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EVALUATION BOTTOM-UP OF THE CARBON EMISSIONS OF A DISTRICT TO SUPPORT THE DESIGN OF A CARBON NEUTRAL DISTRICT IN VALENCIA

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Abstract

This thesis aims to develop a methodology to measure emissions at a district level by taking existing methodologies into account and modifying them by executing a case study. The study aims to be a methodological contribution to the València Ciutat Neutra Mission, approved in 2020 by the city of Valencia. It will also deliver feedback regarding the available data and a model in Microsoft Excel to replicate the study for other districts.

It lacks standardised methodologies to estimate urban greenhouse gas emissions at a district level. This thesis aims to develop one by applying a bottom-up approach methodology to determine the GHG emissions emitted within a district of Valencia. A literature review was conducted to gather important information and the data needed for the case study. The district evaluated was the historic Ciutat Vella. An activity inventory was done for the five sectors: transport, energy, consumption, land use, and waste, and the activities were paired with emission factors to convert them into GHG emissions. The final result was that 368 440.2 CO_2e was emitted in Ciutat Vella in 2020, where scope 1, 2, and 3 accounts for 36.4%, 5.6%, and 58.0%, respectively. The land use sector emitted the most significant part of the total emissions, followed by the consumption and transport sector, with 51.8%, 22.0%, and 18.8%, respectively.

The conclusions from the thesis were that emission inventories through a bottom-up approach at a district level are complex, as the methodology is heavily data-dependent, and data gets less frequent as the evaluated area becomes smaller. However, the weakness of the methodology can transform into a strength if more data is collected, and the accuracy then can increase. A list of recommendations regarding data for districts was collected, including areas such as long-distance travel, consumption patterns, residential living area, and waste treatment.

Keywords: emission accounting, carbon footprint, bottom-up approach, activity inventory, emission factors, district, neighborhood.

Resumen

Este Trabajo Fin de Máster desarrollar una metodología para medir las emisiones a nivel de distrito o barrio en la ciudad de València, teniendo en cuenta las metodologías existentes y modificándolas mediante un estudio de caso. El estudio pretende ser una aportación metodológica a la Misión València Ciutat Neutra aprobada en 2020 por la ciudad de València. También proporcionará información sobre qué datos de partida se encuentran disponibles, así como un modelo en Microsoft Excel para replicar el estudio en otros distritos de la ciudad.

Actualmente se carece de metodologías estandarizadas para estimar las emisiones urbanas de gases de efecto invernadero a nivel de distrito. Esta tesis pretende desarrollar una metodología aplicando un enfoque de abajo arriba (bottom-up) para determinar las emisiones de gases de efecto invernadero en un distrito de Valencia. Para ello se ha realizado una revisión de la literatura que ha permitido recopilar la metodología y los datos necesarios para el caso de estudio. El distrito evaluado es el casco histórico de Ciutat Vella. El estudio ha permitido realizar un inventario de actividades para cinco sectores: transporte, energía, consumo, uso del suelo y residuos. La tasa de actividad se ha multiplicado por factores de emisión obtenidos de bases de datos estándar para convertirlas en emisiones de gases de efecto invernadero. El estudio ha permitido concluir que en Ciutat Vella en 2020 se emitieron 368 440.2 toneladas CO_2e, de las cuales los alcances 1, 2 y 3 representaron el 36.4%, el 5.6% y el 58.0%, respectivamente. El sector del uso del suelo emitió la fracción más significativa, seguido del sector del consumo y del transporte, con un 51.8%, 22.0% y 18.8%, respectivamente.

El estudio muestra que los inventarios de emisiones a nivel de distrito mediante un enfoque bottom up son complejos, ya que la metodología depende en gran medida de la disponibilidad de datos, que son menos frecuentes a medida que el área evaluada es más pequeña. Sin embargo, la debilidad de la metodología puede transformarse en una fortaleza si se recogen más datos, aumentando así la precisión. A partir del análisis realizado, el estudio propone una serie de recomendaciones para mejorar la disponibilidad de datos de actividad en los distritos, incluyendo aspectos como los viajes de larga distancia, los patrones de consumo de consumo, la superficie residencial y el tratamiento de residuos.

Palabaras claves: contabilidad de emisiones, huella de carbono, enfoque bottom-up, inventario de actividades, factores de emisión, distrito, barrio.

Resum

Aquest Treball Fi de Màster desenvolupa una metodologia per a mesurar les emissions a nivell de districte o barri a la ciutat de València, tenint en compte les metodologies existents i modificant-les mitjançant un estudi de cas. L'estudi pretén ser una aportació metodològica a la Missió València Ciutat Neutra aprovada en 2020 per la ciutat de València. També proporcionarà informació sobre quines dades de partida es troben disponibles, així com un model en Microsoft Excel per a replicar l'estudi en altres districtes de la ciutat.

Actualment no es compta amb metodologies estandarditzades per a estimar les emissions urbanes de gasos d'efecte d'hivernacle a nivell de districte. Aquesta tesi pretén desenvolupar una metodologia aplicant un enfocament de baix a dalt (bottom up) per a determinar les emissions de gasos d'efecte d'hivernacle en un districte de València. Per a això s'ha realitzat una revisió de la literatura que ha permés recopilar la metodologia i les dades necessàries per al cas d'estudi. El districte avaluat és el centre històric de Ciutat Vella. L'estudi ha permés realitzar un inventari d'activitats per a cinc sectors: transport, energia, consum, ús del sòl i residus. La taxa d'activitat s'ha multiplicat per factors d'emissió obtinguts de bases de dades estàndard per a convertir-les en emissions de gasos d'efecte d'hivernacle. L'estudi ha permés concloure que a Ciutat Vella en 2020 es van emetre 368 440.2 tones CO_2e, de les quals els abastos 1, 2 i 3 van representar el 36.4%, el 5.6% i el 58.0%, respectivament. El sector de l'ús del sòl va emetre la fracció més significativa, seguit del sector del consum i del transport, amb un 51.8%, 22.0% i 18.8%, respectivament.

L'estudi mostra que els inventaris d'emissions a nivell de districte mitjançant un enfocament bottom up són complexos, ja que la metodologia depén en gran manera de la disponibilitat de dades, que són menys freqüents a mesura que l'àrea avaluada és més xicoteta. No obstant això, la feblesa de la metodologia pot transformar-se en una fortalesa si es recullen més dades, augmentant així la precisió. A partir de l'anàlisi realitzada, l'estudi proposa una sèrie de recomanacions per a millorar la disponibilitat de dades d'activitat en els districtes, incloent-hi aspectes com els viatges de llarga distància, els patrons de consum de consum, la superfície residencial i el tractament de residus.

Paraules claus: comptabilitat d'emissions, petjada de carboni, enfocament bottom-up, inventari d'activitats, factors d'emissió, districte, barri.

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Nomenclature

CCC	Climate Contract of Cities
CNC	Climate Neutral Cities
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2E	Carbon Dioxide Equivalents
CV	Comunidad Valenciana
EoL	End of Life
EU	European Union
GHG	Greenhouse Gas
$IPCC$	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LPG	Liquid Petroleum Gas
$MEFA$	Material and Energy Flow Analysis
NDC	Nationally Determined Contributions
PED	Positive Energy District
$SECAP$	Sustainable Energy and Climate Action Plan
TD	Transmission and distribution
VKT	Vehicle Kilometers Travelled

1 Introduction

Since the middle of the 20th century, the carbon dioxide level has increased significantly and is currently far above the previous highest level [1]. As carbon dioxide works as the Earth's natural temperature regulator, an imbalance of carbon dioxide in the atmosphere increases the global average temperature [2]. In the last 130 years, the average temperature has risen by 0.85 degrees Celsius [3]. The consequences of an increased temperature are several, for example, increased sea levels and more extreme weather, affecting humans worldwide [1].

The global trend of urbanisation that is ongoing has made cities the main target of reducing emissions. In 2013, 64% of the global primary energy use and 70% of the carbon dioxide emissions took place in urban areas, and those shares are expected to rise with increased urbanisation [4]. Today, 55% of the global population lives in urban areas, expected to increase to 68% by 2050. Taking the population's expected growth into account, this would result in an additional 2.5 billion people living in urban areas [5]. The emissions in urban areas are also not only affecting the global climate. It is also a source of local air pollution, causing over 7 million deaths every year [3]. For example, reports show that 93% of children under 15 years old breathe toxic air, putting their health at serious risk [6].

1.1 Initiatives and Programs

To change the current trend of global warming, greenhouse gas (GHG) emissions have to be cut. Several agreements, initiatives, and programs support the necessary work to change the global situation. The main one, the Paris Agreement, was agreed on in 2015, which goal is to limit global warming to well below 2 degrees Celsius compared to pre-industrial levels, is a significant factor in achieving that. The agreement includes 196 parties having national plans, called nationally determined contributions (NDCs), which point out climate change measuring work in each country [7]. Following that, initiatives like EU Climate Contracts of Cities (EU CNC), Positive Energy Districts (PED), C40 Climate Action Plan, and Covenant of Mayors have been launched or intensified, specifically targeting urban areas' transition towards low carbon economies.

a) Covenant of Mayors

The EU Covenant of Mayors for Climate and Energy, often referred to as only Covenant of Mayors, is a voluntary supporting initiative for cities aiming to achieve and exceed the EU targets of 40% reduction of GHG emissions by 2030 [8], [9]. The European Commission launched the initiative in Europe in 2008 but has since then expanded to include cities worldwide [8]. Today, the initiative has attracted 10 555 signatories from 61 countries, including cities as London, Berlin, Valencia, and Milano, in total including over 334 million people [10]. Signing for the initiative, the cities commit to submitting a Sustainable Energy and Climate Action Plan (SECAP) within two years, including a baseline emission inventory and a Climate Risk and Vulnerability Assessment. To that, an adaption plan is developed, describing the planned measures to reduce the cities' emissions. They also commit to reporting the progress of the implementation every second year [11].

The SECAP is a vital part of the program. It is done by filling in a Microsoft Excel template or a form on the website. The general strategy in terms of commitments, staff, and budget allocated is filled in, as well as the emission inventory, mitigating actions, reporting, and assessment of the actions taken. The emission inventory is filled with quantities of activities and multiplying them with the chosen emission factor. The emission factors available in the SECAP are IPCC or LCA. The LCA emission factors come from the European Reference Life Cycle Database [11].

b) C40 Climate Action Plan

C40 is a network for major cities committed to addressing climate change. It aims to help cities achieve the Paris Agreement by being emission neutral and improving resilience against climate change consequences, citizens' inclusivity, and help identify the governments' capacity and possible partners [12]. The network supports collaboration between cities, giving them a forum for sharing knowledge and experiences within the subject [13].

Today, the number of member cities is 97, including over 700 million citizens and a fourth of the global economy. 53 cities have already peaked their emissions or were supposed to do it before the end of 2020 [14]. The framework supporting the transition towards sustainability is typically used to help the members in the early evaluation process and in the later draft plan review. The framework is divided into three different pillars of Commitment and Collaboration, Challenges and Opportunities, and Acceleration and Implementation [12]. In the second, Challenges and Opportunities, the emission inventory takes place. It is essential to report scope 1-emissions from fuel used in buildings, transport, and industry, scope 2-emissions from grid-supplied energy, and scope 3-emissions from waste generated inside the city boundaries. If a member wants to go further, they can also track consumption-based scope-3 emissions [15]. To do the emission inventory, the Global Protocol for Community-scale Greenhouse Gas Emission Inventories is used [16].

c) Positive Energy District

Positive Energy Districts (PED) is a concept launched by the European Commission, aiming to contribute to achieving the Paris Agreement's goals, enhance European capacities, and increase the knowledge about building sustainable districts and cities. This is done by supporting and encouraging climate change measures on a local scale while raising urban life quality. The creation of PEDs is based on a combination of a high level of energy efficiency measures for buildings, with renewable energy generation on-site or near the district. The concept itself does not have a specified methodology for determining the districts' performance [17]. However, one report proposes a methodology for a PED project with the following steps [18]:

1. Define the Positive Energy Districts boundaries
2. Calculate the energy needs
3. Calculate the energy use
4. Calculate the on-site generation
5. Estimate the energy delivered
6. Calculate the primary energy
7. Calculate the energy balance
8. Create a Sankey diagram

In the above, the seventh step is the phase of the operational phases where the performance is determined as the difference between the primary energy delivered to the district and the non-renewable primary energy exported outside the city's boundaries [18].

d) EU Climate Contract of Cities

The EU Climate Neutral Cities, often referred to as "100 Climate-neutral Cities by 2030" is a program launched by the European Commission. The program aims to support, promote, and showcase 100 European cities in their transition to climate neutrality by 2030 by promoting the city's systemic change and transformation. The transformation is also supposed to be permeated by a "by and for the citizens"-thinking. After that, the cities would like role models for other cities to follow, thereby easing those other cities' transitions. Within the program, the contract EU Climate Contract of Cities (EU CCC) exists. The contract is signed between the government of the city or metropolitan area, the European Commission, and relevant authorities in the region. It can be seen as a complement to the Covenant of Mayors, where the contract aims to boost the transition. In difference to the Covenant of Mayors target of 40% GHG emission reduction by 2030, signing up for the EU CCC rises to target to 100%, to be climate neutral. One difference between the EU CCC, the Covenant of Mayors, and several other programs is that the EU CCC provides funding. The mission board proposes that at least 1% of the EU fundings are targeted to citizens to engage them in the development and implementation of measures and action to create a bottom-up effect [19].

The contract itself is an individually developed one, adapted to the conditions of the city. Every contract will include the city's goals and targets, the strategy and action plan to reach them, and the contract's stakeholders and responsibilities. Above all, the contract wants to entice the drivers for transition, seen as an innovative and new form of governance, a new financial model, integrated urban planning, innovation management, and digital technologies. The way of reporting, monitoring, and evaluation is based on the methodology of the Covenant of Mayors [19].

e) Horizon 2020

Horizon 2020 is a financial instrument to implement the Innovation Union, an initiative to support and secure Europe's global competitiveness. The instrument aims to drive economic growth and create jobs. It is open to everyone, with a simple structure, eliminating unnecessary time-consuming processes to increase efficiency [20]. As the initiative and instrument focus broadly and cover most spectra of society, it also includes work towards sustainable societies and cities. One area is "Secure, Clean and Efficient Energy," focusing on energy efficiency, low carbon technologies, and smart cities and communities [21]. Another area, "Smart, Green and Integrated Transport" focuses on, for example, "resources efficient transport that respects the environment" [22].

1.2 Objective

This thesis aims to develop a methodology to measure the emissions at a district level. That is done by taking existing research and methodologies for carbon inventories on a national and city level into account and modify them to fit this purpose. As a case study, the district of Ciutat Vella in Valencia will be used, and a bottom-up approach will be applied. The outcome will also be a Microsoft Excel model that can be used to replicate the study for other districts, both within and outside of the city. The report will also deliver feedback to the city hall of Valencia regarding what data is needed to execute such a project accurately.

2 State-of-the-Art

As GHG emissions are the most impacting climate change factor [1], it is essential to keep track of its level in the atmosphere and evaluate where it is coming from and identify potential areas of improvement. Emission accounting is, therefore, an essential tool in the transition towards a sustainable society and can be used to evaluate investments made or to be made from an environmental perspective [23]. Emission accounting is usually done at a national, regional, or city level. However, in this thesis, it will be applied to a city district level, and that perspective will permeate the thesis.

2.1 Top-Down and Bottom-Up Approach

The way of doing emission accounting can differ. Apart from different standards, concepts and methodologies, there are two main approaches to collecting and compiling data; top-down and bottom-up. The approaches differ in what end the method starts, where the first starts from above, doing emission estimations based on observations of concentration of gases [24] or using a nation's emission to calculate regions. The bottom-up approach starts from below, aggregating the data from, for example, all emitting activities in a city. They are multiplied with an emission factor and summarized into the city's total emitted GHGs [24]. Generally, the top-down approach is used for regional-scale [25], while the bottom-up is well-fitting for cities and districts.

Even though both approaches are well-established in the field, there are a few question marks regarding them. Both approaches should show the exact quantities of emissions in the best of worlds, but that is usually not the case. Instead, top-down tends to show higher values, up to 1.5 times higher, than the bottom-up [25]. The reasons behind the discrepancy are not entirely proven, although there are theories behind it. The main reasons are believed to be the quality of the activity inventory and emission factors for the bottom-up approach. Another contributing factor can be the difference in emission factors depending on where the activity takes place. Hence the lack of national and regional specific factors is a weakness in the approach [24], [25]. The two approaches also have their pros and cons. A pro for the top-down approach is the fewer resources needed and, hence, less expensive to perform—the opposite counts for the bottom-up approach. However, the bottom-up approach is more data-heavy, which is a con, but hence more detailed, generating better grounds for making accurate decisions [26].

2.2 Concepts and Methodologies

There are several different concepts and methodologies used to determine a city's emissions. Which one to use depends on the purpose of the accounting and the data available. An emission inventory is now an essential tool in accounting to identify pollutants and their quantities. A common way of doing an emission inventory is by using the bottom-up approach to identify emission-causing activities and multiply them with the corresponding emission factor [27]. The Intergovernmental Panel on Climate Change (IPCC) has developed one of the most commonly used methodologies, called the IPCC guidelines [28].

Several organizations provide standards for the emission inventory, such as the GHG Protocol. The GHG Protocol provides frameworks for emission accounting and is the most widely used in the field [29]. One of the frameworks is the "Global Protocol for Community-scale Greenhouse Gas Emission Inventories" developed for cities. The protocol seeks to support cities' climate action planning by establishing a base year emission inventory, reduction targets, and tracking process. It also contributes to setting a transparent standard used by the majority and ease aggregation at national and sub-national levels [30]. The methodology used for the inventory is based on the IPCC Guidelines, if not stated otherwise. In some cases, the methodology can differ and must be stated clearly in the inventory report [30]. Other methodologies, often to some extent based on an emission inventory, are carbon budget, ecological and carbon footprint, material and energy flow analysis, and urban metabolism.

a) Carbon Budget

A carbon budget represents the upper limit of carbon emissions to remain below a specific global average temperature. The budget is often associated with the Paris Agreement 1.5 degrees Celsius target [31]. The budget size is decided based on the strong relationship between carbon dioxide concentration and global temperature. Using climate models, the budget can then be estimated. The carbon budget is expressed in the weight of carbon dioxide equivalents ($kg\ CO_2e$) [32].

