MASTER'S THESIS

ENERGY TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

Carbon footprint and Overshoot Day for the city of Valencia:

Current situation and trend scenarios

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ABSTRACT

This document consists on the development of the carbon budget and the calculation of the carbon footprint for the city of Valencia. Firstly, the 'State of the Art' has been carried out to determine the starting point, taking into account that Valencia is a participating city in the Covenant of Mayors: a global movement for climate and energy initiated in 2008, where its signatories seek, in their territories at a local level, to accelerate decarbonization and access to safe, sustainable and affordable energy. Therefore, there is already a previous work on the emissions inventory for the city (electricity consumed by sectors, fuel consumption, etc.).

On this basis, the work is divided into two sections: the first one deals with the evaluation of existing data and calculation methodologies, as well as the development and implementation of possible proposals for their improvement. The second one, on the other hand, studies the possibility of extending the scope of the emissions inventory by other aspects that have not been considered, in order to obtain a more detailed view of the current situation.

Once the emissions inventory for the city has been obtained, the carbon footprint and the so-called Overshoot Day or day of the year in which human activity consumes more resources than the planet/region/city can generate in that year have been calculated. It should be noted that Overshoot Day encompasses all types of land use (agriculture, fishing, forest land use, etc.). However, as this work focuses on carbon, only the forest mass will be considered as a necessary resource to offset the carbon footprint of the city.

Finally, a series of scenarios have been proposed for the year 2030 including new trends for sustainable transition such as the decarbonization of private transport, change in consumption habits, etc., with the aim of estimating the capacity of emission reductions in each area and how much their implementation would cost.

Keywords: carbon budget, CO_2 emissions by sector, carbon footprint, Overshoot Day, environmental indicators, trend scenarios 2030, decarbonisation scenarios

RESUMEN

El presente documento consiste en el desarrollo del inventario de emisiones y el cálculo de la huella de carbono para la ciudad de Valencia. En primer lugar, se ha realizado el «Estado del Arte» para determinar el punto de partida, teniendo en cuenta que Valencia es una ciudad participante en el Pacto de los Alcaldes: un movimiento mundial para el clima y la energía iniciado en 2008, donde sus firmantes buscan, en sus territorios a nivel local, acelerar la descarbonización y el acceso a una energía segura, sostenible y asequible; por tanto, ya existe un trabajo previo sobre el inventario de emisiones de la ciudad (electricidad consumida por sectores, consumo de combustible, etc.).

Sobre esta base, el trabajo se bifurca en dos líneas: la primera trata sobre la evaluación de los datos y metodologías de cálculo ya existentes, así como la elaboración y aplicación de posibles propuestas de mejora de los mismos. La segunda, por otro lado, estudia la posibilidad de ampliar el alcance del inventario de emisiones mediante otros aspectos que no se hayan tenido en cuenta, a fin de obtener una visión más detallada de la situación actual.

Una vez obtenido el inventario de emisiones para la ciudad, se ha calculado la huella de carbono y el denominado Overshoot Day o día del año en el que la actividad humana consume más recursos de los que el planeta/región/ciudad es capaz de generar en dicho año. Cabe puntualizar que el Overshoot Day engloba todos los tipos de uso del terreno (agricultura, pesca, forestal, etc.), sin embargo, como este trabajo se centra en el carbono, solamente se considerará la masa forestal como recurso necesario para compensar la huella de carbono de la ciudad.

Finalmente, se han planteado una serie de escenarios para el año 2030 incluyendo nuevas tendencias para la transición sostenible como pueden ser la descarbonización del transporte privado, cambio en los hábitos de consumo, etc., con el objetivo de estimar la capacidad de reducción de emisiones de cada ámbito y cuánto costaría su implementación.

<u>Palabras Clave</u>: inventario de carbono, emisiones de CO_2, huella de carbono, Overshoot Day, indicadores medioambientales, escenarios tendenciales 2030, escenarios de descarbonización

RESUM

El present document consisteix en el desenvolupament de l'inventari d'emissions i el càlcul de la petjada de carboni per a la ciutat de València. En primer lloc, s'ha realitzat «l'Estat de l'Art» per a determinar el punt de partida, tenint en compte que València és una ciutat participant en el Pacte dels Alcaldes: un moviment mundial per al clima i l'energia iniciat en 2008, on els seus signants busquen, en els seus territoris a nivell local, accelerar la descarbonització i l'accés a una energia segura, sostenible i assequible; per tant, ja existeix un treball previ sobre l'inventari d'emissions de la ciutat (electricitat consumida per sectors, consum de combustible, etc.).

Sobre aquesta base, el treball es bifurca en dues línies: la primera tracta sobre l'avaluació de les dades i metodologies de càlcul ja existents, així com l'elaboració i aplicació de possibles propostes de millora d'aquests. La segona, d'altra banda, estudia la possibilitat d'ampliar l'abast de l'inventari d'emissions mitjançant altres aspectes que no s'hagen tingut en compte, a fi d'obtindre una visió més detallada de la situació actual.

Una vegada obtingut l'inventari d'emissions per a la ciutat, s'ha calculat la petjada de carboni i el denominat Overshoot Day o dia de l'any en què l'activitat humana consumeix més recursos dels que el planeta/regió/ciutat és capaç de generar en aquest any. Cal puntualitzar que el Overshoot Day engloba tots els tipus d'ús del terreny (agricultura, pesca, forestal, etc.), no obstant això, com aquest treball se centra en el carboni, solament es considerarà la massa forestal com a recurs necessari per a compensar la petjada de carboni de la ciutat.

Finalment, s'han plantejat una sèrie d'escenaris per a l'any 2030 incloent noves tendències per a la transició sostenible com poden ser la descarbonització del transport privat, canvi en els hàbits de consum, etc., amb l'objectiu d'estimar la capacitat de reducció d'emissions de cada àmbit i quant costaria la seua implementació.

Paraules clau: inventari de carboni, emissions de CO_2 per sector, petjada de carboni, Overshoot Day, indicadors mediambientals, escenaris tendencials 2030, escenaris de descarbonització

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CHAPTER 1. INTRODUCTION

1.1. BACKGROUND

According to the Intergovernmental Panel on Climate Change (IPCC), human activity is responsible for a global temperature increase of 1°C above pre-industrial levels and is estimated to rise by 1.5°C between year 2030 and 2052, continuing the current trend. Some of the most far-reaching consequences of global warming would be sea level rise due to melting ice, loss of biodiversity and food production capacity and even large economic losses due to increasing weather disasters (IPCC, 2018). In order to avoid the risks and dangers of climate change, 195 nations signed the Paris Agreement in December 2015 with the aim of reducing their greenhouse gas (GHG) emissions and keeping the rise in the Earth's average temperature well below 2°C compared to pre-industrial levels (European Commission, 2016).

Responsible for the 10% of global greenhouse gas emissions, the European Union (EU) is a world leader in the transition to a low-carbon economy, setting out from 2009 a roadmap for 2050, with a reduction in emissions from year 1990 of at least 20% by 2020, at least 40% by 2030 and up to 80–95% by 2050. In relation to energy, the current target is to improve energy efficiency by 32.5% and to increase consumption of renewable energy around 32% of final energy consumption by 2030. The transition to a zero GHG emission economy gives energy a major role, as it is currently responsible for 75% of these emissions. It also requires the expansion of technological innovation in all sectors, the creation of a circular economy capable of eliminating unsustainable consumption habits by reusing and recycling resources, and the establishment of a methodology that allows for continuous monitoring of emissions by public and private organisations (European Commission, 2018).

According to the European Environment Agency (EEA) report, the European Union (EU-28) achieved a 23.5% reduction in GHG emissions (counted in $CO_{2\text{-eq}}$) by 2017 compared to 1990. This emission reduction trend is dominated by the three countries with the highest net emissions (Germany, United Kingdom and France), which represent more than 40% of total emissions in Europe. However, in the case of Spain and Portugal emissions increased by 18–19%. By the same date, emissions decreased in most categories being the most influential ones public electricity and heat generation and energy in manufacturing industry. On the other hand, road transport and HFC cooling follow an increasing trend in greenhouse gas emissions (European Environmental Agency, 2019).

In parallel to these international actions, many other platforms for sustainable transition and fight against climate change are emerging, both at national and international scale. In 2008, the European Commission launched the Covenant of Mayors for Climate and Energy, an initiative that aims to bring together thousands of local governments that voluntarily commit to implementing energy and emission reduction policies beyond the targets set by the European Union, regardless of which nation they belong to. The initiative took place in Europe, but since 2017 it keeps expanding to other regions in America, China, and Japan, among others. Nowadays, 1610 Spanish towns and cities joined to the

Covenant, which have made action plans for climate and energy, including Valencia since 2009 (Covenant of Mayors for Climate Change, 2020).

The city of Valencia, as a member of the Covenant, is committed to achieve the objectives set by the European Union for 2030, developing the **Sustainable Energy and Climate Action Plan (SECAP)**. This document includes an inventory of consumption, emissions and waste generated since 2007, an evaluation of the city's risks and vulnerabilities derived from climate change and shows an updated report at least every two years that can serve as a tool to guide the proposal of measures and to monitor and follow up the actions carried out (SECAP, 2018). This plan will be used as the basis of this work.

As the promoter of this initiative, the Valencia City Council is responsible for monitoring the plan and designing strategies for adapting the city to a sustainable model. The objectives set in the long term go beyond those set by the European Commission and the Covenant of Mayors, as two major strategic issues have been established in parallel: climate justice and energy democracy. Climate justice aims to go beyond the environmental problem, trying to reduce social inequalities and natural imbalances that result from climate impacts. On the other hand, energy democracy aims to guarantee access to energy for development needs, ensuring that it comes from sources that respect the environment and people. In other words, to promote and guarantee access to a safe, sustainable, and universally accessible energy
(SECAP, 2018. pp 5–7).

To achieve these objectives, the Valencia City Council has launched several projects/initiatives. One of the most important is the creation and extension of the urban cycle lane with more than 150 km and, since 2010, the Valenbisi project that is in charge of the bicycle rental for citizen mobility, with 275 stations for a total of 2750 bicycles in its beginnings.

The Las Naves Foundation also plays a main role, as it works on innovation projects for the so-called 'four helix': public sector, private sector, academic sector, and civil society. Linked to this, the **Connecta Energía** network is launched and it is in charge of putting the different agents in contact to achieve a satisfactory energy transition for the whole city. To achieve this transition, four main challenges are established:

- Fight against energy poverty.
- Promotion of energy saving and efficiency.
- Support for the energy production and self-consumption.
- Education for new sustainable energy models.

All of the above being considered, this study comes from an initiative of the Valencia City Council to analyse the carbon inventory of the Sustainable Energy and Climate Action Plan of the city and to make an improvement proposal for future updates.

Commissioned by the Chair of Urban Energy Transition at the Polytechnic University of Valencia, this study has been proposed in the form of a master's thesis. It aims to respond to this request from the City Council and to use the analysis and results obtained to calculate other environmental sustainability indicators such as the carbon footprint and the Overshoot Day of the city of Valencia.

1.2. ENVIRONMENTAL SUSTAINABILITY INDICATORS: ECOLOGICAL FOOTPRINT, CARBON FOOTPRINT AND ECOLOGICAL DEFICIT

To face the environmental problem, it is necessary to use environmental indicators in order to assess the current situation and its evolution.

The concept of **ecological footprint** was coined by William Rees and Mathis Wackernagel (1996) as a result of a doctoral thesis at the University of British Columbia. The ecological footprint is understood as the area of bioproductive land required to produce the resources used and to assimilate the waste generated by human activity; in other words, the ecological footprint consist of the productive footprint and the carbon footprint.

- The **productive footprint** corresponds to the biocapacity of a given area (farmland, grazing land, fishing grounds and forest production) and is expressed in global hectares (gha). A global hectare is the average of the bioproductivity of all the hectares considered as productive areas on the planet which, due to globalization and consumption of resources on a global scale, is increasingly well-known as a unit of measurement in fields such as geography and environmental sciences. Urbanized lands are also included because they reduce the productive space of ecosystems.
- The **carbon footprint** represents the impact of a good, activity or set of activities on the environment and is calculated from the activity data of different sources of pollution. It is strongly linked to CO_2 emissions, as they are the most widespread anthropogenic emissions at present.

If a region's biocapacity is less than its ecological footprint, that area is in **ecological deficit**, as the generation of natural resources is less than its demand.

The **Overshoot Day**, or the day of the year when human activity has consumed more resources than the planet/region/city is capable of generating in that year, is another indicator that relates biocapacity to ecological footprint. This day is the result of dividing the biocapacity by the carbon footprint and multiplying the result by 365. The result is the day of the natural year in which this resource overload occurs.

All these terms have been collected and calculated by the international organization Global Footprint Network (2020).

In 2016 the human ecological footprint on the planet was 20,509 million gha while the biocapacity was 12,169 million gha, resulting in an ecological deficit of 8,421 million gha equivalent to 1.12 gha per inhabitant.

Figure 1 shows the evolution of the ecological footprint and biocapacity since year 1961. The red area shows the ecological deficit of the planet, that is, the years when humanity has consumed more natural resources than the planet can generate in a single year.

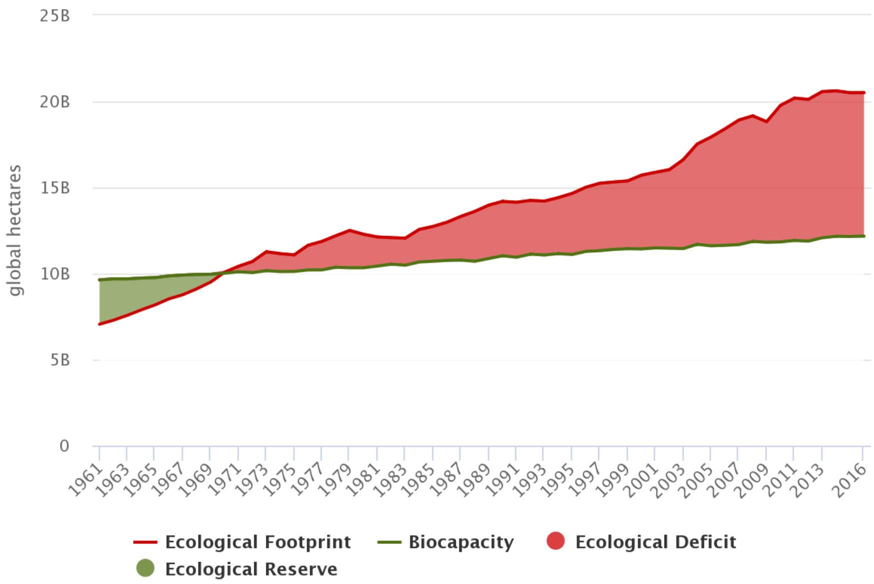


Figure 1. Evolution of the global ecological footprint and biocapacity (gha)
Source: Global Footprint Network, 2019. National Footprint Accounts

When separating the ecological footprint by categories (figure 2), it is shown that the carbon footprint quadrupled over the last 55 years, representing a total of 60% of the current ecological footprint. To illustrate this fact, another indicator called 'number of Earths needed' comes up, showing that by 2016, 1.7 Earths would be needed to supply all the planet demand for natural resources.

