



CHALMERS
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Governing Transitions in Transport Electrification

A Mixed Methods Study of Gothenburg City's Electrification
Plan's Potential to Achieve Climate Targets

Master's thesis in Industrial Ecology

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ABSTRACT

Gothenburg City's Electrification Plan is a plan developed to control and guide the transition towards an electrified transport system within Gothenburg. The plan consists of five goals, where the first three goals have quantitative targets, while the last two focus on creating prerequisites for electrification. This report evaluates the plan's potential for reducing emissions and identifies areas that require more effort. The evaluation includes a literature review, data collection, and calculations based on one current and two future scenarios. In addition, a workshop was held to discuss the transition, and the backcasting method was used to analyze and develop a strategy.

The result from the plan evaluation demonstrated major problems with data follow-up, where the largest data gap was for Gothenburg City's purchased transportations. Hence, calculation on potential emission reduction could only be performed on Gothenburg City's vehicle fleet (goal 1) and the public transportation (goal 3), excluding the purchased transportations (goal 2). Based on two future scenarios, and Scope 3 in the Greenhouse Gas Protocol, the emission levels from Gothenburg City in 2030 would either increase by 50% or reduce by 62% compared to the current state. Further, national and international emission targets include territorial emissions, meaning Scope 1. Including territorial emissions and Scope 1 resulted instead in an emission reduction of 100%. However, for Gothenburg to achieve the 90% target, it will be fundamental to focus on the private and commercial transport sectors.

The workshop and backcasting resulted in four leverage points to emphasize in future actions. The stakeholders stated that digitalization, central management, resources, and behavioral changes are required to overcome transformative barriers and succeed with the transition. We recommend that actions within these aspects should be prioritized, and the focus should be to make a big difference with small changes. In terms of electrification, vehicles with an electric option should be prioritized (e.g., light vehicles), while vehicles that lacks electric options should be deprioritized (e.g., heavy machinery). However, this can only last for a short period of time, and it is still important to demand new electric options. If an electric vehicle is not available, biofuel is recommended as the second-best option.

Keywords: Urban transport system, electrification, emission, emission reduction, climate calculations, emission targets, backcasting, Greenhouse Gas Protocol

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Julia Ekander & Johanna Täuber, Gothenburg, May 2023

ACRONYMS

BRG - Business Region Göteborg
BEV - Battery electric vehicle
CO₂- Carbon dioxide
CO₂e - Carbon dioxide equivalents
DP - Development Pathways
EF - Emission factor
ERO - Emission Reduction Obligation
GHG - Greenhouse Gases
GCL - Gothenburg City Leasing Company
Gothenburg City - The organization “Göteborg Stad”
Gothenburg - The city “Göteborg”
ICEV - Internal combustion engine vehicle
MaaS – Mobility as a Service
PHEV - Plug-in hybrid electric vehicle

TABLE OF CONTENT

1. INTRODUCTION.....	1
1.1 AIM	2
1.2 RESEARCH QUESTION	2
1.3 ETHICAL ASPECTS.....	2
1.4 SCOPE AND DELIMITATIONS	2
2. BACKGROUND.....	4
2.1 GOTHENBURG AND GOTHENBURG CITY.....	4
2.2 GOTHENBURG CITY’S ELECTRIFICATION PLAN	6
2.3 EMISSION TARGETS	8
2.3.1 Local emission targets.....	9
2.3.2 National emission targets.....	9
2.3.3 EU emissions targets.....	9
2.3.4 Global emission targets.....	10
3. METHOD.....	11
3.1 BACKGROUND RESEARCH	12
3.2 DATA COLLECTION	12
3.2.1 Clustering of vehicles.....	12
3.3 CALCULATIONS	13
3.3.1 Framework for the calculations.....	13
3.3.2 Future emission scenarios.....	14
3.3.3. Emissions.....	15
3.3.4 Energy content.....	16
3.3.5 Energy consumption - for goal 1	17
3.3.6 Milage or usage per vehicle - for goal 1	19
3.3.7 Volume of fuel - for goal 3	20
3.3.8 Emission factors.....	20
3.4 WORKSHOP	21
3.4.1 Part 1 - Data gap discussion.....	22
3.4.2 Part 2 - World Café	22
3.5 ANALYSIS	24
3.5.1 Requirements in goal 2.....	24
3.5.2 Goal Alignment.....	24
3.5.3 Sensitivity analysis.....	24
3.5.4 Backcasting.....	25
4. CALCULATION RESULTS & ANALYSIS	27
4.1 GOAL 1 - GOTHENBURG CITY’S OWN VEHICLE FLEET	27
4.2 GOAL 2 - TRANSPORTATION GENERATED BY GOTHENBURG CITY’S PURCHASES.....	30
4.2.1 Requirements on procurements.....	30
4.3 GOAL 3 – PUBLIC TRANSPORTATION	34
4.4 COMBINED FUTURE EMISSIONS	35
4.5 GOAL ALIGNMENT	36
4.5.1 Local emission target.....	36
4.5.2 National, European, and global emissions targets.....	38
4.6 SENSITIVITY ANALYSIS	38
5. WORKSHOP RESULT.....	41

5.1 DATA GAP	41
5.2 DEVELOPMENT PATH 1.....	42
5.3 DEVELOPMENT PATH 2.....	43
5.4 DEVELOPMENT PATH 3.....	44
5.5 PARKING SPACE	45
6. BACKCASTING	46
6.1 STEP 1 - DESIRABLE FUTURE	46
6.2 STEP 2 - GAPS.....	46
6.3 STEP 3 - LEVERAGE POINTS.....	47
6.4 STEP 4 - STRATEGIES	49
7. DISCUSSION.....	50
7.1 ACHIEVING A BIGGER EMISSION REDUCTION	50
7.2 THE CREDIBILITY OF THE ELECTRIFICATION PLAN.....	51
7.3 TRADE-OFFS IN PUBLIC TRANSPORTATION	52
7.4 RECOMMENDATIONS AND FURTHER RESEARCH.....	52
8. CONCLUSION	55
REFERENCES.....	I
A. APPENDIX	V
A.1 GOALS WITHIN GOTHENBURG CITY’S ELECTRIFICATION PLAN	V

1. INTRODUCTION

Today's society faces several sustainability problems, climate change being one of them. Sustainability problems are caused by many interconnected and complex systems (Voulvoulis et al., 2022), where the transportation system is one system interconnected to a larger system. This makes it difficult to change things because there are strong economic, social, and psychological reasons that keep the systems the way they are today.

To mitigate climate change, emission of greenhouse gases and use of fossil fuels must decrease drastically. According to Sveriges Miljömål (2022b), the transport sector uses a large share of these fossil fuels, and hence, electrification of the transport sector is one way to overcome the lock-in on fossil fuels. To succeed with this transition, one needs to consider how an electrified transport system interacts with the urban environment and other functions within the city. It is crucial to adopt a holistic and systems-thinking approach to identify and address the underlying root causes of unsustainability, rather than merely treating its symptoms (Voulvoulis et al., 2022).

By 2045, Sweden intends to achieve net zero greenhouse gas emissions, and has developed an emission target for reducing the greenhouse gas emissions from the transport system with 70% until 2030, compared to 2010 year's emission levels (Sveriges Miljömål, 2022b). In line with the national target, Gothenburg City has developed The Environment and Climate Program, including a more ambitious target for the transport sector with a 90% emission reduction between 2010 and 2030 (Göteborg Stad, 2022b). This program is followed by different action plans, such as Gothenburg City's Electrification Plan. However, the 90%-target does not only account for electrification, but it also covers aspects such as renewable fuels, transport efficiency, and technology improvements.

Gothenburg City's Electrification Plan is developed by Business Region Göteborg (BRG) on behalf of Gothenburg City. It covers the electrification of Gothenburg City's own vehicle fleet, public transportation, transports generated by Gothenburg City's purchases, and measures required to support Gothenburg's inhabitants to choose electrified transports (Göteborg Stad, 2022a). Even though Gothenburg City has set some ambitious goals for electrification, there is an uncertainty how far these goals will reach in relation to the overall emission target.

This project examines the potential of Gothenburg City's Electrification Plan in terms of emission reduction and what measures ought to be implemented in order to achieve a sustainable electrified transport system. This will be covered by calculations on expected emission reduction for each goal within the plan, followed by a workshop involving stakeholders from Gothenburg City. The outcome from these two parts is analyzed through a backcasting process to develop a strategy for the continuous work on electrification.

The structure of the report appears as follows: a background section introduces Gothenburg City, the Electrification Plan, and emission targets related to the transport system. Further, the methods used for data collection, calculations, workshop, and the analysis are presented in a method chapter. Chapter four presents the results and analysis of the calculation for each goal, including goal alignment and a sensitivity analysis. This is followed by two chapters presenting the outcome from the workshop and the backcasting analysis. The report ends with a discussion on further research and a conclusion.

1.1 Aim

The aim of the project is to evaluate the targets within Gothenburg City's Electrification Plan in terms of emission reduction and their interplay with local, national, European, and global emission targets. Further, the aim is to analyze how the work should proceed in order to achieve a sustainable electrified transport system.

1.2 Research question

This project will discuss and answer the following research questions:

- How big is the emission reduction potential with the current targets in Gothenburg City's Electrification Plan, compared to the current emission levels?
- Is Gothenburg City's Electrification Plan in line with local, national, European, and global emission targets?
- How can Gothenburg City and its organizations continue to work with the Electrification Plan to overcome the transformative barriers that hinder the transition?
 - What actions should be prioritized with respect to emission reduction and effort?

1.3 Ethical aspects

It is important to consider ethical aspects that concern the process behind this project. Firstly, several ethical aspects are considered regarding data management, where all data is managed according to the General Data Protection Regulation (GDPR) (<https://gdpr.eu>). When data is collected from organizations within Gothenburg City, all organizations are informed that it will be used to calculate Gothenburg City's overall emissions from its transportations. Hence, this report does not present data connected to each organization, or state from which employee the data was received.

If we receive information that is not purely data-based, we opt to refer to the individual by the name of their organization rather than by their personal name. This is particularly important during dialogues and in the workshop, where one or more individuals are representing the entire organization rather than themselves.

Secondly, the foundation of this project is based on an inquiry from Business Region Göteborg (BRG) where they requested an evaluation of Gothenburg City's Electrification Plan. BRG developed the Electrification Plan on behalf of Gothenburg City, and this project is done in collaboration with them. Consequently, BRG can influence the direction in which the project is developed, as well as its primary focus. However, to compensate for their biased influence, the project is also under supervision from researchers at Chalmers University of Technology (<https://www.chalmers.se>).

1.4 Scope and delimitations

Gothenburg City's Electrification Plan considers electrification to be both fully electric and hydrogen-powered vehicles. Further, no secondary effects are considered within the project. As an example, reduced traffic flows within the private sector due to increased public transportation are not taken into account. The project also excludes all economic aspects of the transition, where the cost for implementing different actions is out of scope. However, some economic aspects will be discussed in the analysis, but not calculated on.

The scope for the project is related to the boundaries within Gothenburg City's Electrification Plan (Göteborg Stad, 2022a). The emission reduction calculations focus specifically on the transportation that Gothenburg City has direct control over, which includes their own vehicle fleet, public transportation, and transportation generated by Gothenburg City's purchases. Hence, emissions from the remaining transport sector, such as private and commercial road traffic, shipping, train traffic and boat traffic, are not included in the scope of this project. Calculations on emission reduction are conducted between the years 2023-2030. Further, the geographical boundaries are limited to Gothenburg, but it is important to be aware that the transport system also covers some parts of Gothenburg Region (i.e., 13 surrounding municipalities). As for the public transportation, the regional buses are covered by the Electrification Plan, and hence included in this project.

The project is also limited to emissions generated from the life cycle of consumed fuels and electricity. Hence, emissions connected to the vehicles themselves are not included in the study.

The intended audience are stakeholders within Gothenburg and Gothenburg City with a direct interest in the electrification transition, i.e., people affected by the Electrification Plan. Moreover, other cities facing similar challenges can also leverage insights into the potential of electrification, and this project can serve as a resource for political decision-making.

2. BACKGROUND

The following section initially describes Gothenburg and Gothenburg City. Gothenburg refers to the whole city, while Gothenburg City refers to the municipal organization consisting of administrations, municipal associations, and municipal companies. Further, the Electrification Plan and its goals and subgoals are shortly summarized, followed by a section on local, national, European, and global emission targets related to the transport system.

2.1 Gothenburg and Gothenburg City

Gothenburg, situated in the Västra Götaland county, is the second largest city in Sweden with a population of nearly 600,000. Its population is increasing at a rate of around 2.7% per year (Ny kommun, 2023). As one of the 13 municipalities that form the Gothenburg Region, Gothenburg has been selected as one of Europe's 100 climate-neutral cities, given the task of leading the transition to sustainability in Europe (Göteborg Stad, n.d.b).

The City Management Office (Stadsledningskontoret), acting on behalf of the municipal management, is responsible for coordinating, leading, and monitoring activities within Gothenburg City (Göteborg Stad, n.d.a). Gothenburg City is the municipal organization, including several administrations, municipal associations, and municipal companies (förvaltningar, kommunalförbund och kommunala bolag), see Figure 1. The administrations have responsibilities for activities that cover the entire city, including traffic, education, health care, and infrastructure. Municipal associations include emergency services, interpretation services and coordination associations. Lastly, the municipal companies are owned by Göteborg Stadshus AB and they are responsible for certain activities such as cultural experiences and premises. However, to simplify the terminology within this project, administrations, associations, and companies fit under the term organizations.

All organizations participating in this project are presented in Figures 2 and 3. However, there are more organizations within Gothenburg City that are not included in the Figures. The ones participating either use, have control over, or are responsible for mobility and the transportation sector in Gothenburg City. It is important to note that the public transport company Västtrafik is not a part of Gothenburg City, and hence, not included in the Figures. However, they are a part of the Gothenburg Region and responsible for the public transport, and consequently, included in the Electrification Plan.

Figure 1. Organizational structure within Gothenburg City

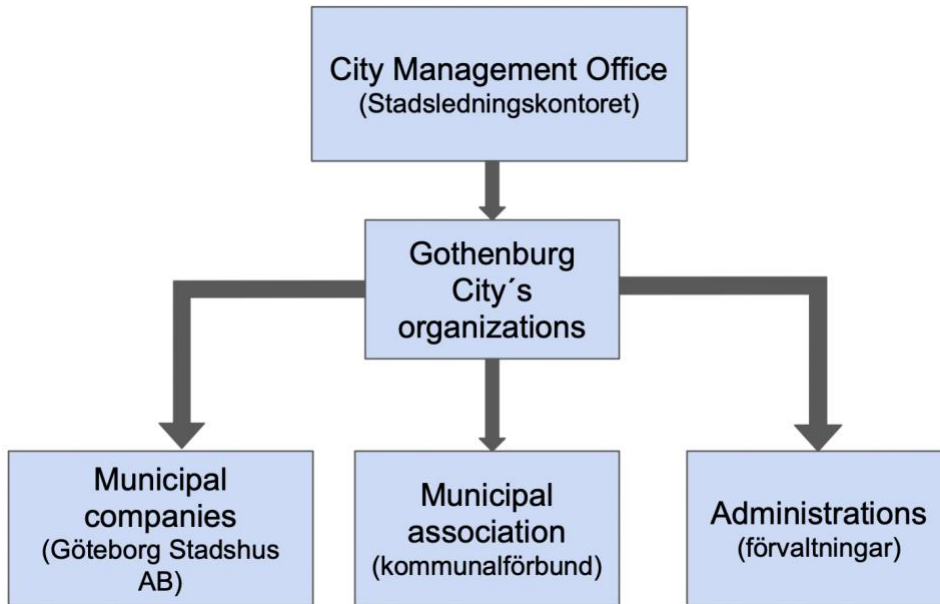
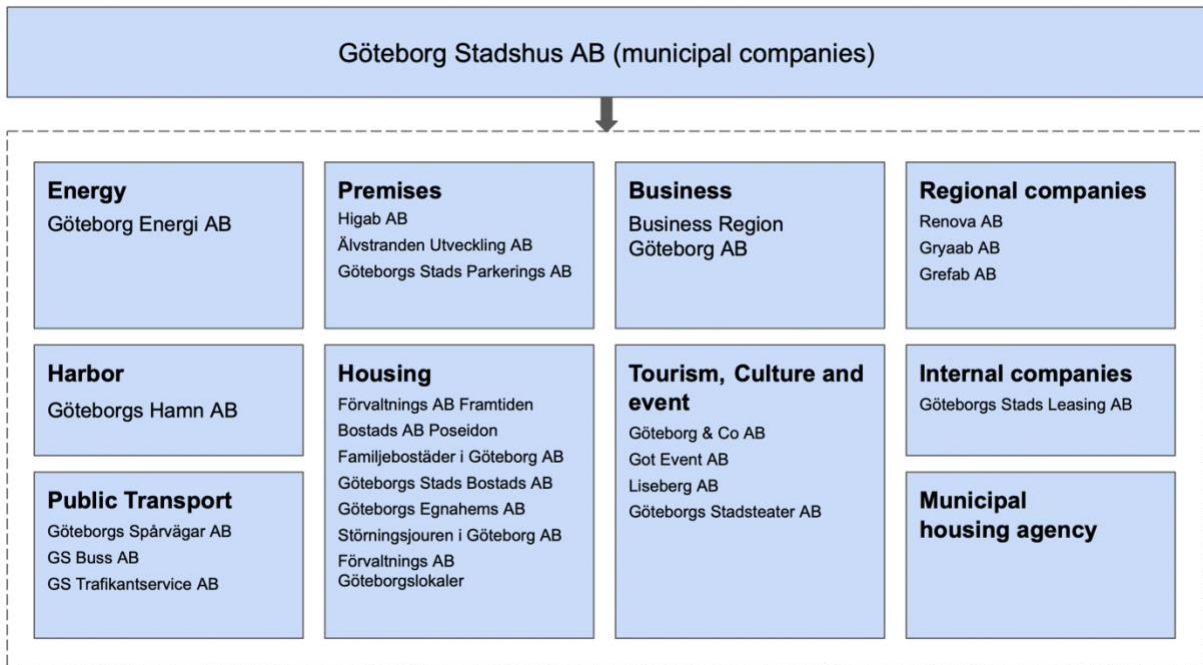
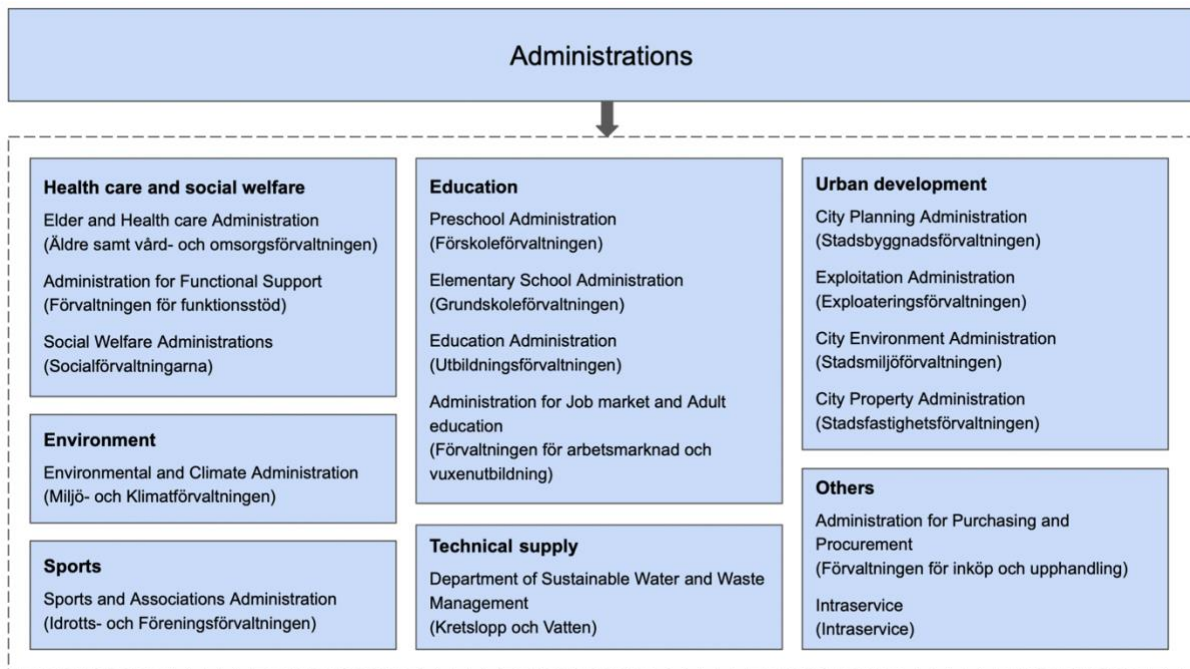


Figure 2. The municipal organizations under Göteborgs Stadshus AB that are participating in this project.