The carbon budget methodology is commonly used. Several cities and regions have used it to determine their upper allowed limit of carbon emissions, such as Manchester [33], Oslo [34], California [35], and all Swedish regions [36]. The budget can also be used in the long-term perspective, where the budget is set for several years ahead, used as a leading document for the transition [34]. However, in the context of city districts or neighborhoods, the methodology is not widely used today.

b) Ecological and Carbon Footprint

An ecological footprint is one way of measure the demand and supply of nature for a city. The methodology adds up all the demand of the chosen area and compares it to land productivity. The demand side includes cropland, grazing land, fishing grounds, built-up land, forest area, and carbon demand on land. However, on the productive side, it includes cropland, grazing land, forest land, fishing grounds, and built-up land. Unharvested areas are considered carbon sinks [37]. When using carbon footprint instead of ecological, only the carbon part of the ecological footprint is considered. The result is normally expressed in global hectares (gha), a standardised unit including the planet's average productivity. However, the carbon footprint can also be expressed in the weight of carbon dioxide equivalents ($kg\ CO_2e$) [37].

Ecological footprint has been used for evaluating several cities' impact on the environment, such as Vancouver [38] and Valencia [39]. When it comes to city districts or neighborhoods, nor this methodology is commonly used. However, the paper "Modeling, Monitoring, and Visualizing CarbonFootprints at the Urban Neighborhood Scale" handles the subject and provides an approach for estimating the footprint of a neighborhood. The estimation is done by looking at different types of household consumption patterns [40].

c) Material and Energy Flow Analysis

Material and Energy Flow Analysis (MEFA) is a tool used to identify and estimate material and energy consumption. It is a systematic assessment of material and energy flows and stacks within a system. The result from a MEFA can be used in, for example, Life Cycle Assessments (LCA) [41]. MEFA has been practiced in city districts and neighborhoods, for instance, for a neighborhood in Toronto where energy, water, and food metabolism was considered. According to a paper, MEFA has been used for evaluating the metabolism of households and regions since the beginning of the 1990s [42].

d) Urban Metabolism

Urban Metabolism is a tool very similar to MEFA, but more focused on cities. The purpose is to identify the different GHG emitting activities inside the set boundaries of the city. The idea is to provide a holistic viewpoint to encompass a city's activities in a single model. It is typically used for sustainability reporting, GHG accounting, and modelling for policy analysis and urban designing [43].

It is done by studying the city as an organism with inputs of material and energy, and outputs as waste and emissions [43]. The concept is usually used for accounting, as when the energy and materials consumed by Vancouver's residential population were quantified in a paper calculating their ecological footprint [38]. However, studies have also studied how it can be applied to urban planning and design [43]. Urban metabolism has not been used to a great extent to calculate the environmental impact of neighborhoods or districts until today. Although, there is a study investigating different approaches for emission accounting at a neighborhood scale that dealt with the concept and considered it useable [44].

2.3 The Emission Scopes

To better understand the type and source of emissions, the GHG Protocol developed categories to divide them. The categories are first hand developed for emission accounting and reporting for businesses but are well suited for nations, regions, cities, and districts. Firstly, the emissions are divided into two types; direct and indirect emissions. Direct emissions are from sources owned and controlled by the reporting party. In contrast, indirect emissions are a consequence of activities of the reporting party but take place at sources owned by another. The emission types are then divided into three scopes. All the direct emissions represent the first scope. An example of emission belonging to the first scope is the combustion of fuels in city- or district-owned vehicles or machinery. The second and third scope, however, are both represented by indirect emissions. The second scope includes the emissions caused by generating the energy consumed by the reporting party. The third scope collects all indirect emissions not included in the second scope, for example, travels outside of the district, purchased goods and services, and the transportation of goods [45]. The scopes and their definitions are presented in table 1.

Table 1. *Overview of the scopes from the GHG Protocol [45].*

Emission type	Scope	Definition
Direct emissions	Scope 1	Emissions from operations that are owned or controlled by the reporting party
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting party
	Scope 3	All indirect emissions (not included in scope 2) that occur in the value chain of the reporting party, including both upstream and downstream emissions

2.4 The Future of the Field

The upsides of assessing city districts could be significant. The level of GHG emissions depends heavily on the neighborhood's circumstances, such as the resident's design, age, and habits. For example, the emissions related to transport are shown to be doubled for a person living in a suburban district, compared to an urban [46]. The same thinking can be used when looking at potential reduction measures. As different districts have different characteristics, some measures will have more significant effects than others in different districts. Local emission accounting can hence help the local government to identify the correct measures for each district.

When using the names of the methodologies described in section 2.2 together with search keywords such as "neighborhood" and "city district" in different databases, the number of relevant results in actual case studies is few. The lack of articles about it is seen as confirmation of emission accounting on a city district or neighborhood scale is still not widely used today. That goes hand in hand with the lack of standards and methodologies that is a reality. Therefore, more research and studies and a framework with guidelines for doing it are well needed. The PED initiative can be seen as a start towards this, as its release will attract more focus towards districts. PED aims to contribute to achieving the Paris Agreement's goals, and increasing the knowledge about building sustainable districts and cities also highlights how local emission accounting and reduction measures can affect cities as a whole and support its transition [17].

3 Methodology

A literature review was conducted to gather information for the introduction, state-of-the-art, and case study. The information has been received from academic papers, grey literature, and governmental documents. The academic papers have primarily been found in scientific databases such as Google Scholar and ScienceDirect, while the government documents are found on their official websites and the grey literature at the author organisations website. Some emission factors have been taken from the ecoinvent 3.5-database, which is a database created by ecoinvent, a global leader in developing life cycle inventory databases.

In general, the sources can be considered reliable. The academic papers are authored by scientists, peer-reviewed, and published in well-known journals and conferences, and the grey literature by respected and long-term active organisations within the field of the subject. The governmental reports are also often conducted by scientists with the government's support, which should be a quality mark. However, some reports always risk a potential underlying agenda, with the highest risk in the grey literature. They are often published by organisations or companies that could have an ideological or economic interest in the question.

Throughout the report, several assumptions have been made to secure that the needed data could be collected. The assumptions will be further explained in the sections where they are done, and the most uncertain will later be evaluated in a sensitivity analysis.

3.1 Case Study

A case study was performed at one of the 19 districts in the city. The case study aimed to identify all the different emission-causing activities that take place. It was done through a bottom-up approach by doing an activity inventory and pairing the activities with emission factors to convert them into GHG emissions. The district chosen was Ciutat Vella, and data about the district, as well as for the city, is seen in table 2. Ciutat Vella was chosen due to its significance for Valencia, with its strong and vibrant community and tradition. It is also a district where many sustainability measures have been implemented in the nearest past time. The data shows that the district is dense, with a small area and a high population. The district inhabits 3.4% of the population in only 1.6% of the city area. The origin of the district explains it. As its name means, it is the old city of Valencia, and therefore is built with narrow streets, and not with the otherwise common avenues. It is also noticed that the average value of the residential area is higher in Ciutat Vella than in the whole city.

Table 2. *District and city data.*

		Ciutat Vella	Valencia
Population	[cap]	27 418 [47]	800 215 [47]
Area	[m^2]	1 689 842 [47]	105 922 599 [47]
Density	[cap/km^2]	16 225	7 567
Average square meter value	[€/year]	526.3 [47]	432.0 [47]

4 The Case Study

In this section, the emission inventory of the district of Ciutat Vella will be explained. The approach used is a bottom-up methodology, resulting in an activity inventory of all emitting activities in the district and a catalog of emission factors to convert the activities into emissions. All emission-causing activities will be considered and accounted out of a life cycle perspective to the greatest extent possible, including all phases of its lifetime. In the end, the total emissions for Cuitat Vella will be presented and divided up between the scopes.

4.1 Activity Inventory

The activity inventory will be presented here and has been divided into five categories; transport, land use, energy, consumption, and waste. To make it easier to follow, lengthy and complicated calculations will be presented in the appendix instead of this section. When it is the case, it will be stated and the referring section of the appendix will be linked.

4.1.1 Transport

To ease the presentation of the transport sector, it has been divided into two sub-categories; private vehicles and public transport. Private vehicles are defined as vehicles registered to private persons or companies used to transport a smaller number of people. In contrast, public transport is defined as the city's provided means of transport, such as bus and metro.

Private Vehicles

For private vehicles, passenger cars, two-wheelers, electric scooters, and bicycles are considered. To that, the activity of taxis will also be presented here. First, the number of passenger cars per European emission regulation and fuel type and their distance is calculated. The distribution of passenger cars per regulation and fuel for the city was applied to Ciutat Vella's number of registered passenger cars to determine the share in the district. The annual distance per car in different age groups was then used to turn the number of vehicles to the annual distance per emission regulation and fuel type. The table of annual distance travelled per vehicle can be found in the appendix, under section B.1. The number of vehicles and the final activity, annual distance, is presented in tables 3 and 4. More details from the calculations are also found in the appendix, under section B.1.1. However, as the distance made from passenger cars is overestimated for the districts, large parts of the distance will be made outside the geographical borders of it. To compensate for that, the estimation of 20% of the distance being made within the district. The 80% left will be assumed to occur outside it, hence being accounted for as scope 3 emissions. As this number is extremely unpredictable and hence uncertain, the assumption and the effect of it will be evaluated in the sensitivity analysis, under section 6.5.

Table 3. *Number of registered passenger cars in the district and annual distance travelled (1/2).*

	Petrol		Diesel Oil		Electricity	
	[vehicles]	[km]	[vehicles]	[km]	[vehicles]	[km]
Pre Euro	1 615	13 682 280	140	1 186 080	0	0
Euro 1	225	1 906 200	76	643 872	0	0
Euro 2	514	4 354 608	452	3 829 344	0	0
Euro 3	1 314	12 756 312	1 749	16 979 292	0	0
Euro 4	1 391	16 208 210	2 492	29 037 282	0	0
Euro 5	796	11 255 599	1 422	20 107 364	1	14 140
Euro 6	970	17 395 786	908	16 283 890	4	71 735

Table 4. *Number of registered passenger cars in the district and annual distance travelled (2/2).*

	LPG		CNG	
	[vehicles]	[km]	[vehicles]	[km]
Pre Euro	0	0	0	0
Euro 1	0	0	0	0
Euro 2	0	0	0	0
Euro 3	0	0	0	0
Euro 4	0	0	0	0
Euro 5	1	14 140	0	0
Euro 6	3	53 801	1	17 934

In general, the same method was applied to the category two-wheelers, which includes motorcycles and mopeds. The difference was that the number of two-wheelers was given for the whole city and then allocated to Ciutat Vella after a per capita average. The result is seen in table 5, and more details in the appendix under section B.1.2. For two-wheelers, an average trip is shorter than for cars. Hence, all of the distance will be assumed to be inside the district's geographical boundaries.

Table 5. *Number of registered two-wheelers in the district and annual distance travelled.*

	Petrol		Diesel Oil		Other	
	[vehicles]	[km]	[vehicles]	[km]	[vehicles]	[km]
Pre Euro	614	1 042 572	3	5 094	5	8 490
Euro 1	541	1 021 949	2	3 778	4	7 556
Euro 2	341	839 542	2	4 924	3	7 386
Euro 3	1 153	3 432 366	5	14 885	9	26 792
Euro 4	287	1 234 889	1	4 303	2	8 606
Euro 5	0	0	0	0	0	0

The number of electric scooters and bicycles allocated to the district, and the distance made of electric scooters, are found in table 6. In contrast to passenger cars and two-wheelers, no actual data of the number of privately owned electric scooters or bicycles were found, neither for Ciutat Vella, Valencia, or Spain. For electric scooters, an estimated number for Spain was found and allocated to the district in terms of a per capita average, while the number of bicycles was determined after estimation of 40% bicycle ownership in Spain [48]. However, this number is likely to be an overestimation and should be analysed with that in mind. More information about the calculation of distance for electric scooters is found under section B.1.3 in the appendix.

Table 6. *Number of electric scooters and bicycles in the district.*

	[vehicles]	[km]
Electric scooters	376	93 049
Bicycles	10 967	-

The last part of the activity inventory for private vehicles is the distance made by taxis. The total number of taxis registered in the city in 2019 was 2 823, where 97 was allocated to Ciutat Vella by a per capita average. By using an estimation of distance per taxi and day of 208 km [49], the number of taxis was converted into annual travelled distance. The result is seen in table 7.

Table 7. *Number of taxis in the district and annual distance travelled.*

	[vehicles]	[km]
Taxis	97	7 343 383

Public Transport

In terms of public transport, the city offers six metro lines, three tram lines, a city-wide bus network, and a bicycle-sharing service, Valenbisi. For all modes of transport, the final activity can be seen in table 8. Metro and tram are treated the same way, divided into two categories: the system, including stations, railway, and the infrastructure around it, and the vehicles, representing the use-phase. An average per capita was calculated to allocate a part of the rail-bound public transport system to Ciutat Vella. The system is represented by the length of the railway system, and for the vehicles, it is represented by the vehicle kilometers travelled (VKT). The VKT is calculated taking the length of each line and the number of departures per weekday, weekend, and holiday into consideration.

The activity of public transport buses is calculated by allocating a share of the total distance made by them to the district. In contrast to the metro and tram allocation, this is done by looking at the share of stations located in Ciutat Vella instead of a per capita average. The per capita average was also calculated, resulting in 692 271 km, a significantly lower number. However, the per station average is considered more accurate as the presence of stations has a high linkage to the presence of buses.

Lastly, the number of Valenbisi-bicycles in Valencia is 2 750 bicycles [50] and was allocated to the district by an average per capita. The calculation of all public transport is explained in more detail in the appendix, under section B.1.4.

Table 8. *Activity inventory of the public transport sector in the district.*

Metro	System	[km]	6.51
	Vehicles	[VKT]	327 116
Tram	System	[km]	0.75
	Vehicles	[VKT]	71 609
Bus		[km]	1 067 097
Valenbisi		[vehicles]	94

Excluded Means of Transport

Some means of transport are excluded from the inventory of the activities in Ciutat Vella and will here be listed and explained. Even though it is a large part of the footprint of humans, long-distance transportation in terms of aviation, buses, and trains has been excluded. Statistics show that 24% of the global footprint comes from transport, whereas, for example, aviation accounts for 11.6% of the transport footprint [51]. The first reason for excluding it is that it is challenging to allocate the emissions to a specific district fairly. The existing data is from the airport, port, and railway companies, giving the numbers of passengers and amount of CO_2 emissions for each transportation method. As the district and city are located in Spain, the country attracting the most tourists in Europe [52], the number of passengers, departures, and hence emissions will not be directly related to the actual traveling habits of the Valencian and the district's inhabitants. The traveling habits also differ between the different districts to a greater extent than, for example, with public transport, and that kind of data is missing. Hence, the allocation would not be done with the desirable quality. The second reason is the interest from the city hall. The decision-makers for the district have minimal influence over the inhabitants travelling outside the city. Therefore, it is assumed that adding it with low quality would not add any value to the result.

4.1.2 Land Use

In this section, the activity inventory of the land use will be explained. It was divided into three categories: buildings, roads, and urban green areas. It was calculated by using the total land area of the district, 1 689 842 m^2 presented in table 2. With the data of 72 979 m^2 being green areas [47] and 33% of the area being roads [53], resulting in 533 565 m^2, 1 083 298 m^2 land area was allocated to buildings. As the construction emissions of buildings are calculated per square meter of living area, an assumption of an average of 4 levels per building was made, due to the older, more historical, and lower design, making the total building area 4 333 193 m^2. This assumption is uncertain and will be analysed in the sensitivity analysis. The final activity is seen in table 9.

Table 9. *Activity inventory of the land use sector in the district [m^2].*

Buildings	4 333 193
Roads	533 565
Urban green area	72 979

4.1.3 Energy

In table 10, the annual electricity consumption and transmission and distribution (T&D) losses, as well as gas consumption, are presented. The electricity and gas consumption were given in total fractured for the whole city and then divided into a per capita average and multiplied with the district's inhabitants. The T&D losses for the electricity were calculated using the coefficient of T&D losses for the national grid in Spain, of 9.6% [54].

Table 10. *Activity inventory of the energy sector in the district [47].*

		[MWh/cap]	[MWh]
Electricity	Consumption	3.2	87 309.0
	T&D losses	-	8 380.8
Gas		1.2	32 173.5

4.1.4 Consumption

The activity inventory of consumption was divided into two categories, consumption of food and goods. Firstly, the consumption of food is examined. It is presented in 27 different categories, where most of them include one single type of product. However, some include several different products added together. It was done as some products are very similar in either type of food or their emission factors. In table 11, it is seen which categories it concerns, and what is included in them.

Table 11. *Explanation of food categories.*

Oil	Olive oil, virgin olive oil, extra virgin olive oil, and rape seed oil
Beverages	Beer, non-alcoholic beer, bottled water, sodas, other alcoholic beverages, and juice
Other meat	Chicken, goat, rabbit, and processed meat
Fresh fruit	Orange, mandarin, peach, apple, pear, melon, banana, strawberry, and ready-to-eat fruit
Fresh vegetables	Tomato, pepper, zucchini, onion, sallad, mushrooms, and ready-to-eat vegetables
Rest	Christmas products, sugar, broths, sweeteners, spices and condiments, honey, salt, and sauces

In table 12, the density of oil, beverages, wine, and milk is presented. They are used to convert consumption of volume to consumption of weight. For oil, wine, and milk, the appropriate conversion factor for the respective liquid was used, while beverages were assumed to have the density of water. The inventory of food consumption is then presented in tables 13 and 14.

Table 12. *Conversion factors from volume to weight.*

Oil	[kg/l]	0.917 [55]
Beverages	[kg/l]	0.998 [56]
Wine	[kg/l]	1.085 [57]
Milk	[kg/l]	1.030 [58]

Table 13. *Annual consumption of food in the district per person and in total (1/2) [59].*

	[kg/cap]	[kg]
Oil	8.49	232 818
Olives	2.96	81 157
Rice	5.05	138 461
Beverages	151.93	4 165 494
Wine	6.82	187 118
Cereals	1.60	43 869
Cookies	4.98	136 542
Coffee & infusions	1.63	44 691
Beef	3.98	109 124
Lamb	1.40	38 385
Other meat	40.67	1 115 090
Chocolate	3.21	88 012
Fresh fruit	86.40	2 368 915
Processed fruit & vegetables	12.62	346 015

Table 14. *Annual consumption of food in the district per person and in total (2/2) [59].*

	[kg/cap]	[kg]
Dried fruit	3.74	102 543
Fresh vegetables	60.92	1 670 305
Egg	8.59	235 521
Milk	64.53	1 769 270
Dairy products	33.45	917 132
Legumes	3.39	92 947
Bread & pastry	37.07	1 016 385
Flour	2.55	69 916
Pasta	4.51	123 655
Potatoes	27.39	750 979
Fish	21.37	585 923
Ready-to-eat	15.05	412 641
Rest	8.10	222 086

The consumption of goods consists of clothing and manufactured products, where manufactured products include appliances, machines, electronics, furniture, and household commodities. No quantified activity was needed for these two categories, as the emission factor found considered the GHG emissions emitted per person in Spain in both cases. The activity for consumption of clothing and manufactured products was hence allocated to only the district's population.

4.1.5 Waste

The waste generation and treatment activity inventory was done in two steps, where the average waste generation in Valencia per waste fraction was first identified. After that, the four different treatment categories of landfilling, recycling, energy generation, and composting were identified. Due to a lack of data on the treatment within each waste fraction, the total was used and multiplied with the four treatment categories shares. The data per waste fraction is seen in table 15 and the final activity in the form of weight of waste per treatment category in table 16.