However, not all regions of the planet are responsible for the global ecological deficit. As figure 3 shows, the most developed countries are currently in deficit, while South American countries or developing countries have ecological credit.

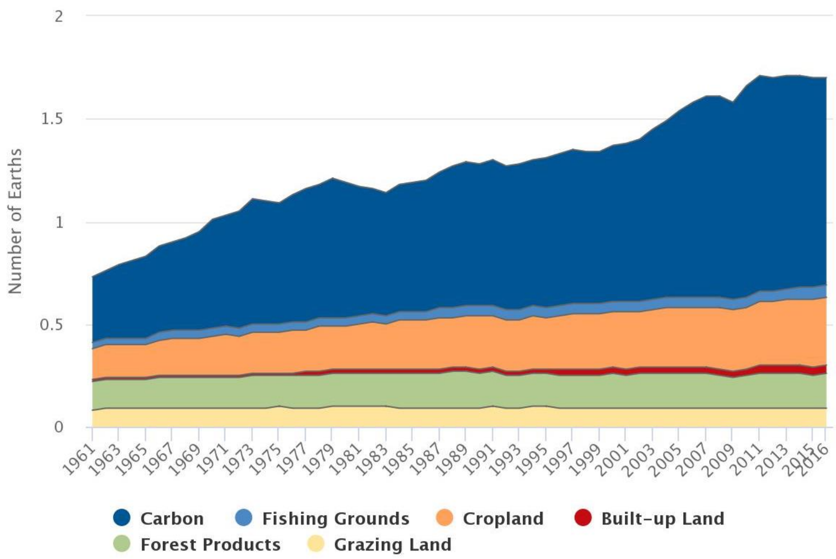


Figure 2. Global ecological footprint by land use type (gha)
Source: Global Footprint Network, 2019. National Footprint Accounts

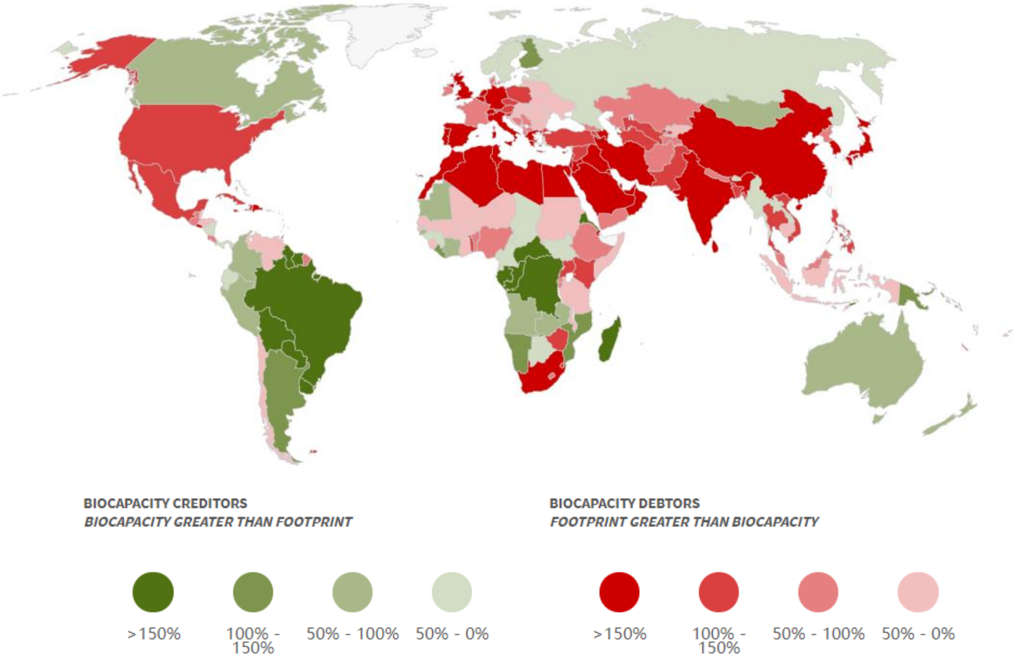


Figure 3. World credit and environmental deficit
Source: Global Footprint Network, 2019. National Footprint Accounts

In the case of Spain, and as shown in figure 4, in 2016 the ecological footprint was 4.04 gha per inhabitant, which resulted in an ecological deficit of 2.6 gha per inhabitant. It can also be seen that in 2007 there was the worst deficit recorded in the last century (about 6 gha per person). In terms of Overshoot Day, this figure indicates that in Spain the production of natural resources was exceeded on 9th May.

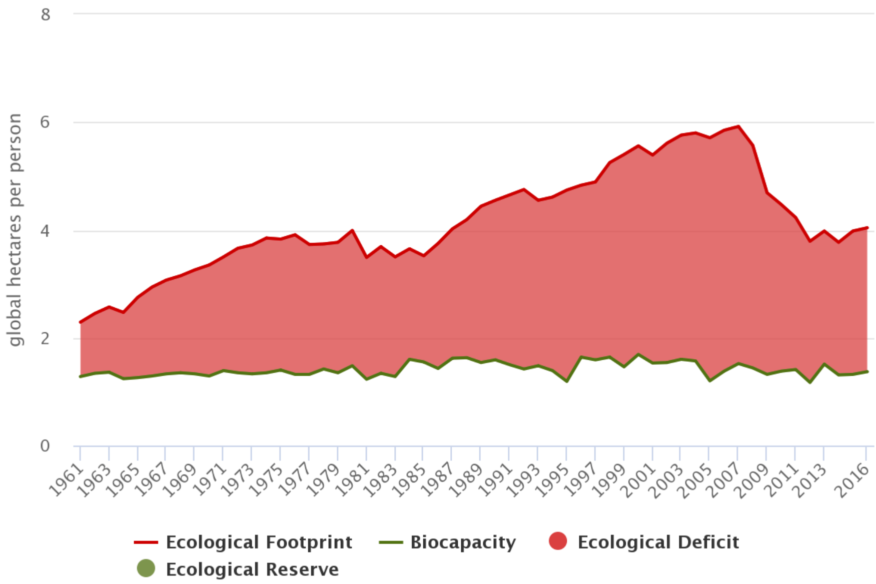


Figure 4. Evolution of the ecological footprint and biocapacity in Spain (gha per inhabitant)
Source: Global Footprint Network, 2019 National Footprint Accounts

1.3. OBJECTIVES OF THE STUDY

The main objective of this study is to calculate the carbon footprint of the city of Valencia in the most detailed and precise way possible, divided by sectors, through a clear and common methodology with other studies allowing:

- To compare the results with other studies carried out for other worldwide cities.
- To serve as a tool for decision-making by public authorities in terms of climate change, in particular, for the Valencia City Council.
- To establish a common methodology capable of being updated every year and monitor the implemented actions.

As the SECAP carbon inventory is going to be used as a baseline for this study, the secondary objectives are in line with the Council's request:

- Carrying out an analysis of the methodology used in SECAP by discussing its strengths and weaknesses.
- Developing a series of improvement proposals for future updates of SECAP, always considering the main objectives of the study.
- Making a comparison between the results reported by the SECAP and the results of this study.

The results obtained will be expressed in tons of CO_2. Furthermore, these results will be translated into the different environmental indicators already mentioned.

1.4. STUDY SUMMARY

The study consists of two main documents: the report and the calculation Annex.

The first one, is divided into seven chapters ordered according to the guide '*Redacción de Trabajos Fin de Máster de la ETSEI*' for writing master's thesis and the international methodology for calculating the carbon footprint.

These chapters separate the research part on the one hand and the engineering and calculation part on the other, evaluating future scenarios to 2030 by modifying some of the current energy and non-energy consumption trends. As for the research part:

- State of the Art on carbon inventory calculation methodologies, carbon footprint and other environmental indicators that are currently used.
- Analysis of the methodologies used today at a municipal and national scale.
- Development of the carbon inventory by emission sources.

The Annex document contains all the tables, emission factors and other data needed to carry out the carbon emissions inventory and the other indicators.

CHAPTER 2. STATE OF THE ART

Nowadays, given the urgency of action on climate change, more and more governments and organisations are joining to achieve a sustainable energy transition from zero greenhouse gas emissions. An essential part of this transition is the quantification and monitorization of current emissions, and therefore carbon footprint studies and emissions inventories are indispensable.

2.1. METHODOLOGY FOR GREENHOUSE GASES (GHG) INVENTORIES

According to the Ministry for the Ecological Transition and the Demographic challenge, an emissions inventory is defined as the quantification of the amount of pollutant emissions from anthropogenic sources released into the atmosphere in a given period (usually one natural year) (MITECO, 2020).

These polluting emissions come from the so-called greenhouse gases (GHG): gases that absorb and emit radiation within the infrared range and produce the greenhouse effect. Due to human activity, especially since the Industrial Revolution, the concentration of these gases in the atmosphere is increasing and, consequently, also the average temperature of the planet.

The IPCC Climate Change 2013 report (fifth update) (Stocker T.F. et al., 2013) lists and updates the various greenhouse gases according to their global warming potential (GWP), measured in relation to the same mass of carbon dioxide and for a given lifetime. Therefore, the emissions data are usually represented in tons of CO_2 equivalent ($CO_{2\text{-}e}$).

IPCC report values: Climate Change 2013		
Name	**Formula**	**GWP (CO_2e)**
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265
Sulphur Hexachloride	SF_6	23,500
Carbon Tretraflouride	CF_4	6,630
Hydrofluorocarbons	HFCs	116 – 12,400

Table 1. Global Warming Potential (GWP) of the most significant greenhouse gases (GHGs)

Even though all the gases in table 1 have an influence on the greenhouse effect, carbon dioxide is the most significant gas both in terms of its anthropological emissions and its concentration in the atmosphere. As a result, and since that the acquisition of CO_2 emissions data is more widespread, emission inventories are commonly simplified when considering only carbon emissions. However, this simplification can lead to interpretation errors if the knowledge or treatment of data is inadequate.

Another major problem facing these studies is the lack of a universal methodology and factors. In other words, there are numerous methodologies proposed by international institutions to carry out emission inventories, and the choice of which one to follow depends on variables such as the area under study, the depth, or the required detail.

Linked to the World Resources Institute (WRI), the Greenhouse Gas Protocol is one of the world's leading organizations providing standards, guidance, and tools for measuring and managing greenhouse gases for both public and private sector companies and organisations. On its website (GHGP, 2020) many documents for this purpose can be found. However, this study will focus on the guide for cities at the community level (GHGP, 2014). Based on this guide, other organisations such as C40[1] (ARUP-C40, 2018) or the Covenant of Mayors itself have adapted their own models to provide a methodology for each of their participants.

The guidebook proposed by the Covenant of Mayors: *How to develop a Sustainable Energy Action Plan (SEAP)* (Paolo Bertoldi et al., 2010) contains, firstly, indications of the process for implementing these plans starting with adaptation and political commitment. Then, it continues through assessment of the current situation, setting of objectives and development of the plan and ends with the monitoring and reporting phase.

As an essential tool, the guide proposes the elaboration of a Emissions Reference Inventory (ERI) that quantifies the amount of CO_2 emissions due to energy consumption in the municipal territory in the reference year and that allows the identification of the main emission sources. This ERI alongside subsequent inventories, will help to set priorities, assess the impact of measures taken and determine progress towards achieving the objectives

The Covenant of Mayors guide aims to enable both large and small-town governments to apply its methodology. The gathering of information and emission data is sometimes a complex task and depends on the sector that produces them and the tools available to the town in question. For this reason, the guide, in an attempt to be as simple and accessible as possible for all participants, proposes methodologies that are validated and accepted internationally but that in the first instance do not seek precision.

[1] The C40 is a network of the world's most important mega-cities committed to climate change that supports collaboration and information exchange between them to advance sustainable climate change actions and strategies.

Regarding the development of the inventories, the guide refers to the following key concepts: **limits, scope, approach, and sectors**, which are fundamental to carry out a study of this type.

First of all, the limit and scope of the study must be established, which will determine the extent of the study and the number of sources covered by the limits. The next step is to choose the approach that will determine the depth and detail of the study. Finally, the pollutant sources to be included in the inventory must be selected and classified by sectors.

Most commonly, only the CO_2 emissions are counted on carbon inventories. However, the guide indicates that CH_4 and N_2O emissions can be added depending on the targets set by the local authority and the approach chosen.

The key concepts mentioned are described below, adding some of the most commonly application examples of each:

a) The **limits** of the study are normally the administrative boundaries of the entity that requires the study. In the case of an ERI of a city, the limits of the study will be the municipal boundaries. Establishing appropriate the limits is essential to count all sources involved and to avoid duplicate counts.

b) The **scope** of an emission is determined by the source and the control that the entity may have over the source. There are three categories in which the different emissions are organized:

- **Scope 1 - Direct Emissions:** those GHG emissions that come from sources located within the area or limit of the inventory. For example, consumption of fossil fuels in fixed and/or mobile sources, unintentional leaks from air conditioning equipment, etc.
- **Scope 2 - Indirect Emissions:** those GHG emissions that are produced by the consumption of electricity, steam and/or air conditioning within the area or limit of the inventory, but which have been generated outside this area by third parties.
- **Scope 3 - Other Indirect Emissions:** those emissions produced outside the area or limit of the inventory as a result of an activity carried out within it. For example, journey of workers to their workplaces, transportation of goods by sea, air, or land to consumption points, etc.