Note: Adapted from Göteborg Stad (n.d.a) and translated by the authors.

Figure 3. The administrations within Gothenburg City that are participating in this project.



Note: Adapted from Göteborg Stad (n.d.a) and translated by the authors.

2.2 Gothenburg City's Electrification Plan

A transportation system based on fossil resources will contribute to noise pollution, degraded air quality and emissions (Göteborg Stad, 2022a). Hence, Gothenburg City has developed an Electrification Plan to ensure that the transition towards an electrified transport system meets the challenges within today's society. In relation to the transition towards an electrified transport system, new infrastructure in Gothenburg will have to be developed. The demand for secure energy supply, land use, and new services means a more comprehensive system with changed roles, behaviors, and dependencies.

The Electrification Plan applies from the year 2022 to 2030, and all Gothenburg City organizations that function as transport execution are included (Göteborg Stad, 2022a). It covers both their own transport, public transportation, transportations generated by their purchases, and measures required to support Gothenburg's inhabitants to choose electrified transports.

The Electrification Plan presents goals and structures that aim to create the best conditions for reaching the climate goals related to the transport system described in The Environment and Climate Program. Further, the Electrification Plan consists of 5 goals divided into several subgoals with different types of indicators (Göteborg Stad, 2022a). To decrease the complexity of the system, the Electrification Plan has defined 11 function areas, each related to some of the goals and subgoals. This division facilitates concrete and specific goals and enables follow-ups for the actions.

The function areas aim to simplify the management of activities and objectives from an operational level. Each area represents a key aspect for the transition and has a connection to the operations of Gothenburg City's organizations. In Table 1, the 11 function areas are listed and briefly described. Furthermore, Table 2, presents the 5 goals and their related functional areas. Goal 1 covers Gothenburg City's vehicle fleet and the subgoals vary between 30-70% electric or hydrogen powered vehicles. Goal

2 covers transportation generated by Gothenburg City’s purchases, and the subgoals vary between 30-100% electric or hydrogen powered vehicles. Goal 3 covers public transportation, and its target is set to 100% electric vehicles by 2025. Further, goal 4 and goal 5 encompass charging and hydrogen infrastructure for the public, where the subgoals state a 95% satisfaction rate for experience of charging possibilities. See Appendix A.1 for a more detailed presentation of the goals, including the subgoals and indicators.

Table 1. Function areas presented in Gothenburg City’s Electrification Plan, including short descriptions.

Function area	Name	Description
1	Gothenburg City’s own light vehicle fleet	Includes vehicles lighter than 3.5 metric tons
2	Gothenburg City’s own heavy vehicle fleet and machine park	Includes vehicles heavier than 3.5 metric tons and all machinery
3	Gothenburg City's purchased goods and service transport	Covers both direct and indirect transport. Direct transport refers to the transport that is separately purchased, while indirect transport occurs when the transport service is included in the purchase of a good or service.
4	Gothenburg City's purchased passenger transport	Includes taxis, school transport and other taxi and bus transport purchased by Gothenburg City.
5	Gothenburg City's purchased contracting works and associated transport	Includes transport associated with construction, operation, and maintenance of infrastructure.
6	Emission-free public transport – bus and ferry services	Includes all public transports owned by Västtrafik, such as busses, trams, and ferries.
7	Electric vehicle charging for residents, public businesses, and business economy	Includes actions to increase the charging possibilities within the city, as well as charging stations for electric carpools.
8	Electric vehicle charging for visitors and the hospitality industry	Includes actions to increase charging possibilities at attraction locations, to make Gothenburg a better visitor destination.
9	Maritime transport and leisure boats	Includes actions to electrify certain parts of the transport chain by e.g., connecting ships to shore electricity and developing the charging infrastructure in the harbor.

10	Charging for heavy vehicles	Includes action to accelerate the transition to electric and hydrogen heavy vehicles by creating opportunities for charging stations.
11	Energy supply	Includes actions to ensure that the capacity within the local and regional power grid can meet the demand without disruption, as well as offer charging stations.

Table 2. Goals presented in Gothenburg City’s Electrification Plan and its connected function areas.

Goal	Definition	Functional area
1	Increase the proportion of fully electric and hydrogen-powered vehicles in Gothenburg City’s own vehicle fleet and machine park.	1 and 2
2	Increase the proportion of fully electric and hydrogen-powered transports generated by Gothenburg City’s purchases	3, 4 and 5
3	Increase the proportion of full-electric or hydrogen-powered transport in public transport	6
4	Good availability of charging options with regard for the demand	7, 8, 9 and 10
5	Sufficient supply of renewable energy for the electrified transport system	11

2.3 Emission targets

The ambitious goals presented in Gothenburg City’s Electrification Plan are based on other emission-related targets on a local, national, European, and global scale. It becomes obvious that the local emission targets are the most ambitious, followed by the national targets. The national targets are based on the European targets, which are even less ambitious. Further, the global emission targets do not present any numbers on emission reduction since they are broader and adaptable to different types of regions. A short overview of the targets is presented in Table 3. To give a further indication on the ambition level, the different targets related to sustainable transportation are presented in more detail below.

Table 3. Summary of local, national, European, and global emissions targets

	GHG emission reduction targets for 2030	Comparison year
Local (Gothenburg)	90%	2010
National (Sweden)	70%	2010
European	55%	1990
Global	-	-

2.3.1 Local emission targets

The Environment and Climate Program for Gothenburg City is a program for the sustainability transition, and it is followed by different action plans, such as Gothenburg City's Electrification Plan (Göteborg Stad, 2022b). The Environment and Climate Program strives to achieve an ecologically sustainable city by 2030. To accomplish this, the program has established three environmental action goals: (i) climate, (ii) nature, and (iii) humans. Comparing the Electrification Plan with the climate action goal, it can be seen that it relates to subgoals 2-4.

- Subgoal 2 mandates that Gothenburg should only generate energy from renewable resources, and it should be achieved by the year 2025.
- Subgoal 3 specifies that Gothenburg should decrease its environmental impact from transportation. Three targets are defined: (i) Gothenburg City's vehicle fleet should be 100% fossil-free in 2023, (ii) the GHG emissions from transportation should be reduced by 90% until 2030 compared to 2010, and (iii) the traffic flows should be reduced by 25% in 2030, compared to 2020.
- Subgoal 4 pertains to the climate impact from purchases made by Gothenburg City. The target includes a reduction in GHG emissions by 30% for food and 90% for building, facilities, and other purchased items, in 2030 compared to 2020 (Göteborg Stad, 2022b).

2.3.2 National emission targets

Sweden has developed 16 environmental objectives that outline the desired targets to be achieved (Sveriges Miljömål, 2022a). One of these objectives, Limited Environmental Impact, aims to significantly reduce greenhouse gas (GHG) emissions in the environment. This objective comprises five specific targets, one of which pertains to the transport sector. As per this target, the GHG emissions originating from the transport sector must be reduced by 70% by 2030, relative to the emission levels recorded in 2010 (Sveriges Miljömål, 2022b). To accomplish this target, three action areas have been identified, namely (i) transportation efficiency enhancements, (ii) energy efficiency improvements, and (iii) replacement of fossil fuels with biofuels or electrification. Nevertheless, it is not stated how the reduction should be distributed between the three action areas, but rather that all action areas are required to achieve the target.

Further, Sweden has defined a net zero emission target for 2045 (Sveriges Miljömål, 2023). The goal is to achieve a reduction in GHG emissions for the entire society by no later than 2045. By this time, Sweden aims to have no net emissions of GHGs to the atmosphere and to subsequently achieve negative emissions. Complementary measures will be taken into account to reach net zero emissions. In addition, emissions from activities within Swedish territory should be at least 85 percent lower than they were in 1990 (Sveriges Miljömål, 2023).

2.3.3 EU emissions targets

The Green Deal is an action plan developed by the European Commission in 2020, where Europe aims to be the first climate neutral continent with net zero emissions by 2050 (European Commission, 2020). The Green Deal includes targets for several industries. Regarding the transport sector, the plan has three objectives: Sustainable Mobility, Smart Mobility and Resilient Mobility. Within Sustainable Mobility, the European Commission has set an overall emission target to reduce greenhouse gas emissions with

90% by 2050. Further, they have also set a target for 2030 which includes an emission reduction of 55% compared to 1990 (commonly known as the Fit for 55-target). To achieve these targets, the Green Deal presents actions for the transport sector concerning its dependence on fossil fuels, availability of alternatives, and pricing that reflect the environmental burden (European Commission, 2020).

In addition, the European Parliament has in February 2023 approved a ban on new petrol and diesel cars (European Parliament, 2023). This ban will apply from 2035, and it means that there will be no manufacturing and sale of new petrol and diesel cars, in order to achieve a climate neutral transport sector in 2050.

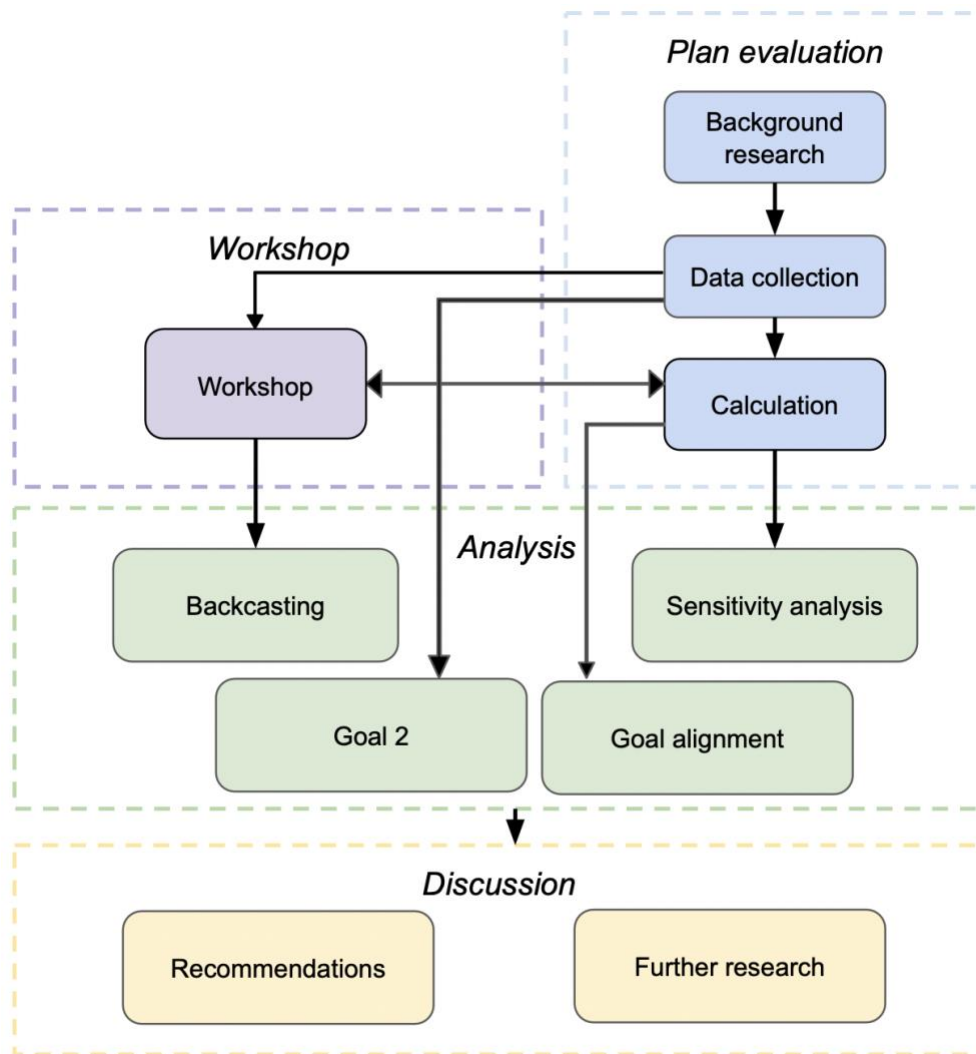
2.3.4 Global emission targets

There are two major climate agreements developed for the global sustainability transition. Firstly, the Paris Agreement states that the global temperature must be limited to below two degrees. However, because of the potentially severe consequences of a two-degree temperature increase, the aim is to limit the increase to 1.5 degrees. These temperature targets should be achieved by reducing the GHG emissions and enabling opportunities for climate adaptations (Globala Målen, 2022). Secondly, the Global Goals and Agenda 2030 is an ambitious agenda agreed upon by the world leaders. The agenda forms a joint plan for how to create a sustainable world by presenting 17 Sustainable Development Goals (SDGs) that should be achieved in 2030 (Globala Målen, n.d). The concept of the SDGs integrates three aspects of sustainability: (i) social, (ii) economic, and (iii) ecological. Within the ecological aspect, SDG 13 presents the urgent need for taking action to combat climate change and its impacts (Globala Målen, 2022).

3. METHOD

The methodology used in this project consists of three main parts, a plan evaluation, a workshop, and an analysis. This is followed by a discussion section. The structure, core steps and their relation are visualized in Figure 4. Initially, the project started with a plan evaluation including (i) background research on Gothenburg, Gothenburg City, the Electrification Plan and how it relates to local, national, EU and global emission targets, (ii) a data collection to give a foundation for the calculations, and (iii) calculations on GHG emissions. The calculations were done for both the current state and for two future scenarios. The second part considers the workshop, where several stakeholders involved in the Electrification Plan were brought together to improve collaboration and incorporate their perspective on the future work of electrification. Lastly, because of lack of data regarding purchased transportation in goal 2, an analysis of requirements on procurements has been conducted. This is followed by an analysis of goal alignment, a sensitivity analysis and a backcasting based on the results from the calculations and workshop.

Figure 4. Overview of the method used in the project



3.1 Background research

A literature review was conducted by looking deeply into the Electrification Plan and comprehending its boundaries and what it covers. A continuous dialogue with employees at BRG responsible for the Electrification Plan has developed throughout the work phase. Furthermore, to get a deeper understanding of the background system, it was investigated how the Electrification Plan is connected to local, national, EU and global emission goals. Research from various websites, reports and organizations was collected and supported by dialogues with organizations such as City Environment Administration (Stadsmiljöförvaltningen) and Environmental and Climate Administration (Miljöförvaltningen).

The literature review has hence been supported by dialogues with companies and stakeholders connected to future sustainable transport, using snowball sampling. Snowball sampling is a method for qualitative research, where stakeholders recommend other stakeholders to participate and to expand the network of knowledge (Parker et al., 2019). The initial contact with the City Environment Administration resulted in further contact with people with different expertise, as well as people working with different projects within The Environment and Climate Program. Consequently, the snowball sampling provided a wider perspective regarding how Gothenburg City works with the sustainability transition, and hence, helped to understand what role electrification will have for the transition.

3.2 Data collection

The data collection provided information concerning the following aspects:

- Vehicle quantity and fuel types for light vehicles, heavy vehicles and machinery owned by Gothenburg City
- Transportations generated by Gothenburg City's purchases
- Fuel consumption
- Mileage
- Vehicle quantity and fuel types used within public transportation.

The initial step was to identify which data could be obtained from which organization. The data collection was subsequently conducted by contacting organizations within Gothenburg City. By approaching the stakeholders involved with the electrification process, data has been obtained from the primary source. However, for the feasibility for the calculations, it was necessary to cluster the data and generalize.

3.2.1 Clustering of vehicles

The vehicles included in the Electrification Plan are classified into four distinct categories: light vehicles, heavy vehicles (including public transportation), light machinery and heavy machinery. The definition of a light vehicle pertains to vehicles weighing less than 3.5 metric tons, while heavy vehicles are those that weigh more than 3.5 metric tons. Light machinery contains machines such as rideable lawnmowers, sweepers, tractors, and trucks, while heavy machinery includes machines such as larger tractors, wheel loaders, excavators, and street sweepers. It should be noted that the category of light machinery excludes hand-operated machines such as leaf blowers and chain saws etc. Each of the four categories may utilize different engines and run on various fuels. The study encompasses the following

types:

- Diesel
- Petrol
- Hybrid (Petrol)
- Plug-in hybrid (Petrol/Electricity)
- Fully electric (Battery)
- HVO100
- Ethanol E85
- Vehicle gas (2% natural gas, 98% biogas)
- Biogas
- Hydrogen
- Hybrid buses (diesel & HVO100)
- Hybrid buses (HVO100 & FAME)

Note that vehicle gas is a Swedish name for the combination of natural gas and biogas that is most commonly used in light gas vehicles. According to Miljöfordon Sverige (n.d), the common proportion between biogas and natural gas used in Sweden is 2% natural gas and 98% biogas, making the fuel almost completely fossil-free.

3.3 Calculations

Calculation of GHG emissions generated from the vehicles and transportations included in the Electrification Plan was conducted for the current state and two future scenarios. The calculations were done for Gothenburg City vehicle fleet (goal 1) and the public transportation (goal 3). Due to lack of data on transportation generated by Gothenburg City's purchases (goal 2), no calculations could be performed on this. Further, the calculations were performed using the Greenhouse Gas Protocol standards (GHG protocol, n.d.). The following sections describe the Greenhouse Gas Protocol, the future scenarios, and how the calculations were performed including descriptions of the different parameters.

3.3.1 Framework for the calculations

The project utilizes the framework and standard values provided by the Greenhouse Gas Protocol, a guide for quantifying GHG emission reporting and reduction for both projects and organizations (GHG protocol, n.d.). In addition, the guide offers three scopes for organizations to select from. Scope 1 encompasses direct emissions, which would mean to only include direct emissions from all fuels, resulting in zero emissions from biofuels and electricity. Scope 2 involves direct emissions and a life-cycle perspective on electricity production, resulting in zero emissions from biofuels. Lastly, Scope 3 encompasses both direct and indirect emissions, meaning all emissions arising from any activity over the vehicle's lifespan, including vehicle and fuel production, material transportation, fossil fuel extraction etc. (GHG protocol, n.d.).

For this project, Scope 3 has been selected as the chosen scope, in order to provide an accurate analysis of emissions. However, the focus is limited to vehicle fuels, and any other activities related to production and end-of-life management of the vehicles are not included in the project. This implies that the calculations for emission reduction consider a life cycle perspective on fuels and electricity.