Table 15. *Annual waste generation in the district per person and in total.*

	[kg/cap]	[kg]
Municipal solid waste	368.412	10 101 112.0
Organic	14.997	411 176.8
Glass	16.405	449 789.5
Paper	20.592	564 594.2
Plastic & light packaging	14.627	401 043.1
Vegetable oil	0.044	1 199.6
Batteries	0.004	108.1
Total	435.080	11 928 915.2

Table 16. *Amount of waste per waste treatment category in the city.*

	[%]	[t]
Landfilling	56.7	6 763.8
Recycling	18.3	2 183.0
Energy generation	13.5	1 610.4
Composting	11.5	1 371.8

4.2 Emission Factor Catalog

A catalog of emission factors was compiled to convert kilometers, square meters, or other final units in the activity lists into emissions. The catalog presented in this section is matched to the activities presented in the activity inventory. To the greatest extent, the factors will be collected from international standards as IPCC and, in some cases, from other organisations and academic reports.

4.2.1 Transport

For private vehicles, most of the emission factors were collected from the database EcoInvent 3.5, via SimaPro. The only factors collected from other sources were the two for production and disposal of private bicycles. The emission factors of passenger cars are presented in table 17 while the rest of the private vehicles is presented in table 18. For taxis, the emission factor of Euro 4 diesel cars is assumed, as it is the most common car in the city.

Table 17. *Emission factors for passenger cars [t CO_2e/km] [60].*

	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	0.00419	0.00368	0.00225	0.00313	0.00350
Euro 1	0.00403	0.00356	0.00225	0.00313	0.00366
Euro 2	0.00387	0.00344	0.00225	0.00313	0.00322
Euro 3	0.00371	0.00332	0.00225	0.00313	0.00308
Euro 4	0.00355	0.00320	0.00225	0.00313	0.00294
Euro 5	0.00342	0.00313	0.00225	0.00313	0.00285
Euro 6	0.00329	0.00306	0.00225	0.00313	0.00276

Table 18. *Emission factors for other private vehicles.*

Two-wheelers		[t CO_2e/km]	0.000124 [60]
Electric scooter		[t CO_2e/km]	0.000022 [60]
Bicycle	Production	[t CO_2e/vehicle]	0.013875 [61]
	Disposal	[t CO_2e/vehicle]	0.007911 [62]

The emission factors for metro and tram are seen in table 19. The emission factor is divided up after which scope the emissions belong. For stations, including the stations and the actual railway, there are both emissions for construction and O&M, where the construction covers material production and transportation and the on-site construction. The O&M only covers the electricity consumption of the O&M, as 99.7% of the emissions related to it comes from electricity consumption [63], and the resting 0.3% is then considered negligible. For the vehicles, both construction, use, and end of life (EoL) are included. Calculations of the station category are found in the appendix, under section C.1. The emission factors for the other two means of public transport, bus and Valenbisi, are found in table 20. For Valenbisi, a lifetime of 10 years is assumed.

Table 19. *Emission factors for the metro and tram.*

Stations	Construction	Material production	[t CO_2e/km]	44.64
		Material transportation	[t CO_2e/km]	0.84
		On-site construction	[t CO_2e/km]	4.37
	O&M	Electricity consumption	[t CO_2/km]	181.74
Vehicle	Construction and EoL		[t CO_2e/VKT]	0.0016 [64]
	Use		[t CO_2e/VKT]	0.0088 [64]

Table 20. *Emission factors for bus and Valenbisi.*

Bus	[t CO_2e/VKT]	0.0033 [65]
Valenbisi	[t CO_2e/vehicle]	0.0478 [66]

4.2.2 Land Use

In table 21, the emission factors related to the land-use sector are presented. It was divided up between the different processes of the life cycle to the greatest extent. For buildings, the possibility of calculating specific life cycle emissions per building type in the district was investigated. However, the lack of data and its complexity resulted in using an emission factor from conventional buildings in Sevilla. It was although modified, and the calculation of it, as well as the factors of roads, and urban green areas, are found in the appendix, under section C.2.

Table 21. *Annual life cycle emission factors for land use.*

Buildings	Material production	[t CO_2/m^2]	0.01388
	Material transportation	[t CO_2/m^2]	0.00104
	On-site construction	[t CO_2/m^2]	0.01978
Roads	Material production	[t CO_2e/m^2]	0.02956
	Material transportation	[t CO_2e/m^2]	0.00222
	On-site construction	[t CO_2e/m^2]	0.04212
	O&M	[t CO_2e/m^2]	0.00227
Urban green areas	Construction	[t CO_2/m^2]	0.00001
	O&M	[t CO_2e/m^2]	0.00005
	Sequestration	[t CO_2e/m^2]	-0.00049

4.2.3 Energy

The emission factors for the energy sector in Comunidad Valenciana are presented in table 22. The factor for electricity is from 2018.

Table 22. *Emission factors for the energy sector.*

Electricity consumption	[t CO_2/MWh]	0.183 [67]
Natural gas	[t CO_2e/MWh]	0.237 [68]

4.2.4 Consumption

In tables 23 and 24, the emission factors for consumption of different food are found. Four of them, beverages, other meat, ready-to-eat, and rest, are calculated, and the calculation is found in the appendix, under section C.3. All of them are average emission factors for the specific food that is included in the category, according to table 11. The rest category is an average of all the emission factors for all types of food.

Table 23. *Emission factors for consumption of food (1/2).*

Oil	[t CO_2e/kg]	0.0022 [39]
Olives	[t CO_2e/kg]	0.0060 [39]
Rice	[t CO_2e/kg]	0.0027[39]
Beverages	[t CO_2e/kg]	0.0006
Wine	[t CO_2e/kg]	0.0020 [39]
Cereals	[t CO_2e/kg]	0.0005 [39]
Cookies	[t CO_2e/kg]	0.0005 [39]
Coffee & infusions	[t CO_2e/kg]	0.0014 [39]
Beef	[t CO_2e/kg]	0.0261 [39]
Lamb	[t CO_2e/kg]	0.0338 [39]
Other meat	[t CO_2e/kg]	0.0051
Chocolate	[t CO_2e/kg]	0.0023 [39]
Fresh fruit	[t CO_2e/kg]	0.0005 [39]
Processed fruit & vegetables	[t CO_2e/kg]	0.0028 [39]

Table 24. *Emission factors for consumption of food (2/2).*

Dried fruit	[t CO_2e/kg]	0.0014 [39]
Fresh vegetables	[t CO_2e/kg]	0.0005 [39]
Egg	[t CO_2e/kg]	0.0034 [39]
Milk	[t CO_2e/kg]	0.0014 [39]
Dairy products	[t CO_2e/kg]	0.0089 [39]
Legumes	[t CO_2e/kg]	0.0007 [39]
Bread & pastry	[t CO_2e/kg]	0.0010 [39]
Flour	[t CO_2e/kg]	0.0010 [39]
Pasta	[t CO_2e/kg]	0.0020 [39]
Potatoes	[t CO_2e/kg]	0.0002 [39]
Fish	[t CO_2e/kg]	0.0065 [39]
Ready-to-eat	[t CO_2e/kg]	0.0052
Rest	[t CO_2e/kg]	0.0052 [39]

The emission factors for annual consumption of goods are presented in table 25. In contrast to food consumption, they are presented per capita instead of the weight of products, as mentioned before.

Table 25. *Emission factors for consumption of goods.*

Clothing	[t CO_2e/cap]	0.30
Manufactured products	[t CO_2e/cap]	1.30

4.2.5 Waste

The emission factors for waste management are presented in table 26. The factor for energy generation was left as zero as the energy coming from waste incineration already is included in the emission factor for electricity in table 22.

Table 26. *Emission factors for waste management [69].*

Landfilling	[t CO_2e/t_{waste}]	0.270
Recycling	[t CO_2e/t_{waste}]	0.042
Energy generation	[t CO_2e/t_{waste}]	-
Composting	[t CO_2e/t_{waste}]	0.038

5 Result

In this section, the result in terms of carbon dioxide or carbon dioxide equivalents will be presented. The result will first be presented as annual GHG emissions activity by activity, sector by sector, and, finally, the total. The allocation of emissions to the different scopes is found in the appendix, under section D.

5.1 Transport

In table 27, the result for the private vehicles is presented. It is seen that the largest contributor to emissions is the fleet of private passenger cars, with 56 479.5 t CO_2e of the total 57 670.7 t CO_2e. Due to the assumption that 80% of emissions from passenger cars are accounted as scope 3, it is the scope with the highest amount of emissions, 45 422.5 t CO_2e. Scope 1 follows as second with 12 242.3 t CO_2e, while scope 2 has the least. The result per European regulation and fuel can be found in the appendix, under section E.1.1.

Table 27. *Emissions for private vehicles in the district per scope and in total.*

		Scope 1	Scope 2	Scope 3	Total
Passenger cars	[t CO_2e]	11 292.0	3.9	45 183.6	56 479.5
Two-wheelers	[t CO_2e]	950.2	-	-	950.2
Electric scooters	[t CO_2e]	-	2.1	-	2.1
Bicycles	[t CO_2e]	-	-	238.9	238.9
Total	[t CO_2e]	12 242.3	5.9	45 422.5	57 670.7

For public transport, the scope with the highest amount of emissions is scope 2, with 4 823.2 t CO_2e out of 9 352.3 t CO_2e, followed by scope 1 with 3 553.1 t CO_2e. The most significant contributor is the bus category, tightly followed by the metro station category. A more detailed result, showing the distribution of the station and vehicle categories for the metro and tram emissions between material production, material transportation, on-site construction, and O&M, is also found in the appendix, under section E.1.

Table 28. *Emission for public transport in the district per scope and in total.*

			Scope 1	Scope 2	Scope 3	Total
Metro	Stations	[t CO_2e]	28.4	1 182.7	295.9	1 507.1
	Vehicles	[t CO_2e]	-	2 875.3	526.3	3 401.7
Tram	Stations	[t CO_2e]	3.3	135.7	34.0	173.0
	Vehicles	[t CO_2e]	-	629.4	115.2	744.7
Bus		[t CO_2e]	3 521.4	-	-	3 521.4
Valenbisi		[t CO_2]	-	-	4.5	4.5
Total		[t CO_2e]	3 553.1	4 823.2	975.9	9 352.3

For the whole transport sector, the result is seen in table 29. Added in the table is also the 2 349.9 t CO_2e emitted by taxis. It is seen that private vehicles contribute to most of the total emissions, 57 670.7 t CO_2e out of the total 69 372.9 t CO_2e. Due to the allocation of scope 3 emissions for passenger cars, the third scope has the highest amount of GHG emissions with 46 398.5 t CO_2e.

Table 29. *Emission for the transport sector in the district per scope and in total.*

		Scope 1	Scope 2	Scope 3	Total
Private vehicles	[t CO_2e]	12 242.3	5.9	45 422.5	57 670.7
Public transport	[t CO_2e]	3 553.1	4 823.2	975.9	9 352.3
Taxis	[t CO_2e]	2 349.9	-	-	2 349.9
Total	[t CO_2e]	18 145.3	4 829.2	46 398.5	69 372.9

5.2 Land Use

The result of the land use sector is presented in table 30. It is in the table seen that the life cycle emissions of buildings are the most significant contributor with 150 396.5 t CO_2e out of a total of 191 001.9 t CO_2e within the sector. Scope 1 has to the highest amount of emissions with 108 163.4 t CO_2e. A more detailed result, per activity within the sector, is seen in the appendix, under section E.2.

Table 30. *Emission for the land use sector in the district per scope and in total.*

		Scope 1	Scope 2	Scope 3	Total
Buildings	[t CO_2]	85 726.0	-	64 670.5	150 396.5
Roads	[t CO_2e]	22 472.5	-	18 164.3	40 636.8
Urban green areas	[t CO_2e]	-35.0	-	3.7	-31.4
Total	[t CO_2e]	108 163.4	-	82 838.5	191 001.9

5.3 Energy

For the energy sector, electricity consumption is the highest contributor to the total emissions, with 15 977.5 t CO_2e out of 25 136.4 t CO_2e. As the electricity consumption emissions are scope 2-emissions, it is also the scope with the highest amount of emissions, followed by scope 1, with 7 625.1 t CO_2e. The result for the sector is seen in 31.

Table 31. *Emission for the energy sector in the district per scope and in total.*

			Scope 1	Scope 2	Scope 3	Total
Electricity	Consumption	[t CO_2]	-	15 977.5	-	15 977.5
	T&D losses	[t CO_2]	-	-	1 533.7	1 533.7
Gas		[t CO_2e]	7 625.1	-	-	7 625.1
Total		[t CO_2e]	7 625.1	15 977.5	1 533.7	25 136.4

5.4 Consumption

The result for the consumption sector is seen in table 32. Emissions related to consumption are all scope 3-emissions, making it the scope with the highest emissions. Food and manufactured products are the larger contributors, with 37 090.2 t CO_2e and 36 643.4 t CO_2e, respectively, out of 80 959.0 t CO_2e. A more detailed result is found in the appendix, under section E.3.

Table 32. *Emission for the consumption sector in the district per scope and in total.*

		Scope 1	Scope 2	Scope 3	Total
Food	[t CO_2e]	-	-	37 090.2	37 090.2
Clothing	[t CO_2e]	-	-	8 225.4	8 225.4
Manufactured products	[t CO_2e]	-	-	35 643.4	35 643.4
Total	[t CO_2e]	-	-	80 959.0	80 959.0

5.5 Waste

In the waste sector, landfilling is the treatment category with the highest emissions. It is 1 826.2 t CO_2e out of 1 970.0 t CO_2e for the whole sector. As waste emissions are classified as scope 3, all of the emissions are scope 3. The result is seen in table 33.

Table 33. *Emission for the waste sector in the district per scope and in total.*

		Scope 1	Scope 2	Scope 3	Total
Landfilling	[t CO_2e]	-	-	1 826.2	1 826.2
Recycling	[t CO_2e]	-	-	91.7	91.7
Energy generation	[t CO_2e]	-	-	-	-
Composting	[t CO_2e]	-	-	52.1	52.1
Total	[t CO_2e]	-	-	1 970.0	1 970.0

5.6 Final Result

In table 34, the final result is displayed. The total annual emissions of Ciutat Vella are 368 440.2 t CO_2e, with scope 3-emissions being the highest of the scopes, with 213 699.7 t CO_2e, just a little higher than the 133 933.8 t CO_2e scope 1-emissions. To scope 3, the land use- and consumption-related emissions are the most contributing and transport. The land use sector is also highly contributing to scope 1. Scope 2 contributes the least to the total annual emissions of the district, with only 20 806.7 t CO_2e. Looking at the sectors, it is seen that the land use sector is the most significant contributor with 191 001.9 t CO_2e. The consumption sector is the second most contributing, with 80 959.0 t CO_2e, followed by the transport sector with 69 372.9 t CO_2e. The share of the total emissions per category is seen in figure 1. The result will be put into context by being compared to the SECAP of Valencia later on in the report, in the discussion section.

Table 34. *Total emissions in the district per sector, scope, and in total.*

		Scope 1	Scope 2	Scope 3	Total
Transport	[t CO_2e]	18 145.3	4 829.2	46 398.5	69 372.9
Land use	[t CO_2e]	108 163.4	-	82 838.5	191 001.9
Energy	[t CO_2e]	7 625.1	15 977.5	1 533.7	25 136.4
Consumption	[t CO_2e]	-	-	80 959.0	80 959.0
Waste	[t CO_2e]	-	-	1 970.0	1 970.0
Total	[t CO_2e]	133 933.8	20 806.7	213 699.7	368 440.2

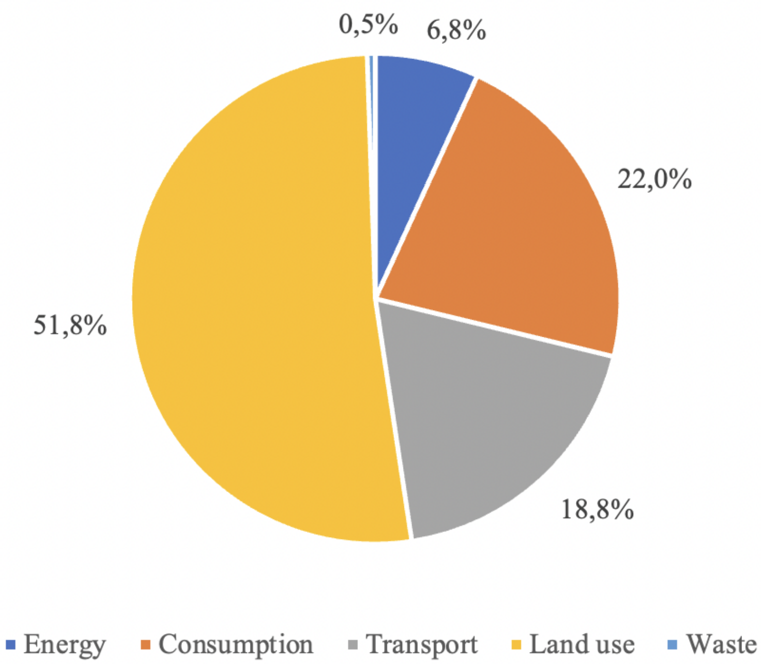

Figure 1. *Share of emissions in the district per category for all scopes.*

6 Sensitivity Analysis

In this section, a number of assumptions and influential factors will be analysed to see their impact on the result.

6.1 Building Area

First out is the number of floors in a building, which was assumed to be four in Ciutat Vella. The number of floors will be set to three and five to evaluate the impact of the assumption on the result. The changes are given in percent and are seen in figure 2. As seen in the figure, scope 2 does not change anything as no construction emissions are allocated to it, but significant changes are happening for the two other scopes and the total. Having three floors decreases the total by 10.2%, while five floors increase it by the same percentage.