The main target of the Covenant of Mayors is energy consumption, so a Sustainable Energy Action Plan must ensure that all emissions from scope 1 and 2 are counted for. However, the scope 3 emissions are proposed as a voluntary inclusion considering that their influence will be small in relation to the energy consumption of the other scopes.

As a general rule, scope 3 emissions tend to be more complex to measure as they might come from uncontrolled sources or require special instrumentation for data acquisition.

Figure 5 shows an example of emissions classification for a city inventory:

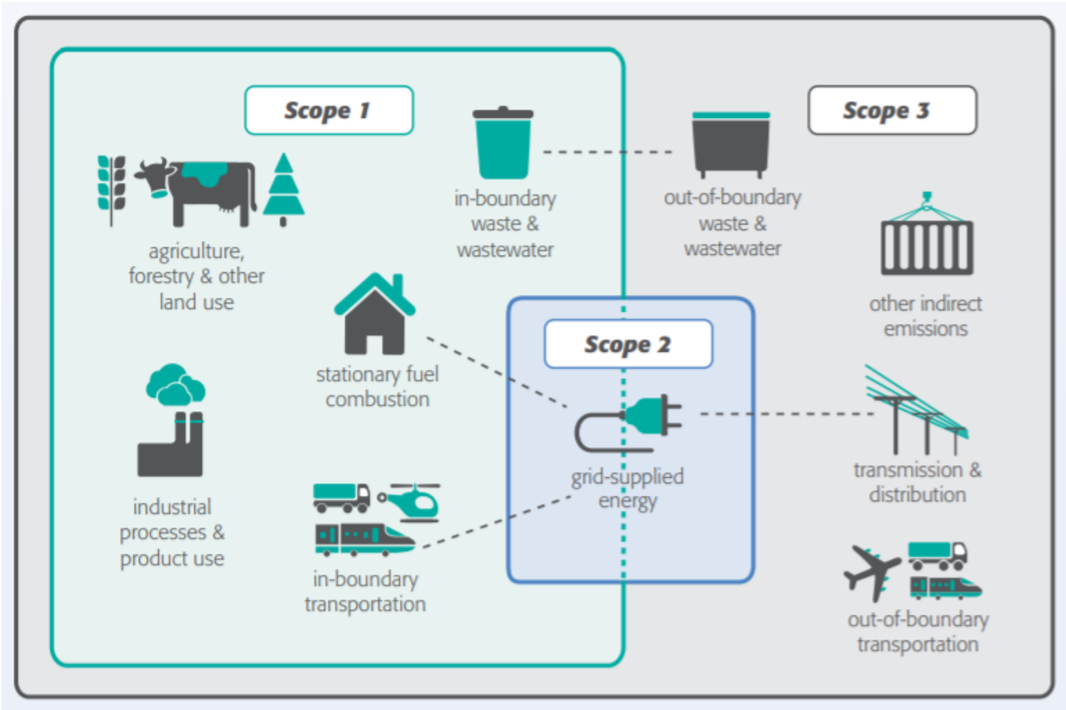


Figure 5. Classification of GHG emissions in a city by sources and boundaries
Source: Greenhouse Gases Protocol (GHGP), 2014. *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*. (page 11)

However, according to (Chen S. et al., 2020), the emissions listed within scope 3 can account for up to 35% of total emissions. For many organizations, either municipalities or companies, a large part of their GHG emissions come from outside their operational and administrative boundaries. In these cases, the most effective emission reduction actions are generated from the measurement and treatment of these scope 3 emissions. Therefore, the benefits of including these emissions in the emissions inventory are:

- Detailed assessment of GHG emission sources.
- Identification of the most influential external sources and possibility of involving them in sustainability initiatives.
- Increase the capacity for performance actions and the number of applicable strategies.

c) The **approach** determines the emission factors used to conduct the emission inventory. Defined by the IPCC, the emission factor is the ratio that relates the activity data to the amount of the chemical which every source is composed of. The most common emission factors are listed in table 2:

Source of emissions	Emission Factor (Unit)
Energy (electricity, heat, etc.)	kg CO_2 / kWh
Fuel consumption	kg CO_2 / $litre_{fuel}$
Consumption of goods or materials	kg CO_2 / kg
Consumption of water or other liquids	kg CO_2 / m^3

Table 2. Most frequent CO_2 emission factors

When determining emission factors, two approaches can be chosen:

- The standard approach using the IPCC emission factors (IPCC, 2001) that encompass all CO_2 emissions from energy consumption either directly (combustion) or indirectly (heat/cold generation or electricity). These factors are based on the carbon content of each source and, since CO_2 emissions are the most influential on climate change, this approach dispenses with emissions of other compounds such as CH_4 or N_2O. The default IPCC emission factors can be replaced by factors adjusted to the local environment (e.g. the emission factor of the local electricity mix).
- The second approach, called Life Cycle Assessment (LCA), considers all phases of the source life cycle, including all emissions from extraction, transport, processing, use and/or disposal. The collection of these factors is more complex and sometimes they are disparate depending on the data source. It is worth to mention that this approach considers all the GHGs involved, expressing the emissions in kg of CO_2 equivalent (CO_{2-e}).

The approach chosen will determine the number of studies with which the results obtained can be compared. The standard approach is the most widespread and is often used in government and other institution reports because of its ease of data acquisition and speed of inventory calculation using available emission factors. It is also used by organisations such as the Covenant of Mayors as it makes it easier for its signatories to monitor progress towards the objectives of the European Union.

On the other hand, the life cycle approach is compatible with research work and environmental projects that attempt to reflect the impact produced as accurately as possible. The advantage of this approach over the first is the degree of detail that can be obtained in the results at the cost of more complex data acquisition and calculations.

d) The **sectors** included in the study classify the origin of the sources with the aim of identifying the most important emission sources. Each sector will have a different methodology for obtaining data depending on the objective of the study. According to the Covenant of Mayors guide, an effective separation for a city's inventory is to distinguish between municipal and non-municipal emissions.

Within the sources dependent on the City Council are the following categories:

- Energy consumption in municipal buildings and equipment.
- Fuel consumption in road transport of the municipal fleet.
- Fuel consumption in urban public transport.
- Wastewater management (collection, treatment, disposal, etc.).
- Urban solid waste management (collection, treatment, disposal, etc.).

The sources of energy-related emissions independent of the City Council are more diverse, and are classified by sectors:

- Residential sector (electrical and thermal energy consumption).
- Tertiary sector (electrical and thermal energy consumption).
- Industrial sector (electrical and thermal energy consumption).
- Private and commercial road transport (fuel consumption).
- Urban rail transport (electricity consumption).
- Port activities: maritime and river transport.
- Aviation.

In addition, there are other sources derived from indirect energy or non-energy consumption more typical of the life cycle analysis approach, such as:

- Agriculture, land use (use of fertilizers, chemicals, etc.).
- Fugitive emissions from processes in production, transport, distribution, etc.
- Consumption of goods (food, clothing, electronic devices, tobacco, etc.).
- Building and construction.

Since the base inventory to be used in this study belongs to the Sustainable Energy and Climate Action Plan (SECAP), other energy plans have been analysed from other Spanish cities.

The city of Barcelona developed the '*Pla d'energia, canvi climàtic i qualitat de l'aire 2011-2020*' (Agència d'Energia de Barcelona, 2011). This document includes an analysis of the consumption, generation and supply of energy in the city in 2011, a study of air quality through an inventory of greenhouse gases (CO_2 as the main one, although it also includes data on N_2O and suspended particles), and a forecast for 2020 that includes environmental actions aimed to meet the objectives of the European Community and the Covenant of Mayors.

Within the carbon inventory carried out, the following sectors are included: municipal consumption dependent on the City Council, domestic, commercial and industrial sectors, mobility, waste and large infrastructures such as the port and airport, giving special importance to road and public transport. While the emissions of the sectors are provided by the corresponding electricity and fuel billing data, the emissions in mobility, waste treatment and port-airport require an indirect or specific methodology.

Another important energy plan would be the '*Plan Energético de la Comunidad de Madrid: Horizonte 2020*' (Subdirección General de Promoción Industrial y Energética de la Comunidad de Madrid, 2016). The document includes an analysis of energy products consumption, energy generation and forecast and measures for the year 2020. Although this study does not express the results in terms of the quantity of GHGs emitted, it works with the equivalent oil energy unit for the different sources, which are sectorised and allows to see the percentage of final consumption of every energy source in each sector.

In short, two key points will be considered when developing the carbon inventory for the city of Valencia. The first one is to include as many sectors as possible within the scope of the study and to have them analysed in other cities as well in order to be able to compare the results. The second key point is the acquisition and processing of data. In order to compare results between different cities, the methodology used for each sector, as well as the emission factors and other variables considered in the calculations, must have the same basis.

2.2. CARBON FOOTPRINT METHODOLOGY

As with emission inventories, there is no single method of calculation. However, the two most widespread methodologies are:

- Top-Down methodology.

This methodology uses the MRIO (multiregional input-output) tables and bioproductivity data of the area to calculate a CLUM (Consumption land-use matrix). Studies such as (Galli A. et al., 2020) use Global Footprint Network's ecological footprint data.

The MRIO tables provide statistics and economic data on imports and exports of raw materials with which, together with the area's bioproductivity data, the matrix containing consumption data by category (food, water and electricity in households, transport, etc.) is calculated according to the type of land use. The results (including the carbon footprint) are expressed in global hectares (gha).

This methodology is used for large-scale studies, although the results obtained can be extrapolated to regions or cities within the area depending on the number of inhabitants. Its main advantage is that the ecological footprint per type of use can be calculated for any area from national and international data that are generally more accessible.

- Bottom-Up methodology.

Similar to the carbon inventory methodology, it starts with the gathering of local data until the result is obtained. This methodology is usually used in small-scale studies such as: calculation of the carbon footprint of private companies, ecological footprint of consumer goods or, as in the case of this study, the carbon footprint of a city.

The main disadvantage of this methodology is the data acquisition, as the data usually come from different sources that might be private or external to the boundaries of the study.

Therefore, obtaining the full data can be quite tedious. However, this type of study adds more detail to the final results and offers more room for manoeuvre when acquiring and processing data from each source.

The results obtained are expressed in tons of CO_2 (or CO_2 equivalent if all other GHGs are considered). Given that the ecological footprint and biocapacity are expressed in global hectares (gha), in order to compare with other similar studies, the results obtained must be expressed in the same units. Two conversion factors are to be used for this:

a) Fixing capacity of the local forest, which relates the amount of CO_2 that a hectare of forest can store. For this study, the Mediterranean forest will be considered, whose fixing capacity is between 2 and 4 tons of CO_2 per hectare and per year (see section 4.1.1 Methodology for calculating the carbon footprint).
b) Forest Land and Carbon Equivalence Factor, which relates local forest bioproductivity to global biocapacity. In other words, it relates the hectares of local forest obtained to the global hectares of forest. According to (Lin D. et al., 2019, p55) this factor is 1.29 gha/ha local.

Before choosing the methodology followed by this study, different studies on the carbon footprint will be analysed:

The study (Galli A. et al., 2017) is an example of the application of the Top-Down methodology. With the aim of calculating food consumption patterns in various countries, the ecological footprint by category has been obtained for 15 Mediterranean countries. The results in global hectares per person are shown in figure 6. It should be noted that food, drink, and clothing consumption, together with transport, are the sectors with the greatest influence on the carbon footprint. This trend is similar in all the countries of the study. Nevertheless, more developed countries like France, Italy or Spain show a carbon footprint per person several times higher than less developed countries like Turkey, Albania, or Morocco.

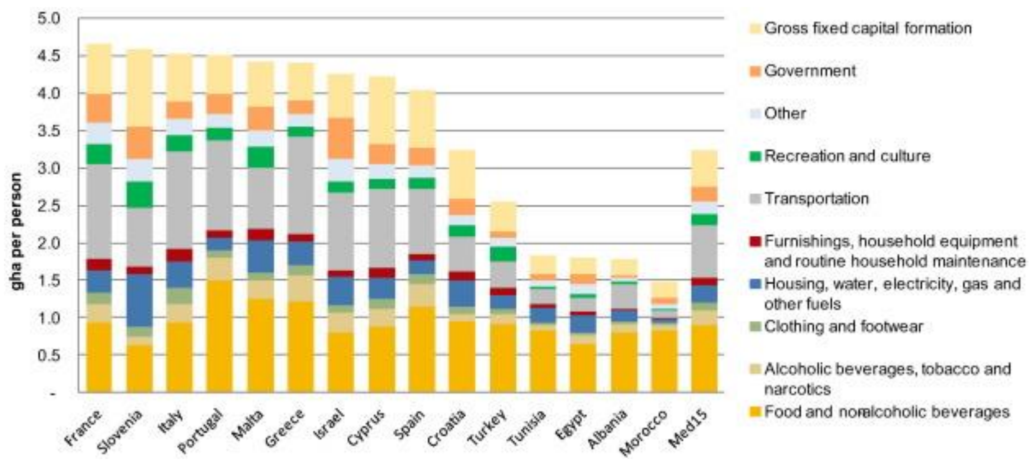


Figure 6. Ecological footprint of consumption for 15 Mediterranean countries (2010)
Source: Galli A. et al., 2017. Mediterranean countries' food consumption and sourcing patterns: An Ecological Footprint viewpoint

Another example of a Top-Down methodology is the ecological footprint study of Mediterranean cities (Baabou W. et al., 2017), where the ecological footprint was calculated in different cities, including Barcelona and Valencia. In addition, it contains an overview of other studies that calculate the ecological footprint in other cities and the methodology that each one uses.

In line with the previous study, figure 7 shows similar results. In general, European cities tend to have a larger ecological footprint than North African cities. In the cases of Barcelona and Valencia, the calculated footprint amounts to 4.52 and 4.07 gha per person respectively, with food and transport again being the most influential categories.

Figure 8 shows the ecological footprint disaggregated by types of land use. In Valencia around 55-60% of the total footprint corresponds to the carbon footprint, with agriculture being the second most influential category with around 27%.