3.3.2 Future emission scenarios

To investigate the expected future emissions, two future scenarios were developed based on different traffic flows and electricity mixes. Table 4 presents the scenarios and their differences. The first scenario is considered to be a minimum emission scenario, where all parameters are expected to result in minimum emission levels. The second scenario on the other hand, represents a maximum emission scenario where the parameters are expected to result in maximum emission levels. It is important to be aware that the scenarios are not intended to represent realistic futures. They aim to demonstrate that the most likely outcome will result in an emission reduction somewhere between them.

As for the traffic flows, this parameter considers the number of trips carried out with vehicles. It was assumed that a reduced traffic flow will result in an equal reduced number of vehicles. The parameters for the minimum emission scenario were established based on a target to reduce traffic flows, whereas the parameters for maximum scenario were derived from a projected increase in traffic flow, based on historical trends. It should be noted that a larger traffic flow for public transportation will result in increased emissions for these calculations. This will, however, most likely reduce the traffic flows generated by the citizens, meaning that the overall emissions from Gothenburg's transportation system will be reduced. A deeper analysis of this aspect is not included in this project but is further discussed in section 7.3.

Further, emissions from electricity depend on the electricity mix used in the future. Based on a conversation with the public energy company Göteborg Energi AB (personal communication, March, 2023), the future can consist of either a Nordic electricity mix or a European electricity mix. The estimation on future emissions from each electricity mix in 2030 were based on the Green Deal, where Europe should achieve climate neutrality by 2050 (European Commission, 2020). Hence, the emission reduction was assumed to be linear until reaching net zero emissions in the year 2050. This estimation is based on a similar estimation done by Morfeldt et al., (2021).

Table 4. Parameters for future emission scenarios

	Minimum emission scenario	Maximum emission scenario
Traffic flows (light, heavy vehicles and machinery)	Reduction of 25% between 2020 and 2030 (Göteborg Stad, 2022b)	Annual increase of 1.3% according to the forecast developed by Trafikverket (Trafikverket, 2014)
Traffic flows (public transportation)	Not changed	Annual increase of 3.6% according to the forecast developed by Västtrafik (Västtrafik, personal communication, March, 2023)
Electricity mix	Linear emission reduction to reach net zero emissions in 2050, based on the Nordic electricity mix.	Linear emission reduction to reach net zero emissions in 2050, based on the European electricity mix.

3.3.3. Emissions

The emission calculations for the current and the two future scenarios were performed using specific equations for each vehicle category. The following sections provide a detailed description of how these calculations were carried out.

3.3.3.1 Current emissions

For goal 1, the current emissions have been calculated by taking into account each organization's contribution in terms of the numbers of vehicles and their mileage or usage. Further, this has been multiplied by the vehicle's energy consumption and the emission factors for the different fuels, meaning, the emissions from each organization were initially calculated, as can be seen in equations 1, 2, 3 and 4. To determine the overall emissions within goal 1, each organization's contribution has been summed up. The equations separate vehicles from machinery, since emissions from light and heavy vehicles are determined based on their mileage per year, whereas emissions for machinery are determined based on the number of hours used per year. This variation is because machinery is typically stationary during use. The equations for vehicles also differ depending on if the organizations have reported their mileage or not.

For goal 2, no calculations on current emission levels could be performed due to lack of data. However, with available data, the emission levels could be calculated by taking into account the numbers of trips or the consumption of volume of fuels.

For goal 3, the current emissions have been calculated by taking into account Västtrafiks contribution in terms of the number of vehicles, annual consumption of volume of fuel, energy content and emission factor, see equation 5. The current emissions were determined by summing up each vehicle's emission contribution in Västtrafik's fleet. This was made possible because of the highly relevant data provided for each vehicle.

A further explanation of all parameters used in equations 1-5 is provided in the following sections below (see sections 3.3.4 – 3.3.8).

Light and heavy vehicles – Goal 1

Organizations with a given mileage:

$$\frac{\text{Annual emission}_{\text{organization}}}{\text{Emission factor}_{\text{diesel,petrol etc.}}} = \sum \text{number of vehicles}_{\text{diesel,petrol,etc.}} * \text{mileage}_{\text{diesel,petrol,etc.}} * \text{Energy consumption}_{\text{diesel,petrol etc.}} * \quad (1)$$

Organizations with no given mileage:

$$\frac{\text{Annual emission}_{\text{organization}}}{\text{Emission factor}_{\text{diesel,petrol etc.}}} = \sum \text{number of vehicles}_{\text{diesel,petrol,etc.}} * \text{average mileage}_{\text{diesel,petrol,etc.}} * \text{Energy consumption}_{\text{diesel,petrol etc.}} * \quad (2)$$

Machinery – Goal 1

Organizations with seasonal usage:

$$\frac{\text{Annual emission}_{\text{organization}}}{\text{Energy consumption}_{\text{diesel,petrol etc.}} * \text{Emission factor}_{\text{diesel,petrol etc.}}} = \sum \text{number of vehicles}_{\text{diesel,petrol,etc.}} * \text{average seasonal usage}_{\text{diesel,petrol,etc.}} * \quad (3)$$

Organizations with yearly usage:

$$\frac{\text{Annual emission}_{\text{organization}}}{\text{Emission factor}_{\text{diesel,petrol etc.}}} = \sum \text{number of vehicles}_{\text{diesel,petrol,etc.}} * \text{average yearly usage}_{\text{diesel,petrol,etc.}} * \text{Energy consumption}_{\text{diesel,petrol etc.}} \quad (4)$$

Public transportation – Goal 3

$$\text{Annual emissions} = \sum \text{number of vehicles}_{\text{diesel,petrol,etc.}} * \text{annual volume of fuel}_{\text{diesel,petrol,etc.}} * \text{Energy content}_{\text{diesel,petrol etc.}} * \text{Emission factor}_{\text{diesel,petrol etc.}} \quad (5)$$

3.3.3.2 Future emissions

Based on the two future scenarios, the same calculations as for the current emissions were conducted, using the same equations. Emission factors for 2030 were used for the electricity mix and hydrogen, which is presented further down in Table 10. Further, the size of the vehicle fleet was changed based on an increased or decreased traffic flow. As mentioned above, an additional target is set for 2023 where the vehicle fleet should be fossil free. Consequently, it had to be assumed that the vehicles powered by fossil fuels (petrol, diesel, hybrid, and plug-in-hybrid) were the first to be electrified, while the rest of the fleet were distributed between biofuels (HVO100, vehicle gas and ethanol).

For light vehicles within Gothenburg City’s own vehicle fleet, the electrification target is set on 800 fully electric vehicles by 2023. However, since no target is determined for 2030, the calculations for 2030 were based on the result from the workshop, which is 80% electrified, see section 5.2. For heavy vehicles, the electrification target is set on 30% fully electric or hydrogen-powered vehicles by 2030, hence it was assumed that half of the electrification was achieved by fully electric vehicles, and the other half by hydrogen-powered vehicles. For light and heavy machinery, the electrification target is set to 70% and 40% fully electric or hydrogen powered vehicles by 2030. However, it had to be assumed that all electrification was achieved by fully electric machinery since no accurate data were found on hydrogen-powered machinery.

3.3.4 Energy content

Data for energy content for each fuel type was obtained from Drivkraft Sverige (2023) and Swedish Energy Agency (2022). The energy content describes how much energy (MJ), one liter or kilo of fuel contains. All figures are presented in Table 5.

Table 5. Energy content for different fuel types

Fuels	Energy Content	Reference
Petrol	32.2 MJ/L	(Drivkraft Sverige, 2023)
Diesel	35.3 MJ/L	(Drivkraft Sverige, 2023)
HVO100	34 MJ/L	(Drivkraft Sverige, 2023)
Vehicle gas	49.1 MJ/kg	(Swedish Energy Agency, 2022)
Biogas	49.1 MJ/kg	(Swedish Energy Agency, 2022)

Ethanol (E85)	32.2 MJ/L	(Drivkraft Sverige, 2023)
Hydrogen	119 MJ/kg	(Vätgas Sverige, n.d)

3.3.5 Energy consumption - for goal 1

The methodology used to calculate energy consumption involved different approaches depending on the vehicle category and type of fuel. The chosen approach for each category was determined based on the available data and the characteristics of the specific vehicles. The energy consumption describes how much energy (MJ) is required to drive one kilometer. To calculate the energy consumption, information on fuel consumption was necessary for some cases. The fuel consumption describes how much fuel (liter, kilogram, or kWh) is required to drive one kilometer.

Light vehicles

Due to lack of data regarding fuel consumption for light vehicles, a grouping was necessary to calculate an average energy consumption per kilometer. Vehicles with internal combustion engines were grouped under the category of internal combustion engine vehicle (ICEV) (Morfeldt et al., 2021), because fuels such as diesel, petrol, and HVO100 have similar energy content, see Table 5. Hybrid vehicles run almost exclusively on petrol and therefore also belong to the ICEV category. Plug-in hybrid electric vehicles (PHEVs) were estimated to be driven half on petrol and half on electricity, while fully electric vehicles were grouped as battery engine vehicles (BEVs) (Morfeldt et al., 2021), see Table 6.

An exception has been made for vehicles with ethanol engines since this fuel has a significantly different energy content compared to other types of combustion engine fuels. The energy consumption was instead based on one of the most commonly used ethanol cars in Gothenburg City's vehicle fleet, a Volkswagen Golf Sport Combi. This has also been adapted for city driving behaviors. Similarly, to determine the energy consumption for gas-powered vehicles, a comparable method to the one used for ethanol vehicles was used. The average energy consumption has been calculated based on the fuel consumption of the two most commonly used gas vehicles in Gothenburg City's vehicle fleet, the Volkswagen Caddy Maxi and the Volkswagen Golf Sports Combi.

Table 6. Fuel and energy consumption for light vehicles

Vehicle types	Fuel consumption	Energy consumption	Reference
ICEV		2.41 MJ/km	(Morfeldt et al., 2021)
PHEV		1.20 MJ/km	(Morfeldt et al., 2021)
BEV		0.792 MJ/km	(Morfeldt et al., 2021)
Ethanol engine vehicle		1.44 MJ/km	(Miljöfordon, n.d)
Gas engine vehicle	0.07 L/km	1.98 MJ/km	(Bonde, 2023a)
	0.051 L/km		(Bonde, 2023b)

Heavy vehicles

To calculate the energy consumption of heavy vehicles, one had to first calculate an average fuel consumption for each vehicle type. Due to the fact that only a few organizations in Gothenburg City own and use heavy vehicles, reliable data has been obtained from the data collection. However, some generalizations had to be made since certain organizations had more representative data than others. For instance, one organization provided valuable data on fuel consumption for heavy HVO100 vehicles. As a result, fuel consumption for the remaining heavy HVO100 vehicles were based on their data.

The same method was used for biogas and fully electric heavy vehicles. However, fuel consumption for hydrogen power vehicles was missing and had to be obtained from an external source. When each fuel consumption was determined, it could then be multiplied by the fuel's energy content (see Tabel 5) to determine the energy consumption. Fuel and energy consumptions for heavy vehicles are presented in Table 7.

Table 7. Fuel and energy consumption for heavy vehicles

Fuel	Fuel consumption	Energy consumption	Reference
Diesel	0.49 L/km	17.3 MJ/km	(Renova, personal communication, March, 2023)
HVO	0.49 L/km	16.7 MJ/km	(Renova, personal communication, March, 2023)
Biogas	0.57 L/km	27.7 MJ/km	(Department of Sustainable Water and Waste Management, personal communication, March, 2023)
Electricity	1.85 kWh/km	6.7 MJ/km	(Department of Sustainable Water and Waste Management, personal communication, March, 2023)
Hydrogen	0.09 kg/km	10.7 MJ/km	(Basma et al., 2022)

Light and heavy machinery

Fuel consumption for light and heavy machinery was received from one organization. Based on their data, average fuel consumption was calculated. Data for machinery powered by electricity was collected by selecting one light and one heavy machine from Volvo to represent all electric light and heavy machinery. No data could be found on hydrogen powered machinery, and hence, it had to be assumed that all machinery substituted according to the targets in the Electrification Plan would be fully electric.

The energy consumption was again calculated by multiplying the fuel consumption with the energy content presented in Table 5. Figures on fuel and energy consumption for light and heavy machinery are presented in Tables 8 and 9.

Table 8. Fuel and energy consumption for light machinery

Fuel	Fuel consumption	Energy consumption	Reference
Petrol	4.3 L/h	137 MJ/h	(City Environment Administration, personal communication, March, 2023)
Diesel	4.3 L/h	152 MJ/h	(City Environment Administration, personal communication, March, 2023)
HVO	4.3 L/h	145 MJ/h	(City Environment Administration, personal communication, March, 2023)
Electricity		3.3 MJ/km	(SWECON, 2023a)

Table 9. Fuel and energy consumption for heavy machinery

Fuel	Fuel consumption	Energy consumption	Reference
Petrol	9.6 L/h	309 MJ/h	(City Environment Administration, personal communication, March, 2023)
Diesel	9.6 L/h	340 MJ/h	(City Environment Administration, personal communication, March, 2023)
HVO	9.6 L/h	327 MJ/h	(City Environment Administration, personal communication, March, 2023)
Electricity		48 kWh/h	(SWECON, 2023b)

3.3.6 Milage or usage per vehicle - for goal 1

The mileage per vehicle for each organization has been collected and used to calculate the emission. However, there is insufficient data on the mileage of approximately half of the organizations for light vehicles, and for a few organizations for heavy vehicles. To address this gap, an average mileage has been used, which was calculated based on all the reported mileages for each category.

For machinery, only one organization gave an estimation of hours used per year for some of their machinery. This organization has both annual and seasonal machines, where the seasonal machines are rented or used for approximately 7 months per year. Based on their data, an average use for seasonal and annual machines has been calculated to fill up the data gap. However, as none of the other organizations using machines gave an indication of their use per year, we had to make a judgment regarding if the use was annual or seasonal. Most of the machinery is assumed to be used seasonally as

they primarily consist of lawn mowers and snowplows. However, there still exist some machines that are assumed to be used annually.

3.3.7 Volume of fuel - for goal 3

For vehicles used in public transportation, the annual volume of fuel used per vehicle was reported in the data collection. This detailed data enabled simple calculations with a small margin of error, where calculations of energy consumption were not needed.

3.3.8 Emission factors

In addition to the data provided from the data collection, as well as energy content and energy consumption, emission factors (EF) for different types of fuels were needed to calculate the emissions. EFs were collected from Drivkraft Sverige (2023), but for biogas and vehicle gas, the Swedish Energy Agency (2022) provided the data. Further, the Emission Reduction Obligation (ERO) had to be considered as the emissions from petrol and diesel will change over time. The ERO is a legal responsibility imposed by the Swedish Government that aims to reduce the emission from petrol and diesel by increasing the blending degree of biofuels (Swedish Government, 2022). As a result of a changed blending degree of biofuels, the EF for petrol and diesel were recalculated for year 2023. For this project, the ERO is mainly important when calculating the emission from the current scenario, since it is assumed that Gothenburg City's vehicle fleet will be fossil-free after the year 2023, meaning no petrol, diesel, hybrid, or plug-in hybrid cars will be available in 2030. The ERO states the following emission reductions compared to 100% fossil petrol and diesel:

Year	Petrol	Diesel
2023	7.8%	30.5%

It is important to highlight that the calculations on ERO is based on an assumption that the Swedish Government will not remove it within their mandate period. However, during the course of this project, the government has decided to reduce the ERO to 6% for both petrol and diesel after 2023 (Berglund & Marmorstein, 2023). This reduction will not affect the calculations for this project, since it will be applied starting next year. Unfortunately, this will have a great impact on emissions from other parts of the transport system that are not expected to be fossil free next year.

In Table 10, the EFs per MJ of fuel are presented for the different types of fuels and for the current and future scenarios. As described in section 3.3.2, the emission from the electricity depends on what electricity mix that is used and how those emissions are expected to decrease over time. The emissions from hydrogen production come primarily from the use of electricity, and hence, these emissions are also dependent on the current and future electricity mix. Vätgas Sverige, (n.d) states that 50 kWh electricity is required to produce 1 kg of hydrogen, and as shown in Table 5, one kilo of hydrogen consists of 119 MJ. Multiplying these two parameters with the EF for electricity resulted in an EF for one MJ of hydrogen, as follows:

$$Y \frac{gCO_2 eqv}{MJ} = 50 \frac{kWh_{el}}{kg_{hydrogen}} \div 119 \frac{MJ}{kg_{hydrogen}} * X \frac{gCO_2 eqv}{kWh_{el}} \quad (6)$$

As for the electricity, Sandgren & Nilsson (2021) states that the average emission from a Nordic electricity mix between year 2016 and 2018 was 90 gCO₂e/kWh. For the European electricity mix, the European Environmental Agency (2022) states that the emissions in the year 2021 was 280 gCO₂e/kWh.

This was the most recent data available and had therefore to be recalculated for both year 2023 and 2030 based on a linear reduction until reaching net zero emissions in 2050. The EF for the current state emissions (year 2023) is based on the Nordic electricity mix.

Table 10. Emission factors for different types of vehicle fuels [gCO₂e/MJ]

Fuels	100% fossil fuels	2023	2030 – Minimum emission scenario	2030 – Maximum emission scenario
Petrol	98.0	91.18		
Diesel	100.81	70.06		
HVO100		15.2	15.2	15.2
FAME		30	30	30
Vehicle gas		10	10	10
Biogas		8.7	8.7	8.7
Ethanol (E85)		57.3	57.3	57.3
Electricity		21	16	54
Hydrogen		31.9	23.5	82.3

Note: Diesel vehicles can be fueled with HVO100 and vice versa.

3.4 Workshop

The aim of the workshop was to involve stakeholders in order to incorporate their perspectives in future decision-making, and to improve collaboration and communication between the organizations. By involving stakeholders, gaps between a desirable electrified transport system and the current transport system could be identified, followed by finding leverage points for how these gaps can be overcome. The project behind the Electrification Plan has a well-established ‘mobility group’ that includes people with a lot of influence or that have the formal title as a ‘mobility manager’. Each organization within Gothenburg City has at least one mobility manager, but not all of them are included in this well-established mobility group. It is important to recognize that the transitions impact more than mobility managers. Hence, when inviting stakeholders, we choose to invite all mobility managers, and people that we have had contact with but that lack this formal title. The group that participated in the workshop is called ‘working group’.

The total number of stakeholders invited to the working group was 68 people, representing all the organizations listed in Figure 2 and 3. It was not expected that all of them would participate, since several stakeholders from the same organizations were invited. A total of 27 stakeholders signed up to participate, covering most of the organizations. On the day of the workshop, several people reported to be sick or did not show up, resulting in the participation of 17 stakeholders. The participating stakeholders represented the organizations with most of the heavy vehicles and machinery, and a small share of the light vehicles. However, no one represented the public transportation and transportations generated by Gothenburg City’s purchases.

The workshop was divided into two parts. The first part concerned the lack of data, and how organizations can collect, track, and use data to improve their sustainability work. The second part was designed as a World Café, where three different development pathways (DP) related to a sustainable transport system were discussed.

Throughout the workshop, notes and conclusions were written down and summarized by us. In addition to this, three employees from BRG were appointed to the responsibility of being moderator during the World Café. One moderator was located at each table to summarize the discussions. Hence, it is important to highlight the fact that all information has been filtered through a biased person, where the conclusions can be slightly moderated from the original conversation.