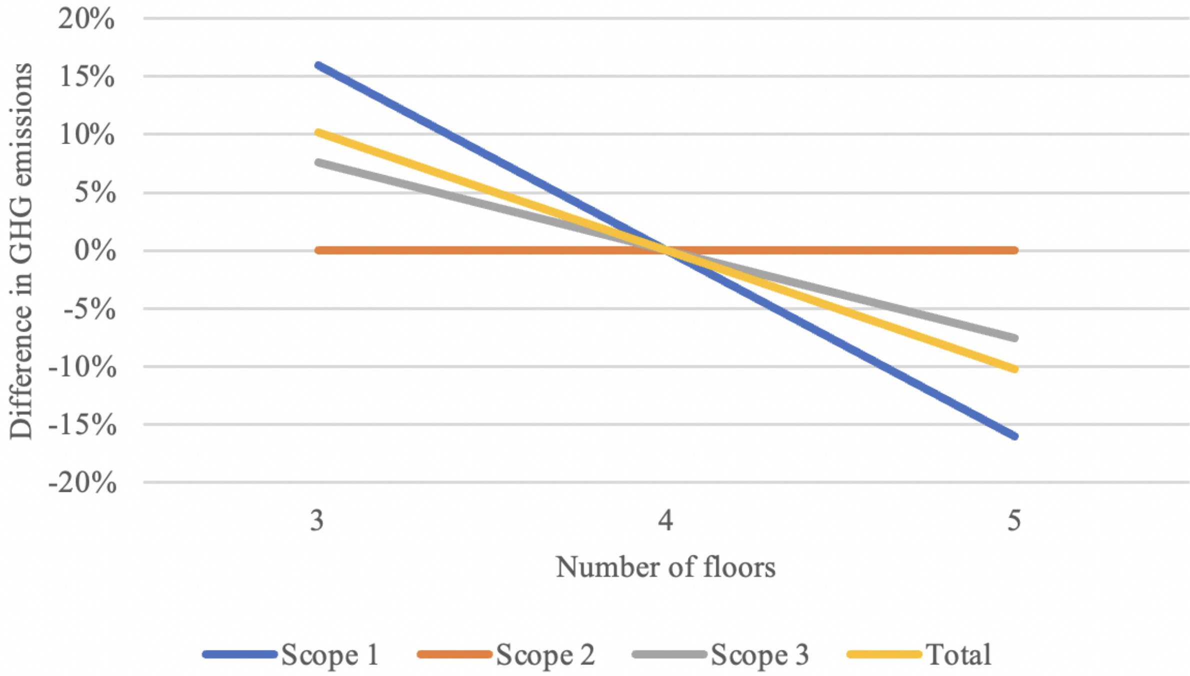

Figure 2. *Sensitivity analysis of the impact of the number of floors on total emissions in the district.*

6.2 Bus Distance Allocation

As mentioned in section 4.1.1, the allocation of the total distance made by buses in the city was allocated after the distribution of stations, instead of per capita. Now, that assumption will be evaluated, and the result from the other allocation method will be presented. It is seen in table 35 that the distance is 373 674.7 VKT less when allocation it depending on the number of inhabitants. It is also seen that it does affect the emissions from buses significantly, by a 35.0% decrease. It also affects the whole public transport by 13.5%, but the impact becomes small when looking at the entire transport sector and the total emissions. It decreases the transport sector by 1.8% and the total emissions by 0.3%.

Table 35. *Sensitivity analysis of the impact of bus distance allocation to the district.*

			Per stations	Per capita	Difference
Allocation		[VKT]	1 067 097	693 422	373 674.7
Result	Bus	[t CO_2e]	3 521.4	2 288.3	-35.0%
	Public transport	[t CO_2e]	9 352.3	8 119.2	-13.2%
	Transport sector	[t CO_2e]	69 372.9	68 139.8	-1.8%
	Total	[t CO_2e]	368 440.2	367 207.1	-0.3%

6.3 Road Percentage

Due to the old city planning in Ciutat Vella with mostly only pedestrian roads or a single-laned oneway road, the distribution between roads and buildings could be different from the used one. In the case study, the model knows the square meters of the park. Hence the only changing variables are buildings and roads. In the case study, a share of 33% of the land area was assumed to be roads, but there is a chance of it being significantly less in Ciutat Vella. To see the impact of the used share and the result could have been with another one, the share will be changed from 28% to 38% in the model. Figure 3 shows the impact. It is seen that by decreasing the share of roads, the emissions caused by them decreases. However, when looking at the emissions of the land use sector and in total, it is seen that as the share decreases, the emission increases. When an area of road disappears, it is replaced by building area and multiplied by four to represent the living area in the model. Hence, the carbon footprint is smaller in areas where roads occupy more of the land area.

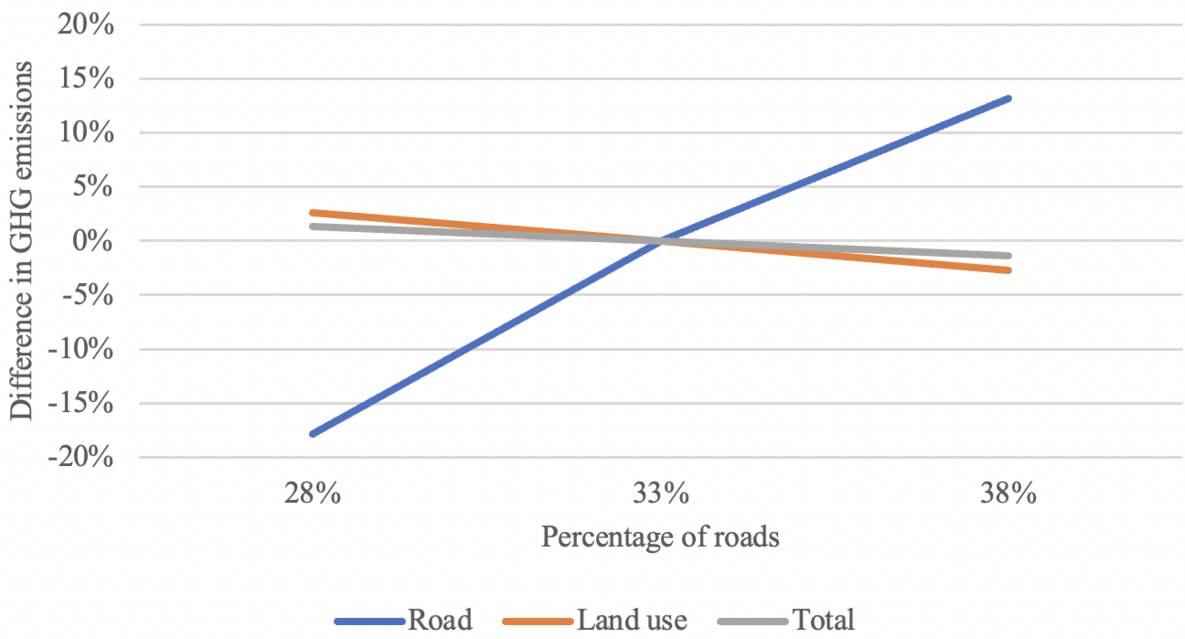

Figure 3. *Sensitivity analysis of the impact of the percentage of roads in the district.*

6.4 Long-distance Travels

As mentioned in section 4.1.1, long-distance transport for private persons was excluded from the original inventory due to difficulties with finding well-representing data and allocate it to the persons living in the district. However, an estimation was done to indicate the effect and significance of the carbon footprint. Statistics show that aviation and road transport plays the most prominent role in transport sector emissions of the considered modes for long distance transport [51]. Hence, aviation and bus will be considered and estimated, while railway and ferries will be neglected. It was done by looking at European average annual emissions per capita. In table 36, the calculated emissions are presented in total and per scope. More information about the calculations is found in the appendix, under section F.

Table 36. *Emissions in the district per scope when including long distance transport.*

		Scope 1	Scope 2	Scope 3	Total
Bus	[t CO_2e]	-	-	455.1	455.1
Aviation	[t CO_2e]	-	-	11 323.6	11 323.6
Total	[t CO_2e]	133 933.8	20 806.7	225 478.4	380 218.9

It is seen that while bus transport does not add any significant level of emissions, aviation does. However, it does not affect the total to a great extent. The added annual emissions for long-distance transport, accounted as scope 3-emissions, is 11 778.7 t CO_2e. When comparing it to the result without long-distance transport, it is in figure 4 seen that the share of scopes does not change significantly, even if there are an extra 1.3% scope 3 emissions.

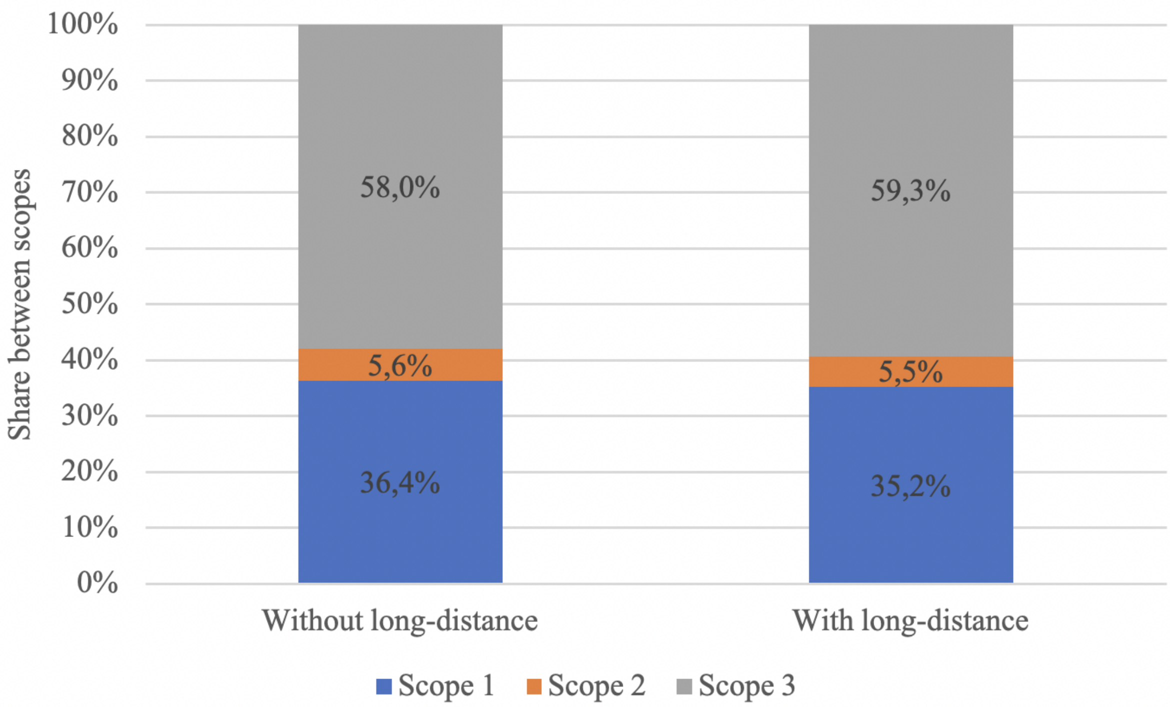

Figure 4. *Share of emissions in the district per scope when including long distance transport.*

6.5 Scope Distribution for Passenger Cars

The assumption of distributing passenger car emissions between scope 1 and scope 3 as 20% scope 1 and 80% scope 3 was made in the activity inventory. Now it is evaluated how the impact of that assumption is on the final share of emissions per scope. It is essential to notice that it does not change anything for the total number of emissions, only the distribution between scope 1 and 3. The analysis was done by changing the share of scope 1 from 10% to 30%, and scope 3 from 90% to 70%. In figure 5, the outcome in terms of distribution between scopes is seen. It shows that increasing the share of scope 3 emissions from passenger cars by 10% increases the final scope 3 emissions by 1.5%, decreasing the scope 1 share with the same amount. Scope 2 does not change in this analysis. The opposite occurs when instead decreasing it by 10%.

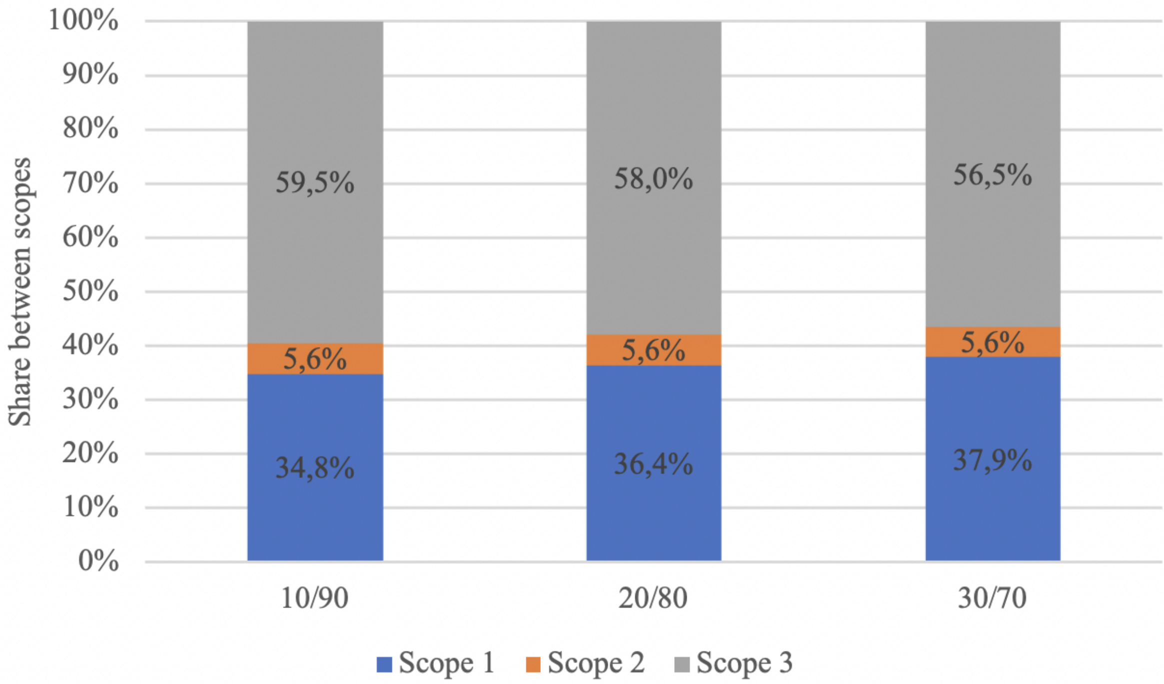

Figure 5. *Share of emissions in the district per scope at the different distribution of passenger cars.*

6.6 Exclution of Construction

The last part evaluated is the role of construction. The transport sector was done by taking away the material production, material transportation, and on-site production while keeping the O&M of the system, and construction, use, and disposal of the vehicles. The land use sector was also done by taking away all activities related to materials and construction, while O&M was kept. Also, to represent that the land still is occupied, the avoided typical, natural sequestration of 1 689 842 m^2 in the area is considered as emissions. The annual natural sequestration in the area of Valencia is 0.000004 t CO_2/m^2, and resulting in 6.2 t CO_2 annually. In table 37, the result is seen. It is seen that for the transport sector, it does not make any significant difference. However, for the land use sector, the emissions decrease by 99.4%. For the total, the scope 1 and 3 emissions have decreased significantly, and the total by 51.6%. The result is also compared visually in figure 6.

Table 37. *Comparison of emissions in the district with and without construction.*

			Scope 1	Scope 2	Scope 3	Total
Transport	With construction	[t CO_2]	18 145.3	4 829.2	46 398.5	69 372.9
	Without construction	[t CO_2]	18 113.6	4 829.2	46 068.6	69 011.3
Land use	With construction	[t CO_2]	108 163.4	-	82 838.5	191 991.9
	Without construction	[t CO_2]	6.2	-	1 215.1	1 221.3
Total	With construction	[t CO_2]	133 933.8	20 806.7	213 699.7	368 440.2
	Without construction	[t CO_2]	25 744.9	20 806.7	131 746.4	178 298.9

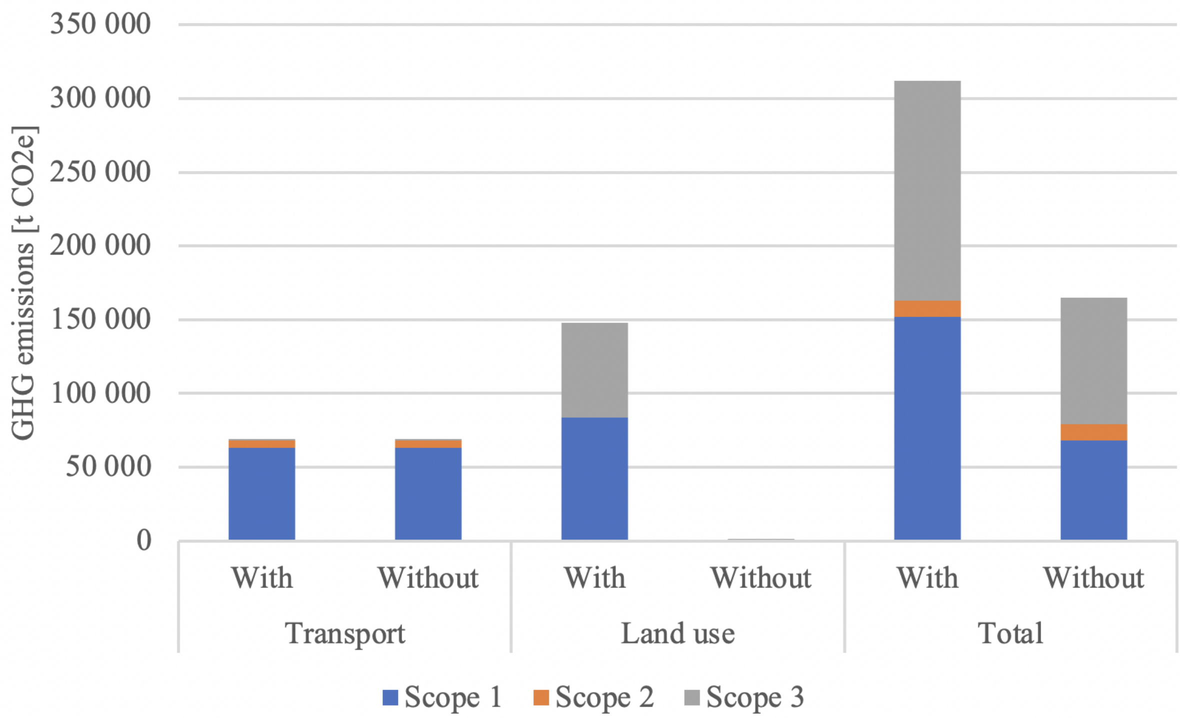

Figure 6. *Emissions in the district per scope with and without construction.*

7 Discussion

In this section, the result from the bottom-up approach and sensitivity analysis will be discussed and analysed. To start, the result section showed that the land-use sector is the most contributing sector, followed by consumption and transport, with 51.8%, 22.0%, and 18.8%, respectively, of the total emissions. The energy and waste sectors only contribute with 6.8% and 0.5%. It was also seen that only 5.6% of the emissions were categorised as scope 2, as the only emissions being scope 2 is electricity from the national grid. Furthermore, scope 3 accounted for 58.0% of the total GHG emissions, while scope 1 had 36.4%.

To put the result in context, it was compared with the total emissions accounted in the 2016 SECAP of Valencia, which was 1 913 296.4 t CO_2 [70]. As seen in table 38, is that the emissions per capita are around 5.5 times as high as the SECAP. However, as the SECAP does not include scope 3 emissions, it was also compared to the result without them but even when excluding scope 3, the emissions for Ciutat Vella are almost 2.5 times as high. An exact explanation is hard to give, but looking at the distribution of scope 1 and 2 emissions between the five sectors in figure 7, it is seen that land use is playing a significant role. One explanation is that the on-site construction is more comprehensively considered in this case study than in the SECAP. The SECAP is also using a mixture of top-down and bottom-up approaches in the inventory [71], making the methodology applied different between the two evaluations. As mentioned in section 2.1, the final result does not always match between the methodologies, which also is an explanation for this difference. The fact that SECAP is measured in $t\ CO_2$ while the case study in $t\ CO_2e$ is also an explanation, as equivalents include more types of greenhouse gases.