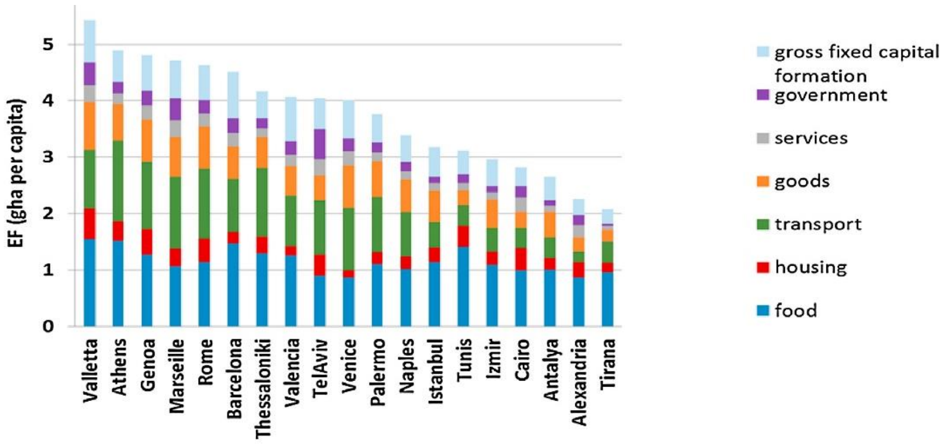


Figure 7. Ecological footprint of Mediterranean cities by consumption category (2015)
Source: Baabou W. et al., 2017. The Ecological Footprint of Mediterranean cities: Awareness creation and policy implications

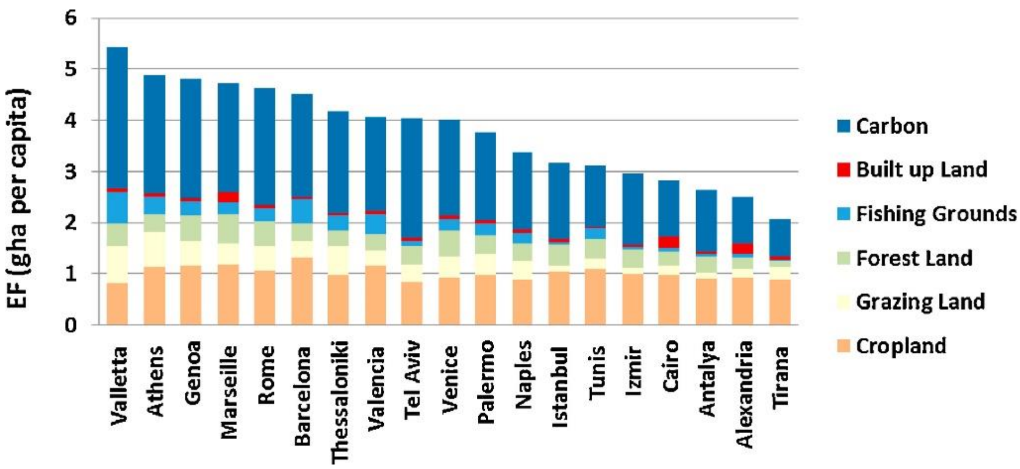


Figure 8. Ecological footprint for Mediterranean cities by land use (2015)
Source: Baabou W. et al., 2017. The Ecological Footprint of Mediterranean cities: Awareness creation and policy implications

On the other hand, the Bottom-Up methodology has spread in Spain, especially in university and research fields. The closest cases to this study are the carbon footprint calculations of the University of Valencia (UV) (Puchades M. et al. 2011) and the Polytechnic University of Valencia (UPV) (Torregrosa López J.I., 2009).

Other universities with studies on their carbon footprint are the Autonomous University of Madrid (Olalla Tárraga M.A., 2003), the University of León (Arroyo Hernández P. et al., 2009), the Polytechnic University of Catalonia (Sunyer Roca, J. and Busquets, P., 2016) or the Escuela Politécnica de Valladolid (Hernández Gallego E. et al., 2014), among others.

These studies share the followed methodology, based on Mathis Wackemagel and William Rees' original method. The calculation of the carbon footprint can be expressed as the sum of CO_2 of each category previously obtained as the product of the category measurement by its corresponding emission factor. The categories considered are the following: energy, water and paper consumption, emissions, mobility, waste and built area. In the case of the Polytechnic University of Valencia, the food category is also added when doing extrapolation due to the lack of data found. In the rest of universities, the absence of other sources such as food, goods or services is justified by the lack of data.

Figures 9 and 10 show the results obtained for the Polytechnic University and the University of Valencia. The main difference between them is that the first one has included food in the carbon footprint. However, the difference between the construction and mobility categories in both studies is notable. This might simply happen due to the different areas of buildings constructed by each university. Nevertheless, since the calculations require specific indirect methodologies, other variables such as the reliability of mobility data from surveys or the emission factors chosen may alter the results and decrease their accuracy.

In brief, categories that require indirect methodologies must be treated with special care, trying to use those that offer the most reliable and detailed results while checking their veracity in other similar studies.

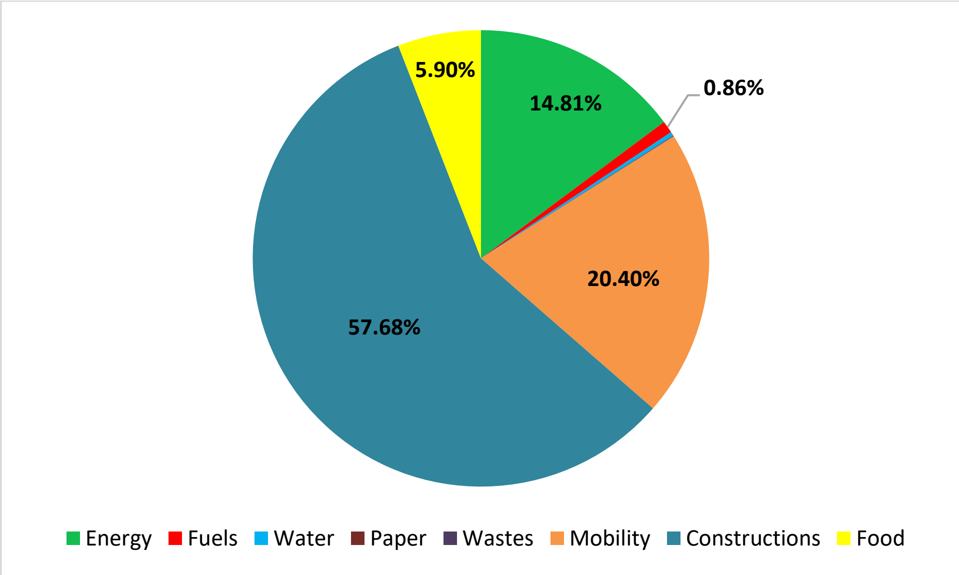


Figure 9. Ecological footprint of the Polytechnic University of Valencia by categories (2009)
Source: ***Torregrosa J.I. et al., 2009. La huella ecológica: Caso de estudio de la Universidad Politécnica de Valencia.***

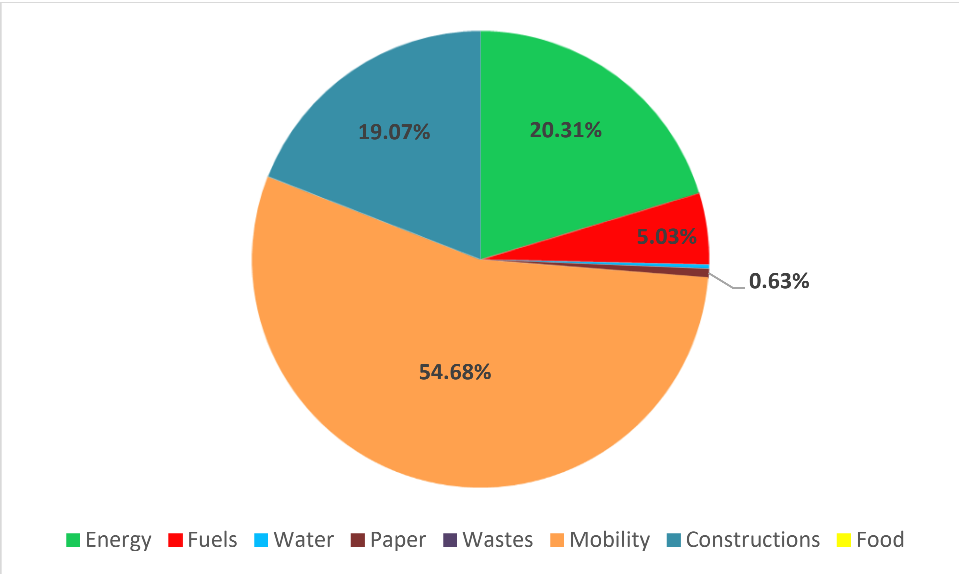


Figure 10. Ecological footprint of the University of Valencia by categories (2011)
Source: Puchades M. et al., 2011. ***La huella de carbono de la Universitat de València: diagnóstico, análisis y evaluación***

CHAPTER 3. CARBON INVENTORY

3.1. BASE INVENTORY: SUSTAINABLE ENERGY AND CLIMATE ACTION PLAN (SECAP – VALENCIA)

3.1.1. SECAP methodology

The Sustainable Energy and Climate Action Plan of Valencia Plan has been developed in accordance with two main documents: the guide mentioned in previous sections '*How to develop a Sustainable Energy Action Plan*', provided by the Covenant of Mayors and '*Metodología para el Desarrollo de documentos del Pacto de los Alcaldes y Alcaldesas para el Clima y la Energía en la provincial de Valencia*', established by the Valencia Provincial Council as territorial coordinator.

The baseline inventory was done in 2007. However, this work focuses on the last update available in 2016, since during this time different methodological changes have been incorporated such as the replacement of the national electricity emission factor, calculated in 2006 by the IPCC, with the Valencian Community's emission factor, that is updated annually according to the electricity mix obtained each year, or the inclusion of urban rail transport, among others.

The limit of the inventory is focused within the municipal territory of Valencia. The inventory is aimed exclusively at CO_2 emissions, including all direct energy consumption, indirect consumption in the form of electricity and their respective emissions, in other words, scope 1 and 2 emissions.

The fields that the inventory currently includes are classified into two general categories: fields that depend on the City Council and fields that do not depend on the City Council. The first category focuses on public consumption sources where the municipality can act directly to reduce its emissions. The second category includes the rest of the sources and areas in which the City Council cannot intervene directly, but is committed to reduce their emissions.

The sources of data acquisition for each area are diverse. The following information comes from Valencia City Council or entities contracted by this authority:

- Energy consumption (electricity and fuel) related to buildings, equipment, public lighting, and municipal vehicles can be found in the statistical yearbook of the City Council itself.
- Consumption of electricity and natural gas disaggregated by residential, industrial, and service sectors can also be found in the statistical yearbook of the City Council.
- Fuel consumption in public transport comes from EMT Valencia.
- The fuel consumption of the waste management vehicles and the electrical consumption of the water depuration plants come from the contracted entities.

For the rest of the fields, the information comes from other regional or national entities:

- Urban rail transport consumption can be found in the annual management report of Ferrocarrils de la Generalitat Valenciana (FGV) (Valencian Community’s Urban Rail).

- Data on renewable energy production and production by source come from the Ministry of Industry, Trade and Tourism and from Red Eléctrica Española (REE) (Spanish Electric Grid)
- Private transport consumption has been estimated on the basis of the registered vehicle fleet which comes from the DGT (Spanish Directorate-General of Traffic) and extrapolated data on fossil fuel consumption in the province of Valencia, from the Corporación de Reservas Estratégicas de Productos Petrolíferos (CORES) (Corporation of Strategic Reserves of Oil Products).

Other fields have not been included for three reasons:

- Due to a lack of data, such as consumption in long-distance rail transport or emissions not associated with direct energy consumption.
- Because they are partially or totally included in some of the previous sources, for example, fuel consumption in road transport or for electricity generation, since these consumptions are included in the municipality’s global consumption, but it was not possible to break them down.
- The port of Valencia, for example, as it is outside the management scope of the City Council in terms of emission reduction measures.

With all of the above, the carbon inventory is composed of the areas of table 3:

Fields included for assessment and action	
Dependent on the City Council	**NOT dependent on the City Council**
Municipal buildings, equipment and facilities	Residential sector (domestic)
Public lighting	Industry sector
Public and municipal transport	Tertiary sector
	Private and commercial transport
	Urban rail transport
	Urban solid waste management

Table 3. Fields contemplated in the SECAP - Valencia

Once the consumption data from all sources is obtained, the corresponding emission factors are used to express the results in CO_2. Table 4 shows the factors used in the Valencia Energy Plan, from the Institute of Business Competitiveness (IVACE by its acronym in Spanish).

Source	Emission Factor	Units
Electricity	0.188	tCO_2 / MWh
Petrol	0.242	tCO_2 / MWh
Diesel oil	0.265	tCO_2 / MWh
LPG (butane, propane)	0.225	tCO_2 / MWh
Natural Gas	0.201	tCO_2 / MWh
Urban solid waste	0.305	tCO_2 / MWh

Table 4. Emission factors used in SECAP
Source: IVACE: Energy data of the Valencian Community 2016

3.1.2. Analysis of results: SECAP 2016

Figure 11 shows the distribution of CO_2 emissions accounted for in the carbon inventory of the city of Valencia. Fuel consumption in private and commercial transport is the main source of emissions, close to 60% of total CO_2 emissions, followed by the residential sector and the service sector with 15% and 13% respectively. On the other hand, the industrial sector does not have an important contribution, since most of the industry is located in other municipalities of its metropolitan area.

Due to this, the number of daily work journeys between municipalities is manifested in the large percentage of emissions due to transport.