3.4.1 Part 1 - Data gap discussion

This part of the workshop was designed based on the identified demand on data from the data collection and calculation parts. Currently, the electrification transition is expensive and requires resources, knowledge, and coordination. Lack of data hinders effective collaboration between organizations. Further, it makes the electrification process and efficient resource utilization more difficult, as well as aggravating calculations of climate impacts from various actions.

The data gap discussion aimed to increase the understanding of how data is currently collected, how that can be improved, and what structures and changes that are required to follow up relevant data. Examples on questions discussed are:

“How can we improve and reduce the data gap? What structures and organizational change need to be put in place to increase access to relevant data?”

3.4.2 Part 2 - World Café

The second part of the workshop was designed in accordance with the World Café concept. The World Café is a process that aims to create a better future through deep and meaningful conversations (Brown, 2010). The process emphasizes the fact that people want to talk about things that matter to them, and during the conversations, greater wisdom can be found in the collective.

The process is characterized by seven fundamental aspects: belief in everyone, diversity, invitation, listening, movement, good questions, and energy (Brown, 2010). For the sake of the process, it is fundamental to assume that everyone can work together, regardless of how diversified the group may be. Diversity is also of key importance to get all perspectives and fully understand a complex system. The spirit and atmosphere during the process should be open and welcoming, where the café facilitators are responsible for creating this environment. However, the whole process is dependent on deep and active listening, where the whole room participates and reflects with curiosity.

In the World Café, people move around between different tables, where they discuss different topics. The topics should be supported by good questions that invite the participants to explore new pathways, think beyond and open new insights. At each movement, new perspectives will emerge.

As for the structure in this workshop, the working group rotated between three tables, each table containing a new discussion topic based on different development pathways (DP). One moderator from BRG was located at each table. The task of the moderator was not to intervene in the conversation, but

rather to ask open-ended questions and make sure that the conversation stayed on topic. Further, the moderator summarized the conversations and conclusions to present for the next group. This enabled an opportunity where each group could participate in all DPs and build upon the conversation that the previous group had. All conclusions from the discussions were summarized through a short presentation by the participants at the end of the workshop.

Parking Space

To favor the flow of the conversation, an additional table was located in between the discussion tables. We decided to call this additional table “Parking Space”, as it aimed to park thoughts or aspects that the conversation got stuck on. Aspects that are both important and central for the transition, but which are beyond the organizations control, were put in the parking space. These aspects were further important to highlight, as they indicated what type of additional changes or prerequisites that need to be put in place for the transition to be successful.

3.4.2.1 Development Pathways (DP)

In combination with the World Café, three different DPs were designed for the working group to discuss. The DPs aimed to create prerequisites for electrification and think beyond electrification to achieve a sustainable transport system. They were constructed based on different factors that can be used to achieve a sustainable transport system, where electrification was one of the factors. Further, the DPs are somewhat connected to each other, where they need to interact if a sustainable transport system is to be achieved. However, the working group was asked to treat them as if they were not connected to each other.

DP 1 - The Electrification Plan is fulfilled

The Electrification Plan has specified several collective targets, whereas the ongoing work takes place without coordination between the actions. The Electrification Plan does not present what actions that are required to fulfill the targets, or with whom the responsibility lies. Hence, the first DP was based on the following future:

A future where we have achieved the targets within the Electrification Plan

The aim of the first DP was to both discuss how the work should be distributed between the organizations to achieve the targets within the Electrification Plan, and to increase the understanding on what type of actions that are required. Questions such as “*What types of vehicles should be prioritized for electrification?*” and “*How can each organization work to achieve a higher degree of electrification within their purchased transportations?*” were discussed by the working group.

DP 2 - Transport efficiency to simplify and/or complement electrification

To achieve a sustainable transport system, changes that go beyond electrification will be necessary. This requires both behavioral change and increased cooperation between the organizations. The second DP was based on the following future:

A future where we get closer to the 90% target with the help of behavioral changes

The aim of the second DP was to discuss how to optimize the use of vehicles and associated resources/infrastructure as a prerequisite for or as a complement to electrification. Further, it aimed to deepen the collaboration between the organizations to reduce the number of vehicles within the city.

Questions such as “*What do we need to be able to share vehicles/charging infrastructure more easily?*” and “*What do we need to increase our confidence in using electric vehicles in our business?*” were discussed by the working group.

DP 3 - Organizational changes

Goal achievement related to both the Electrification Plan and The Environment and Climate Program can be impeded or slowed down by organizational structures and barriers. Hence, the third DP was based on the following future:

A transparent future where collaboration and division of responsibilities between businesses is optimal and everyone has the same conditions and access to information.

The aim was to discuss what organizational barriers slow down/impede goal fulfillment and which structures, tools and processes that are required to overcome these barriers. The discussion was centered around the question “*What is needed to overcome the organizational barriers that make cooperation between businesses difficult?*”. Further, the working group was invited to discuss competence and responsibility distribution, financing, and data sharing.

3.5 Analysis

As part of the evaluation process, four distinct analyses were performed. These included an assessment of the transportation procurement requirements in relation to goal 2, an examination of goal alignment, a sensitivity analysis, and, finally, a backcasting analysis.

3.5.1 Requirements in goal 2

To complement the lack of data for goal 2, an analysis of environmental requirements for procured transportation has been performed. This gives an overview of possible emissions generated by procured transportation. The analysis consists of both a literature review and communication with concerned organizations such as The Administration for Purchasing and Procurement.

3.5.2 Goal Alignment

To determine if the Electrification Plan is in line with local, national, European, and global emissions targets, it was evaluated what type of emissions are included in each target, as well as ensuring that the numbers are comparable. The previous calculations were conducted by using Scope 3 in the Greenhouse Gas Protocol. However, the local 90%-target includes territorial emissions and to make it comparable, the emissions had to be recalculated using Scope 1. The local emission target is developed based on the national target and if the Electrification Plan is in line with this target, it will also be in line with the other targets. Hence, this section focuses primarily on the alignment with the local target.

3.5.3 Sensitivity analysis

A sensitivity analysis was conducted in order to identify how sensitive the result is to changed conditions. The different assumptions were evaluated by changing the parameters separately and identifying their impact on the result. The following parameters were assessed:

Mileage and usage – Goal 1

Initially, the average mileage was used to fill up the data gap for light and heavy vehicles within goal 1. However, there was a large variation between the shortest and longest reported mileage, and hence, it was assessed how the emissions would vary if the shortest or longest mileage were used to fill up the data gap.

In addition, machinery could be used either annually, or seasonally, depending on what type of machinery it is. We had to make this judgment ourselves, where most of the light machinery was assumed to be seasonally used, and all the heavy machinery was assumed to be annually used. It was assessed how this assumption affected the emissions by using the annual and seasonal hours for all machinery.

Future emission scenarios – Goal 3

The two important parameters for the future emission scenarios presented in section 3.3.2 were the electricity mix and changes in traffic flows. Due to significant variations in the result for goal 3, public transportation, it was necessary to investigate the impact of each parameter in the future scenarios. To assess their respective contributions, the emission levels for 2030 were calculated by changing the traffic flows and electricity mix separately.

Number of vehicles

The data collection resulted most likely in a margin of error regarding the number of vehicles within Gothenburg City's vehicle fleet (goal 1). It became obvious that they had no clear idea of exactly how many vehicles each organization owns. It was assessed how the size of the vehicle fleet affected the result, by increasing and reducing the number of vehicles by 10%.

Energy consumption

The energy consumption for different types of vehicles were derived from various sources, including the data collection, articles, and specific product information sheets. Hence, there is an uncertainty as the number can vary depending on its origin. To assess how sensitive the result is to these parameters, they were increased and reduced by 10%.

Energy content and emission factors

Energy content and emission factors were derived from sources with reliable data, but with constant development of technologies, the efficiency of vehicles is improving. Hence, it was assessed how the energy content and emission factors impacted the result by increasing and reducing them by 10%.

3.5.4 Backcasting

The backcasting method is a valuable tool for achieving sustainability transitions, and it has recently gained more attention with regards to actions related to Agenda 2030 and global sustainability goals (Holmberg & Holmén, 2020). This tool has proven to be effective in working with system innovation.

The backcasting method has its starting point in a desirable future and explores various paths that can lead us to that future (Holmberg & Holmén, 2020). This approach differs from other common tools, such as forecasting or scenario analyzes, which are based on historical trends and hypothetical future scenarios. Backcasting is not reliant on forecasts or future scenarios, as the point is to move away from the current situation and create a vision for a desirable future. It wants to emphasize that the future is not predetermined, and we have the power to shape it as we wish. The problems we face in today's

situation can make the major changes required for the transition difficult. If we work towards a desirable future instead of focusing on changing the current situation, we may be able to identify the underlying problem and avoid the need for small fixes. However, small fixes must not be ignored, but rather be implemented in interplay with principles formulated for the desirable future (Holmberg & Holmén, 2020).

In this project, the backcasting process was constructed and completed based on the discussions within the workshop. It was important to create an open and safe environment and ensure that the working group had diversity and no hidden agenda. Hence, this was considered when inviting stakeholders to the workshop. The following four steps within the backcasting process was performed in this project:

1. Desirable future

In the first step, we create a desirable future, which means thinking beyond the current situation and what seems realistic and achievable. Within this step, we create a sense of direction, and ask questions regarding what is important and desirable. The guiding principles were formulated using the tool The Sustainability Lighthouse (Holmberg & Holmén, 2020). The framework aims to facilitate the conversation on sustainable futures by formulating guiding principles in four interdependent dimensions (i) human needs & wellbeing, (ii) social, (iii) economic, and (iv) ecological. The ecological dimension provides conditions for human needs and wellbeing, while the social and economic dimensions create structures.

2. Gaps

In this step, we defined the current situation by using The Socio-Technical System tool. The Socio-Technical System is a tool used to describe systems theory, which means describing relationships between different structures and disciplines within an analyzed system (Interaction design, n.d.). In this case, the current transport sector in Gothenburg is studied through a systems perspective. This allowed us to get a deeper understanding of the system and identify the gaps between the current situation and the desirable future. It was important to follow the guiding principles established in step one as a basis when analyzing the current situation, since it ensures that the analysis is conducted with the same foundation when searching for gaps between the future and the current situation (Holmberg & Holmén, 2020).

3. Leverage points

This step focuses on identifying a few leverage points, where small changes in the system can have a big impact. The leverage points aim to reduce the gap identified in the previous step but should also be in line with the guiding principles formulated in the first step. Based on the workshop discussion and the identified gaps, four leverage points have been defined.

4. Strategies

In this step we change the focus from understanding the problems, to finding concrete ideas on how to overcome and working with the leverage points. Sometimes, the solutions can be straightforward, but in this case, three recommendations for how to continue working with the transition and the leverage points have been formulated.

4. CALCULATION RESULTS & ANALYSIS

In this chapter, the outcomes of the data collection and emission calculations are presented and analyzed. The results for goal 1 and 3 are presented in detail, while the section on goal 2 primarily addresses the insufficiency of available data and transportation procurement requirements. The chapter proceeds with an analysis of the combined emissions, followed by a sensitivity analysis and an examination of goal alignment. The findings from this chapter provide important insights into the feasibility and effectiveness of the Electrification Plan and will serve as a basis for further decision-making and implementation.

4.1 Goal 1 - Gothenburg City’s own vehicle fleet

Data collection

When collecting data on the number of vehicles within Gothenburg City’s own vehicles fleet, it was found that the majority of the light vehicles and light machinery were leased through Gothenburg City Leasing (GCL). However, GCL was not able to provide data on how many vehicles each organization had, but instead the total number of vehicles leased through them. Hence, much of this data had to be recollected through each organization, and a margin of error emerged. As for heavy vehicles and heavy machinery, all organizations reported their data which resulted in a smaller margin of error. Based on the clustering of vehicles, Table 11 presents the total number of vehicles within Gothenburg City’s vehicle fleet.

Table 11. Number of vehicles within Gothenburg City’s vehicle fleet

	Light vehicles	Heavy vehicles	Light machinery	Heavy machinery	Total
Petrol	3		16		19
Diesel	148	6	148	19	321
HVO100	259	241	22	11	533
Vehicle gas	729				729
Biogas		21			21
Ethanol	46				46
Hybrid	302				302
Plug-in-hybrid	19				19
Fully electric	668	8	127		803
Hydrogen		2			2
Total	2174	278	313	30	2795

Data on mileage was received from approximately half of all organizations with light vehicles, meaning a large data gap had to be filled by using an average mileage. The received data had a large variation, where the use of light vehicles differed a lot between organizations.

Specified annual mileage for light vehicles [km/year and vehicle]:

Shortest	Longest	Average
1,070	25,800	7220

As for heavy vehicles, the organizations with the majority of all heavy vehicles reported detailed data on their annual mileage. Hence, only a small data gap had to be filled by an average mileage. This received data also had a large variation, but still with less spread compared to the light vehicles.

Specified annual mileage for heavy vehicles [km/year and vehicle]:

Shortest	Longest	Average
14,640	29,250	18,410

The annual usage of light and heavy machinery resulted in large uncertainties, as only one organization gave an indication of how many hours their machinery operated each year. The organization that provided the data owns or uses approximately 20% of all machinery within Gothenburg City's vehicle fleet, where they had both annual and seasonal machinery. To fill up the data gap for the other organizations, we had to make a judgment regarding if the usage was annual or seasonal.

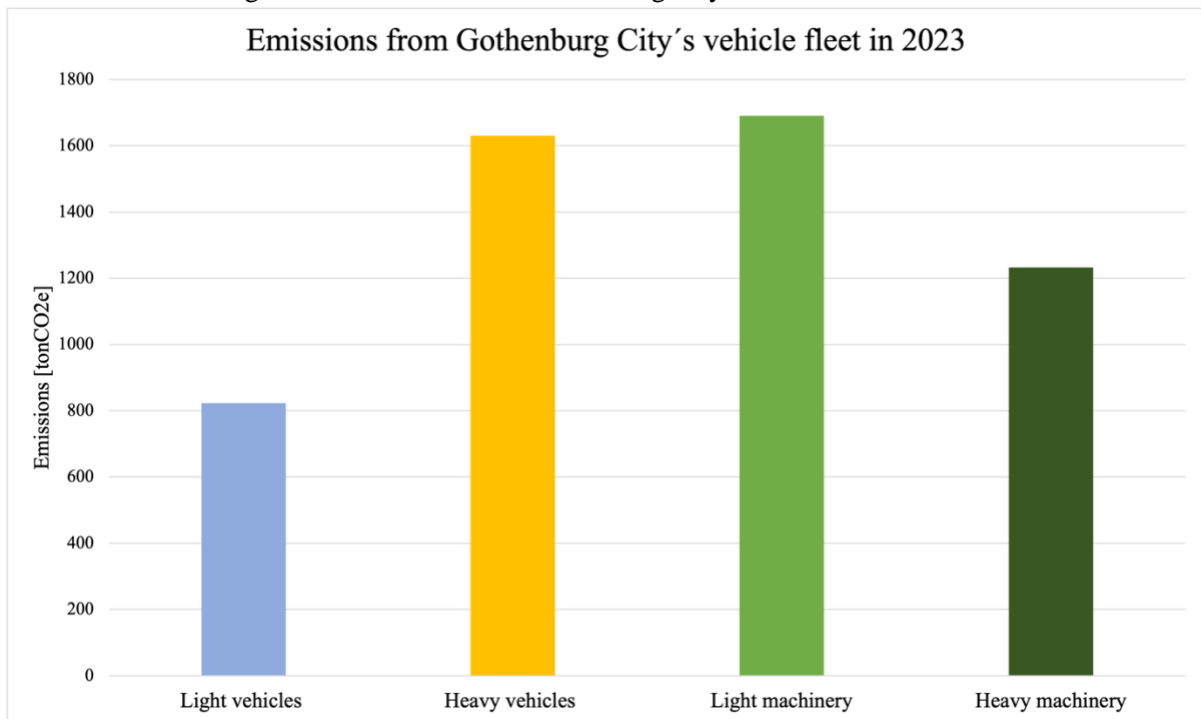
Specified annual usage of light and heavy machinery [h/year and machine]:

Annual usage	Seasonal usage
3,000	325

Current emission

The current vehicle fleet within Gothenburg City resulted in an emissions level of 28,400 metric tons of CO_{2e} during 2023. The emissions distribution between the different vehicle types are presented in Figure 5. Gothenburg City's vehicle fleet consists of approximately 2800 vehicles, where light vehicles make up for 78%. However, light vehicles contribute only 15% of the emissions generated from their own vehicle fleet. The largest share of the emissions is instead generated from heavy vehicles and light machinery.

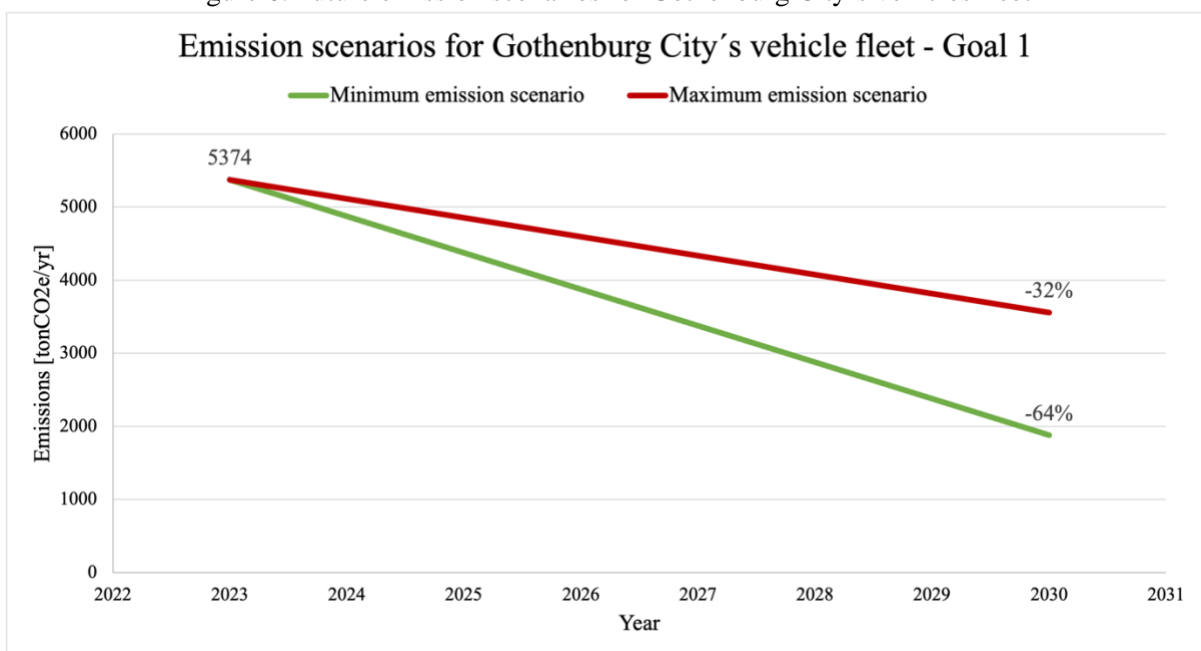
Figure 5. Emissions from Gothenburg City's vehicle fleet in 2023



Future emission

The future emission reduction generated by Gothenburg City's vehicle fleet is presented in Figure 6. The result shows that the emissions will be reduced regardless of scenario, where the maximum emission scenario resulted in a reduction of 32%, whereas the minimum emission scenario will double that reduction.

Figure 6. Future emission scenarios for Gothenburg City's vehicles fleet



4.2 Goal 2 - Transportation generated by Gothenburg City's purchases

The result for goal 2 did not turn out as expected. Unfortunately, there was not sufficient data available to calculate the emissions from goal 2. The data available would not have reflected a value close to reality. Due to that, calculations on emission reduction from goal 2 have been excluded from the study. However, some data has been obtained and analyzed.

