about metal and glass segregation. As a result, due to the lack of information the results are not seen significantly different to results with proper data from paper, metal and glass but is somehow inaccurate. Generally, waste reporting in all needs to be improved by the waste companies to provide more exact numbers also to their residential clients. At least more detailed calculation methods to attain more exact estimated should be found in future studies.

Impact of property maintenance was relatively low within both of the case assets covering only 1-2 % of the total emission. This can partly be explained by the nearby location of storage and offices of the maintenance companies. The actual work carried out within the site has relatively similar emissions regardless of the location but is more related to the solutions and yard area design of the site. Main difference in emission generation would occur from the distance travelled between the storage in which all equipment are stored and the asset. Especially in smaller cities and outside of the city centres the distances can be relatively longer than in case assets of this study. It would be interesting to find out the impact in such cases.

Unfortunately, within the case assets the impact of renovations could not be assessed. However, it can be concluded that all kind of renovations will have significant impact and some sort of carbon peak related to the emissions to the year in question. Within larger perspective it can se assumed that for example renovations related to energy system, building envelope tightness and other energy efficiency improvements will have impact to the results for the coming years. Direction of emissions can be assumed downward. This subject would need more detailed examination.

Recognising the improvement potential and how to decrease emissions is vital when activating and involving housing companies into emission reductions. Other important viewpoints could be found through carbon handprint assessments. Carbon handprint is to measure the positive impacts which housing company could generate for example to the residents or to the community.

Generally, carbon handprint would increase the carbon footprint of a housing company but would generate emission reduction elsewhere. As an example, by providing electric car recharging stations, carbon footprint of a resident related to commuting would assumably decrease, if the resident would invest in an electric car and use it to one's travel instead of traditional fossil-fuel powered passenger car. On the other hand, the charging point itself and probably the electricity used would increase carbon footprint of a housing company. However, the positive impact is generated through emission reduction of others. Solar power utilization through photovoltaic panels could be assessed similarly. If the electricity generated is also used to cover the electricity demand of residents or sold to the communal electricity network, emissions are avoided elsewhere. Possibilities of carbon handprint should be examined in more detail to find improvement potential on a larger scale.

It should also be noted that the age of the building does not define the technical condition nor the level of carbon emissions of the asset. The results are more impacted on the general upkeep and maintenance and especially larger renovations made. As the case assets reveal, the asset constructed in the 1960's seems more energy efficient and less carbon intensive than the other asset constructed in 2005. The main difference between the case assets is large energy renovation made in which district heating system was replaced with local renewable energy production. Similar kind of more extensive renovations can be seen to lift up the existence of a building. Result of an asset from the 60s without heating system renovation can be predicted to very different than the case asset in this thesis in question.

With annual carbon footprint housing company can identify its carbon intensive activities. Minor and major potential improvements suggested to decrease the emissions should activate housing companies to participate into the national emission reductions. This could be done, for example, by monitoring level of carbon footprint annually, including low-carbon solutions into asset's long-term plan of future maintenance and by setting up selection criterion for service providers related to environmental aspects.

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