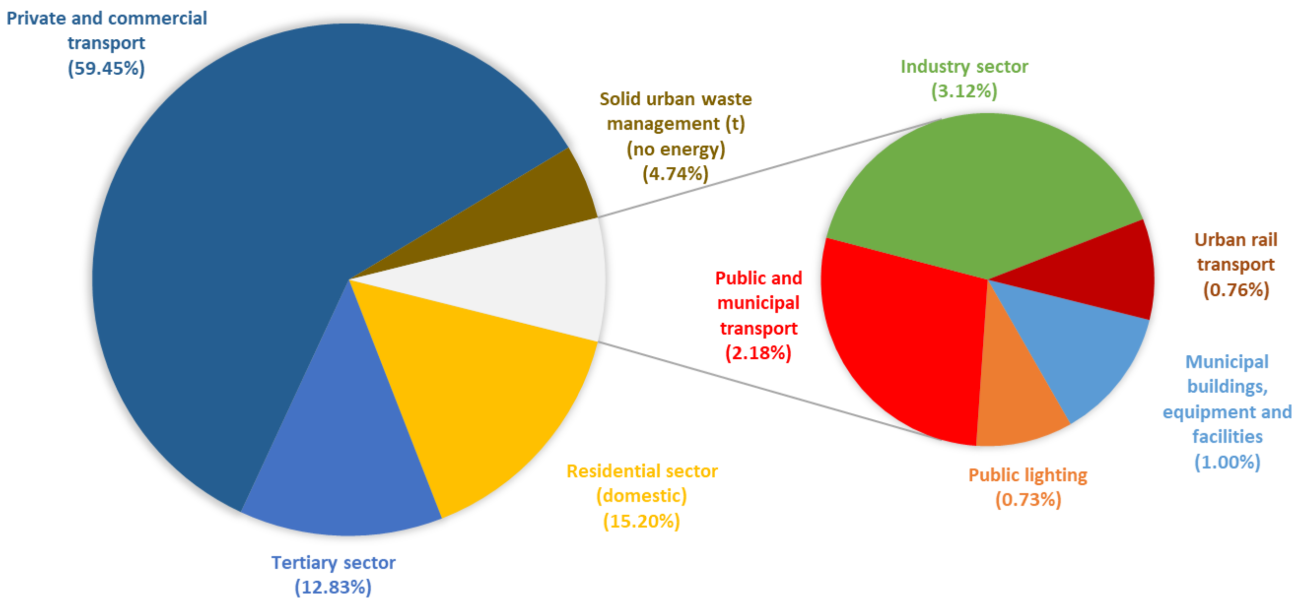


Figure 11. Distribution of CO_2 emissions by source (Valencia 2016)
Source: SECAP - Valencia (2016)

A comparison of the emission inventory with the baseline inventory carried out in 2007 (see figure 12) shows that the distribution of emissions has not changed significantly. Nevertheless, in the year 2016 emissions have been reduced by 28.7% compared to the baseline. If each source is examined in detail, the residential, industrial and service sectors have reduced their emissions by between 37% and 55% while emissions from private and commercial transport have only been reduced by 18%. On the other hand, it should be noted that the areas that directly depend on the municipality only represent 4% of total emissions, where more than half of them come from fuel consumption in public and municipal transport.

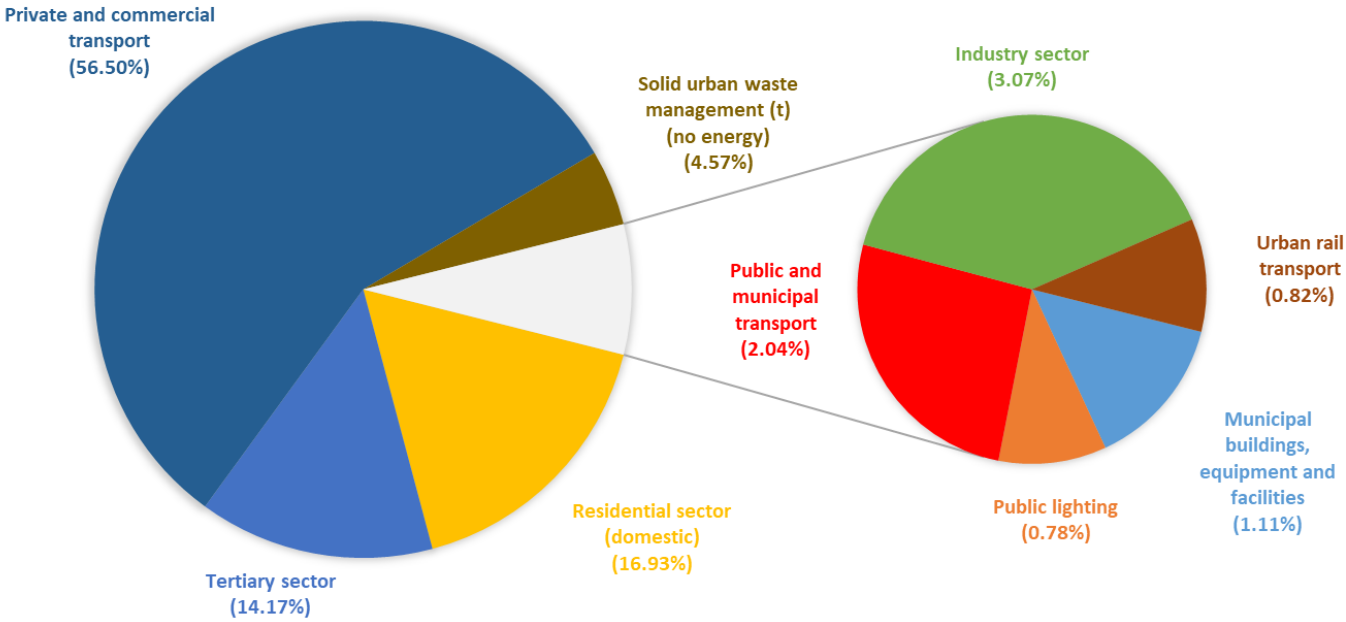


Figure 12. Distribution of CO_2 emissions by source (SECAP emission reference inventory 2007) Source: SECAP - Valencia (2016)

As figure 13 shows, emissions fell considerably until 2014 due to the financial crisis and the implementation of energy efficiency improvements. However, from 2015 onwards the tendency changes, slightly increasing each year.

In conclusion, the current methodology includes most of the scope 1 and 2 emissions. The results provided by the Valencia SECAP show that:

- More than 65% of emissions come from the consumption of fossil fuels, mainly in the field of public, private, and commercial transport.
- The rest of the emissions come from the consumption of electricity in other areas, with the domestic and service sectors being the most influential. In addition, only a small percentage belongs to areas directly dependent on the City Council.
- Therefore, the main measures to achieve a sustainable energy transition must focus on reducing emissions in transport, increasing the efficiency of buildings, insulation, air conditioning systems, etc.

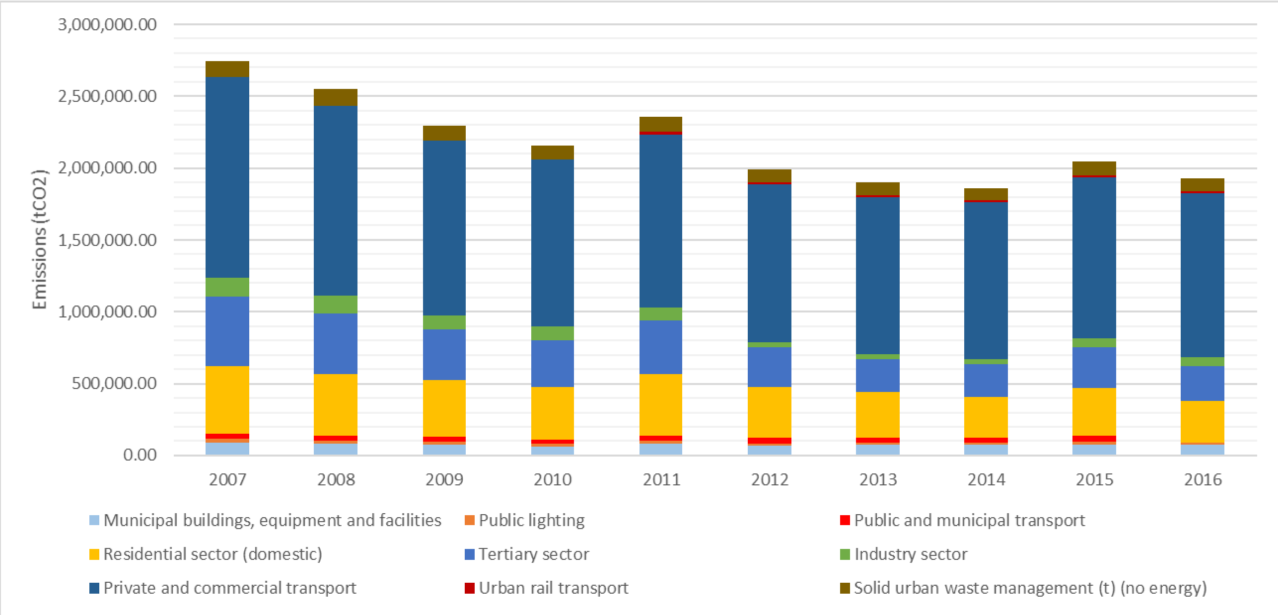


Figure 13. Evolution of CO_2 emissions in Valencia 2007–2016
Source: SECAP – Valencia (2016)

3.1.3. Analysis of weaknesses: current methodology

The results of the carbon inventory carried out in the city of Valencia show a situation that is repeated to a greater or lesser extent in the other large cities in the planet, where the consumption of fossil fuels in transport is the largest source of direct emissions of greenhouse gases.

Nevertheless, this conclusion arises from an analysis where only direct emission sources and indirect emissions through electricity have been taken into account, leaving many other sources outside the study that, if included, are likely to reduce the weight of transport emissions.

Given that the objective of the work is to calculate the carbon footprint in the most detailed way possible, two lines of action have been differentiated: the first is to analyse the current SECAP methodology and find its weaknesses with the aim of improving it, while the second is the viability study to incorporate these other sources of emissions not included in order to find out their influence on the carbon footprint.

Regarding the current SECAP methodology, the following can be highlighted:

- Much of the data used comes from the City Council's statistical yearbook. The advantage of this is that it makes data acquisition easier, so updating the inventory is simple and the Energy Plan can be monitored properly. However, these consumption data are not divided into area, neighbourhood, etc., which would be advisable when carrying out energy saving measures.
- It has been observed that fossil fuel consumption is the main source of emissions in Valencia. However, its calculation methodology is based on the sale of fuels at points of sale within the city limits. Although this methodology is one of the options accepted by the Greenhouse Gas

Protocol, it is not very suitable for the case of Valencia, given that journeys between the city and its metropolitan area are one of its main characteristics and this methodology would only account for this type of journey in cases where the refuelling was carried out in one of the stations within the limits. Furthermore, this methodology requires an extrapolation from the data of the registered fleet, which can lead to errors since the total number of vehicles stopped and their characteristics do not necessarily correspond to the number of vehicles that travel daily. Finally, it should be noted that through this methodology, the results cannot be divided into scopes, which would be interesting given the importance of this source of emissions in the city's total carbon footprint.

- In the area of municipal solid waste (MSW), only emissions caused by the collection and transport of such waste are taken into account, and emissions caused by the burning of such waste are not.
- No areas of non-energy emissions (life cycle analysis) nor indirect scope 3 emissions have been considered, which can contribute a significant amount of emissions to the carbon footprint. This fact can be seen in GHG reports from large national (and international) energy system operators such as Iberdrola (2018) or Endesa (2018), which show scope 3 emissions equal to or greater than scope 1 emissions, depending on the fields or the area of the study.

Once the aspects with the possibility of improving the carbon inventory of SECAP are analysed, a series of proposals will be developed to improve and extend the inventory. In the next section, each of the proposals can be found separately.

3.2. IMPROVEMENT PROPOSALS AND EXPANSION OF THE INVENTORY

3.2.1. Improvement proposal: residential sector

The residential sector is one of the most influential sources of greenhouse gas emissions, representing around 17% of total emissions in Valencia in 2016, according to the results of the SECAP carbon inventory. Furthermore, if we add to these ones the emissions derived from the construction of these buildings by the residential sector, it will concentrate one third of the total emissions in Spain.

According to the report '*Potential Energy Savings and CO_2 Emissions Reduction form Spain's existing residential buildings*' (WWF/Adena, 2010), the construction of new highly efficient and low emission buildings is not sufficient to achieve a significant reduction in consumption and emissions in this sector. For that aim, it is essential to reduce the energy demand of buildings, being the most effective measure the improvement of insulation, which can reduce energy consumption by between 57% and 72% depending on the level of insulation used.

If this fact is considered, knowing the energy consumption of the residential sector grouped by areas or neighbourhoods would be a good tool for locating and acting in the areas most sensitive to improvements in insulation. However, the data published in the Valencia City Council yearbook only shows the total fuel and electricity consumption values in the municipality. In other words, these disaggregated consumption data must be obtained from trading and electricity supply companies, which has not been possible for this study, but is planned for future updates of the SECAP.

3.2.2. Improvement proposal: private and commercial transport

Today, the transport sector is one of the main sources of greenhouse gas emissions into the atmosphere worldwide and therefore one of the key points in the sustainable development of cities and countries. Its influence is so extensive due not only to the need for people to move around on a daily basis, but also to the large amount of food and other goods that are transported from the production points to the sale and/or consumption points. In other words, emissions caused by transport always affect, to a greater or lesser extent, the carbon footprint of other sectors and activities.

Because of this, there is a lot of controversy when it comes to allocating these types of emissions. If the objective is to conduct an emissions inventory for a region or city, should these emissions be included even if they are produced outside the limits? To answer this question, there are numerous methodologies and simplifications of these, with the aim of adapting them to each case study (GHGP, 2014, p. 77).

When choosing an appropriate methodology for this work, the following considerations were considered:

- The port of Valencia is a very important enclave on a national and world level (Valenciaport [APV], 2019) and, therefore, it is to be expected that a large part of the goods received by sea will be transported by road to other cities.
- In the Valencian Community, interprovincial mobility is very reduced (IDOM-EPYPSA, 2018, p.10).
- The main mobility flows in the Metropolitan Area of Valencia are between this and its adjacent municipalities. In addition, there are detailed data on them (IDOM-EPYPSA, 2018, p.21).

Based on the above, a '**Resident Activity**' type methodology would be appropriate for the city of Valencia. This methodology accounts for emissions from residents' transport activities while leaving unaccounted for transit journeys and journeys from other provinces. It is estimated that these non-counted emissions would represent a small percentage compared to the total and, consequently, this methodology is proposed in order to obtain the most detailed and precise results.

As shown in figure 14, these shall be considered as **scope 1** emissions**:**

- Journey from and to within the city limits.
- Journeys with origin in nearby municipalities of the metropolitan area and destination within the limits (considering only the section within the city limit).
- Journeys with origin in the city and destination in nearby municipalities of the metropolitan area (only the section within the city limit is considered).

The rest of the section not considered in scope 1, corresponding to journeys with origin or destination outside the city limits, will be considered as **scope 3** emissions.