Subgoal 2.1 consists of transportations generated by Gothenburg City's purchased goods and services. Approximately $\frac{1}{3}$ of Gothenburg City's financial capital intended for purchased goods and services are distributed to one organization (The Administration for Purchasing and Procurement), which is responsible for major procured framework agreements. This organization has begun a follow-up on Gothenburg City's most transport-intensive framework agreements. Since this follow-up is an ongoing work, the data was not yet complete. Hence, data was only received for a smaller part of all transport-intensive framework agreements, whereas there was no way to estimate the size of the data gap. Consequently, no accurate calculations could be made on emissions from transportations generated by Gothenburg City's purchased goods and services.

Subgoal 2.2 includes purchased passenger transportation. This type of purchase occurs within three different organizations (City Environment Administration, Administration for Functional Support, Social Welfare Administrations). Detailed and specific data was received from one of the organizations resulting in a lack of data. Our interpretation was that the data was not sufficiently compiled, and the other organization did not have knowledge or time to compile it for the sake of our project. Consequently, we could not estimate the size of the data gap and no accurate calculation could be made on emissions from purchased passenger transportation.

Subgoal 2.3 contains Gothenburg City's purchased contracting work and its associated transport. Unfortunately, this category lacks any collected data. While collecting the data, it appeared unclear who is responsible for collecting information about these machineries. Many organizations within Gothenburg City operate large construction projects, where a contracting company is hired to carry out the work. When a contracting company is hired, the organization has no knowledge of how many or what type of machines are being used, or how frequently they are used. This made it impossible to make any kind of calculations of its potential emission reduction.

4.2.1 Requirements on procurements

To reduce emissions generated from Gothenburg City's purchases, Gothenburg City has specified environmental requirements for different types of procurements. Below, a summary of the requirements are presented, divided into the different subgoals within goal 2. However, this is a summary including only the environmental requirements that impact the emission levels from transport, and hence, there are further requirements that are not stated below. In relation to the goals within the Electrification Plan, not many of the requirements cover electrification, but rather focuses on the share of fossil fuels and emissions, which indirectly covers electrification as a part of the solution.

Subgoal 2.1. Requirements on transports related to purchased goods and services

The Administration for Purchasing and Procurement has developed guidelines and requirements on transport related to purchased goods and services (Administration of Purchasing and Procurement, n.d). In addition, they have defined an internal goal that all transport intensive framework agreements should be fossil-free by 2030, and 30% should use electric or hydrogen-powered vehicles.

Further, transport and vehicle requirements are defined depending on if the supplier uses their own vehicle or a third party for the transportation of the goods or services (Administration of Purchasing and Procurement, n.d). The guidelines state that a third party should always be used if they offer a more climate-smart solution for the transportation. The following requirements are placed on a third-party delivery:

- A detailed action plan that is in line with the Gothenburg City's objectives to reduce transport climate impact needs to be implemented over the whole agreement period.
- They need to have routines for logistics planning, route optimization, coordination, vehicles filling levels, and driving styles.
- They need to have routines for how the systematic transport work and commitments stated above are passed on in the supply chain.

As for their own vehicles, the following requirements are specified, and must be met within 12 months after the contracts starting date:

- All heavy vehicles must comply with Euro VI¹ (or later).
- All light trucks must be a maximum of 8 years old.
- All light trucks must be powered by vehicle gas, hydrogen, electricity, or alternatively biodiesel.
- Light trucks with diesel engines can emit a maximum of 0.005 grams of particles per km, alternatively complying with Euro VI (or later).
- Electric vehicles must only be powered by an electric motor. They cannot be plug-in hybrids.

Subgoal 2.2. Requirements on procured passenger transports

Serviceresor (2023) has defined requirements on procured passenger transport, including both vehicle and fuel requirements. For passenger cars, the following requirements are stated:

- All passenger cars must be classified as a Clean Vehicle (Miljöbil)²
- All passenger cars must run on fuel consisting of a maximum of 20% fossil fuels.

Requirements on wheelchair cars and buses states the following:

- Wheelchair cars and buses must be powered by fuel consisting of a maximum of 80% fossil fuels.

Subgoal 2.3. Requirements on transports related to contracting work

The requirements put on transport related to contracting work include both fuel and vehicle requirements. The requirements are shared by Stockholm, Gothenburg, and Malmö, where a renewed requirement proposal has been developed for approval. The new proposal suggested by Göteborg Stad (2023) includes higher environmental requirements and are presented below.

The following requirements are put on fuels used by vehicles and machines within the contracting work:

- Specified criteria for fossil- and bio- fuels such as petrol, diesel, vehicle gas etc.
- In addition to these fuels, all electric and hydrogen powered vehicles are allowed.
- The owner of the vehicle/machine is responsible for ensuring that the engine manufacturer has

¹ Euro classes are used to set requirements for vehicle emissions. They indicate the maximum allowable emissions of a range of air pollutants for cars, trucks, and buses (Miljöfordon, 2022)

² A vehicle powered by environmentally friendly fuels such as electricity, ethanol, biogas, or other renewable fuels (Miljöfordon, 2023). It can also be a very fuel-efficient gasoline or diesel car.

approved the use of a specific fuel.

- The total energy consumption for vehicles/machines should consist of electricity from renewable sources and/or sustainable high-blend and pure biofuels not covered by the emissions reduction obligation, according to the percentages presented in Table 12.

Table 12. Share of renewable fuel in the total energy consumption for vehicles and machines.

Year	Share of renewable fuel [%]
2020	20
2024 - 2025	50
2026 - 2027	70
2028 - 2029	90
2030 and onwards	100

Requirements on light vehicles states the following:

- Must comply with Euro class VI (or later).

Requirements on heavy vehicles states the following:

- Must comply with Euro class VI (or later).
- Vehicles that use electricity within their work and a combustion engine for displacement must not use the combustion engine during work or for generating electricity.

Requirements on machinery states the following:

- Age requirement of 12 years.
- Machines that comply with Stage IV³ (or later) can be used even if the age requirements are not fulfilled.
- Machinery that uses electricity within their work and a combustion engine for displacement must not use the combustion engine during work or for generating electricity. These vehicles have a prolonged age requirement of 16 years.

To promote a transition towards electrification, requirements are put on the share of vehicles with zero emissions. These “zero emission vehicles” are defined as a vehicle that do not emit carbon dioxide during operation, regardless of the origin of the electricity. Fully electric, hydrogen powered, vehicle gas and biogas vehicles are considered to be “zero emission vehicles”. Further, plug-in hybrids are partly included, using a factor of 0.5 or 0.25 depending on the vehicle. The shares of “zero emission vehicles” presented in Table 13 should be met.

³ Stage classes are used to set requirements on engine efficiency and they indicate the maximum allowable emissions of a range of air pollutants for machinery (Dieselnet, n.d).

Table 13. Shares of vehicles with zero emissions

Year	Passenger cars	Light trucks	Heavy trucks	Machinery
	Share of "zero emission vehicles" [%]	Share of "zero emission vehicles" [%]	Share of "zero emission vehicles" [%]	Share of "zero emission vehicles" [%]
2024	40	10	<i>Will be supplemented later</i>	
2025	40	10		
2026	50	15		
2027	60	20		
2028	65	30		
2029	70	35		
2030	100	40		

Follow-ups

In addition to this, The Administration for Purchasing and Procurement highlights the importance of follow-up to ensure that these requirements are met. For the purchased goods and services, the follow-up process is quite specified, including a directive to carry out systematic framework agreement follow-ups approximately twice during a framework agreement period. The follow-up consists of randomly checking the registration number on the vehicles that have been used. For procured passenger transport, no follow-up requirements could be found. Further, there are specified accounting requirements for contracting work, where they should report the fuels and electricity used by the vehicles and machines, using receipts and invoice documents. They should also document and report all vehicles, including vehicle type, brand, model, registration number, emission class (Euroclass) and fuel.

However, it does not state how it should be accounted for, but instead that the accounting should be according to the client's requested format, meaning the organizations within Gothenburg City. As discussed in the workshop, many organizations within Gothenburg City demand clear guidelines and directives for what should be reported, and how. This is contrary to how the current requirements are designed, where they want the organization themselves to create the format. Further, the importance of follow-ups needs to be put in relation to the cost. There is a trade-off between more information and more costs, where more requirements, data reporting and follow-up will increase the investment cost. One must decide whether this is economically beneficial, or if the effort would be better put somewhere else.

Our recommendations are to develop a format and work structure for how to go about these things. The understanding is that the organization does not want space for interpretation where they must make decisions regarding these things. Instead, it should either be operated by central management, or a clearer format similar to a method with several steps for requirements, follow-ups and reporting are needed.

4.3 Goal 3 – Public transportation

Data collection

Concerning public transportation, all requested data was received from Västtrafik, as they are the primary operators in the city. The received data was detailed and specified, where one could perceive information on all vehicles and their annual consumption of fuel volumes. In Table 14, the total number of vehicles are clustered based on their fuel types, together with the total volume of fuels consumed during 2022.

Table 14. Number of vehicles and volume of fuels consumed during 2022 for Gothenburg City's public transportation.

	Number of vehicles	Volume of fuel consumed during 2022
Petrol	44	565,819 L
Diesel	64	1,620,160 L
FAME	115	2,318,156 L
Vehicle gas	40	592,072 kg
Biogas	274	7,961,061 kg
Hybrid (Diesel & HVO100)	68	Diesel: 3,524,250 L HVO100: 630,982 L
Hybrid (HVO100 & FAME)	45	HVO100: 856,124 L FAME: 143,347 L
Fully electric	532	68,532,960 kWh
Total	1182	

Current emission

The public transportation during 2023 resulted in an emissions level of 22,481 metric tons of CO_{2e}. The vehicle fleet used for public transportation consists of 1182 different types of heavy vehicles such as trams, buses, ferries etc. all being utilized to a high degree. It is further important to highlight that regional buses are included, which means that the geographical boundaries of Gothenburg do not apply for this goal. Instead, the public transportation includes the whole Gothenburg Region. The different geographical region also partly explains why the emission from the public transportation is approximately 75% higher than the emission from Gothenburg City's own vehicle fleet.

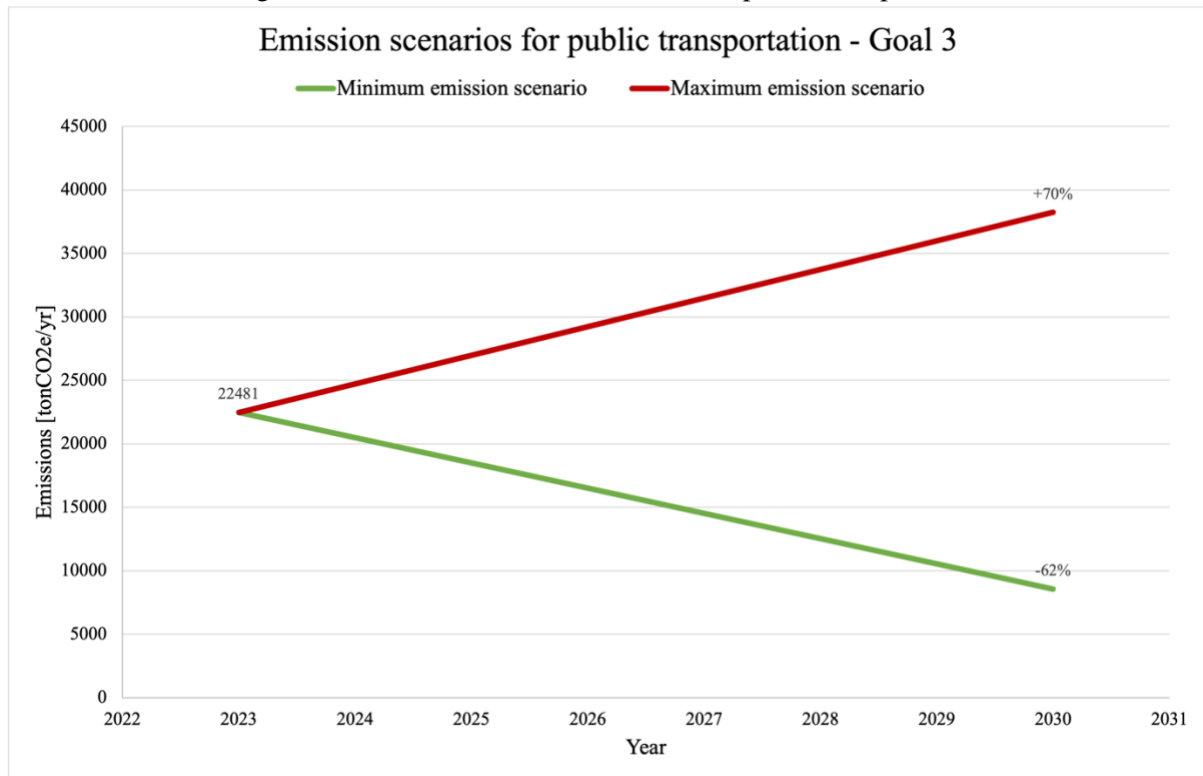
Future emission

The future emission generated by public transportation will result in a reduction of 62% with the minimum emission scenario, while the maximum emission scenario will result in an increase up to 70%, see Figure 7. The increase is because all public transportation should be electrified by 2025, and it already consists of 45% fully electric vehicles, and hence, an increased traffic flow together with a European electricity mix (maximum emission scenario) will naturally increase the emissions. How

much the electricity mix and traffic flow impact the emission levels are further investigated in the sensitivity analysis, see section 4.6.

Furthermore, it is important to consider the fact that an expansion of public transportation will most likely result in reduced traffic flow from the private sector. Emissions from the private sector are out of the scope of this project but having a holistic perspective can show that increased emissions from public transportations might reduce the overall emissions from Gothenburg's transport sector, and hence, be a positive thing. This is further discussion in section 7.2.

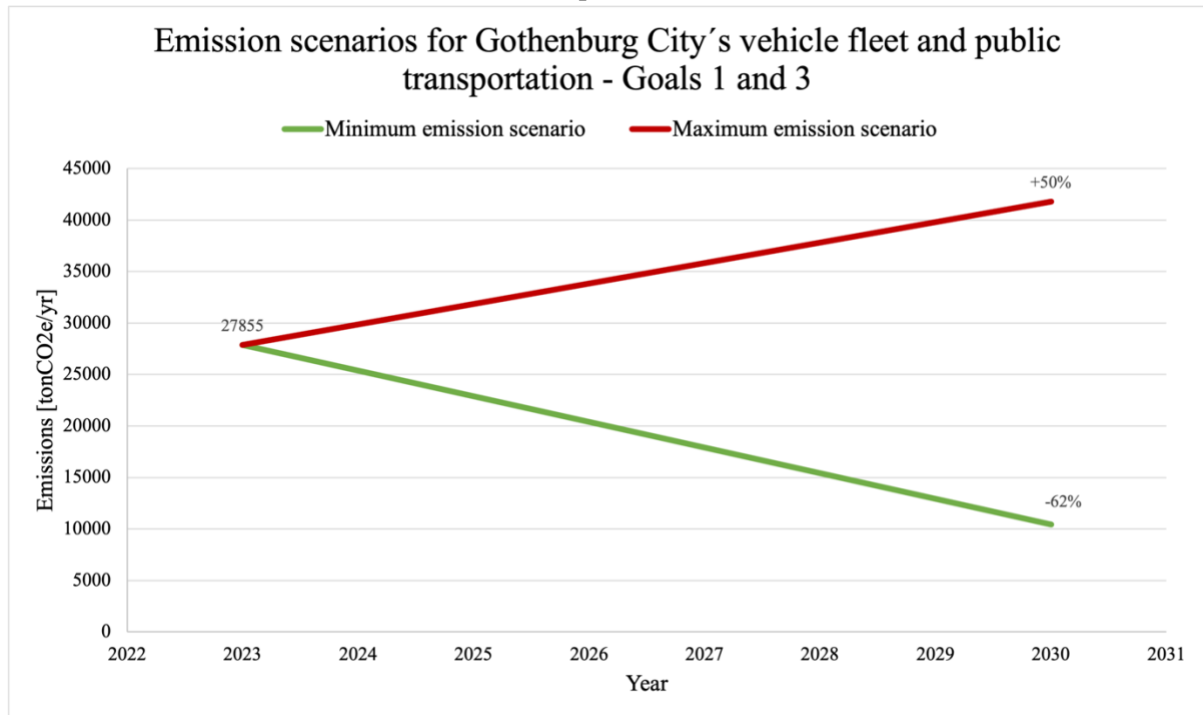
Figure 7. Future emission scenarios for the public transportation



4.4 Combined future emissions

Provided that all goals within the Electrification Plan are fulfilled and Gothenburg City's own vehicle fleet is fossil-free after 2023, the emissions levels in 2030 are highly dependent on the conditions presented in the minimum and maximum emission scenarios. As can be seen in Figure 8, the emissions from Gothenburg City's vehicle fleet and public transportation will decrease by 62% between 2023 and 2030 with the minimum emission scenario, but instead increase by 50% with the maximum emission scenario. Again, it becomes obvious that public transportation has a big impact on the overall emission, but this is not necessarily a bad thing. Public transport is more efficient than passenger car transport, and while the emission from public transport increases, the potential for reducing the overall emissions in Gothenburg.

Figure 8. Future emission scenarios for Gothenburg City's vehicles fleet and the public transportations



4.5 Goal Alignment

All emission targets, including national and international, consider territorial emissions (Naturvårdsverket, n.d.a). This covers all emissions emitted within the geographical boundaries of the nation or region. Hence, they are not related to the scopes within the Greenhouse Gas Protocol but can be connected to them. In order to explore how the goals are in line with the Electrification Plan, emission levels for the comparison year had to be estimated. However, issues arose as Gothenburg City has no data on emission levels from their transport sector in 2010 or 1990. Consequently, the emissions reduction could only be estimated compared to the current emissions levels.

4.5.1 Local emission target

For the local target, it is assumed that no fuel or electricity was produced within the geographical boundaries of Gothenburg. Meaning, only direct emissions from the use-phase (Scope 1) can be related to the 90%-target, and a recalculation from Scope 3 to Scope 1 was performed. Consequently, all biofuels (HVO100, FAME, vehicle gas, biogas, and ethanol), fully electric and hydrogen powered vehicles have zero emissions, since none of these have any direct emissions from the use phase. This resulted in lower emission levels for the current state (year 2023). Furthermore, since the vehicle fleet aims to be 100% fossil-free after 2023, as well as all vehicles used in public transportation should be electrified until 2030, the direct emissions in 2030 would be zero.

As can be seen in Table 15, Scope 1 would theoretically result in an emission reduction of 100%, regardless of if we compare it to 2023 or 2010 emission levels. This differs a lot from Scope 3, where we previously saw an emission reduction of maximum 62%. Consequently, one naturally starts questioning how sufficient the 90%-target is, and to what purpose the Electrification Plan is developed

if the 90%-target can be fulfilled by simply substituting fossil fuels with biofuels. Based on Scope 3 and our calculations, it was found that biofuel cars have higher emissions per kilometer compared to electric cars. For example, emissions from HVO100 are more than twice as high as those from electric cars, if a lifecycle perspective is considered. Therefore, even if the entire vehicle fleet is made up of biofuel vehicles that are considered geographically emission-free in theory, one can understand that they are not as good as electric vehicles in practice.