Table 38. *Comparison between the case study and SECAP.*

		[t CO_2e/cap]	[t CO_2e/m^2]
Case Study	With scope 3	13.44	0.22
	Without scope 3	5.64	0.09
SECAP		2.39	0.02

Given the information in table 2, where it was stated that Ciutat Vella is a dense district, with a higher than average income or price of living, it can also be assumed to be realistic that Ciutat Vella has a higher carbon footprint than the average numbers of the city. However, it is essential to keep in mind that more extensive consumption patterns that are assumed to take place in wealthier districts are not taken into account in the case study, so the actual difference could be more significant than it is in table 38. If long-distance travel were included, the same principle would count for them: wealthier people travel more.

As scope 3 accounts for a whole 58.0%, even when not including long-distance travel, it shows the importance of including the scopes emissions when accounting. Even though consumption patterns are complex for decision-makers to affect, it still plays a significant part of the emissions caused by humans. The inventory tells that material production and transport contribute the most to this scope, and materials in construction projects should therefore be considered carefully to limit the emissions. The second most contributing is the consumption of food and manufactured goods. Looking at food consumption specifically, meat, fish, milk, and dairy products stand for 65.4% of the emissions related to

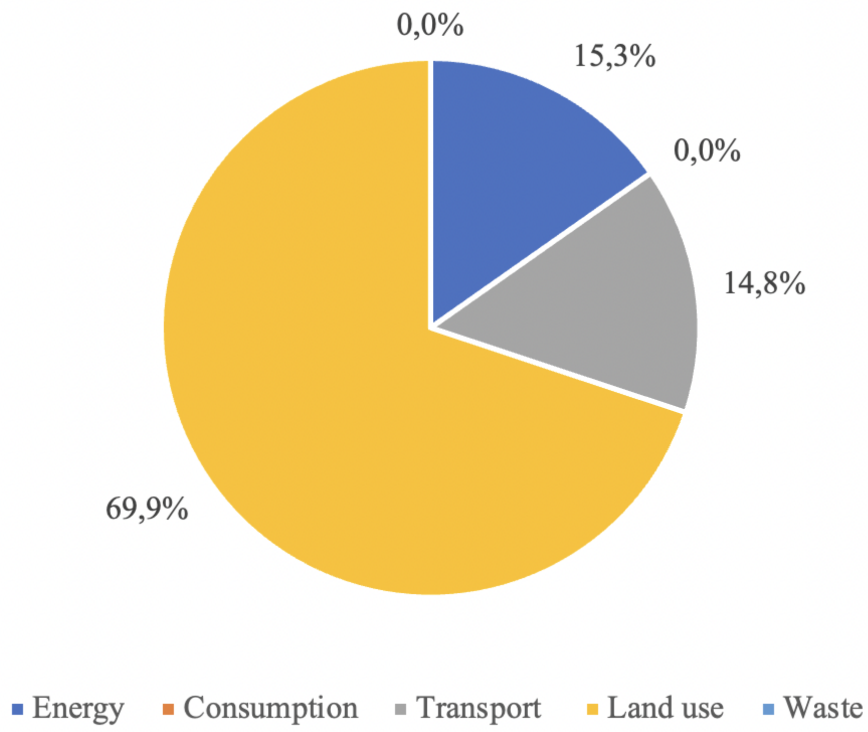

Figure 7. *Share of scope 1 and 2 emissions in the district per category.*

food. That is explained by the much higher emission factors and consumption in weight of these foods. Comparing with the emission factors of fresh fruit and vegetables and legumes and potatoes, it is seen that increasing the intake of these foods instead of meat, fish, milk, and dairy products would decrease the emissions. Unfortunately, the emissions related to manufactured goods cannot be investigated further because the emission factor is per capita and, therefore, information of "what causing what" is lacking.

In the sensitivity analysis, some assumptions and factor's contributions to the result were evaluated. First, it is interesting to see how assumptions regarding the most contributing sector, the land use sector, affected the result. As mentioned earlier, the assumption of the number of floors was made after the design of the old Ciutat Vella, with a generally lower building height than in order parts of Valencia. The assumption is, however, uncertain. The effect of decreasing it to three or increasing to four affects the result significantly, as the total emissions change by 10.2%. This makes a weakness of the study, and more specific data of this is desirable.

Continuing with the land use sector, the percentage of roads in the district was also evaluated in the sensitivity analysis. Also affected by the old design, the streets are more narrow than in other parts of the city, probably making the percentage of roads less than the 33% used in the case study. When analysing its effect, it is seen that even though it affects the road emissions significantly, the total only changes 1.4% when changing the share of roads with 5%. This could imply that the final result could be a little higher than in the case study. However, more detailed data on land use would be beneficial for studies like this.

Looking at the sensitivity analysis of the transport sector more closely, it was done in two steps, where the first considered the allocation of distance made by public transport buses. There, it was shown that the allocation of bus distance did not affect the final result significantly, even though the transport sector decreased its emissions by 1.8% when allocation per capita instead of per station. More interesting was the sensitivity analysis of the inclusion of long-distance transport by bus or aviation. There it was seen that it increased the annual emissions by 11 778.7 t CO_2e, which is only an increase of 3.1%. Even though it is desirable to include all emissions, excluding it due to the lack of quality data is considered supported in this case. As mentioned before, the allocation would not be fair to the district as most travellers visiting the airport of Valencia are foreigners. However, this is also an area where more detailed data would be desirable, so it in the future can be included with more quality with a city and district-based estimation.

At last, a factor that can be affecting the result is the unit some of the emission factors were given in. Weight of carbon dioxide equivalents was searched for to all activities but not always found, and therefore was just weight of carbon dioxide used in some cases. As the second does not include all greenhouse gases, the actual GHG emissions for Ciutat Vella can be assumed to be higher than this case study implies. In the case study, 45.9% of the emissions are calculated in only carbon dioxide, where the majority comes from the construction of buildings. This percentage of emissions could hence be assumed to be higher.

8 Conclusion and Recommendations

From the result and discussion, some conclusions could be drawn. Methodology-wise, it could be seen that the application city-specific data is complex and does not serve the district correctly in all cases. Hence, more specific detailed data should be gathered to make the assessment better represent each district's differences. The heavy data dependency of a bottom-up approach is today, in this study, a weakness of the methodology. With more data available, it has the potential to become a strength and allow an accurate study to be done. For future projects, a top-down approach could also be made to see the difference between them.

Looking at the result, the significant contribution of emissions from the construction phase of buildings and roads was identified and highlights the importance of using life cycle assessments when planning projects to limit the emissions to the greatest extent. For transport, the large contribution from the combustion of fossil fuels, and a relatively small share of electric vehicles, also highlights the need for a transition towards a larger share of electric vehicles as well as zero- or low-emission transport modes, such as bicycles, electric scooters, walking and public transport, in the district and city. From the consumption sector, it was seen that a transition to a less meat-heavy diet would be beneficial and reduce the emissions related to food. The excel file for replication of district-level emission accounting is shown in the appendix, under section G.

8.1 Recommendations

To execute emission accounting studies in the future with more precision, several points could benefit from improvements. The most crucial factor is the data available. In some parts, the data is detailed and easily accessible, but not in all cases. The energy sector does not need a significant improvement, while the other sectors need better data in some aspects. The suggestions can be seen in the list below.

- Transport sector
  - More detailed data of long-distance travelling by train, aviation, bus and ferry.
  - Data of bicycles ownership.
  - Data of electric scooter ownership.
  - Data of two-wheeler ownership per district.
- Land use
  - Data of how the land area is used, in terms of share of buildings, roads, plazas, and parks.
  - Number of floors for buildings, or total living area.
- Consumption
  - Data of consumption of clothing and manufactured products.
- Waste
  - Data of share of waste stream per treatment method.

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Appendices

A General Data

In this section of the appendix, general data used in different calculations is presented. Firstly, the population used for Spain is the 2021 population, at 47 394 223 persons [72]. In table 39 the share of type of days for 2020 in Valencia is shown.

Table 39. *Share of types of days in Valencia [73].*

Workdays	[days]	251
Weekends	[days]	104
Holidays	[days]	10

B Activity Inventory

B.1 Transport

In the transport section, the calculations for the transport sector will be presented. Firstly, the European emission standards for passenger cars and two-wheelers are presented in table 40 and 41 below. After that, in table 42, the average distance travelled per vehicle type and age is found.

Table 40. *European emission standards for passenger cars [74].*

Regulations	Span
Pre Euro	-1992
Euro 1	1992-1995
Euro 2	1996-1999
Euro 3	2000-2004
Euro 4	2005-2009
Euro 5	2010-2014
Euro 6	2015-

Table 41. *European emission standards for two-wheelers [75].*

Regulations	Span
Pre Euro	-1999
Euro 1	1999-2002
Euro 2	2003-2005
Euro 3	2006-2015
Euro 4	2016-2019
Euro 5	2020-

Table 42. *Average distance travelled per vehicle type and age [km/year] [76].*

Age [years]	Span	Passenger cars	Motorcycles
0-4	2021-2017	19 689	4 656
5-9	2016-2012	15 301	3 243
10-14	2011-2007	12 399	2 867
15-19	2006-2002	10 532	2 462
>20	2011-	8 472	1 692

B.1.1 Passenger Cars

The total number of cars registered in the district was divided between the different European emission regulations and fuel for the activity inventory for passenger cars. The distribution for the whole city of Valencia is seen in tables 43 and 44.

Table 43. *Share of passenger cars in Valencia per European emission regulation and fuel type (1/2) [39].*

	Total		Petrol		Diesel Oil	
	Number	Share [%]	Number	Share [%]	Number	Share [%]
Pre Euro	44 579	12.5	41 022	92.0	3 556	8.0
Euro 1	7 646	2.1	5 756	74.9	1 920	25.1
Euro 2	24 534	6.9	13 065	53.3	11 469	46.7
Euro 3	77 813	21.8	33 374	42.9	44 439	57.1
Euro 4	98 660	27.6	35 348	35.8	63 312	64.2
Euro 5	56 401	15.8	20 232	35.9	36 129	64.1
Euro 6	47 927	13.4	24 647	51.4	23 086	48.2
Total	357 560	100.0	173 414	48.5	183 911	51.4

Table 44. *Share of passenger cars in Valencia per European emission regulation and fuel type (2/2) [39].*

	Electricity		LPG		CNG	
	Number	Share [%]	Number	Share [%]	Number	Share [%]
Pre Euro	1	0.0	-	0.0	-	0.0
Euro 1	-	0.0	-	0.0	-	0.0
Euro 2	-	0.0	-	0.0	-	0.0
Euro 3	-	0.0	-	0.0	-	0.0
Euro 4	-	0.0	-	0.0	-	0.0
Euro 5	13	0.0	26	0.0	1	0.0
Euro 6	109	0.2	67	0.1	18	0.0
Total	123	0.0	93	0.0	19	0.0

The distribution of cars is then applied to the number of registered passenger cars in the district and is seen in tables 45 and 46.

Table 45. *Share of passenger cars in the district per European emission regulation and fuel type (1/2).*

	Total		Petrol		Diesel Oil	
	Number	Share [%]	Number	Share [%]	Number	Share [%]
Pre Euro	1 755	12.5	1 615	92.0	140	8.0
Euro 1	301	2.1	225	74.9	76	25.1
Euro 2	966	6.9	514	53.3	452	46.7
Euro 3	3 063	21.8	1 314	42.9	1 749	57.1
Euro 4	3 883	27.6	1 391	35.8	2 492	64.2
Euro 5	2 220	15.8	796	35.9	1 422	64.1
Euro 6	1 886	13.4	970	51.4	908	48.2
Total	14 073 [47]	100.0	6 825	48.5	7 238	51.4

Table 46. *Share of passenger cars in the district per European emission regulation and fuel type (2/2).*

	Electricity		LPG		CNG	
	Number	Share [%]	Number	Share [%]	Number	Share [%]
Pre Euro	-	0.0	-	0.0	-	0.0
Euro 1	-	0.0	-	0.0	-	0.0
Euro 2	-	0.0	-	0.0	-	0.0
Euro 3	-	0.0	-	0.0	-	0.0
Euro 4	-	0.0	-	0.0	-	0.0
Euro 5	1	0.0	1	0.0	-	0.0
Euro 6	4	0.2	3	0.1	1	0.0
Total	5	0.0	4	0.0	1	0.0

The final activity, the annual distance travelled, is shown in table 47. It was calculated by using the average distance travelled for passenger cars in different age spans, presented in table 42.

Table 47. *Calculated distance travelled by passenger cars in the district [km/year].*

	Total	Petrol	Diesel Oil	Electricity	LPG	CNG
Pre Euro	14 868 360	13 682 280	1 186 080	-	-	-
Euro 1	2 550 072	1 906 200	643 872	-	-	-
Euro 2	8 183 952	4 354 608	3 829 344	-	-	-
Euro 3	29 735 605	12 756 312	16 979 292	-	-	-
Euro 4	45 245 493	16 208 210	29 037 282	-	-	-
Euro 5	31 391 244	11 255 599	20 107 364	14 140	14 140	-
Euro 6	33 823 147	17 395 786	16 283 890	71 735	53 801	17 034
Total	165 797 871	77 558 995	88 067 125	85 875	67 942	17 934

B.1.2 Two-wheelers

The same principle as when calculating the passenger car activity was used when calculating the activity of two-wheelers in Ciutat Vella. However, the input data was only the city-registered two-wheelers per fuel type, and the number allocated to the district was calculated first in table 48.

Table 48. *Calculation of the number of two-wheelers per fuel type in the district.*

Two-wheelers in Valencia	Petrol	[units]	85 696 [47]
	Diesel oil	[units]	389 [47]
	Other	[units]	684 [47]
Two-wheelers per person	Petrol	[units/cap]	0.1071
	Diesel oil	[units/cap]	0.0005
	Other	[units/cap]	0.0009
Two-wheelers in district	Petrol	[units]	2 936
	Diesel oil	[units]	13
	Other	[units]	23

The numbers were then multiplied with the distribution of two-wheelers per European emission regulation, giving the number of two-wheelers per emission regulation and fuel type. The result is shown in tables 49 and 50.

Table 49. *Share of two-wheelers in the district per European emission regulation and fuel type (1/2) [39].*

	Total		Petrol	
	Number	Share [%]	Number	Share [%]
Pre Euro	622	20.9	614	20.9
Euro 1	5467	18.4	541	18.4
Euro 2	346	11.6	341	11.6
Euro 3	1 167	39.3	1 153	39.3
Euro 4	290	9.8	287	9.8
Euro 5	-	0.0	-	0.0
Total	2 972	100.0	2 936	100.0

Table 50. *Share of two-wheelers in the district per European emission regulation and fuel type (2/2) [39].*

	Diesel Oil		Other	
	Number	Share [%]	Number	Share [%]
Pre Euro	3	20.9	5	20.9
Euro 1	2	18.4	4	18.4
Euro 2	2	11.6	3	11.6
Euro 3	5	39.3	9	39.3
Euro 4	1	9.8	2	9.8
Euro 5	-	0.0	-	0.0
Total	13	100.0	23	100.0

Finally, the distance travelled was calculated using the average annual distance from table 42. The result is presented in table 51.

Table 51. *Calculated distance travelled by two-wheelers in the district [km/year].*

	Total	Petrol	Diesel Oil	Other
Pre Euro	1 056 156	1 042 572	5 094	8 490
Euro 1	1 033 283	1 021 949	3 778	7 556
Euro 2	851 852	839 542	4 924	7 386
Euro 3	3 474 042	3 432 366	14 885	26 792
Euro 4	1 247 798	1 234 889	4 303	8 606
Euro 5	-	-	-	-
Total	7 663 131	7 571 318	32 983	58 830

B.1.3 Electric Scooters

As no exact data about the number of electric scooters existing in Valencia, nor Spain, was to be found, an estimation of the number of scooters in Spain was used to estimate the number of scooters in the district. The estimation was done by calculating the average electric scooters per capita in the country and then multiplying the number with the inhabitants of the district, and it is seen in table 52.

Table 52. *Calculation of electric scooters in the district.*

Electric scooters in Spain	[units]	650 000 [77]
Electric scooters per person in Spain	[units/cap]	0.0137
Electric scooters in district	[units]	376

To convert the number of electric scooters into emissions, an estimation of the distance travelled per scooter was made in table 53 and 54. The number of trips per day and vehicle was estimated in the first table out of statistics of the usage of electric scooters, and then in the later table combined with the average distance for a trip for an electric scooter to get the average annual distance per vehicle.

Table 53. *Usage patterns for electric scooters.*

Daily use	[%]	24.4 [78]
Several times a week	[%]	46.3 [78]
Several times a month	[%]	24.4 [78]
Less than once a month	[%]	2.4 [78]
Used it once	[%]	2.4 [78]
Estimated daily trips per vehicle	[trips/vehicle]	0.6

Table 54. *Calculation of annual distance travelled for an electric scooter in the district.*

Average distance per trip	[km/trip]	1.13 [79]
Average annual distance	[km/vehicle]	247.47

B.1.4 Public Transport

In this section, the calculations of the distance made by public transport vehicles will be explained. In table 55, the calculation of buses is shown. The city's annual distance of public transport buses is allocated to Ciutat Vella after how many of its bus stations are located within its borders.

Table 55. *Calculation of annual distance driven by buses allocated to the district.*

Total distance travelled in the city	[km]	20 238 038 [47]
Total number of stations in the city	[stations]	1 100 [47]
Number of stations in the district	[stations]	58 [47]
Distance per station	[km/station]	18 398
Distance for district	[km]	1 067 097

Next, the calculation of the activities representing the metro and tram system will be explained. As explained in section 4.1.1, it is divided into the system, including stations, railway, and the infrastructure around it, while vehicles represent the use-phase. In table 56, the allocation of the total length to the district is done. As data of stations per district is not available, the total length is divided by the population of Valencia multiplied by the district's population and finally expressed in terms of kilometers of railway.

Table 56. *Length of rail-bound public transport systems in the city [47].*

		Metro	Tram
Length of system	[km]	189.93	21.80
Length per capita	[km/cap]	0.00024	0.00003
Length for district	[km]	6.51	0.75

For the use-phase, the aim was to express the activity in vehicle kilometers travelled (VKT). To reach that, the annual distance travelled by metro- and tram-trains needed to be determined. Table 57 express the length of the metro and tram lines, as well as the number of departures per line and type of day.