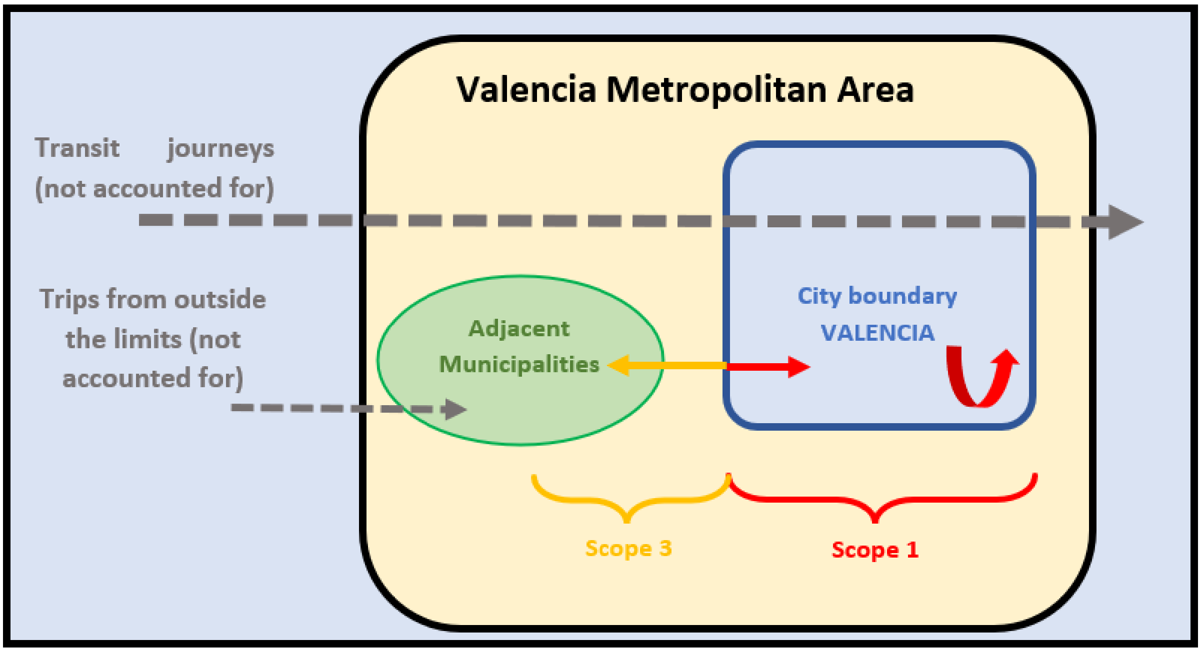


Figure 14. Scheme of journeys accounted for according to the scope of emissions

CHARACTERISATION OF URBAN MOBILITY

When talking about urban mobility, it is necessary to distinguish between the city of Valencia and its metropolitan area. According to figure 15, in the city it is estimated that 53% of citizens' daily journeys are made in a sustainable way (on foot or by bicycle), while the remaining 47% is made by private vehicle or public transport in equal parts (Ayuntamiento de Valencia, 2013).

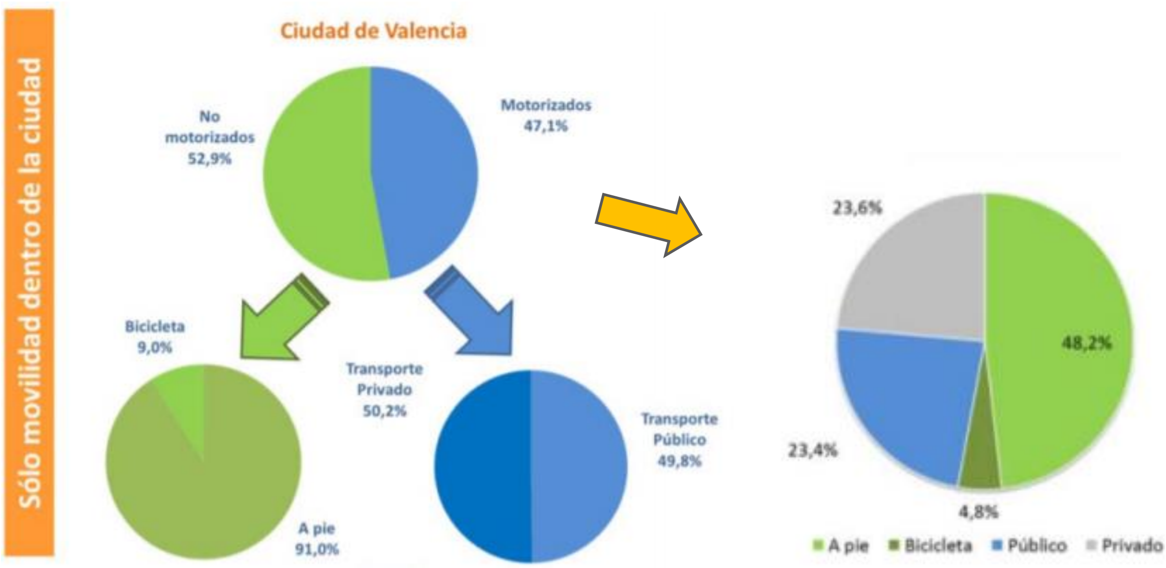


Figure 15. Modal distribution of journeys in the city of Valencia (2013)
Source: Sustainable Urban Mobility Plan of Valencia (PMUS) December 2013

However, according to the Mobility Plan for the Metropolitan Area, these data undergo an important change when taking into account this entire area, since it increases the number of journeys by mechanized means to 57%, of which approximately 73% use private transport to the detriment of public transport. This influence of the private vehicle is determined, to a large extent, by the large number of industries and industrial estates in the municipalities surrounding Valencia, the most important being Paterna, Torrent, Manises and Alboraya. If we consider the total number of daily-mechanised journeys, almost 50% take place between Valencia and the municipalities mentioned above.

Therefore, given the influence of the private vehicle on the city's economy, it is to be expected that the CO_2 emissions produced will have a strong influence on the city's carbon footprint. Therefore, and with the aim of estimating emissions as accurately and thoroughly as possible, it is essential to know the vehicle fleet and, more specifically, the age and characteristics of the vehicles that make it up.

VEHICLE FLEET CHARACTERIZATION

In table 5, shows the composition of the census of cars in the city of Valencia, classified according to current EURO regulations (DGT, 2017). The complete data of the registered fleet classified by type of vehicle and age can be found in the Annex. The composition of the vehicle fleet, if only the municipality of Valencia is taken into account, is very similar to that of the entire metropolitan area. Therefore, the same mix of vehicles will be used to do the calculations, regardless of their origin/destination.

Nevertheless, there is a difference between the **registered vehicle fleet** and **the active one**, since the number and characteristics of the cars that circulate daily in the city and its metropolitan area do not necessarily correspond to the total number of vehicles registered. In the case of the city of Barcelona, which is similar to Valencia, the average age of the vehicle fleet in circulation in 2009 was 5.5 years, while the average age of the vehicle fleet in the census was up to 9 years, assuming that the person who uses the car frequently also renews it as soon as possible (Agència d'Energia de Barcelona, 2011).

So, a good methodology for measuring and monitoring the vehicle fleet would be to carry out representative samples using traffic cameras to read license plates in order to obtain the origin, type, brand and age of each vehicle and, therefore, the emission factors associated with each one.

Due to the lack or inaccessibility of these data for the city of Valencia, the real circulating park has been estimated by adjusting the data of the registered park with the data of daily journeys for the city of Valencia and its metropolitan area, from mobility surveys carried out in the Valencian Metropolitan Mobility Plan (PMoMe) and the Sustainable Urban Mobility Plan (SUMP, PMUS in Spain). The data extracted from these surveys can be found in the Annex.

The methodology for making this correction consists of counting the number of mechanised journeys per day (in a private vehicle) and classifying them according to their origin and destination, distinguishing between internal journeys and those ones with destination/origin outside the municipal limits of Valencia. Once this number of journeys is known, they were compared with the number of vehicles registered, eliminating the oldest vehicles from the fleet, under the premise of the PEQC that people who use their car frequently to travel tend to renew it more frequently.

Regulation	Age	Type of fuel					Total by
		Petrol	Diesel oil	Electricity	LPG	CNG	
PRE EURO	Antes 1990	38,374	3,070	1	-	-	41,445
	1990	1,352	260	-	-	-	1,612
	1991	1,296	226	-	-	-	1,522
	SUBTOTAL	41,022	3,556	1	0	0	44,579
Euro 1	1992	1,481	271	-	-	-	1,752
	1993	1,167	310	-	-	-	1,477
	1994	1,595	576	-	-	-	2,171
	1995	1,483	763	-	-	-	2,246
	SUBTOTAL	5,726	1,920	0	0	0	7,646
Euro 2	1996	1,893	1,280	-	-	-	3,173
	1997	2,429	1,910	-	-	-	4,339
	1998	3,577	3,163	-	-	-	6,740
	1999	5,166	5,116	-	-	-	10,282
	SUBTOTAL	13,065	11,469	0	0	0	24,534
Euro 3	2000	5,668	6,088	-	-	-	11,756
	2001	6,570	6,990	-	-	-	13,560
	2002	6,302	7,910	-	-	-	14,212
	2003	7,012	10,176	-	-	-	17,188
	2004	7,822	13,275	-	-	-	21,097
	SUBTOTAL	33,374	44,439	0	0	0	77,813
Euro 4	2005	8,278	14,406	-	-	-	22,684
	2006	8,349	14,545	-	-	-	22,894
	2007	7,916	14,332	-	-	-	22,248
	2008	5,591	10,143	-	-	-	15,734
	2009	5,214	9,886	-	-	-	15,100
	SUBTOTAL	35,348	63,312	0	0	0	98,660
Euro 5	2010	4,457	9,360	-	-	-	13,817
	2011	3,659	6,981	3	1	-	10,644
	2012	3,428	6,137	1	2	-	9,568
	2013	3,896	6,311	4	7	-	10,218
	2014	4,792	7,340	5	16	1	12,154
	SUBTOTAL	20,232	36,129	13	26	1	56,401
Euro 6	2015	6,750	8,280	17	16	3	15,066
	2016	8,334	8,272	20	7	2	16,635
	SUBTOTAL	15,084	16,552	37	23	5	31,701
Euro 6 (2017-2019)	2017	9,563	6,534	72	44	13	16,226
	2018	-	-	-	-	-	-
	2019	-	-	-	-	-	-
	SUBTOTAL	9,563	6,534	72	44	13	16,226
TOTAL		**173,414**	**183,911**	**123**	**93**	**19**	**357,560**

Table 5. Census of tourisms in Valencia
Source: DGT (December 2017)

Figure 16 shows the relationship as a percentage between the number of registered cars and the estimated number of active cars in circulation in 2018. The results indicate that the average age would be 12.85 and 9.68 years, respectively. The complete results can be found in the Annex.

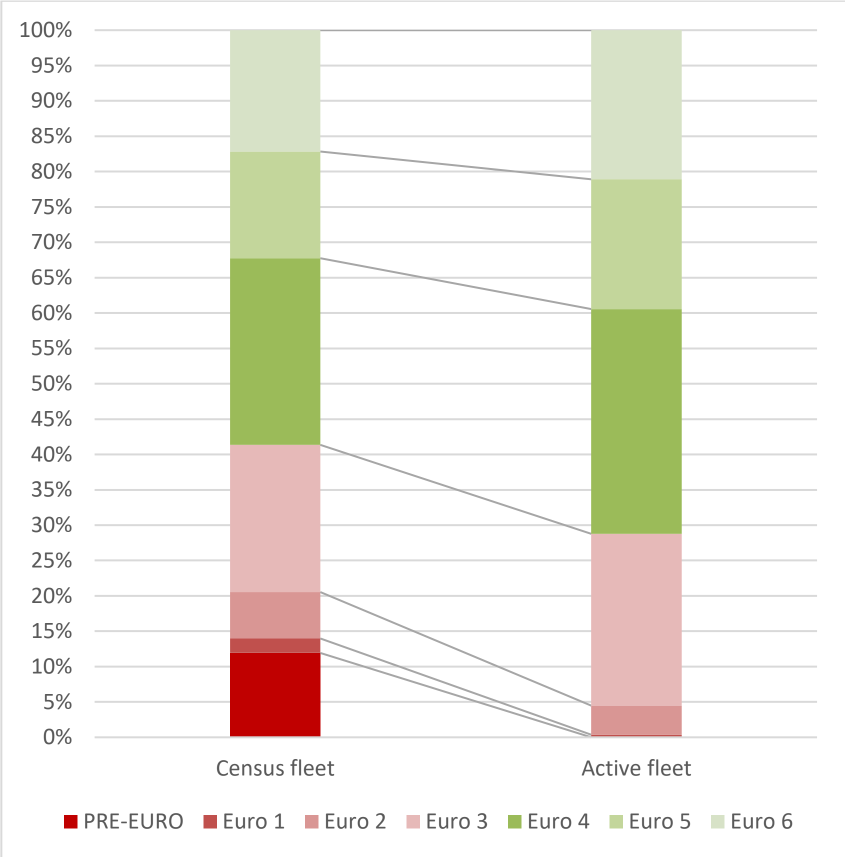


Figure 16. Comparison between the census fleet and the active fleet, according to Euro regulations (2018)

CALCULATION OF EMISSIONS: SOFTWARE USED

Once the actual number of active cars in the municipality of Valencia is estimated, the CO_2 emissions generated each year are calculated.

The COPERT 5.2 software, specialized in the calculation of local emissions in transport and air quality, has been used to calculate the emissions. The main reasons for its use have been:

- Free license for university research work.
- Simple and intuitive design, usable for both complex works and simple calculations.
- Large breakdown of results and possibility of data processing.

The input data used by the program are as follows:

- Weather conditions in the area.

The climatic conditions for the city of Valencia were obtained from the software Climate Consultant - Energy Tools.

- *Stock of vehicles, by type and euro regulations*.

The stock of vehicles corresponds to the active fleet that is estimated.

- Average distance travelled annually, by type and euro regulations.

The average distances travelled by vehicle type and age, in kilometres per year, are shown in table 6:

Vehicle Type / Age	Buses	Trucks > 3500	Trucks < 3500	Vans	Tourisms	Motorcycles
0 – 4 years	81,082	119,559	26,278	30,251	19,689	4,656
5 – 9 years	62,329	77,045	19,017	22,460	15,301	3,243
10 – 14 years	47,808	46,438	15,623	14,968	12,399	2,867
15 – 19 years	35,705	29,509	12,898	11,010	10,532	2,462
> 20 years	24,867	16,923	11,153	8,780	8,472	1,698
Average	52,951	47,543	14,844	14,467	12,266	2,903

Table 6. Statistics on kilometres travelled by type of vehicle and age
Source: http://www.dgt.es/es/seguridad-vial/estadisticas-e-indicadores/publicaciones/infografias/analisis-km-itv.shtml

- Displacement situations (fluid traffic in the city, dense traffic, highway, etc.).
- Average circulation speeds, associated with the previous point.