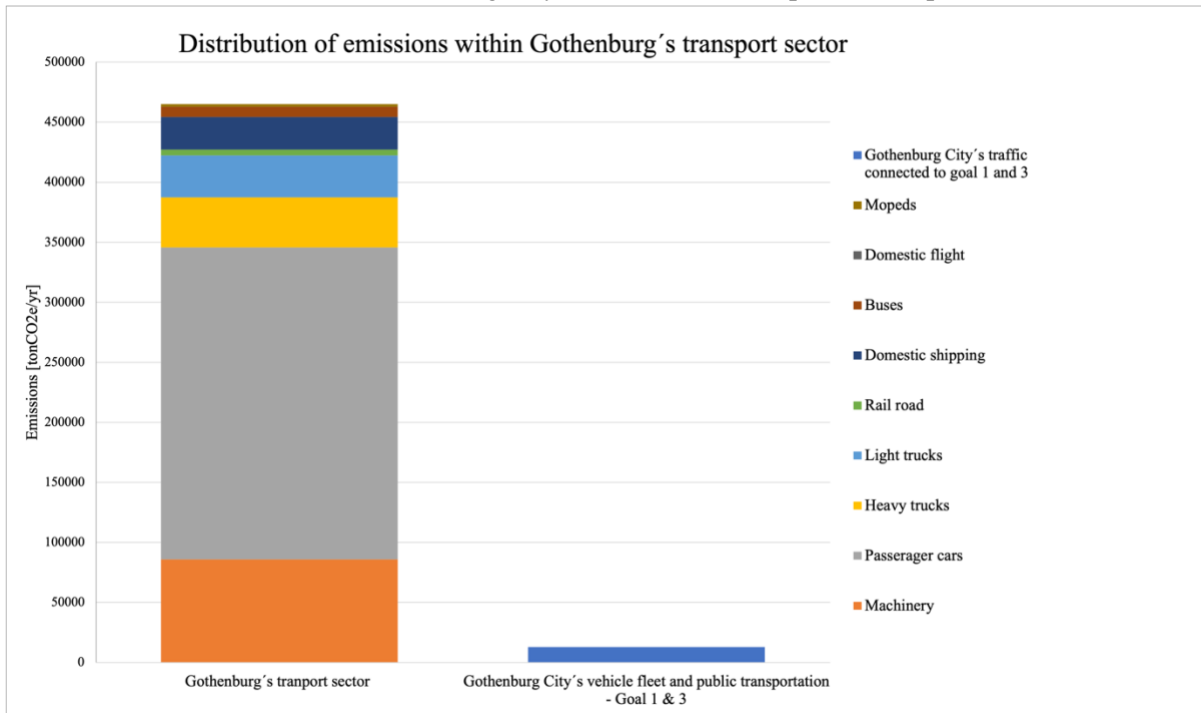
Table 15. Emissions from Gothenburg City’s vehicle fleet and public transportation, using Scope 1 and 3 in the Greenhouse Gas Protocol

	Emissions in 2023 [ton CO ₂ e]	Emission levels in 2030 [ton CO ₂ e]		Emission reduction	
		Current state	Minimum emission scenario	Maximum emission scenario	Minimum emission scenario
Scope 3	28,400	10,060	41,401	-62%	+50%
Scope 1	13,212	0	0	-100%	-100%

The 90%-target is not limited to the transportation that are under direct influence of Gothenburg City’s, but instead includes all geographical emissions from the transport sector within Gothenburg. The geographical emissions from Gothenburg’s transport sector has been measured and reported by SMHI (n.d), and as can be seen in Figure 9, emissions from Gothenburg City’s vehicle fleet and public transportation make up for a very small share of the total geographical emissions. Hence, it can be concluded that this emission reduction will not have a great influence on the 90%-target, regardless of which scope that is being used. Since the emissions from goal 2 have not been calculated on, it cannot be estimated how much this goal contributes to the 90%-target.

The Electrification Plan does, however, also include actions that focus on the whole transport sector. Goal 4 and goal 5 focus on expanding the charging and hydrogen infrastructure for inhabitants, businesses, visitors, heavy trucks, and the harbor. These two goals create prerequisites for reducing the geographical emissions from the whole transport sector and hence, contribute to the 90%-target. Further, expanding public transportation is a tool to reduce the traffic flow and emissions from the private sector, and as can be seen in Figure 9, the majority of the geographical emissions comes from passenger cars.

Figure 9. Geographical emissions from the transport sector within Gothenburg, compared to Scope 1 emissions from Gothenburg City’s vehicle fleet and public transportation.



Note: The emissions from Gothenburg’s transport sector is derived from SMHI (n.d) and represents 2020 years territorial emission levels. Emissions from Gothenburg City’s vehicle fleet and public transport is calculated by the authors using Scope 1 in the Greenhouse Gas Protocol and representing the current vehicle fleet.

To conclude, even if scope 1 is used and Gothenburg City reduces their emissions by 100%, we would be far away from reaching the 90%-target since no direct actions in the Electrification Plan are focusing on electrifying the private and commercial sector.

4.5.2 National, European, and global emissions targets

For national, European, and global emission targets, it could not be assumed that all fuels and electricity were produced outside or inside of their geographical boundaries. In reality, there are both domestic productions, imports, and exports, which need to be considered for the calculations. Hence, it could not be as easily connected to the scopes and calculated on. Emission levels will differ depending on what is included and declaring emissions a certain way can result in goal achievement. Real climate change does not take into account different emission scopes or at what time or location the emissions occur. The formulation of emission targets and associated action plans needs to be in line with each other, but also do its best to represent the real world.

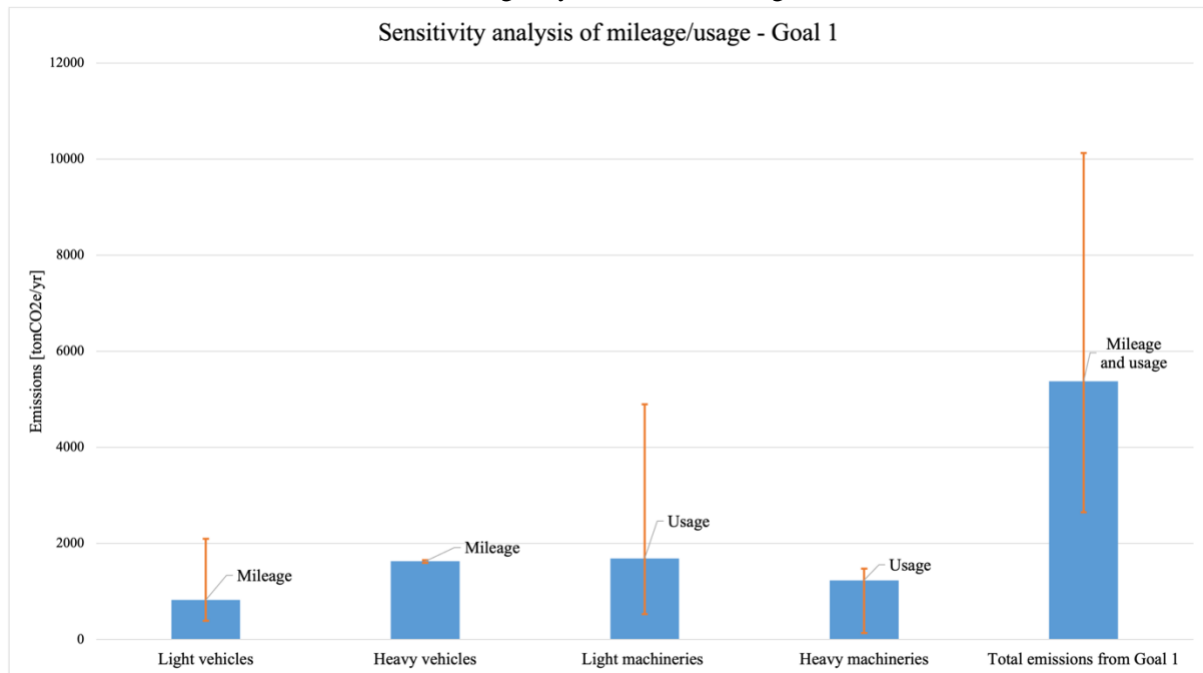
4.6 Sensitivity analysis

Mileage and usage – Goal 1

Assumptions and generalizations made concerning mileage and usages of vehicles within Gothenburg City’s vehicle fleet had a big impact on the emission levels in 2023, as can be seen in Figure 10. The most sensitive parameter was usage (number of hours per year) of light machinery, where the emission levels could be more than doubled or halved depending on if all machinery are used annually or

seasonally. Meanwhile, the least sensitive parameter was mileage of heavy vehicles. The emissions were almost completely unaffected due to small data gaps.

Figure 10. Sensitivity analysis using shortest and longest mileage/usage of vehicles within Gothenburg City's vehicle fleet - goal 1

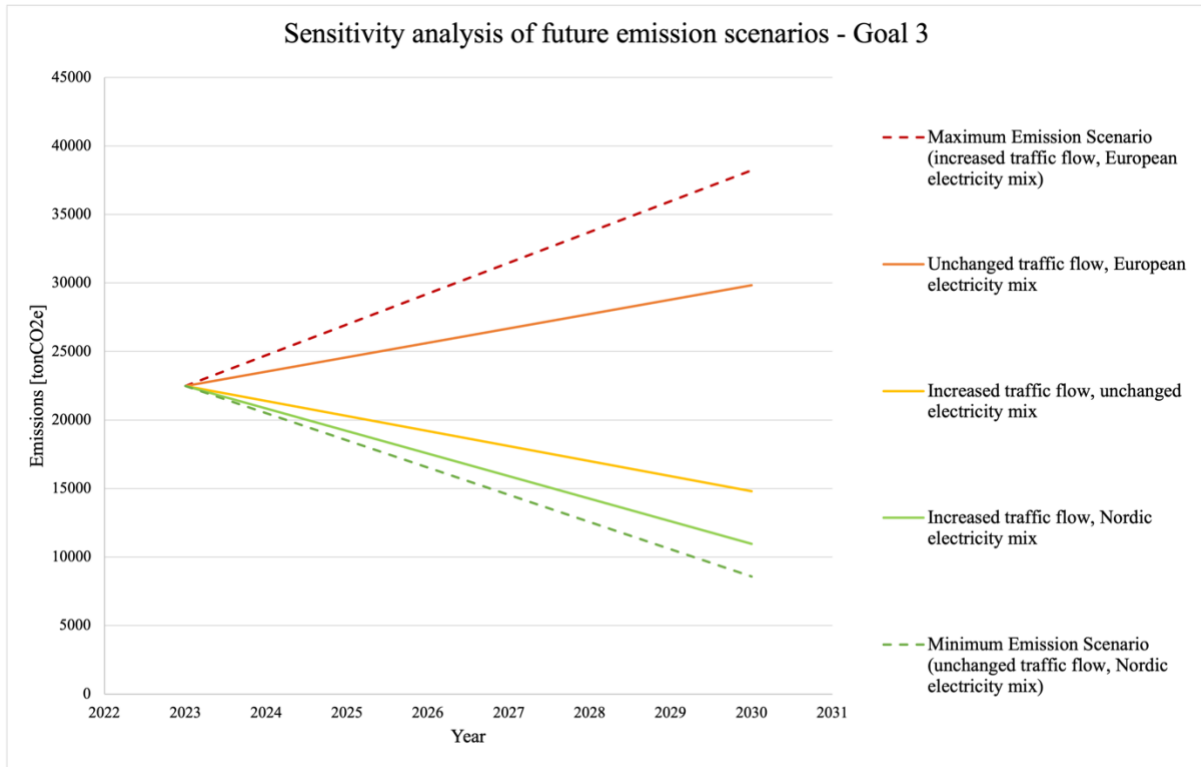


Note: The blue bars represent annual emission from each vehicle category, using the average mileage and usage. The orange extensions show how the emissions would vary if using the shortest/longest mileage, or only annual and seasonal usage of machinery. Shortest mileage and seasonal usage results in the lowest emission levels, while longest mileage and annual usage results in highest emissions levels.

Future emission scenarios – Goal 3

The parameters in the future emission scenarios impacted the emission levels from the public transportation differently, as seen in Figure 11. Figure 11 presents different combinations of the parameters, where they are changed both separately and in combination with each other. As can be interpreted from the figure, none of the combinations result in emission levels that are in line with the 90%-target. Further, it can be concluded that the electricity mix had a greater impact on the emission levels compared to an increased traffic flow. Regardless of the electricity mix, the emissions were reduced by 25% when the traffic flows were unchanged compared to annual increases of 3.6%. In addition, regardless of traffic flow, emissions will be approximately 70% lower if Nordic electricity mix is used compared to European electricity mix. Hence, the result is highly sensitive to changes in the electricity mix.

Figure 11. Sensitivity analysis of how traffic flows and electricity mixes impact future emissions.



Note: Increased traffic flow = annual increase of 3,6%. Unchanged traffic flow = traffic flows stay the same as in 2023. Unchanged electricity mix = same electricity mix as in 2023.

Amount of vehicle, energy consumption, energy content, and emission factors

Lastly, the amount of vehicle, energy consumption, energy content, and emission factors have a linear relation to the emission levels. Meaning, if one of the parameters increases by e.g., 10%, then the emission levels will also increase by 10%. Hence, large variation in these parameters will result in large uncertainties in the result.

5. WORKSHOP RESULT

The aim of this chapter is to provide a concise overview of the outcomes of the workshop. The conclusions and insights presented here are based on the input and opinions shared by the stakeholders during the discussions. To facilitate clarity, the chapter is structured into five sections. These sections cover various topics, including the identified data gap, the three development paths, and the aspects put on the “parking space”.

5.1 Data gap

The data gap discussion aimed to increase the understanding of how data is currently collected, how that can be improved, and what structures and changes that are required to follow up relevant data.

During the workshop, one of the major issues highlighted by the working group was the lack of clear structures for reporting relevant information within the organization. There are no specified requirements for what should be followed up, how it should be defined, and when it is of interest. Our interpretation is that if no one requests the data, it will not be collected or followed up by the organizations. This ignorance and lack of knowledge is a part of the problem, and this is primarily where the organization’s need help and support. This is a general problem within the organizations and not just for the sake of data collection in this project. The working group emphasizes the importance of having strict guidelines from higher decision-making bodies. A possible solution could be to use the Environmental Management System (Miljöledningssystemet) as a tool for data follow-up.

To address challenges with data follow-ups, it was suggested by the working group that a simple and automated system with clear guidelines is needed, where everyone works from the same document and method. Unfortunately, there are currently many different information systems that do not communicate with each other and lack clear directives for follow-ups. The Environmental and Climate Administration is considering imposing stricter requirements on organizations to follow up and report using the same method, such as the Greenhouse Gas Protocol. Allowing them to use the same approach for measuring and managing their climate impact would indirectly result in stricter data follow-ups. It would be possible to conduct climate calculations in-house or get external support. Either way, the same type of data follow-ups would be needed.

Another limitation to data collection is the lack of clear guidelines on how to share and distribute information according to GDPR. One organization is addressing a case in which this problem has become highly visible, and they have indicated that sharing and gathering information is greatly impeded by this issue. However, this issue is not connected to the data collection within this project, but rather a general challenge that many organizations highlighted. Sharing personal data among organizations within Gothenburg City is not an issue, but when external companies and suppliers are included, the issue arises.

One of the major issues with data follow-ups arose when data related to purchased transport was demanded. It became obvious that obtaining information from suppliers is challenging, and only a few requirements for data reporting are placed on the procurements. As discussed in section 4.2.1, data follow-ups within procurements need to be stricter and come with clear guidelines. The working group stated that data follow-ups related to the procurements are time-consuming, and more resources are needed, both in terms of time and money. The economic aspect is a barrier for electrification, given that

electrification comes with additional costs. Suppliers cannot meet higher demands if Gothenburg City is not willing to pay for them. If Gothenburg City increases demands for data delivery, they must consider the added value it would bring to the cost it will entail. If they want to increase the demands for the transition, they must be prepared to pay more.

5.2 Development path 1

DP 1 - The Electrification Plan is fulfilled: A future where we have achieved the targets within the Electrification Plan.

In DP 1, the working group focused on discussing how electrification would be distributed and prioritized among the organizations. However, a clear answer was not found as not all organizations were present, and time was limited. The working group did, however, establish a level of electrification for each vehicle category of the total vehicle fleet that should be electrified by 2030. This was constructed based on what is expected to be reasonable and assuming that charging infrastructure is available.

- Heavy vehicles: 40%
- Machinery: 60%
- Light vehicles: 80% (Passenger cars: 100%)

Regarding electrifying their own vehicle fleet, the working group concluded that Gothenburg City should prioritize based on the need for new acquisitions and the potential impact of electrification. The economic factor also plays a significant role in the progression of the substitution. At present, vehicles that do not have viable electric alternatives should be deprioritized in order to minimize costs and emissions. This is crucial as heavy machinery may become electrically viable during the next years, as the current technology is not sufficient. By prioritizing the electrification of unavailable vehicles at a later time, organizations can avoid investing and committing to new contracts. However, the working group highlights that the deprioritization should only be within a reasonable timeframe and it is important to continue demanding electric alternatives. For vehicles that are not expected to be electrified by 2030, a fossil-free alternative should be used.

The second topic the working group discussed was how they can increase the share of electric vehicles used within transportation generated by Gothenburg City purchases. Currently, there is a significant lack of information and knowledge on how to address purchased transportation. To decrease this knowledge gap, the working group discussed the need to improve the requirements for electrified and emission-free deliveries ordered by Gothenburg City. They stated that this must be handled through direct and distinct directives from higher authorities since purchased transport covers more than just Gothenburg City. They also suggested that better cooperation with the Gothenburg region is needed.

In addition, there is also a lack of knowledge within the organizations regarding the requirements in procurements, and therefore, efforts should be made to spread information and knowledge about this. One proposal the working group suggested was to use tools such as a shared PowerPoint presentation that all organizations can use to inform their employees.

5.3 Development path 2

DP 2 - Transport efficiency to simplify and/or complement electrification: A future where we get closer to the 90% target with the help of behavioral changes.

One of the major outcomes from DP 2 is that maximizing the utilization of vehicles requires changes in behavior and mindset. Currently, a mindset of owning instead of sharing is dominating in the organization. Further, the comfort of using conventional combustion vehicles hinders the electrification transition. The working group noted that it is a challenge to change behaviors in the absence of clear guidelines from higher level authorities. Altering the behavior is not feasible unless all employees modify their mindset and actions. Furthermore, they stated that all organizations must overlook their travel policy and question whether they really need to travel in the way they do today.

The working group delivered several proposals on how they could share vehicles and infrastructure between the organizations. One proposal was to organize a type of "vehicle pool" that encompasses transportation alternatives other than just cars. This vehicle pool can include vehicles such as heavy vehicles, machinery, electric cargo bikes, etc. The vehicle pool must be easily accessible, and the support system must be user-friendly and meet expectations from Gothenburg City. This means providing simple payment methods, identifying the location of each vehicle, and clarifying individual responsibilities for the vehicles. Moreover, the system must be digital and provide recommendations for charging locations. The vehicle pool will not only optimize each organization's vehicle fleet, it will also give them the opportunity to test vehicles before committing to new leases. In addition, it also allows them to choose the vehicle best suited to their destination for the day, e.g., a bicycle can be the best option today, and an electric car tomorrow. This means that they are not stuck with only one transport option.