Table 57. *Data for metro and tram lines [47].*

Line	Mode	Length [km]	Departures		
			Workdays	Weekends	Holidays
Line 1	Metro	72.15	157	122	97
Line 2	Metro	39.45	152	119	98
Line 3	Metro	24.69	143	115	93
Line 4	Tram	17.00	311	263	242
Line 5	Metro	13.29	146	116	100
Line 6	Tram	3.57	197	106	98
Line 7	Metro	15.50	138	109	94
Line 8	Tram	1.23	86	78	76
Line 9	Metro	24.86	128	107	78

The kilometers travelled for a weekday, weekend, and holiday are determined by multiplying the length by the number of departures. Then, multiplying the distance by the number of days presented in table 39, and adding all together, resulting in the annual vehicle kilometers travelled, which is seen in table 58.

Table 58. *Annual vehicle kilometers travelled per metro and tram line.*

Line	Mode	VKT per type of day			Annual VKT
		Workdays	Weekends	Holidays	
Line 1	Metro	11 326.8	8 801.7	6 998.1	3 828 374.4
Line 2	Metro	5 995.6	4 694.0	3 865.6	2 031 733.1
Line 3	Metro	3 530.8	2 839.5	2 296.3	1 204 501.1
Line 4	Tram	5 286.7	4 470.7	4 113.8	1 833 053.2
Line 5	Metro	1 940.8	1 542.0	1 329.3	660 795.0
Line 6	Tram	703.5	378.5	350.0	219 441.5
Line 7	Metro	2 138.6	1 689.2	1 456.7	727 026.3
Line 8	Tram	105.8	95.9	93.5	37 463.3
Line 9	Metro	3 182.0	2 659.9	1 939.0	1 094 690.9

The last step is to allocate the distance to the district, which is done by dividing the distance by the city's population and multiplying it by the district's population. This is presented in table 59.

Table 59. *Annual vehicle kilometers travelled for the district.*

		Metro	Tram
Annual distance	[VKT]	9 547 121	2 089 958
Distance per capita	[VKT/cap]	11.9	2.6
Distance for district	[VKT]	327 116	71 609

C Emission Factors

C.1 Transport

Emission factors for the system- and infrastructure part of the metro and tram system were calculated. A case study of the life cycle emissions of the Shanghai metro was used to calculate the emission factors for the rail-bound public transport in Valencia. The construction phase was divided into material production, transportation, and on-site construction to be able to allocate the emissions to the correct scope. The length of the systems was used to get the emissions as the weight of CO_2e per kilometer of system. For the electricity consumption for the O&M, the energy was converted to emissions using the emission factor for electricity in Comunidad Valenciana, seen in table 22. The calculation and result are presented in table 60.

Table 60. *Calculation of life cycle emission factor for metro and tram system [63].*

Lifetime of system		[years]	100
Length of system		[km]	538
Share of electricity for stations		[%]	39.0
Construction phase	Material production	[t CO_2e]	2 401 374.6
		[t CO_2e/km/year]	44.6
	Material transportation	[t CO_2e]	45 001.9
		[t CO_2e/km/year]	0.8
	On-site construction	[t CO_2e]	235 051.6
		[t CO_2e/km/year]	4.4
O&M	Electricity consumption	[MWh]	1 370 000
		[MWh]	534 300
		[t CO_2/year]	97 776.9
		[t CO_2/km/year]	181.7

C.2 Land Use

The life cycle emissions per square meter of road per year were calculated per material production, material transportation, on-site construction, and maintenance, and are seen in table 61. It was done using emission data, and lifetime and length of the road from a life cycle analysis of road construction and use. The emissions from the construction phases and maintenance were distributed over the expected lifetime of a road to have an identical emission factor each year.

Table 61. *Calculation of annual emission factors for roads [80].*

Lifetime of road	[years]	60
Length of road	[m]	8 500
Width of road	[m]	9.5
Road area	[m^2]	80 750
Construction emissions	[t CO_2e]	358 000
Material production	[%]	40.0
	[t CO_2e]	143 200
	[t CO_2e/m^2]	0.02956
Material transportation	[%]	3.0
	[t CO_2e]	10 740
	[t CO_2e/m^2]	0.00222
On-site construction	[%]	57.0
	[t CO_2e]	204 060
	[t CO_2e/m^2]	0.0421
Maintenance	[t CO_2e]	11 000
	[t CO_2e/m^2]	0.00227

The annual emissions and sequestration per square meter and year by urban greens areas, including GHG emitted during construction and maintenance, were calculated in table 62. It was done by using emission data of the construction, maintenance, and sequestration. The emissions were distributed over the park's expected lifetime to have an equal contribution each year.

Table 62. *Calculation of annual emission factors for urban green areas.*

Urban green area	[m^2]	3 609 970 [81]
Lifetime of urban green area	[years]	50 [82]
Construction phase	[t CO_2/ha]	4.85 [82]
	[t CO_2e/m^2]	0.0000097
Maintenance	[t CO_2e]	181.81 [81]
	[t CO_2e/m^2]	0.0000501
Annual fixed emissions	[t CO_2e/year]	-1 768.24 [81]
	[t CO_2e/m^2]	-0.0004898

In table 63, the calculation of emission factors for buildings is presented. The factors for material transportation and on-site construction were not found but estimated using the same shares as in the construction phase of roads, in table 61, scaling the found factor for material production.

Table 63. *Calculation of annual emission factors for buildings.*

Lifetime of buildings		[years]	50 [83]
Share	Material production	[%]	40.0
	Material transportation	[%]	3.0
	On-site construction	[%]	57.0
Material production	Total	[t CO_2/m^2]	0.69416 [84]
	Per year	[t CO_2/m^2]	0.01388
Material transportation		[t CO_2/m^2]	0.00104
On-site construction		[t COe/m^2]	0.01978

The emission factor for natural sequestration was calculated in table 64. The sequestration of carbon was converted into carbon dioxide to have it comparable to the rest of the factors.

Table 64. *Calculation of annual emission factor for natural sequestration.*

Carbon to carbon dioxide	[-]	3.67 [85]
Sequestration	[t C/ha/year]	0.01 [86]
	[t CO_2/m^2/year]	0.000004

C.3 Consumption

The emission factor for beverages was calculated by taking the average emission factor from six different beverages. The emission factor of each beverage and the total average can be seen below in table 65. The same procedure was done in table 66 for meat other than beef and lamb by taking the average emission factor from four different types of meat.

Table 65. *Calculation of annual emission factor for beverages [39].*

Beer	[kg CO_2e/kg]	0.640
Cider	[kg CO_2e/kg]	0.770
Spirits	[kg CO_2e/kg]	0.770
Juice	[kg CO_2e/kg]	0.680
Bottled water	[kg CO_2e/kg]	0.300
Soft drinks	[kg CO_2e/kg]	0.630
Average emission factor	[kg CO_2e/kg]	0.632

Table 66. *Calculation of annual emission factor for meat [39].*

Chicken	[kg CO_2e/kg]	4.12
Pork	[kg CO_2e/kg]	5.60
Turkey	[kg CO_2e/kg]	6.04
Rabbit	[kg CO_2e/kg]	4.70
Average emission factor	[kg CO_2e/kg]	5.12

Emission factors for seven different portions were used to determine the emission factor of a typical ready-to-eat portion of food. However, the emission factor was per portion and needed to be converted to weight of emissions per weight of food. The weight of a normal portion of food was then needed and can be seen in table 67. The calculation per type of ready-to-eat portion takes place in table 68, where the factor per portion is divided by the weight of a portion, and finally, an average of them all is calculated.

Table 67. *Average weight of a portion [87].*

Carbohydrates	[kg/portion]	0.15
Protein	[kg/portion]	0.13
Vegetables	[kg/portion]	0.08
Complete portion	[kg/portion]	0.36

Table 68. *Calculation of annual emission factor for ready-to-eat portions.*

Rainbow trout casserole	[kg CO_2e/portion]	1.650 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	4.583
Ham casserole	[kg CO_2e/portion]	1.750 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	4.861
Vegetable casserole	[kg CO_2e/portion]	1.780 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	4.944
Barley porridge with berry fool	[kg CO_2e/portion]	1.810 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	5.028
Chicken-pasta casserole	[kg CO_2e/portion]	1.880 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	5.222
Minced meat-macaroni casserole	[kg CO_2e/portion]	1.930 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	5.361
Chicken in cream sauce with rice	[kg CO_2e/portion]	2.350 [88]
	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	6.528
Average emission factor	[kg CO_2e/$kg_{ready\text{-}to\text{-}eat}$]	5.218

D Scope Allocation

D.1 Transport

As mentioned in section 4.1.1, 80% of the distance cars are doing is assumed to be scope 3 emissions. In table 69, the allocation of emissions between scope 1 and 2 is seen. Except for electric cars, all emissions are allocated to scope 1 due to the combustion of fuels. Electric cars are allocated to scope 2. The construction and disposal of cars, usually scope 3, are assumed to be such a small part of the life cycle emissions that they can stay as scope 1.

Table 69. *Scope per European emission regulation and fuel type of passenger car.*

	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1
Euro 1	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1
Euro 2	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1
Euro 3	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1
Euro 4	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1
Euro 5	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1
Euro 6	Scope 1	Scope 1	Scope 2	Scope 1	Scope 1

The allocation of emissions from two-wheelers, electric scooters, bicycles, and taxis is seen in table 70. Two-wheelers and taxis are assumed to belong to scope 1 due to fossil fuel combustion, while electric scooters are scope 2 because they are electricity-driven. For bicycles, only the construction and disposal are emitting, and those are scope 3.

Table 70. *Scope per other means of personal transport.*

Two-wheelers	Scope 1
Electric scooters	Scope 2
Bicycles	Scope 3
Taxi	Scope 1

For public transport, bus emissions are allocated to scope 1 due to the combustion of fossil fuels. As for passenger cars, two-wheelers, and electric scooters, manufacturing is assumed to be a neglectable part of the life cycle emissions. The metro and tram system is divided up between scope 3 material production and transportation, scope 1 on-site construction, and scope 2 O&M. On-site construction is scope 1 due to the emissions being direct emissions, taking place within the geographical boundary and is controlled by the city hall, while O&M is scope 2 due to it to 99.7% being electricity consumption [63]. Transport outside of the district and material production is scope 3 due to indirect emissions of no electricity. The allocation is seen in table 71.

Table 71. *Scope per activity of public transport.*

Metro and tram	System	Material production	Scope 3
		Material transportation	Scope 3
		On-site construction	Scope 1
		O&M	Scope 2
	Vehicle	Construction and disposal	Scope 3
		Use	Scope 2
Bus			Scope 1
Valenbisi			Scope 3

D.2 Land Use

In table 72, the scope allocation of the land use sector is seen. The three categories of buildings, roads, and urban green areas have been divided into different activities, such as material production, material transportation, on-site construction, and O&M. Like for public transport, material production and transportation are scope 3, while on-site construction is scope 1. However, here the O&M is allocated to scope 3, as it is assumed to be more material consumption than the energy used within the district. The natural sequestration that would have taken place in the district is seen as scope 1, as it is direct emissions inside the geographical boundary.

Table 72. *Scope allocation per activity of land use.*

Buildings	Material production	Scope 3
	Material transportation	Scope 3
	On-site construction	Scope 1
Roads	Material production	Scope 3
	Material transportation	Scope 3
	On-site construction	Scope 1
	O&M	Scope 3
Urban green areas	Construction	Scope 1
	O&M	Scope 3
	Sequestration	Scope 1
Natural sequestration		Scope 1

D.3 Energy

In table 73, the allocation of energy activities is seen. Fossil fuel combustion of gas is scope 1, while electricity consumption is scope 2. T&D losses outside of the district are scope 3.

Table 73. *Scope allocation per activity of energy.*

Electricity	Consumption	Scope 2
	T&D losses	Scope 3
Gas		Scope 1

D.4 Consumption

Consumption of goods is all allocated to scope 3, due to being indirect emissions but not electricity. It is presented in table 74.

Table 74. *Scope allocation per activity of consumption.*

Food	Scope 3
Clothing	Scope 3
Manufactured products	Scope 3

D.5 Waste

In table 75, it is seen that all treatment methods of waste are allocated as scope 3. It is due to it, like consumption of goods, being indirect emissions but not electricity.

Table 75. *Scope allocation per activity of waste treatment.*

Landfilling	Scope 3
Recycling	Scope 3
Composting	Scope 3

E Result

E.1 Transport

E.1.1 Private Vehicles

In tables 76 and 77, the final GHG emissions per European emission regulation and fuel type is seen.

Table 76. *GHG emissions in the district per European emission regulation and fuel type for passenger cars [t CO_2e].*

	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	5 732.9	436.5	-	-	-
Euro 1	768.2	229.2	-	-	-
Euro 2	1 685.2	1 317.3	-	-	-
Euro 3	4 732.6	5 637.1	-	-	-
Euro 4	5 753.9	9 291.9	-	-	-
Euro 5	3 849.4	6 293.6	3.2	4.4	-
Euro 6	5 723.2	4 982.9	16.1	16.8	4.9

Table 77. *GHG emissions in the district per European emission regulation and fuel type for two-wheelers [t CO_2e].*

	Petrol	Diesel Oil	Other
Pre Euro	129.3	0.6	1.1
Euro 1	126.7	0.5	0.9
Euro 2	104.1	0.6	0.9
Euro 3	425.6	1.8	3.3
Euro 4	153.1	0.5	1.1
Euro 5	-	-	-

E.1.2 Public Transport

In tables 78 and 79, the detailed result for the metro stations and vehicles are seen, while the result for the tram stations and vehicles are presented in tables 80 and 81.

Table 78. *Result for metro stations.*

			Scope 1	Scope 2	Scope 3	Total
Construction	Material production	[t CO_2e]	-	-	290.5	290.5
	Material transportation	[t CO_2e]	-	-	5.4	5.4
	On-site construction	[t CO_2e]	28.4	-	-	28.4
O&M	Electricity consumption	[t CO_2]	-	1 182.7	-	1 182.7
Total		[t CO_2]	28.4	1 182.7	295.9	1 507.1

Table 79. *Result for metro vehicles.*

		Scope 1	Scope 2	Scope 3	Total
Construction and EoL	[t CO_2e]	-	-	526.3	526.3
Use	[t CO_2e]	-	2 875.3	-	2 875.3
Total	[t CO_2e]	-	2 875.3	526.3	3 401.7

Table 80. *Result for tram stations.*

			Scope 1	Scope 2	Scope 3	Total
Construction	Material production	[t CO_2e]	-	-	33.3	33.3
	Material transportation	[t CO_2e]	-	-	0.6	0.6
	On-site construction	[t CO_2e]	3.3	-	-	3.3
O&M	Electricity consumption	[t CO_2]	-	135.7	-	135.7
Total		[t CO_2]	3.3	135.7	34.0	173.0

Table 81. *Result for tram vehicles.*

		Scope 1	Scope 2	Scope 3	Total
Construction and EoL	[t CO_2e]	-	-	115.2	115.2
Use	[t CO_2e]	-	629.4	-	629.4
Total	[t CO_2e]	-	629.4	115.2	744.7

E.2 Land Use

In table 82, the result per scope for all activities in the land use sector is seen.

Table 82. *Detailed result for the land use sector.*

			Scope 1	Scope 2	Scope 3	Total
Buildings	Material production	[t CO_2]	-	-	60 158.6	60 158.6
	Material transportation	[t CO_2]	-	-	4 511.9	4 511.9
	On-site construction	[t CO_2]	85 726.0	-	-	85 726.0
Roads	Material production	[t CO_2e]	-	-	15 770.2	15 770.2
	Material transportation	[t CO_2e]	-	-	1 182.8	1 182.8
	On-site construction	[t CO_2e]	22 472.5	-	-	22 472.5
	O&M	[t CO_2e]	-	-	1 211.4	1 211.4
Urban green areas	Construction	[t CO_2e]	0.7	-	-	0.7
	O&M	[t CO_2e]	-	-	3.7	3.7
	Sequestration	[t CO_2e]	-35.7	-	-	-35.7
Total		[t CO_2]	108 163.4	-	82 838.5	191 001.9

E.3 Consumption

In tables 83 and 84, the emissions per type of food is seen.

Table 83. *Detailed result of the food consumption (1/2).*

Oil	[t CO_2e]	512.2
Olives	[t CO_2e]	487.8
Rice	[t CO_2e]	368.3
Beverages	[t CO_2e]	2 631.2
Wine	[t CO_2e]	374.2
Cereals	[t CO_2e]	23.3
Cookies	[t CO_2e]	72.4
Coffee & infusions	[t CO_2e]	62.1
Beef	[t CO_2e]	2 842.7
Lamb	[t CO_2e]	1 299.0
Other meat	[t CO_2e]	5 703.7
Chocolate	[t CO_2e]	202.4
Fresh fruit	[t CO_2e]	1 184.5
Processed fruit & vegetables	[t CO_2e]	972.3

Table 84. *Detailed result of the food consumption (2/2).*

Dried fruit	[t CO_2e]	145.6
Fresh vegetables	[t CO_2e]	785.0
Egg	[t CO_2e]	798.4
Milk	[t CO_2e]	2 459.3
Dairy products	[t CO_2e]	8 125.8
Legumes	[t CO_2e]	61.3
Bread & pastry	[t CO_2e]	996.1
Flour	[t CO_2e]	68.5
Pasta	[t CO_2e]	244.8
Potatoes	[t CO_2e]	150.2
Fish	[t CO_2e]	3 808.5
Ready-to-eat	[t CO_2e]	2 153.3
Rest	[t CO_2e]	557.4

F Sensitivity Analysis

In table 85, the allocation of long distance bus VKT is done. The annual national distance is divided by the country's inhabitants and then multiplied by the number of inhabitants in the district. The emission factor used for public transport buses is then used to convert it into emissions.

Table 85. *Emissions from long distance bus travels.*

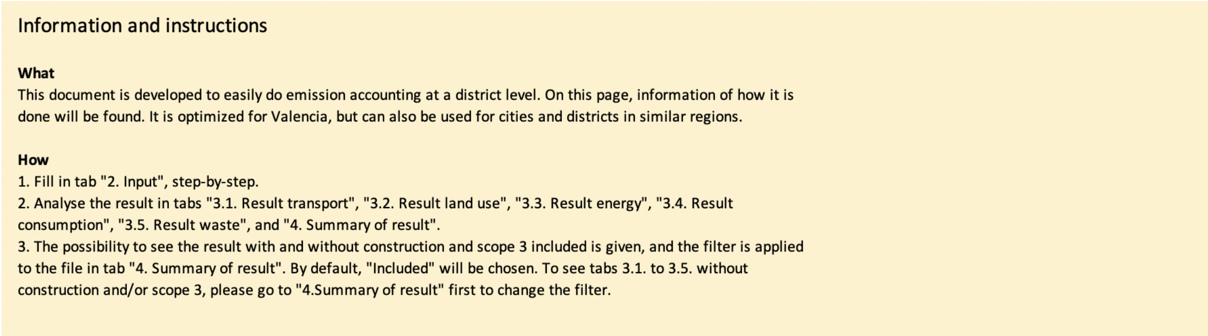
Total annual national distance	[VKT]	238 364 000 [89]
Distance per capita	[VKT/cap]	5.03
Distance for district	[VKT]	137 896
Annual emissions	[t CO_2e]	455.1

In table 86, the calculation of annual emissions from air travel is seen. A European average per capita was used and multiplied with the inhabitant of the district.