Both points were estimated based on average travel distances (within Valencia, from Valencia to the most important adjacent municipalities and vice versa), data on the sections and time in situations of poor traffic flow and speed limits by type of road.

- Emission factors, associated with the distance travelled by each vehicle (g/km).

The default factors used by the program have been used, since each vehicle is assigned to an emission factor according to its type and age.

RESULTS

Once all the necessary input parameters are entered, the emissions corresponding to the circulating fleet are calculated. The results calculated by the program can be exported to tables in Excel .xls format.

Although the programme calculates emissions of all types of GHGs, only energy consumed and CO_2 emitted were considered as shown in tables 7 and 8 respectively, broken down into type of vehicle, fuel used and extent of emissions. It is interesting to analyse the scope 3 emissions, i.e. the emissions from journeys with origin/destination outside the municipal limits of Valencia, as they make up a third of the city's total emissions in terms of private mobility.

ENERGY (MWh)				
Vehicle Type	**Fuel**	**Scope 1**	**Scope 3**	**TOTAL**
Tourisms	Petrol	1,375,500.34	620,463.88	1,995,964.22
	Diesel oil	1,402,423.69	733,939.01	2,136,362.70
Light Transport	Petrol	57,927.96	23,977.33	81,905.29
	Diesel oil	405,212.64	233,167.74	638,380.38
Motorcycles	Petrol	52,293.32	27,559.06	79,852.38
		3,293,357.94	**1,639,107.03**	**4,932,464.97**
	TOTAL Petrol	**1,485,721.61**	**672,000.28**	**2,157,721.89**
	TOTAL Diesel oil	**1,807,636.32**	**967,106.76**	**2,774,743.08**

Table 7. Energy consumed in private and commercial transport (2018). Data exported from COPERT 5.2

EMISSIONS (tCO_2)				
Vehicle Type	**Fuel**	**Scope 1**	**Scope 3**	**TOTAL**
Tourisms	Petrol	357,934.14	161,567.45	519,501.60
	Diesel oil	376,774.56	197,211.03	573,985.59
Light Transport	Petrol	15,067.15	6,241.23	21,308.38
	Diesel oil	108,797.56	62,600.53	171,398.10
Motorcycles	Petrol	13,643.75	7,155.87	20,799.62
		872,217.17	**434,776.11**	**1,306,993.28**
	TOTAL Petrol	**386,645.05**	**174,964.55**	**561,609.60**
	TOTAL Diesel oil	**485,572.12**	**259,811.56**	**745,383.68**

Table 8. CO_2 emissions from private and commercial transport (2018). Data exported from COPERT 5.2

3.2.3. Expansion of the inventory: port

The port of Valencia is one of the most important ports on the Mediterranean coast, as it is among the 30 most important commercial ports in the world according to the United Nations (Valenciaport [APV], 2019). Given this importance in the city's economy, it is to be expected that its impact on the carbon footprint will be significant and, therefore, it is appropriate to include the port's activities in the city's carbon inventory, with the aim of providing information to the City Council and the port itself to develop its policies and improvements in the face of climate change (Villalba G. and Gemechu E., 2011). Among the GHG emitting activities included in the port, the entire supply chain can be considered, from the use of fossil fuels for the movement of ships, through the loading and unloading of containers, to the electricity and fuel consumption of offices and vehicles operating within the port (Martínez-Moya J. et al., 2019).

For data acquisition, the port of Valencia has a GHG emissions report that is updated every year, developed by the Port Authority of Valencia (PAV) (APV, 2016). In this document you can find the volumes of goods (in tonnes), broken down into type of goods and the emissions associated with the port activity, classified into scope 1, 2 and 3.

Scope 1 considers the direct emissions derived from the fuel consumption of the PAV's own vehicle fleet, and distinguishes between petrol and diesel.

Scope 2 considers the indirect emissions derived from the electrical consumption of the port's activities (lighting and power, air conditioning and lighting of port roads).

Scope 3 considers the direct and indirect emissions of the PAV's concessionary companies, as well as those derived from the transport of goods **within the port area** and associated with the cargo ships that call at the port of Valencia.

The following emissions were excluded from the inventory:

- New constructions, installations, and states of emergency, due to their punctual nature.
- Workers' mobility emissions to their workplaces (covered by the private mobility point).

Given that the methodology used by the PAV takes into account all the scopes of emissions and includes a large part of the emitting sources within the limits of the study, coinciding with the methodology followed in this study, the data in the report will be used directly, extrapolated for 2018 in accordance with the trend shown in recent years.

RESULTS

Figure 17 shows the historical progression of emissions and energy associated with the activity of the port, placing 2008 as the base case. Due to the financial crisis, it was possible to observe a decrease in emissions linked to the reduction of activity. However, the trend from 2015 onwards is one of a continuous increase in emissions due to economic recovery and the growth of port activity.

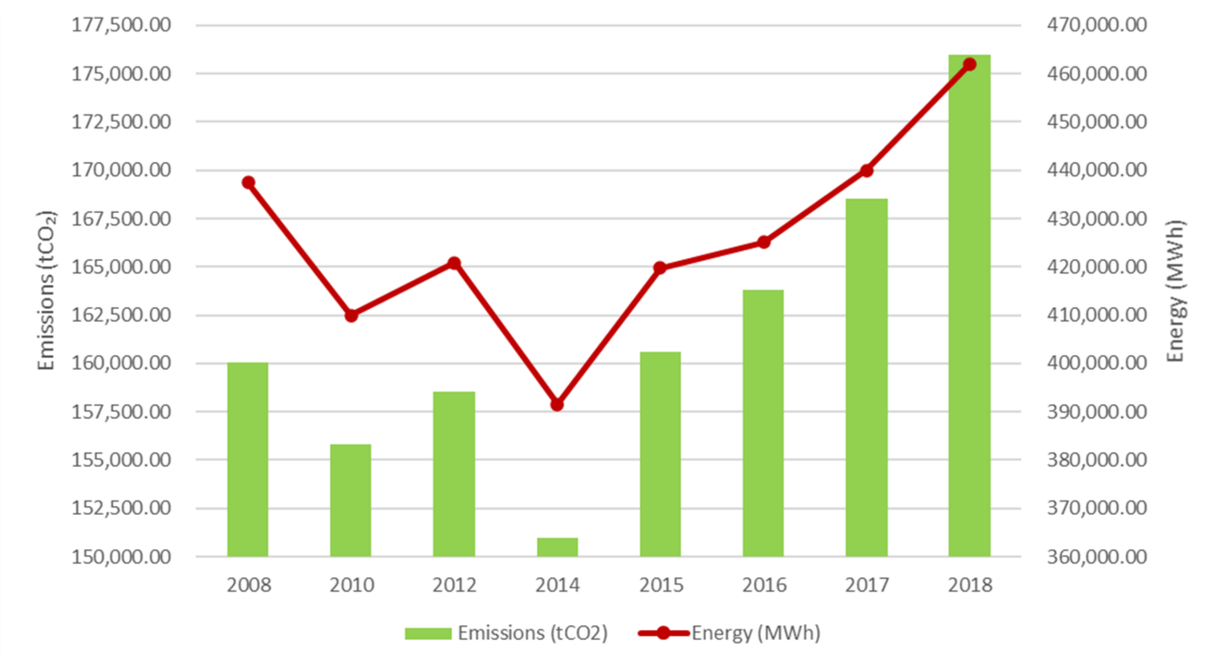


Figure 17. Historical evolution of energy consumption and CO_2 emissions from port activity in Valencia (2008–2016, 2017–2018* extrapolated)

The vast majority (98%) of the total emissions recorded by the port, are allocated to scope 3. Figure 18 shows the composition of the emissions of this scope, where the most part of the port emissions comes from the fuel consumption of both the ships calling and the machines and vehicles used to load/unload and transport the goods.

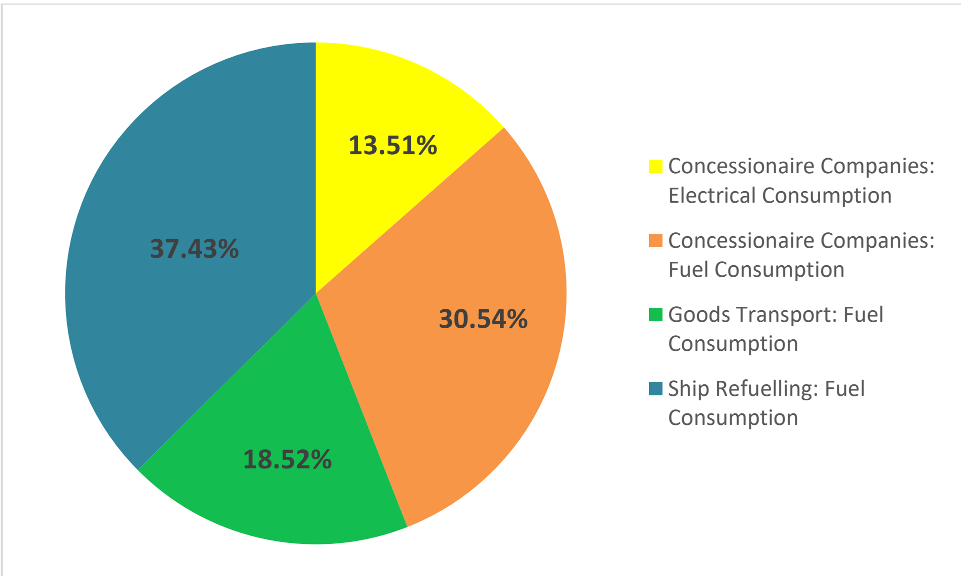


Figure 18. Decomposition of scope 3 port CO_2 emissions (2018)

3.2.4. Expansion of the inventory: airport

As with the port, the airport of Valencia is one of the most important airports in the country nowadays. Although it is located between the municipalities of Manises and Quart de Poblet, it can be associated with the city of Valencia, as this is the main destination for personal and commercial flights.

The managing company of the airport is AENA and, according to its statistical report on air traffic (AENA, 2019-A), in 2019 Valencia airport was the eighth national airport with the highest number of passengers, reaching 8.5 million, and the sixth in terms of goods, reflecting the importance of this airport in national and international transport and trade.

The airport also has a compliance report with the Environmental Report, which is updated annually, also prepared by AENA (2019-B). This document provides information on the number of flights made, the number of passengers, goods, water and energy consumption and the amount of waste generated. It also includes carbon dioxide emissions broken down into scope 1, which considers the direct emissions derived from the consumption of fuel by the company's own vehicle fleet, and scope 2, which considers the indirect emissions derived from electricity consumption. However, this report does not include the emissions derived from scope 3.

Likewise, another document on its website provides data on the total CO_2 emissions of each airport, which also includes scope 3 emissions (AENA, 2019-C). Therefore, once the variation in emissions between 2017 and 2018, the total emissions (including the three scopes for 2017), and the emissions broken down into scopes 1 and 2 for 2018 are known, the scope 3 emissions for the year 2018 are obtained.

Since the airport's environmental reports use a similar methodology to this study and it was possible to disaggregate the emissions by scope, it was not necessary to add data from other sources.

RESULTS

Figure 19 shows the historical progression of emissions and energy associated with the activity of the airport; whose baseline year is 2008. Figure 20 shows that the most part of emissions (89%) comes from the direct and indirect consumption of aircraft fuels (scope 3). It should be noted that energy consumption and emissions continue to rise due to the increase in activity, registering an increase of 2.01% in 2018 compared to 2017. However, if energy consumption per passenger is taken into account, it decreases by 11.44% compared to 2017 due to energy saving improvements in lighting and air conditioning and the increase in the number of passengers per flight.

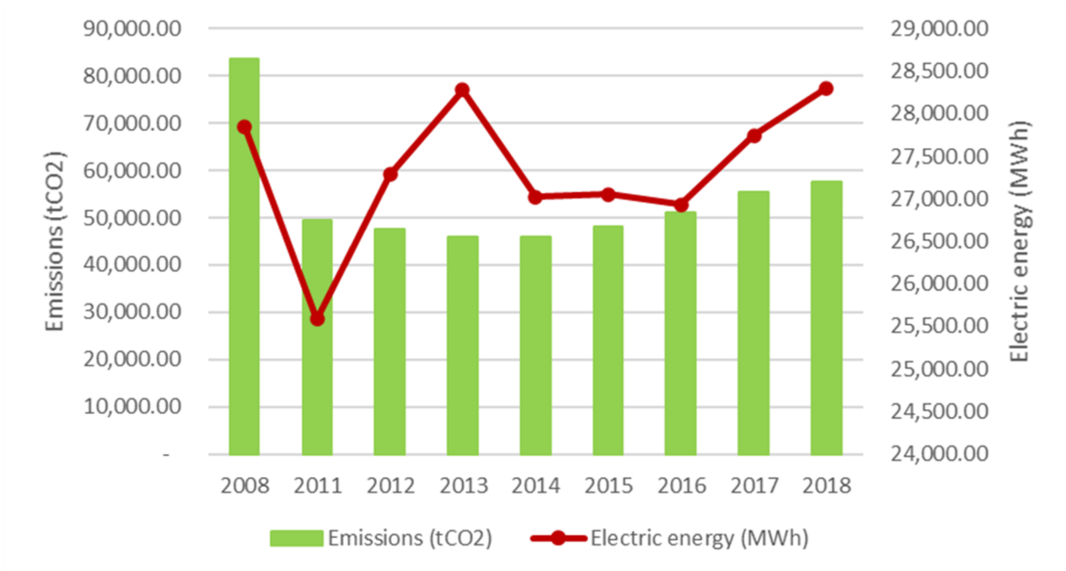
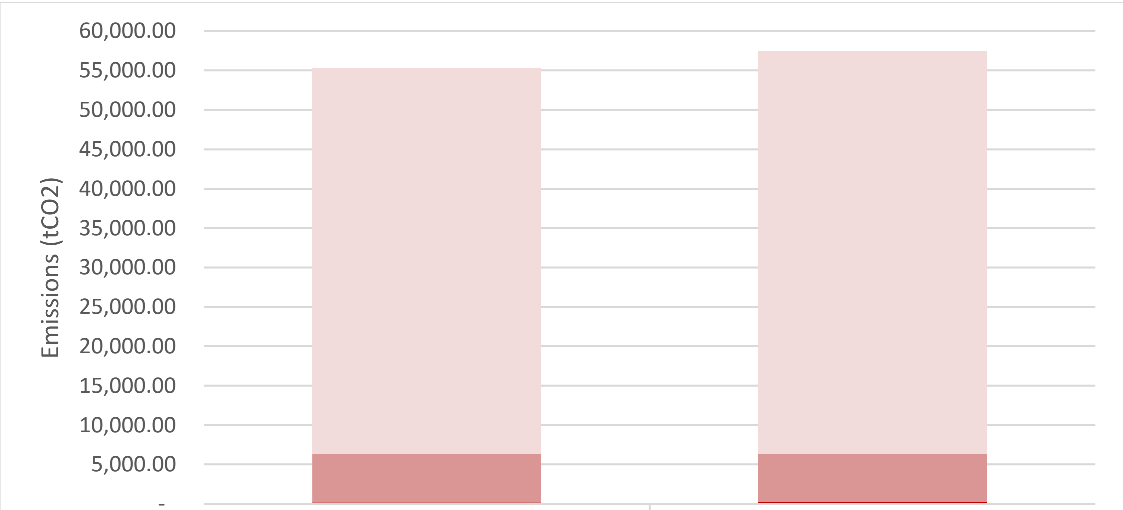