The working group also shortly mentioned that the same approach could be implemented for the whole city, available for all citizens. Currently, there are several different platforms available, such as "styr och ställ" for bicycles, different carpooling services, and a ticket purchasing service for public transport. Is it possible to cluster all these services into a single, unified app and create a "mobility card" that gives access to all of them? This approach is called Mobility-as-a-Service (MaaS), and its effectiveness remains uncertain due to challenges such as fostering cooperation between transportation service providers and promoting behavior changes to increase demand for MaaS (Lyons, 2019). Additionally, practical transportation alternatives to private cars are necessary for MaaS to be successful. Previous behavior changes programs have shown limited success in the pilot stage and have not scaled up effectively. Therefore, market research is essential to understand user attitudes, needs, and preferences to avoid unexpected challenges and develop effective business plans.

The working group further mentioned feelings of uncertainty when using electric vehicles. They stated that using a conventional car with an internal combustion engine creates a sense of comfort and convenience compared to electric cars. This was primarily due to lack of knowledge on battery sufficiency and charging options. Currently, organizations cannot charge at all charging stations in Gothenburg. The working group discussed how introducing a "charging card" that provides access to more charging stations than today could reduce this feeling of uncertainty. They also suggested other measures such as mobile battery storage, and better dissemination among employees about where to charge the vehicle. In addition, the vehicle fleet may also contribute to increasing the feeling of security in using an electric vehicle since you can test it when it suits you.

To sum up the conversations in this development path, the working group discussed various measures that require great cooperation between the organizations. Unfortunately, all these actions cannot be done for free, and the organizations know it will be expensive. Implementing a vehicle pool can have additional investment costs, but it is notable that it will reduce the costs over time. Today it is unclear how the financial aspect should be handled, and in order to make a quick transition it will be important to investigate how this should be addressed. The working group discussed that it is important to use a systems perspective for the transition, and therefore, a joint budget is needed for new investments. A Climate Change Fund for Gothenburg City is available, but it seems, however, that the organizations have not utilized it to their fullest extent due to lack of knowledge regarding this fund.

5.4 Development path 3

DP 3 - Organizational changes: A transparent future where collaboration and division of responsibilities between businesses is optimal and everyone has the same conditions and access to information.

The results obtained by the working group in DP 3 resulted in 8 crucial bullet points. These points highlight the most significant changes necessary to overcome the organizational barriers that hinder the electrification and sufficient cooperation between the organizations. It is important to remember that much of what has been discussed in this development path has also been brought up in the two other development paths. The reason why many of the activities proposed in the other two development paths are not already established within the organizations is due to the organizational barriers. As mentioned in section 3.4.2.1, the three development pathways overlap and build on each other.

1. **More time, resources, and authority are needed for the mobility managers to succeed with the electrification** - The current organizational structure lack conditions for the mobility manager to take actions and work with electrification. Their responsibilities are not properly defined, and they have neither time nor resources to work on the matter.
2. **Centralized management of mobility managers for stronger control and better coordination (central management)** - The city should have a centralized management unit where they coordinate and support the mobility managers in terms of communication, legal and procurement competence, practical and economic issues, etc. This central management unit is also responsible for ensuring that all strategic documents and environmental management systems are aligned, in order to reduce conflicts and the risk of counteracting different actions.
3. **GCL should support the mobility managers with administration of data, fleet optimization and guidance** - GCL should collect all data and manage everything related to car optimization. A map-system with a “helicopter perspective” can be used to identify where all vehicles are located and help coordinate the organizations to share more vehicles. GCL should also support the organizations with charging infrastructure when entering a new leasing contract.
4. **Change the culture of "we do things as we have always done"** - Ensure that managers and employees have a more open-minded approach to this new way of working with electric cars, charging infrastructure, car sharing and its related work methods.

5. **Clarify what responsibilities the organizations have** - Clear guidelines from higher authorities are required to govern organizations responsibility. The guideline should present a clear number for each target, that each organization can work towards. In addition, a joint budget with financial conditionals must be in place.
6. **Digitization of systems, tools, and lists** - Data sharing and automation with linked information, rather than just loose documents and excel sheets, will result in better system support. A shared user-friendly platform should be used and accessed via the main management system.
7. **Make requirements in the procurement to contribute with input data** - Require suppliers and employees to report daily on fuel, charging, distance traveled, etc.
8. **Central vehicle pool for Gothenburg City's vehicles** - increase car sharing and optimize the use of vehicles, as discussed in section 5.3.

5.5 Parking Space

The “parking space” resulted in five things that were highlighted to be central and important for electrification, but which were beyond the influence of the organizations. The following five things were parked and stated as uncertainties for the future:

1. Charging infrastructure in 2030
2. Legislation regarding requirements for charging infrastructure
3. Electricity supply. Back-up system that can kick in at shutdowns or when electricity demand is high.
4. National coordination with a common information and support system: Is this something the Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Regioner) can arrange and have responsibilities for?
5. Differentiated road taxes. Can road taxes be different for environmentally friendly vehicles?

6. BACKCASTING

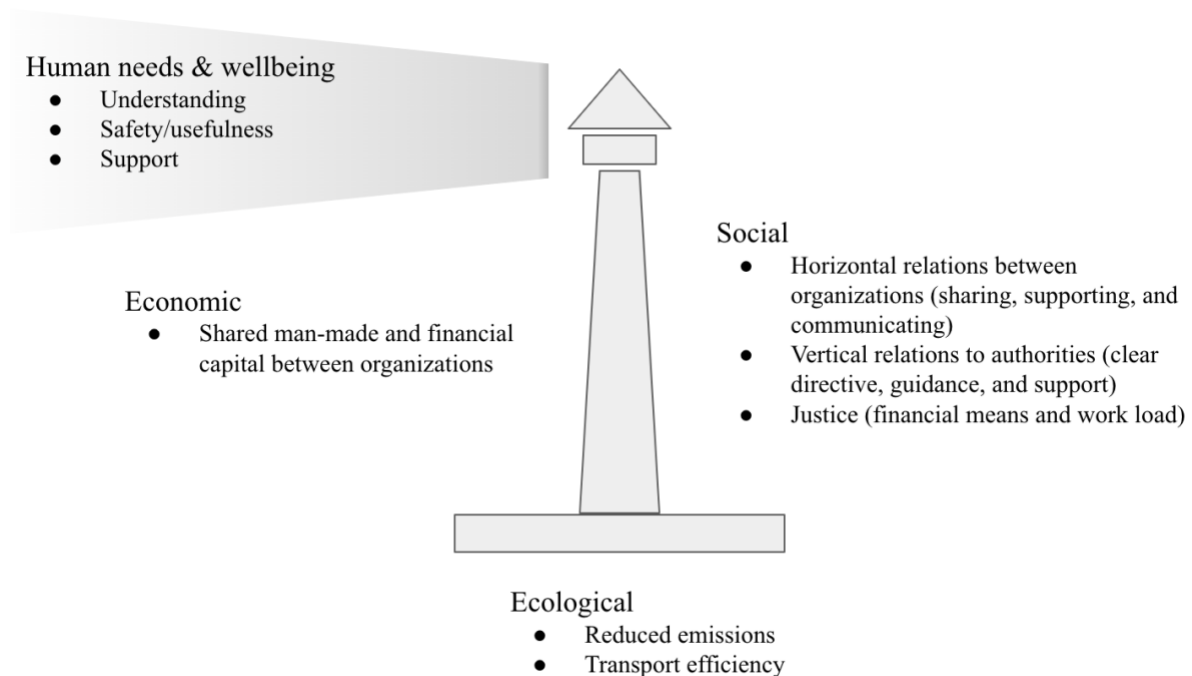
This chapter presents a backcasting approach that draws on the discussions and findings from the workshop. The backcasting process consists of four distinct steps: defining a desirable future, identifying gaps between the present and future state, formulating leverage points, and developing a comprehensive strategy. These steps are discussed in detail in this chapter.

6.1 Step 1 - Desirable future

The desirable future for a sustainable electrified transport system in Gothenburg has been developed using The Sustainability Lighthouse tool. Figure 12 shows the four dimensions of sustainability, together with its guiding principles. By following these guiding principles, we aim to achieve a desirable future described as follows:

A sustainable electrified transport system with great collaboration and communication, where the organizational structures act in favor of the transition.

Figure 12. The desirable future for a sustainable electrified transport system in Gothenburg



6.2 Step 2 - Gaps

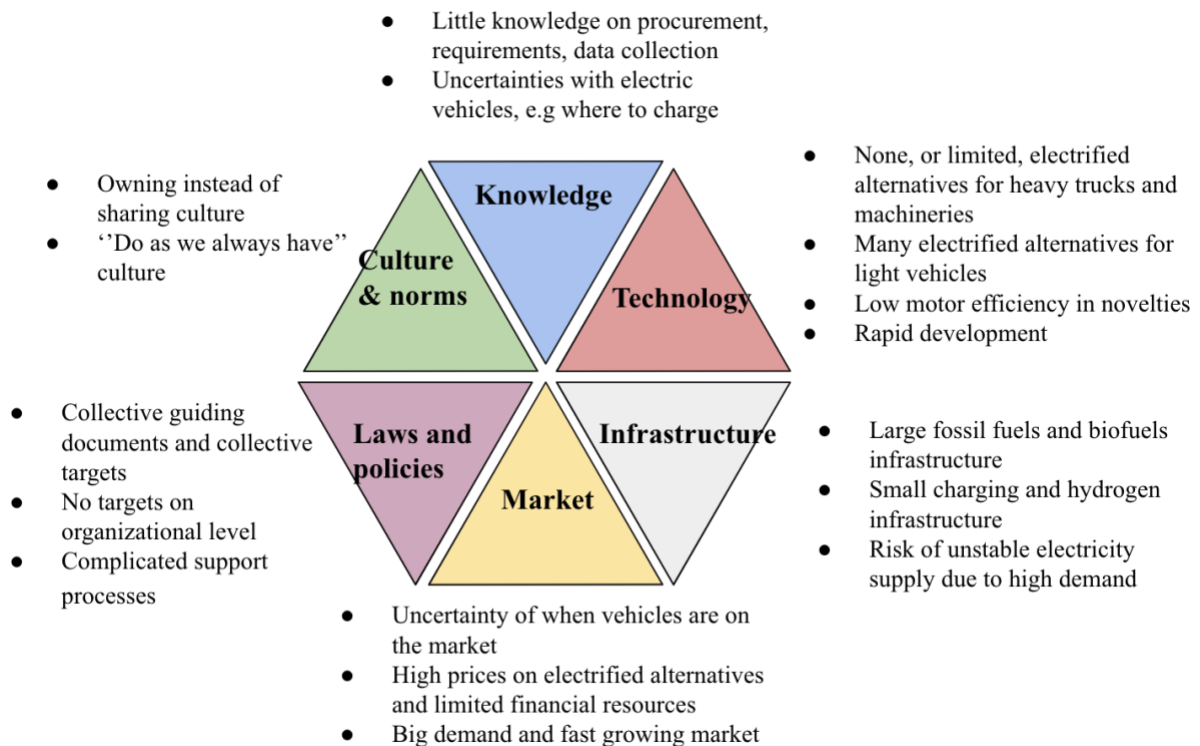
In order to identify the gaps between the current state and the desired future state, it was necessary to define the current system. The current system was constructed by analyzing the workshop results and structuring it with the support of the Socio-Technical System, as shown in Figure 13. Most of the identified gaps are transformative challenges, meaning they are barriers that hinder the transition. Currently, there is a *lack of mandate, no emission targets on organizational levels, limited knowledge on procurement, requirements, and data collection*. Furthermore, there are no strong *support systems* in place, and the ones available are too complicated. This makes it challenging for organizations to

understand what is needed and expected of them, thereby reinforcing their *unawareness of the situation* and how to work towards the desired future.

Moreover, there are crucial *communication issues* between organizations, employees, and higher authorities. It is unclear *who is responsible* for what and when tasks need to be completed. Organizations follow the attitude of "doing things as we always have," and a *culture of ownership* instead of sharing, which amplifies *cooperation issues* between them. Another significant barrier, which also amplifies cooperation issues and other problems connected to the transition, is a *lack of time*. Although it may be possible to achieve the desired future within a reasonable timeframe, there is often insufficient time to put plans into action.

In addition to transformative challenges, there are gaps that are sustainability challenges, meaning that they create negative consequences for the future and cannot be changed quickly. One example of this is society's dependence on fossil fuels. The current transportation system is built around *infrastructure dominated by fossil fuel vehicles*. Electric vehicles cannot be charged at any fuel station, and the employees at organizations are *unsure of where to charge* them. Additionally, this leads to reduced demand for electric vehicles, which amplifies their *high prices* and limited production. *All electric vehicles demanded by Gothenburg City are not currently available on the market.*

Figure 13. Socio-Technical System of the current transportation system in Gothenburg

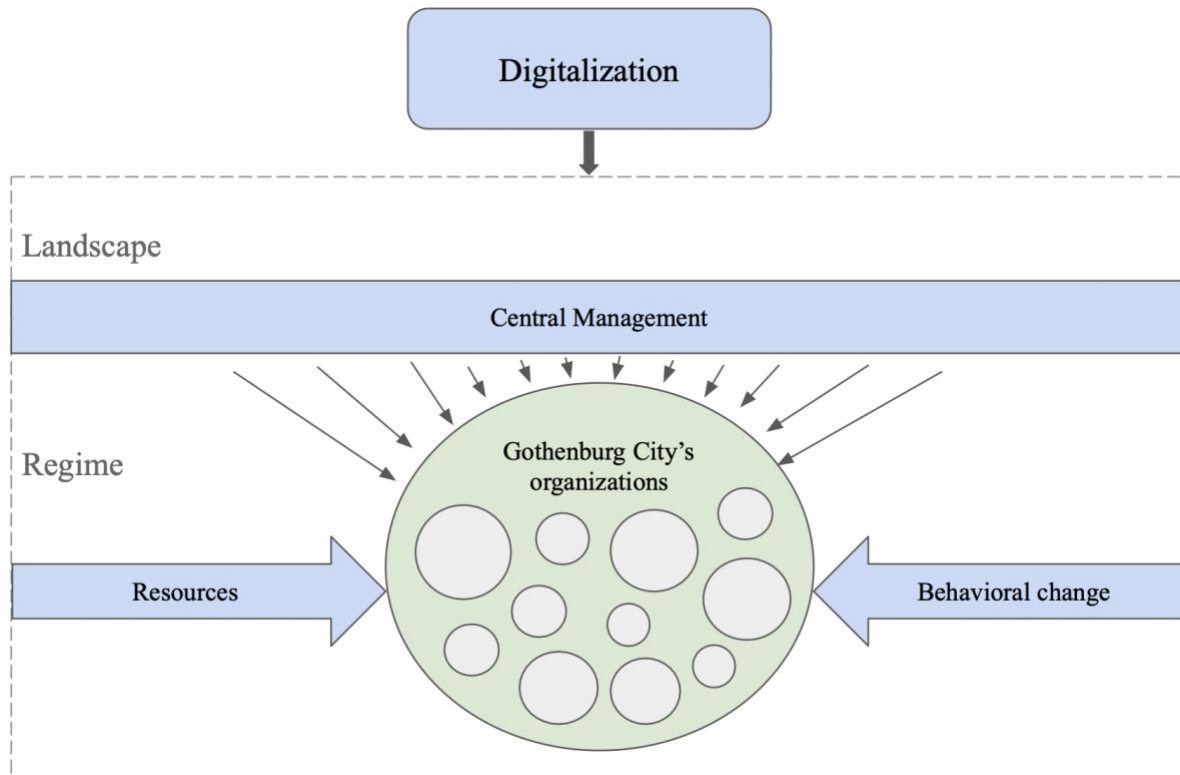


6.3 Step 3 - Leverage points

When searching for leverage points, it is important to focus on the transformative challenges in the first case. Based on the identified gaps, four leverage points can be identified: *resources*, *central management*, *digitalization*, and *behavioral changes*. All these leverage points are interdependent and focus on different levels within the system. Figure 14 illustrates the relation between the leverage points.

The organizations within Gothenburg City need to be given clear directives and support from a central management unit, they need to be provided with required resources, and undergoing behavioral changes. Lastly, digitalization is a fundamental leverage point with the power to provide prerequisites for the other leverage points. Further, it is important to recognize that the landscape and regime are all interconnected and dependent on each other.

Figure 14. Illustration of leverage points



At the landscape level, mobility managers must be coordinated through a central management unit, where it needs to be clarified what responsibility each organization has, what data should be reported, and how this should be carried out. The central management unit should also provide support to mobility managers in terms of coordination, dialogues, expertise around legal issues and procurement processes, as well as practical and financial questions. They should also be responsible for informing organizations and employees about required data follow-ups. As a suggestion, GCL can take responsibility for collecting data, optimizing the vehicle fleet, and implementing a sufficient charging infrastructure. Thereby, everything related to Gothenburg City's vehicle fleet is coordinated through one organization.

At the regime level, more resources in terms of time and money need to be assigned to the organizations. More specifically, the mobility managers need to be given a larger mandate for decision making and taking responsibility, which requires them to have the necessary financial means, and intended time for working with the transition. Resources can also be distributed between organizations differently, where we shift away from ownership and move towards a sharing economy.

Furthermore, behavioral changes are required both within and between organizations. It has been noted that employees experience significant insecurity when using electric vehicles. Therefore, providing additional information and support is necessary to reduce uncertainty surrounding their use. Additionally, behavioral changes can involve modifying transportation choices to align with specific

work tasks. The organizations must work with changing their mindset to sharing instead of owning. For example, an electric bike may be more suitable in certain situations, while an electric car may be preferable in others. A vehicle pool with a simple booking and payment system, together with a map system where it is easy to identify where the vehicles are, can be used to coordinate the organizations to share more vehicles.

All leverage points rely on digitalization. The organizations need a simple and digitized system with clear directives where everything is controlled centrally. An information platform is needed where all information is entered automatically and is available to everyone. The platform needs to be coordinated and communicate with several different functions in everyday work, e.g., data follow-up, booking transport and vehicles via a vehicle pool, requirements, purchases, payment systems, etc.

6.4 Step 4 - Strategies

The developed strategy consists of recommendations for how to continue working with the transition. This project has mapped up what changes are needed and how to make the biggest impacts, based on discussions by the stakeholders. However, much work is still needed to get to the finish line, where this project has created a foundation that can be further built upon. The work needs to be undertaken by someone with a mandate to influence and make changes in the system.

We recommend three important actions to pick up where this project ends.

Firstly, one needs to build up visions for how the transition journey can develop to reach the desirable future. There can be many pathways for the journey and different ways to reach it, and we recommend addressing the identified leverage points (resources, central management, digitalization, and behavioral changes) when moving towards the desirable future. The visions should also consider when to electrify and when to optimize other parts of the transport sector. The result from this project indicates that electrification is not a silver bullet, and it needs to be complemented with other types of actions such as fleet optimization and behavioral changes. We recommend broadening the perspective and to not considering electrification as the only solution but rather as a part of a bigger solution.

Secondly, one must develop an action plan. It has been obvious from the beginning of this project that an action plan for how to work with the Electrification Plan is needed. It should present who, when, and how the actions should be performed to achieve the goals. The current gaps identified in the transition include communication issues between organizations, employees, and higher authorities. To address this, there should be coordinated efforts to increase communication and collaboration, including clarifying responsibilities and setting targets on organizational levels. We recommend that an organization, or a group of individuals with central overview, are given the responsibility to develop and follow up this action plan. The action plan should be based on the leverage points presented in section 6.3, as well as the visions for the transition journey.