Table 86. *Emissions from aviation.*

Annual average per capita in Europe	[t CO_2e/cap]	0.413 [90]
Annual emissions	[t CO_2e]	11 323.6

G Excel Model



Information and instructions

What

This document is developed to easily do emission accounting at a district level. On this page, information of how it is done will be found. It is optimized for Valencia, but can also be used for cities and districts in similar regions.

How

1. Fill in tab "2. Input", step-by-step.
2. Analyse the result in tabs "3.1. Result transport", "3.2. Result land use", "3.3. Result energy", "3.4. Result consumption", "3.5. Result waste", and "4. Summary of result".
3. The possibility to see the result with and without construction and scope 3 included is given, and the filter is applied to the file in tab "4. Summary of result". By default, "Included" will be chosen. To see tabs 3.1. to 3.5. without construction and/or scope 3, please go to "4.Summary of result" first to change the filter.

Figure 8. *Tab with information and instructions.*

1. General information

What: *In this section, information about the country, city and the date will be filled in.*

Source: Click here to reach the source for Spain.

Click here to reach the source for Valencia.

Country:	Spain		**City name:**	Valencia	
Population:	47 394 223	*habitants*	**Population:**	800 215	*habitants*
Date:	2021-08-17		**Area:**	105 922 599	*sqm*

2. District information

What: *In this section, information about the district will be filled in. If it is desired to do it on a city-level, use the data for the city here as well.*

Source: Click here to reach the source.

Name:	Ciudad Vieja	
Population:	27 418	*habitants*
Area:	1 689 842	*sqm*

3. Energy consumption

What: *In this section, the total annual electricity and gas consumption at city level will be filled in.*

Source: Click here to reach the source.

Electricity:	2 548 179	*MWh/year*
Gas:	939 009	*MWh/year*

4. Private food consumption

What: *Information about the annual food consumption per person in Comunidad Valenciana will be filled in. To see what the categories "Oil", "beverages", "other meat", "fresh food", "fresh vegetables" and "rest" includes - put the pointer over the cell.*

Source: Click here to reach the source.

Oil:	9,26	*l/cap*
Olives:	2,96	*kg/cap*
Rice:	5,05	*kg/cap*
Beverages:	152,23	*l/cap*
Wine:	6,29	*l/cap*
Cereals:	1,60	*kg/cap*
Cookies:	4,98	*kg/cap*
Coffee & infusions:	1,63	*kg/cap*
Beef:	3,98	*kg/cap*
Lamb:	1,40	*kg/cap*
Other meat:	40,67	*kg/cap*
Chocolate:	3,21	*kg/cap*
Fresh fruit:	86,40	*kg/cap*
Processed fruit & vegetables:	12,62	*kg/cap*
Dried fruit:	3,74	*kg/cap*
Fresh vegetables:	60,92	*kg/cap*
Egg:	8,59	*kg/cap*
Milk:	62,65	*kg/cap*
Dairy products:	33,45	*kg/cap*
Legumes:	3,39	*kg/cap*
Bread & pastry:	37,07	*kg/cap*
Flour:	2,55	*kg/cap*
Pasta:	4,51	*kg/cap*
Potato:	27,39	*kg/cap*
Fish:	21,37	*kg/cap*
Ready-to-eat:	15,05	*kg/cap*
Rest:	8,10	*kg/cap*

Figure 9. *Input tab (1/3).*

5. Private transport

What: *Information about the private transport sector is filled in here. All data is at a district level. If data about electric scooters and bicycles is found, it can be put in. If not, leave it as "0" and an average will be calculated. The estimated share of passenger cars decide how much emissions will be scope 1 or scope 3, and can be changed if it is desired.*

Source: Click here to reach the source for passenger cars and two-wheelers.

Passenger cars:		14 073	*vehicles*
Two-wheelers	**Petrol:**	85 696	*vehicles*
	Diesel oil:	389	*vehicles*
	Other:	684	*vehicles*
Electric scooters:		0	*vehicles*
Bicycles:		0	*bicycles*

Estimated share of passenger car distance

Inside:	20%
Outside:	80%

6. Public transport

What: *Information about the public transport is filled in here. All data is on a city level, if not other is stated. If it is desired to add an additional metro and tram line, it can be done. If not; leave the "Type"-cell empty and the rest as "0".*

Source: Click here to reach the source for bus, metro and tram.

Click here to reach the source for Valenbisi.

Distance travelled by buses:	20 238 038	*km*
Total number of bus stations:	1 100	*stations*
Number of bus stations in district:	58	*stations*
Length of metro system:	189,93	*km*
Length of tram system:	21,80	*km*

Metro and tram lines	Type	Length		Departures Workday	Weekend	Holiday
Line 1:	Metro	72,15	*km*	157	122	97
Line 2:	Metro	39,45	*km*	152	119	98
Line 3:	Metro	24,69	*km*	143	115	93
Line 4:	Tram	17,00	*km*	311	263	242
Line 5:	Metro	13,29	*km*	146	116	100
Line 6:	Tram	3,57	*km*	197	106	98
Line 7:	Metro	15,50	*km*	138	109	94
Line 8:	Tram	1,23	*km*	86	78	76
Line 9:	Metro	24,86	*km*	128	107	78
Additional line:		-	*km*	-	-	-
Additional line:		-	*km*	-	-	-

Number of Valenbisi-bicycles: 2 750 *bicycles*

7. Services

What: *Information about taxis at a city level will be filled in here.*

Source: Click here to reach the source.

Taxis in the city: 2 823 *vehicles*

8. Land use

What: *Information of the land use at district level will be filled in here.*

Source: Click here to reach the source.

Urban green area in district: 72 979 *sqm*

Figure 10. *Input tab (2/3).*

9. Waste generation

What: *Information about the waste treatment at city level is filled in here.*

Source: Click here to reach the source.

Municipal solid waste:	368,412	*kg/cap*
Organic:	14,997	*kg/cap*
Glass:	16,405	*kg/cap*
Paper:	20,592	*kg/cap*
Plastic and light packaging:	14,627	*kg/cap*
Vegetable oil:	0,044	*kg/cap*
Batteries:	0,004	*kg/cap*

Figure 11. *Input tab (3/3).*

Result from the transport sector

Source	**Unit**	**Scopes** *Scope 1*	*Scope 2*	*Scope 3*	**Total**	
Passenger cars	*t CO2e*	11 292,0	3,9	45 183,6	56 479,5	81,4%
Two-wheelers	*t CO2e*	950,2	-	-	950,2	1,4%
Electric scooters	*t CO2e*	-	2,1	-	2,1	0,0%
Bicycles	*t CO2e*	-	-	238,9	238,9	0,3%
Metro	*t CO2e*	28,4	4 058,1	822,2	4 908,7	7,1%
Tram	*t CO2e*	3,3	765,2	149,2	917,6	1,3%
Bus	*t CO2e*	3 521,4	-	-	3 521,4	5,1%
Valenbisi	*t CO2*	-	-	4,5	4,5	0,0%
Taxis	*t CO2e*	2 349,9	-	-	2 349,9	3,4%
Total	***t CO2e***	**18 145,3**	**4 829,2**	**46 398,5**	**69 372,9**	
	%	**26,2%**	**7,0%**	**66,9%**		

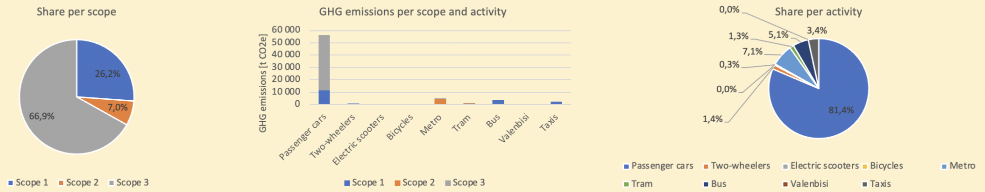


Figure 12. *Tab with result of transport sector.*

Result from the built environment

Source	**Unit**		**Scopes** *Scope 1*	*Scope 2*	*Scope 3*		**Total**	
Buildings	*t CO2*		85 726,0	-	64 670,5		150 396,5	78,7%
Roads	*t CO2e*		22 472,5	-	18 164,3		40 636,8	21,3%
Urban green areas	*t CO2e*	-	35,0	-	3,7	-	31,4	0,0%
Total	***t CO2e***		**108 163,4**	**-**	**82 838,5**		**191 001,9**	
	%		**56,6%**	**0,0%**	**43,4%**			

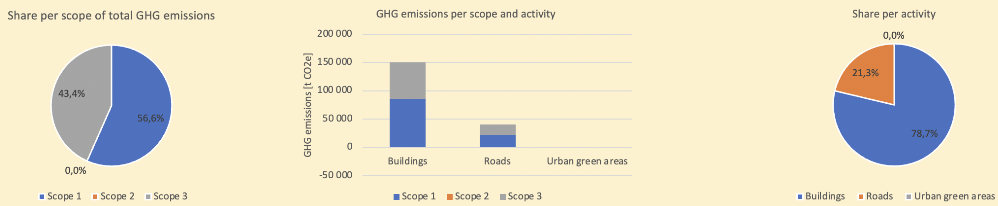


Figure 13. *Tab with result of land use sector.*

Result from the energy sector

Source		Unit	Scopes: Scope 1	Scope 2	Scope 3	Total	
Electricity	Consumption	t CO2	-	15 977,5	-	15 977,5	63,6%
	T&D losses	t CO2	-	-	1 533,7	1 533,7	6,1%
Gas		t CO2e	7 625,1	-	-	7 625,1	30,3%
Total		*t CO2e*	**7 625,1**	**15 977,5**	**1 533,7**	**25 136,4**	
		%	**30,3%**	**63,6%**	**6,1%**		

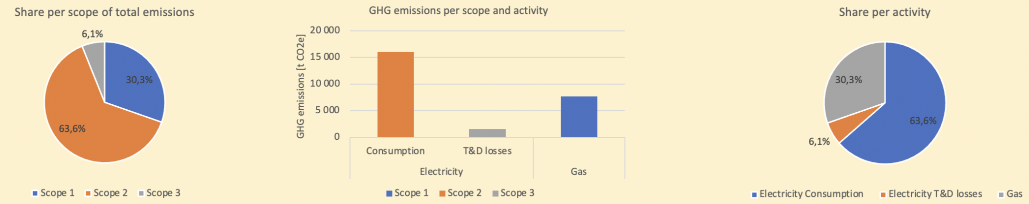


Figure 14. *Tab with result of energy sector.*

Result from consumption

Source	Unit	Scopes: Scope 1	Scope 2	Scope 3	Total	
Food	t CO2e	-	-	37 090,2	37 090,2	45,8%
Clothing	t CO2e	-	-	8 225,4	8 225,4	10,2%
Manufactured products	t CO2e	-	-	35 643,4	35 643,4	44,0%
Total	*t CO2e*	**-**	**-**	**80 959,0**	**80 959,0**	
	%	**0,0%**	**0,0%**	**100,0%**		

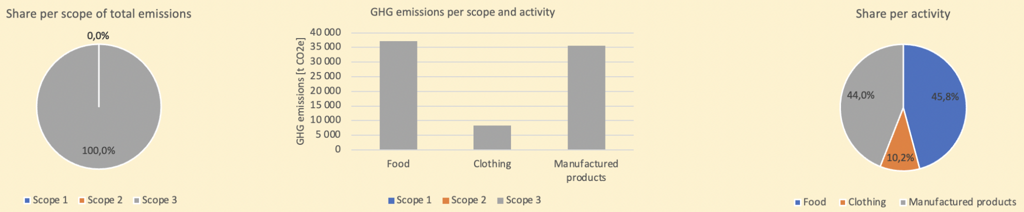


Figure 15. *Tab with result of consumption sector.*

Result from the waste sector

Source	Unit	Scopes: Scope 1	Scope 2	Scope 3	Total	
Landfilling	t CO2e	-	-	1 826,2	1 826,2	92,7%
Recycling	t CO2e	-	-	91,7	91,7	4,7%
Energy generation	t CO2e	-	-	-	-	0,0%
Composting	t CO2e	-	-	52,1	52,1	2,6%
Total	*t CO2e*	**-**	**-**	**1 970,0**	**1 970,0**	
	%	**0,0%**	**0,0%**	**100,0%**		

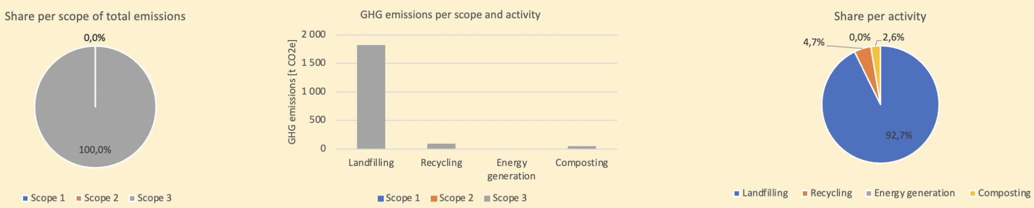


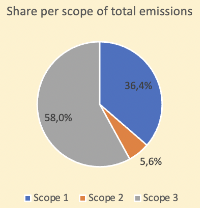
Figure 16. *Tab with result of waste sector.*

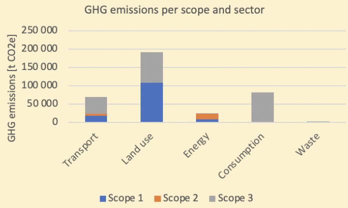
Result

Sector	Unit	Scopes			Total	
		Scope 1	*Scope 2*	*Scope 3*		
Transport	*t CO2e*	18 145,3	4 829,2	46 398,5	69 372,9	18,8%
Land use	*t CO2e*	108 163,4	-	82 838,5	191 001,9	51,8%
Energy	*t CO2e*	7 625,1	15 977,5	1 533,7	25 136,4	6,8%
Consumption	*t CO2e*	-	-	80 959,0	80 959,0	22,0%
Waste	*t CO2e*	-	-	1 970,0	1 970,0	0,5%
Total	***t CO2e***	**133 933,8**	**20 806,7**	**213 699,7**	**368 440,2**	
	%	**36,4%**	**5,6%**	**58,0%**		

Filter

Construction:	Included
Scope 3:	Included





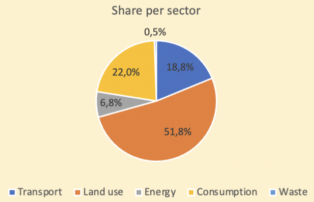


Figure 17. *Tab with result summary.*

About the document

This document was developed as a part of the master thesis "Evaluation bottom-up of the Carbon emissions of a district to support the design of a Carbon neutral district in Valencia." at Universitat Politecnica de Valencia and Cátedra de Transición Energética Urbana UPV-Las Naves, by the MSc student Eric Wieselblad.
Supervisors during the thesis was Tomás Gómez Navarro, Carlos A. Vargas Salgado, and Iván Cuesta Fernández.

Figure 18. *Tab with information about the document.*

Calculation

Energy		
Electricity consumption:	87 309	*MWh*
T&D losses:	8 381	*MWh*
Gas consumption:	32 174	*MWh*

Private food consumption		
Oil:	232 818	*kg/year*
Olives:	81 157	*kg/year*
Rice:	138 461	*kg/year*
Beverages:	4 165 494	*kg/year*
Wine:	187 118	*kg/year*
Cereals:	43 869	*kg/year*
Cookies:	136 542	*kg/year*
Coffee & infusions:	44 691	*kg/year*
Beef:	109 124	*kg/year*
Lamb:	38 385	*kg/year*
Other meat:	1 115 090	*kg/year*
Chocolate:	88 012	*kg/year*
Fresh fruit:	2 368 915	*kg/year*
Processed fruit & vegetables:	346 015	*kg/year*
Dried fruit:	102 543	*kg/year*
Fresh vegetables:	1 670 305	*kg/year*
Egg:	235 521	*kg/year*
Milk:	1 769 270	*kg/year*
Dairy products:	917 132	*kg/year*
Legumes:	92 947	*kg/year*
Bread & pastry:	1 016 385	*kg/year*
Flour:	69 916	*kg/year*
Pasta:	123 655	*kg/year*
Potato:	750 979	*kg/year*
Fish:	585 923	*kg/year*
Ready-to-eat:	412 641	*kg/year*
Rest:	222 086	*kg/year*

Figure 19. *Tab with the calculations (1/6).*

Passenger cars

Distribution of cars per european regulation and fuel in Valencia:

	Total		Petrol		Diesel oil		Electricity		LPG		CNG	
	Number	Share	Number	Share	Number	Share	Number	Share	Number	Share	Number	Share
Pre Euro	44 579	12,5%	41 022	92,0%	3 556	8,0%	1	0,0%	-	0,0%	-	0,0%
Euro 1	7 646	2,1%	5 726	74,9%	1 920	25,1%	-	0,0%	-	0,0%	-	0,0%
Euro 2	24 534	6,9%	13 065	53,3%	11 469	46,7%	-	0,0%	-	0,0%	-	0,0%
Euro 3	77 813	21,8%	33 374	42,9%	44 439	57,1%	-	0,0%	-	0,0%	-	0,0%
Euro 4	98 660	27,6%	35 348	35,8%	63 312	64,2%	-	0,0%	-	0,0%	-	0,0%
Euro 5	56 401	15,8%	20 232	35,9%	36 129	64,1%	13	0,0%	26	0,0%	1	0,0%
Euro 6	47 927	13,4%	24 647	51,4%	23 086	48,2%	109	0,2%	67	0,1%	18	0,0%
Total	357 560	100,0%	173 414	48,5%	183 911	51,4%	123	0,0%	93	0,0%	19	0,0%

Distribution of cars per european regulation and fuel in the district:

	Total		Petrol		Diesel oil		Electricity		LPG		CNG	
	Number	Share	Number	Share	Number	Share	Number	Share	Number	Share	Number	Share
Pre Euro	1 755	12,5%	1 615	92,0%	140	8,0%	-	0,0%	-	0,0%	-	0,0%
Euro 1	301	2,1%	225	74,9%	76	25,1%	-	0,0%	-	0,0%	-	0,0%
Euro 2	966	6,9%	514	53,3%	452	46,7%	-	0,0%	-	0,0%	-	0,0%
Euro 3	3 063	21,8%	1 314	42,9%	1 749	57,1%	-	0,0%	-	0,0%	-	0,0%
Euro 4	3 883	27,6%	1 391	35,8%	2 492	64,2%	-	0,0%	-	0,0%	-	0,0%
Euro 5	2 220	15,8%	796	35,9%	1 422	64,1%	1	0,0%	1	0,0%	-	0,0%
Euro 6	1 886	13,4%	970	51,4%	908	48,2%	4	0,2%	3	0,1%	1	0,0%
Total	14 073	100,0%	6 825	48,5%	7 238	51,4%	5	0,0%	4	0,0%	1	0,0%