Thirdly, we recommend creating the opportunity to test activities on a small scale before expanding to full scale, e.g., test different digitization methods and small-scale vehicle pools. Currently, car and bicycle pools exist, but there is a lack of other pool systems that allow for testing different modes of transportation, such as cargo bikes and electric cars, within the same pool. By initially conducting small-scale tests on these systems, we can lower expenses and assess their potential and profitability.

7. DISCUSSION

This chapter focuses on discussing if the emission reduction can exceed the calculated value in this report. It will also discuss the credibility of Gothenburg City's Electrification Plan and how likely it is that the plan will be fulfilled. This is followed by a discussion on trade-offs between public transportation and different functions within the urban environment, such as private transportation and land use. Lastly, recommendations and further research related to the Electrification Plan and sustainable transport systems are discussed.

7.1 Achieving a bigger emission reduction

This report demonstrates that the emissions from Gothenburg City's vehicle fleet and public transportation will decrease by 62% in the minimum emission scenario. This leads to questioning whether it is possible to achieve even bigger emission reductions through electrification. The emission scenarios are based on different electricity mixes and traffic flows, which both influence the size of the emission reduction.

While a local electricity mix in Gothenburg may have lower emissions than the Nordic electricity mix, the climate impact of consumed electricity is not solely determined by the contracted electricity type (Göteborg Energi AB, personal communication, February, 2023). The climate impact is also influenced by the entire mix of electricity in the connected system. It is worth noting that Gothenburg is not an independent electricity system but depends on power generation in other regions of Sweden and Europe. It is linked to both the Nordic and Northern European electricity systems, so the climate impact of electricity consumption in Gothenburg is similar to that of the Nordic or Northern European electricity mix, depending on the timing of electricity usage (Göteborg Energi AB, personal communication, February, 2023). Selecting the appropriate electricity mix is crucial when evaluating the climate impact. Hence, using a Nordic electricity mix for the calculations will result in less emission as it consists of more renewable energy compared to the Northern European electricity mix. It was challenging to anticipate how the electricity mix would look in the future, and hence, it had to be assumed that the emissions from electricity production will be reduced according to the Fit for 55-target.

Further, the 62% emission reduction is also based upon achieving the local target of reduced traffic flows, which has been set to a significant reduction of 25% between 2020 and 2030, exceeding the historical increase. The reduction in traffic flow is measured by the total number of kilometers driven by all types of motorized vehicles. In this project, the assumption is that if there are fewer cars on the road, there will be fewer kilometers driven. If the number of vehicles is reduced by 25% and the remaining cars drive the same distance as before, the total kilometers driven will be reduced by 25%, thereby achieving the target. However, we are aware that it is also possible to achieve the target by keeping the number of cars on the road the same but reducing the total kilometers driven by 25%. It is worth noting that this project only measures emissions from fuel and not from vehicle production. Furthermore, The City Environment Administration has stated that there is no dedicated working group established to develop a specific action plan aimed at achieving the target (personal communication, February, 2023). While there are various approaches to reducing traffic, there is currently no clear strategy in place for moving forward. This means that any actions taken will be uncoordinated and inefficient. During conversation with many of the organizations within Gothenburg City, we got the impression that this traffic reduction target will not be achieved.

In conclusion, it is unlikely that the emission reduction will surpass 62%. Nevertheless, it is important to note that factors such as efficiency and technological improvements may contribute to further reductions beyond what has been analyzed. By solely extrapolating the combined emissions from section 4.4, the emissions from Gothenburg City's vehicle fleet and public transportation could reach zero as early as 2034, surpassing the national Net Zero Emission target.

7.2 The credibility of the Electrification Plan

A critical factor to take into account is the credibility of the goals specified in the Electrification Plan. BRG stated in a personal communication (February, 2023) that the goals were established through dialogues with each organization in Gothenburg City. This means that BRG constructed the goals in the Electrification Plan based on the individual goals of each organization, making them reliable and theoretically achievable by 2030. However, it's important to note that forecasting the future is difficult, and there may be gaps in achieving the Electrification Plan's goals.

With regard to public transportation (goal 3), it is unclear which vehicles are included in the Electrification Plan. Although the goal mentions that it includes regional buses, it does not specify whether this applies only to buses operating within the city or if it also covers buses operating exclusively outside the city. During a conversation with Västtrafik in February 2023, they mentioned that all their city driving vehicles will be electric by 2030, except for ferries (of which 80% will be electrified). However, their regional vehicles and ferries are more difficult to electrify due to a lack of technology and fixed-term contracts. This means that Västtrafik would not be able to achieve a 100% electrified vehicle fleet by 2025 or even 2030. It is possible that when Västtrafik discussed its future goals with BRG, they assumed that the technology would be available by 2030. Alternatively, it could be due to a lack of communication between BRG and Västtrafik. Our interpretation, after talking to both companies, is that the goal's scope is not clearly defined. If the goal only takes into account vehicles within the city, Västtrafik would probably reach the goal with its vehicles except the ferries. However, if the goal also includes vehicles that operate in the region, Västtrafik will not nearly reach the goal in 2030. In this project, we have calculated the mileage for all public transport in the entire Gothenburg Region.

Another aspect to consider is that Gothenburg City's vehicle fleet (goal 1) does not have a defined electrification target for light vehicles. Although there is a target for 2023, there is no target specified for 2030. To continue with the Electrification Plan's efforts in this regard, a new target must be set for the electrification of light vehicles. For the sake of this project, we had to establish a temporary target for 2030 in order to estimate future emissions from light vehicles. As the workshop participants are the individuals who will execute this action, we decided to use the recommended target presented in development pathway one (see section 5.2) for the calculations. According to this target, 80% of light vehicles (inclusive of 100% electric passenger cars) should be electrified by 2030. We believe that this value is fitting because, despite the fact that there are many light vehicles in Gothenburg City's vehicle fleet, they emit the least emissions compared to other vehicle categories. This signifies that their emission reduction will be less significant than other vehicle categories, and therefore, the overall outcome for goal 1 will not show significant variations if we were to adopt a higher or lower percentage.

7.3 Trade-offs in public transportation

The results demonstrate that future emissions from public transportation can increase, depending on the electricity mix and traffic flow. Therefore, it is important to have a holistic perspective on the transport system and consider the trade-offs involved with increased traffic flow from public transport.

Taking a holistic outlook on the transport system is crucial, as increased traffic flow in public transportation can help reduce emissions from the private transport sector. Public transportation is more energy-efficient than passenger cars and can substitute for up to 50 passenger cars, resulting in fewer emissions (Sveriges Bussföretag, 2019). Evaluating the emission per passenger, the United Nations (n.d) states that substituting one passenger car with public transportation can reduce the annual emission by 2.2 tonCO₂e/person. Putting this into context, an average Swedish person emitted approximately 8 tonCO₂e/person during 2020 (Naturvårdsverket, n.d.b), meaning that the per capita emissions can be reduced by 28% if passenger cars are substituted with public transport. However, a condition for increased public transportation is that the usage also increases. To increase the usage of public transportation, other means need to be implemented, such as economic incentives and time-saving measures. In addition, aspects like urban planning can be used to reduce the amount of parking space in areas with good public transport, in order to reduce traffic flows. To test the idea of emission free transport system, Gothenburg has developed a project called Gothenburg Green City Zone, consisting of three different zones where new technologies and solutions can be tested in real urban environment, to find solutions that can expand over the city (Business Region Göteborg, 2023). This encompasses infrastructural change to benefit micro mobility services and public transportation.

Additionally, public transportation can reduce the demand for parking spaces, as one bus reduces the land space for approximately 35 cars (Sveriges Bussföretag, 2019). This can free up land for other purposes such as parks, bike lanes, or housing. However, it assumes that when space is freed up for other purposes, it is necessary to quickly implement an infrastructure that prioritizes public transport, as well as pedestrian and bicycle paths.

7.4 Recommendations and further research

Strategies for the Electrification Plan

We recommend that further research be put on coordinating and developing Gothenburg City's Electrification Plan according to the four leverage points and strategies constructed in the backcasting. In addition, a closer investigation of the goals within the Electrification Plan in relation to the organization's ambition levels is needed. As seen in this project, some of the goals are not in line with what the organization works towards, and an electrification goal for the light vehicles within goal 1 is lacking. A strategy plan with concrete steps for how the Electrification Plan should be achieved and who should do what needs to be developed in cooperation with all involved organizations and stakeholders.

Further, additional actions can complement the electrification and it needs to be investigated how the electrification relates to aspects such as vehicle optimization and efficiency improvements. It is important to make sure that different plans and programs are in line, for example, for electrified transport to be climate-neutral, the electricity needs to be fossil-free.

Climate Change Fund

One of the major challenges in the transition towards a sustainable transport system is the economic barriers that organizations face. The process of adopting new technologies, transitioning to renewable energy sources, and implementing sustainable practices can often come with high costs and financial risks. However, during the workshop, it was informed that a Climate Change Fund is available for Gothenburg City (Västra Götalandsregionen, 2023). This fund has been designed to support local organizations and initiatives in their efforts to tackle climate change and promote sustainability. The organizations pay an additional fee to the fund when choosing transportation modes with high climate impacts during business trips. All organizations can later apply to the fund and get financial support when investing in action to reduce the organization's climate footprint. We recommend that the organizations in Gothenburg City take the time to investigate this fund and explore how they can benefit from it.

Improve data accessibility for purchased transport - Goal 2

An additional challenge that arose during this project was the collection of sufficient data. To improve data accessibility, we suggest implementing data reporting requirements for the organizations. Availability of data can be used to follow-up the goals within the Electrification Plan, but also for other types of climate calculations and work optimization. The lack of data became especially clear when collecting data for goal 2. A small amount of data was received but could not be used for calculations due to its limitations. Hence, we recommend that the following research is put on each subgoal.

1. *Subgoal 2.1: Transportation generated by purchased goods and services.* Since one organization is responsible for the procurement of the most transport-intensive framework agreements, the requirements are clear and simple for them to follow. However, much effort needs to be put into follow-ups and reporting data, where it is currently lacking. As seen in section 4.2, the result shows that the follow-up is newly started, and this process will most likely take a long time. Hence, to further evaluate the potential of this subgoal, it is important to emphasize the importance of follow-ups, as well as making them more efficient, preferably through automation and digitalization. Only when the data is available is it possible to evaluate the emission reduction results from the Electrification Plan.
2. *Subgoal 2.2: Purchased passenger transportation.* More effort needs to be put into identifying the reason for the data gap on purchased passenger transportation. Due to lack of time, it was not possible for this project to evaluate the root cause for this issue. Hence, a first step for the further evaluations of subgoal 2 would be to have a conversation with the three organizations responsible for purchased passenger transportations to get a deeper understanding of what type of data they have and where there are shortcomings. Based on this knowledge, it would be possible to determine how to proceed and what further actions are needed. Afterwards, a deeper analysis of emissions from passenger transport could be performed.
3. *Subgoal 2.3: Procured contracting work and its associated transport.* As mentioned in section 4.2, the interpretation of the purchased contracting work was that it appeared unclear with whom the responsibility over the associated transportation lies. The organizations within Gothenburg City lack knowledge on what type of machines are being used, and how much. Hence, the next step would be to contact the contracting companies to investigate whether they possess this data, or if a third party is contracted for the use of machines only.

Addressing the entire transportation sector in Gothenburg

It is worth noting that the Electrification Plan does not include any direct measures to reduce emissions from private and commercial transportation, apart from providing sufficient charging infrastructure. The Environment and Climate Program clearly defines what the 90% target encompasses. However, it has come to our attention that stakeholders at Business Region Göteborg had the impression that the target only applies to Gothenburg City's own transportation and not the entire transportation sector of Gothenburg. As a result, we recommend putting more effort into increasing understanding of how the Environment and Climate Program and the Electrification Plan are connected, so that they work together and align with one another. In addition, we recommend disclosing how the emissions from Gothenburg's transport sector will be addressed through a well-defined action plan that outlines how all transportation emissions in Gothenburg will be tackled. This can include transitioning to electric, hydrogen, and biofuels, enhancing public transportation, reducing traffic flows, and extending pedestrian and bicycle pathways. By looking at the bigger picture, more aspects will be considered, resulting in a more substantial reduction in emissions overall. However, implementing these changes will require decisions that affect the everyday lives of residents, requiring behavioral changes and new travel habits.

Consumption-based emission targets in Gothenburg

Currently, all emission targets in Sweden and Europe are territorial, and it can be argued that Gothenburg instead should have consumption-based emission targets. A consumption-based approach would mean to include a life cycle perspective on all consumed goods and services, while a territorial approach refers to direct emissions that occur within a geographical area. Reformulating the emission target would facilitate climate calculations using the Greenhouse Gas Protocol, and hence provide a common approach for emission calculations.

Emissions from vehicle production

This project shows that Gothenburg is very ambitious in relation to the national emission target. However, even if the project investigates a life-cycle perspective, it is limited to the fuels and does not include the vehicle itself. To get a more accurate result, an analysis with a life cycle perspective of vehicles is recommended. Del Pero et al., (2018) has performed a life cycle analysis (LCA) on battery electric vehicles (BEV) and internal combustion engine vehicles (ICEV), which clearly reports that the production of BEV has a larger environmental footprint compared to ICEV, due to metals used in high-voltage batteries. This aspect is not considered within this project, but it is important to bear in mind. However, the overall emission for a BEV is still much smaller compared to an ICEV.

8. CONCLUSION

The evaluation of Gothenburg City's Electrification Plan reveals a significant data gap around purchased transportation. As a result, the calculation of potential emission reduction could only be performed on Gothenburg City's own vehicle fleet (goal 1) and public transportation (goal 3), excluding purchased transportation (goal 2). The report presents two possible scenarios for the future, where the combined emission levels in 2030 could either decrease by 62% or increase by 50% compared to current levels. The contribution of goal 1 resulted in either a 64% or 32% reduction, while goal 3 led to a decrease of 62% or an increase of 70%, depending on the scenario. Regarding goal 2, an analysis of the procurement requirements showed that they are making efforts to improve their environmental footprint. However, further work is needed to develop an adequate follow-up method.

In terms of electrification, the report recommends prioritizing vehicles with established electric options (e.g. light vehicles) and deprioritizing those with no or limited electric options (e.g. heavy machinery). However, this strategy is not sustainable in the long run, and it is essential to demand new electric options. In cases where electric vehicles are unavailable, the report suggests using biofuels as the second-best option.

To ensure that the Electrification Plan aligns with local, national, European, and global emission goals, the report recalculated the emissions to meet the same requirements. The recalculation was done only for the local target since it is based on the other targets. The report found that including only territorial direct emissions (Scope 1) resulted in a 100% reduction in emissions from Gothenburg City's vehicle fleet and public transportation, while using a lifecycle perspective (Scope 3) resulted in a 62% emission reduction. However, to achieve Gothenburg's 90% emission reduction target, it will be fundamental to focus on the private and commercial transport sectors.

Further, to overcome the challenges and achieve a successful transition towards sustainable electrified transportation, the report recommends prioritizing four key leverage points: digitalization, central management, adequate resources, and behavioral changes. The report addresses the significance of a coordinated and centralized approach to mobility management, which involves the establishment of a central management unit to provide coordination and support, using a digitized platform for information sharing, increasing resources, and empowering mobility managers, and promoting knowledge dissemination and collaboration between organizations.

Overall, the report provides valuable insights and recommendations for Gothenburg City and its organizations to overcome the transformative barriers and achieve their emission reduction goals. By prioritizing the recommended actions, the city can make significant progress towards creating a sustainable and environmentally friendly community.

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A. APPENDIX

A.1 Goals within Gothenburg City's Electrification Plan

Goal 1. Increase the proportion of fully electric and hydrogen-powered vehicles in Gothenburg City's own vehicle fleet and machine park

Indicator	Current state 2022	Target value 2025	Target value 2030
Subgoal 1.1 Increase the proportion of fully electric and hydrogen-powered vehicles in Gothenburg City's vehicle and machinery fleet			
Proportion of fully electric or hydrogen-powered light vehicles	425	800 (2023)	
Proportion of fully electric or hydrogen-powered heavy vehicles	2%	10%	30%
Proportion of fully electric or hydrogen-powered light machinery	6%	20%	70%
Proportion of fully electric or hydrogen-powered heavy machinery	0%	10%	40%

Goal 2. Increase the proportion of fully electric and hydrogen-powered transports generated by Gothenburg City's purchases

Indicator	Current state 2022	Target value 2025	Target value 2030
Subgoal 2.1 Increase the proportion of fully electric or hydrogen-powered transport generated by Gothenburg City's purchases of goods and services.			
Proportion of fully electric or hydrogen-powered vehicles that are used in pure transport services	1.5%		30%
Proportion of fully electric or hydrogen-powered vehicles that are used in goods transport	5%		30%
Subgoal 2.2 Increase the proportion of fully electric or hydrogen-powered road-bound passenger transport that Gothenburg City buys and have the opportunity to make a demand on			
Proportion of hours that transports paid by the public is carried out with fully electric or hydrogen-powered vehicles	20%		100%
Subgoal 2.3 Increase the proportion of fully electric machines and transports associated with construction on behalf of Gothenburg City's operations			
Proportion of fully electrical energy consumption for work machines and transports associated with construction		10%	70%

Goal 3. Increase the proportion of fully electric or hydrogen-powered transport in public transport

Indicator	Current state 2022	Target value 2025	Target value 2030
Subgoal 3.1 Increase the proportion electric vehicles in the ordinary traffic in Gothenburg City within Västtrafik's work range			
Proportion of fully electric vehicles or ships used on the bus and ferry lines in Gothenburg (including regional buses and ferries)	45%	100%	
Subgoal 3.2 Increase the proportion of electric vehicles in ordinary traffic in Gothenburg, financed by Gothenburg City			
Proportion of fully electric vehicles or ships used on bus and ferry lines commissioned by Gothenburg City	9.7%	100%	

Goal 4. Good availability of charging options with regard for the demand

Indicator	Current state 2022	Target value 2025	Target value 2030
Subgoal 4.1 Good charging facilities for residents with regard for the demand			
Proportion of electric car users in Gothenburg that experience the availability of charging possibilities to be good	44%	80%	95%
Subgoal 4.2 Good charging possibilities for business with light vehicles with regard for the demand			
Proportion of businesses with fully electric or hydrogen-powered cars in Gothenburg that experience the availability of charging possibilities to be good		80%	95%
Subgoal 4.3 Good charging possibilities for visitors with regard for the demand			
Proportion of electric car-using visitors in Gothenburg that experience the availability of charging possibilities to be good	44%	80%	95%
Proportion of electric car-using visitors in Gothenburg that experience the charging possibilities to be user-friendly	33%	80%	95%

Proportion of public charging within municipal areas in the city with uniform payment options	70%	100%	
Subgoal 4.4 Increase the possibility to charge leisure boats in Gothenburg leisure marinas with regard for demand			
Numbers of fast chargers in Grefrab's ports	0	5	11
Minimum numbers of charging points in each of Grefab's port	0	10	20
Subgoal 4.5 Increase the possibility to charge heavy vehicles with regard for the demand			
Proportion of electric heavy vehicle users in Gothenburg the experience the availability of charging possibilities to be good		80%	95%
Number of public high-power chargers for heavy vehicles in the city	1	4	

Goal 5. Sufficient access to renewable energy for the electrified transport system

Indicator	Current state 2022	Target value 2025	Target value 2030
Subgoal 5.1 Sufficient supply of renewable energy for the electrified transport system			
Proportion of hydrogen vehicle users in Gothenburg that experience that the availability of hydrogen refueling is good		80%	95%
Number of public hydrogen filling stations in Gothenburg		3	