Annual distance travelled by car per european regulation and fuel in the district [*VKT*]:

	Total	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	14 868 360	13 682 280	1 186 080	-	-	-
Euro 1	2 550 072	1 906 200	643 872	-	-	-
Euro 2	8 183 952	4 354 608	3 829 344	-	-	-
Euro 3	29 735 604	12 756 312	16 979 292	-	-	-
Euro 4	45 245 493	16 208 210	29 037 282	-	-	-
Euro 5	31 391 244	11 255 599	20 107 364	14 140	14 140	-
Euro 6	33 823 147	17 395 786	16 283 890	71 735	53 801	17 934
Total	165 797 871	77 558 995	88 067 125	85 875	67 942	17 934

Figure 20. *Tab with the calculations (2/6).*

Two-wheelers

Number of two-wheelers	Total	86 474	*vehicles*
	Petrol	85 696	*vehicles*
	Diesel oil	389	*vehicles*
	Other	684	*vehicles*
Two-wheelers per person	Total	0,108063	*vehicles/hab*
	Petrol	0,107091	*vehicles/hab*
	Diesel oil	0,000486	*vehicles/hab*
	Other	0,000855	*vehicles/hab*
Two-wheelers in District	Total	2 963	*vehicles*
	Petrol	2 936	*vehicles*
	Diesel oil	13	*vehicles*
	Other	23	*vehicles*

Distribution of two-wheelers per european regulation and fuel in Valencia:

	Total		Petrol		Diesel oil		Other	
	Number	Share	Number	Share	Number	Share	Number	Share
Pre Euro	622	20,9%	614	20,9%	3	20,9%	5	20,9%
Euro I	547	18,4%	541	18,4%	2	18,4%	4	18,4%
Euro II	346	11,6%	341	11,6%	2	11,6%	3	11,6%
Euro III	1 167	39,3%	1 153	39,3%	5	39,3%	9	39,3%
Euro IV	290	9,8%	287	9,8%	1	9,8%	2	9,8%
Euro V	-	0,0%	-	0,0%	-	0,0%	-	0,0%
Total	2 973	100,0%	2 936	100,0%	13	100,0%	23	100,0%

Annual distance travelled by two-wheelers per european regulation and fuel in the district [*VKT*]:

	Total	Petrol	Diesel Oil	Other
Pre Euro	1 056 156	1 042 572	5 094	8 490
Euro I	1 033 283	1 021 949	3 778	7 556
Euro II	851 852	839 542	4 924	7 386
Euro III	3 474 042	3 432 366	14 885	26 792
Euro IV	1 247 798	1 234 889	4 303	8 606
Euro V	-	-	-	-
Total	7 663 131	7 571 318	32 983	58 830

Figure 21. *Tab with the calculations (3/6).*

Other private vehicles

Electric scooters in Spain:	650 000	*vehicles*
National average:	0,014	*vehicles/cap*
Electric scooters in district:	376	*vehicles*
Average annual distance:	247,47	*km/vehicle*
Annual distance:	93049	*km*
Number of bicycles:	10 967	*vehicles*

Bus

Distance travelled by buses:	20 238 038	*km*
Total number of bus stations:	1 100	*stations*
Number of bus stations in district:	58	*stations*
Distance per station:	18 398	*VKT/station*
Distance for district:	1 067 097	*VKT*

Metro

Length of system:	189,93	*km*
Length per person:	0,00024	*km/cap*
Length for district:	6,51	*km*

Calculation of vehicle travelled distance

	Length per type of day			Annual distance
	Workdays	Weekends	Holidays	travelled
Line 1	11 326,77	8 801,69	6 998,07	3 828 374,4
Line 2	5 995,64	4 693,96	3 865,61	2 031 733,1
Line 3	3 530,81	2 839,47	2 296,26	1 204 501,1
Line 5	1 940,78	1 541,99	1 329,30	660 795,0
Line 7	2 138,59	1 689,17	1 456,72	727 026,3
Line 9	3 181,95	2 659,91	1 939,00	1 094 690,9
Additional	-	-	-	-
Additional	-	-	-	-
			Total:	9 547 120,8

VKT metro train:	9 547 121	*km*
VKT per person:	11,931	*km/cap*
VKT for district:	327 116	*km*

Figure 22. *Tab with the calculations (4/6).*

Tram

Length of system:	21,80	*km*
Length per person:	0,00003	*km/cap*
Length for district:	0,75	*km*

Calculation of vehicle travelled distance

	Length per type of day			Annual distance
	Workdays	Weekends	Holidays	travelled
Line 4	5 286,69	4 470,74	4 113,76	1 833 053,2
Line 6	703,49	378,53	349,96	219 441,5
Line 8	105,78	95,94	93,48	37 463,3
Additional	-	-	-	-
Additional	-	-	-	-
			Total:	2 089 958,0

VKT tram train:	2 089 958	*km*
VKT per person:	2,612	*km/cap*
VKT for district:	71 609	*km*

Valenbisi

Number of Valenbisi-bicycles:	2 750	*bicycles*
Valenbisis per capita:	0,0034	*bicycles/cap*
Valenbisis in district:	94	*bicycles*

Taxis

Per capita:	0	*vehicles/cap*
Taxis in district:	97	*vehicles*
Average distance:	208	*km/vehicle/day*
Total distance:	7 343 383	*km*

Figure 23. *Tab with the calculations (5/6).*

Land use				
Urban green area:	72 979	*sqm*		
Roads:	533 565	*sqm*		
Buildings:	4 333 193	*sqm*		
Buildings (without construction):	1 083 298	*sqm*		
			0	
Waste				
Municipal solid waste:	368,412	*kg/cap*	10 101 112	*kg*
Organic:	14,997	*kg/cap*	411 177	*kg*
Glass:	16,405	*kg/cap*	449 790	*kg*
Paper:	20,592	*kg/cap*	564 594	*kg*
Plastic and light packaging:	14,627	*kg/cap*	401 043	*kg*
Vegetable oil:	0,044	*kg/cap*	1 200	*kg*
Batteries:	0,004	*kg/cap*	108	*kg*
Total:	435,080	*kg/cap*	11 929 023	*kg*

	Share	Weight	
Landfill:	56,7%	6 763,8	*t*
Recycled:	18,3%	2 183,0	*t*
Energy:	13,5%	1 610,4	*t*
Composting:	11,5%	1 371,8	*t*

Figure 24. *Tab with the calculations (6/6).*

Emission factor catalog

Energy		
Electricity:	0,183	*t CO2/MWh*
Natural gas:	0,237	*t CO2e/MWh*
Food		
Oil:	0,00220	*t CO2e/kg*
Olives:	0,00601	*t CO2e/kg*
Rice:	0,00266	*t CO2e/kg*
Beverages:	0,00063	*t CO2e/kg*
Wine:	0,00200	*t CO2e/kg*
Cereals:	0,00053	*t CO2e/kg*
Cookies:	0,00053	*t CO2e/kg*
Coffee & infusions:	0,00139	*t CO2e/kg*
Beef:	0,02605	*t CO2e/kg*
Lamb:	0,03384	*t CO2e/kg*
Other meat:	0,00512	*t CO2e/kg*
Chocolate:	0,00230	*t CO2e/kg*
Fresh fruit:	0,00050	*t CO2e/kg*
Processed fruit &	0,00281	*t CO2e/kg*
Dried fruit:	0,00142	*t CO2e/kg*
Fresh vegetables:	0,00047	*t CO2e/kg*
Egg:	0,00339	*t CO2e/kg*
Milk:	0,00139	*t CO2e/kg*
Dairy products:	0,00886	*t CO2e/kg*
Legumes:	0,00066	*t CO2e/kg*
Bread & pastry:	0,00098	*t CO2e/kg*
Flour:	0,00098	*t CO2e/kg*
Pasta:	0,00198	*t CO2e/kg*
Potato:	0,00020	*t CO2e/kg*
Fish:	0,00650	*t CO2e/kg*
Ready-to-eat:	0,00522	*t CO2e/kg*
Rest:	0,00251	*t CO2e/kg*
Other consumption		
Clothing:	0,3	*t CO2e/cap*
Manufactured products:	1,3	*t CO2e/cap*

Figure 25. *Tab with the emission factors (1/4).*

Passenger cars			
Pre Euro	Petrol:	0,000419	*t CO2e/km*
	Diesel oil:	0,000368	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000350	*t CO2e/km*
Euro 1	Petrol:	0,000403	*t CO2e/km*
	Diesel oil:	0,000356	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000336	*t CO2e/km*
Euro 2	Petrol:	0,000387	*t CO2e/km*
	Diesel oil:	0,000344	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000322	*t CO2e/km*
Euro 3	Petrol:	0,000371	*t CO2e/km*
	Diesel oil:	0,000332	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000308	*t CO2e/km*
Euro 4	Petrol:	0,000355	*t CO2e/km*
	Diesel oil:	0,000320	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000294	*t CO2e/km*
Euro 5	Petrol:	0,000342	*t CO2e/km*
	Diesel oil:	0,000313	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000285	*t CO2e/km*
Euro 6	Petrol:	0,000329	*t CO2e/km*
	Diesel oil:	0,000306	*t CO2e/km*
	Electricity:	0,000225	*t CO2e/km*
	LPG:	0,000313	*t CO2e/km*
	CNG:	0,000276	*t CO2e/km*

Figure 26. *Tab with the emission factors (2/4).*

Two-wheelers			
Pre Euro	Petrol:	0,000124	*t CO2e/km*
	Diesel oil:	0,000124	*t CO2e/km*
	Other:	0,000124	*t CO2e/km*
Euro 1	Petrol:	0,000124	*t CO2e/km*
	Diesel oil:	0,000124	*t CO2e/km*
	Other:	0,000124	*t CO2e/km*
Euro 2	Petrol:	0,000124	*t CO2e/km*
	Diesel oil:	0,000124	*t CO2e/km*
	Other:	0,000124	*t CO2e/km*
Euro 3	Petrol:	0,000124	*t CO2e/km*
	Diesel oil:	0,000124	*t CO2e/km*
	Other:	0,000124	*t CO2e/km*
Euro 4	Petrol:	0,000124	*t CO2e/km*
	Diesel oil:	0,000124	*t CO2e/km*
	Other:	0,000124	*t CO2e/km*
Euro 5	Petrol:	0,000124	*t CO2e/km*
	Diesel oil:	0,000124	*t CO2e/km*
	Other:	0,000124	*t CO2e/km*

Other means of transport		
Electric scooter:	0,0000224	*t CO2e/km*
Bicycle:	0,0217862	*t CO2e/vehicle*
Taxi	0,0003200	*t CO2e/km*

Metro and tram			
Stations	Material production:	44,64	*t CO2e/km*
	Material transportation:	0,84	*t CO2e/km*
	On-site construction:	4,37	*t CO2e/km*
	O&M:	181,74	*t CO2/km*
Vehicles	Construction and EoL:	0,0016	*t CO2e/VKT*
	Use:	0,0088	*t CO2e/VKT*

Bus:	0,0033	*t CO2e/VKT*
Valenbisi:	0,0478	*t CO2/vehicle*

Figure 27. *Tab with the emission factors (3/4).*

Land use

Buildings	Material production:	0,013883	*t CO2/sqm*
	Material transportation:	0,001041	*t CO2/sqm*
	On-site construction:	0,019784	*t CO2/sqm*
Road	Material production:	0,029556	*t CO2e/sqm*
	Material transportation:	0,002217	*t CO2e/sqm*
	On-site construction:	0,042118	*t CO2e/sqm*
	O&M:	0,002270	*t CO2e/sqm*
Urban green area:	Construction:	0,000010	*t CO2/sqm*
	O&M:	0,000050	*t CO2e/sqm*
	Sequestration:	- 0,000490	*t CO2e/sqm*
Natural sequestration:		- 0,000004	*t CO2/sqm*

Waste

Landfill:	0,270	*t CO2e/t*
Recycling:	0,042	*t CO2e/t*
Energy:	-	*t CO2e/t*
Composting:	0,038	*t CO2e/t*

Figure 28. *Tab with the emission factors (4/4).*

Scope allocation

Energy

Electricity consumption:	*Scope 2*
T&D losses:	*Scope 3*
Gas consumption:	*Scope 1*

Consumption

Food	*Scope 3*
Clothing	*Scope 3*
Manufactured products	*Scope 3*

Passenger cars

	20%	80%
Petrol	*Scope 1*	*Scope 3*
Diesel oil	*Scope 1*	*Scope 3*
Electricity	*Scope 2*	*Scope 3*
LPG	*Scope 1*	*Scope 3*
CNG	*Scope 1*	*Scope 3*

Two-wheelers

Petrol	*Scope 1*
Diesel oil	*Scope 1*
Other	*Scope 1*

Other private vehicles

Electric scooter	*Scope 2*
Bicycle	*Scope 3*
Taxi	*Scope 1*

Metro and tram

Stations	Material production	*Scope 3*
	Material transportation	*Scope 3*
	On-site construction	*Scope 1*
	O&M	*Scope 2*
Vehicles	Construction and EoL	*Scope 3*
	Use	*Scope 2*

Figure 29. *Tab with the scope allocation (1/2).*

Other means of public transport

Bus	*Scope 1*
Valenbisi	*Scope 3*

Land use

Buildings	Material production	*Scope 3*
	Material transportation	*Scope 3*
	On-site construction	*Scope 1*
Road	Material production	*Scope 3*
	Material transportation	*Scope 3*
	On-site construction	*Scope 1*
	O&M	*Scope 3*
Urban green area:	Construction	*Scope 1*
	O&M	*Scope 3*
	Sequestration	*Scope 1*
Natural sequestration		*Scope 1*

Waste

Landfill	*Scope 3*
Recycling	*Scope 3*
Energy	*Scope 3*
Composting	*Scope 3*

Figure 30. *Tab with the scope allocation (2/2).*

Filters

Construction:	Included
	Excluded
Scope 3:	Included
	Excluded

Figure 31. *Tab with the filters.*

Data

Share of days

Weekdays:	251	*days*
Weekends:	104	*days*
Holidays:	10	*days*

Electric data

T&D losses: 9,599%

Densities

Oil:	0,917	*kg/l*
Beverages:	0,998	*kg/l*
Wine:	1,085	*kg/l*
Milk:	1,030	*kg/l*

Distance travelled per type of vehicle [km/year]

Age	Buses	Passenger cars	Two-wheelers
0 – 4	81 082	19 689	4 656
5 – 9	62 329	15 301	3 243
10 – 14	47 808	12 399	2 867
15 – 19	35 705	10 532	2 462
> 20	24 867	8 472	1 698
Average	52 951	12 266	2 903

Figure 32. *Tab with general data.*

Budget

In the following pages, a detailed budget for the project will be presented. It will contain a description of the phases of the project, the resources used, and in the end, a summary of the total budget.

Information

Approximately 850 hours were put into the project by the student in around six months. During the project, the activities of literature review, data acquisition, modelling, writing, and creation of a Microsoft Excel model took place. For the supervisors, weekly meetings took place regularly during the project, and the report was reviewed in the end phase. The budget will present costs for human resources and equipment amortisation over the project duration.

Human Resources

Four individuals performed the activities; one student and three supervisors. Table 1 shows the cost per hour for a student and supervisor.

Table 1. *Cost of human resources.*

Student	[€/h]	25
Supervisor	[€/h]	60

The activities performed in the thesis was the following:

- Literature review: Gather information about emission accounting.
- Data acquisition: Collecting the data needed for the activity inventory and emission factor catalog from databases and scientific reports.
- Modelling: Create the case study model in Microsoft Excel.
- Writing: Writing the final report.
- Creation of Microsoft Excel model: Create the model for easy replication of the case study for other districts.
- Revision and guidance: Weekly meetings between student and supervisors and report revision in the end phase.

The five first activities were performed by the student, while the three supervisors performed the last one. Table 2 shows the costs related to the time put into the project.

The final cost of human resources is 28 450.0€.

Table 2. *Final costs for human resources per activity.*

	Number of persons	Time per person	Total time	Total cost
	[persons]	[h/person]	[h]	[€]
Literature review	1	213	213	5 312.5
Data acquisition	1	247	247	6 162.5
Modelling	1	170	170	4 250.0
Writing	1	111	111	2 762.5
Creation of Microsoft Excel model	1	111	111	2 762.5
Revision and guidance	3	40	120	7 200.0
Total	-	-	970	28 450.0

Software and hardware costs

Four units of hardware were used in this project: computers for the student and the supervisors. The student used a Macbook Pro 13', while the supervisors used HP Elitebook 850. The first was used over the whole period, while the supervisors' computers were used during the time they put into the project (40 hours per person). In addition to the hardware, software was also used. The most used were Microsoft Office (Excel), Overleaf LaTeX, and SimaPro. The two later were free, while the first one is paid for. The costs for hardware and software are seen in table 3.

Table 3. *Cost of hardware and software.*

Macbook Pro 13'	[€/unit]	1 449.0
HP Elitebook 850	[€/unit]	1 489.0
Microsoft Office	[€/year]	69.0

In table 4, the total cost of hardware and software is seen. The amortisation period is assumed to be five years for the hardware, while the software is one year. For the products used by the student, the Macbook Pro 13' and Microsoft Office, the number of months using it account to 6 periods. The 40 hours the supervisors put in approximated to account for one month. The final cost of hardware and software is 235.9€.

Table 4. *Final costs for hardware and software per product.*

	Price per unit [€/unit]	Full amortisation [years]	Used time [months]	Total cost [€]
Macbook Pro 13'	1 449.0	5	6	144.9
HP Elitebook 850	1 489.0	5	1	24.8
HP Elitebook 850	1 489.0	5	1	24.8
HP Elitebook 850	1 489.0	5	1	24.8
Microsoft Office	69.0	1	6	34.5
Total	-	-	-	253.9

Other costs

Except for human resources and equipment, there were some other costs identified. To do the project, internet and electricity were needed. In table 5, the costs are presented. The total cost is 570.0€.

Table 5. *Other costs per type of cost.*

	Quantity [units]	Unit cost [€/unit]	Total cost [€]
Electricity bill	6	75.0	450.0
Internet bill	6	20.0	120.0
Total	-	-	570.0

Summary

Here, the final budget will be summarised. The costs are from human resources, hardware, software, and other costs, as presented above. To that, an industrial profit of 6% is included and the regular IVA tax of 21%. The budget summarised is seen in table

6, and the final project budget is 37 546.6€.

Table 6. *Summarised budget, including profit and tax.*

	Cost [€]
Human resources	28 450.0
Hardware	219.4
Software	34.5
Other costs	570.0
Gross budget	29 273.9
Industrial profit (6%)	1 756.4
Industrial budget	31 030.3
Tax (IVA 21%)	6 516.4
Total	37 546.6