Figure 19. Historical evolution of energy consumption and CO_2 emissions from airport activity (2008-2018)



	2017	2018
Scope 3	48,930.67	51,098.59
Scope 2	6,236.88	6,193.53
Scope 1	175.45	213.00

Figure 20. Composition of airport CO_2 emissions by scope

3.2.5. Expansion of the inventory: consumption of goods

According to (Isman M. et al., 2018), the ecological footprint can be classified into three categories: household consumption, government dependent consumption and investments in infrastructure and buildings, representing 56%, 13% and 31% respectively of their ecological footprint and, by extension, their carbon footprint.

This study of 15 Canadian cities has been taken as a reference since the population of each one has been considered, and the population of Valencia is very similar to some of these cities such as Vancouver, Edmonton or, the capital, Ottawa (675,000, 981,000 and 995,000 respectively). Furthermore, there is also a certain similarity at the economic and technological level.

If the first category 'household consumption' is broken down, as shown in figure 21, consumer goods (food, clothing, medicines, equipment, etc.) can represent between 17% and 40% of the city's carbon footprint (between 9.5% and 22.4% of the total, if the other two categories are taken into account). These percentages vary greatly depending on the characteristics of the city, with the cities with the largest populations occupying the highest percentages in these subcategories. However, if the carbon footprint is considered in absolute value, the cities in the study with the largest populations have a consumption of goods lower than average, which also indicates a certain degree of optimisation (recycling system, good infrastructure, etc.)

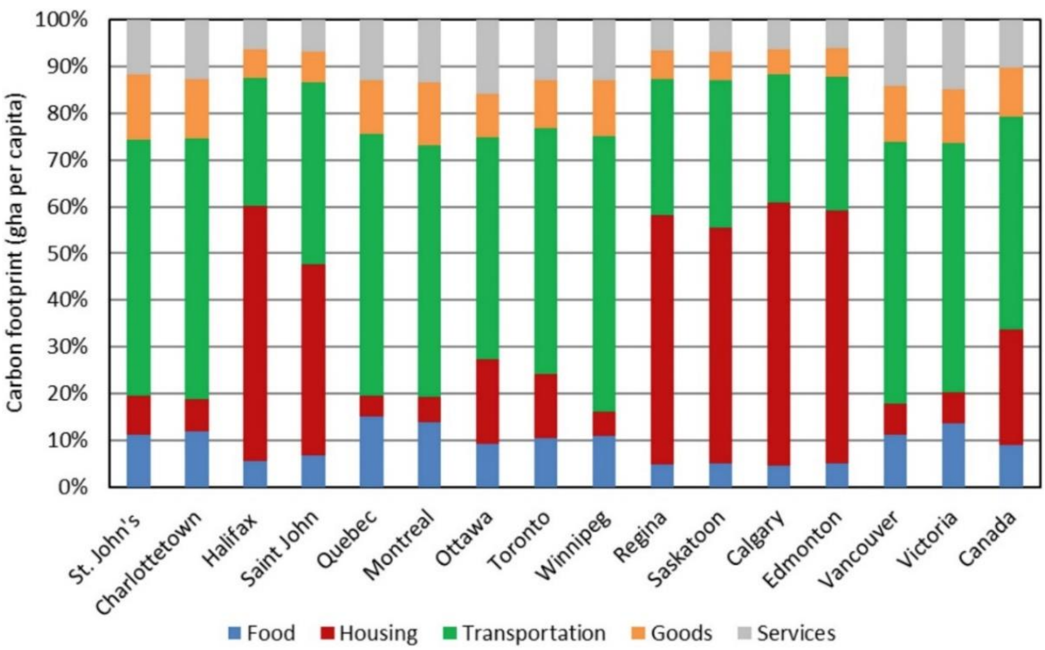


Figure 21. Carbon footprint (in percentage) by consumption area for 15 Canadian cities (average between 2010–2015) Source: (Isman M. et al., 2018)

On the one hand, when looking in detail at the carbon footprint of the food subcategory, food represents approximately between 80 to 90% of the footprint, with the remaining percentage divided between alcoholic and non-alcoholic beverages, as shown in figure 22.

On the other hand, as shown in figure 23, the consumption of goods is more spread out, with clothing having the most important impact (approximately 25-40% of the carbon footprint of this subcategory).

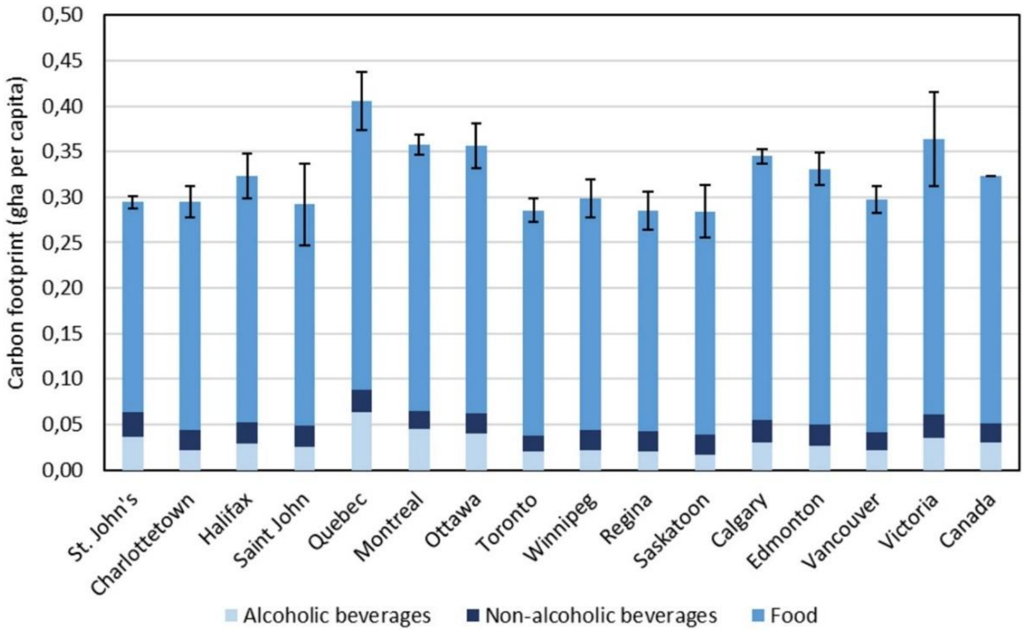


Figure 22. Carbon footprint of the subcategory 'food' for 15 Canadian cities (average between 2010–2015) Source: (Isman M. et al., 2018)

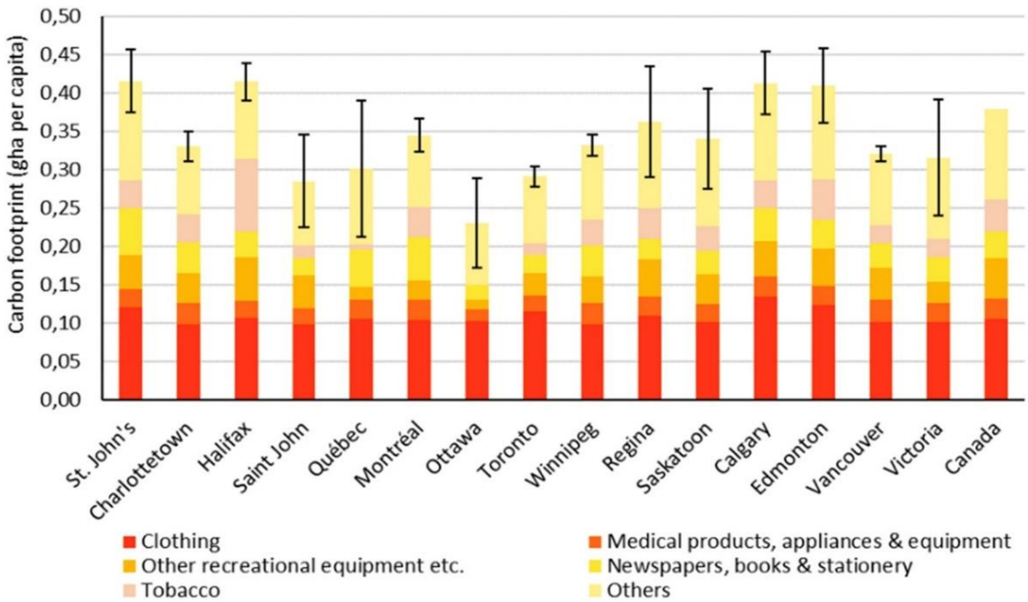


Figure 23. Carbon footprint of the subcategory 'consumer goods' for 15 Canadian cities (average between 2010–2015) Source: (Isman M. et al., 2018)

CARBON INVENTORY: FOOD

As observed, food has a significant impact on the carbon footprint of any city or country. According to (Galli A. et al., 2017), and as seen in figures 24 and 25, Spain produces more food than it consumes in terms of its ecological footprint, importing mainly cereals and fish and exporting vegetables and fruit. Due to this, the carbon footprint in relation to other countries must be lower since, the less food is imported, the greater number of emissions due to transport are avoided.

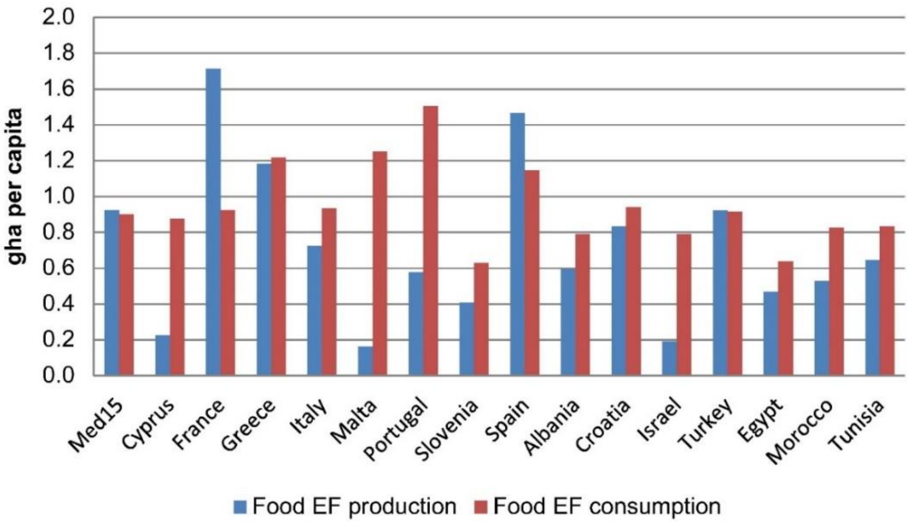


Figure 24. Ecological footprint and ecological production (in gha per inhabitant) of 15 Mediterranean countries (2010)
Source: (Galli A. et al., 2017)

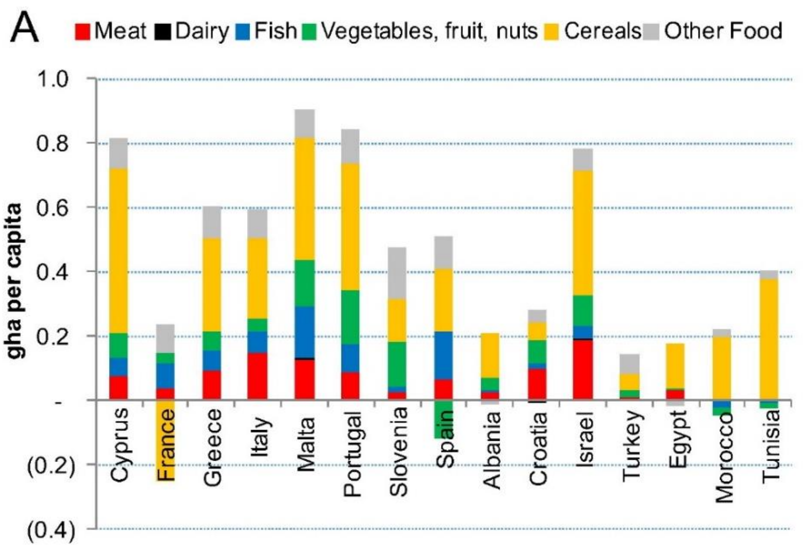


Figure 25. Ecological footprint resulting from net trade (in gha per inhabitant) of 15 Mediterranean countries (2010)
Source: (Galli A. et al., 2017)

In order to obtain a detailed carbon inventory for the city of Valencia, the equivalent emission factor has been calculated ($kgCO_2e/kg$ consumed). To do this, the mix of food consumed per year (kg/year) has been used for the Valencian Community, with the total for Spain and Valencia being 769 kg/hab and 786 kg/hab and year respectively (Ministerio de Agricultura, Pesca y Alimentación, 2019). Figure 26 represents the mix for each type of food for an average inhabitant of Valencia.

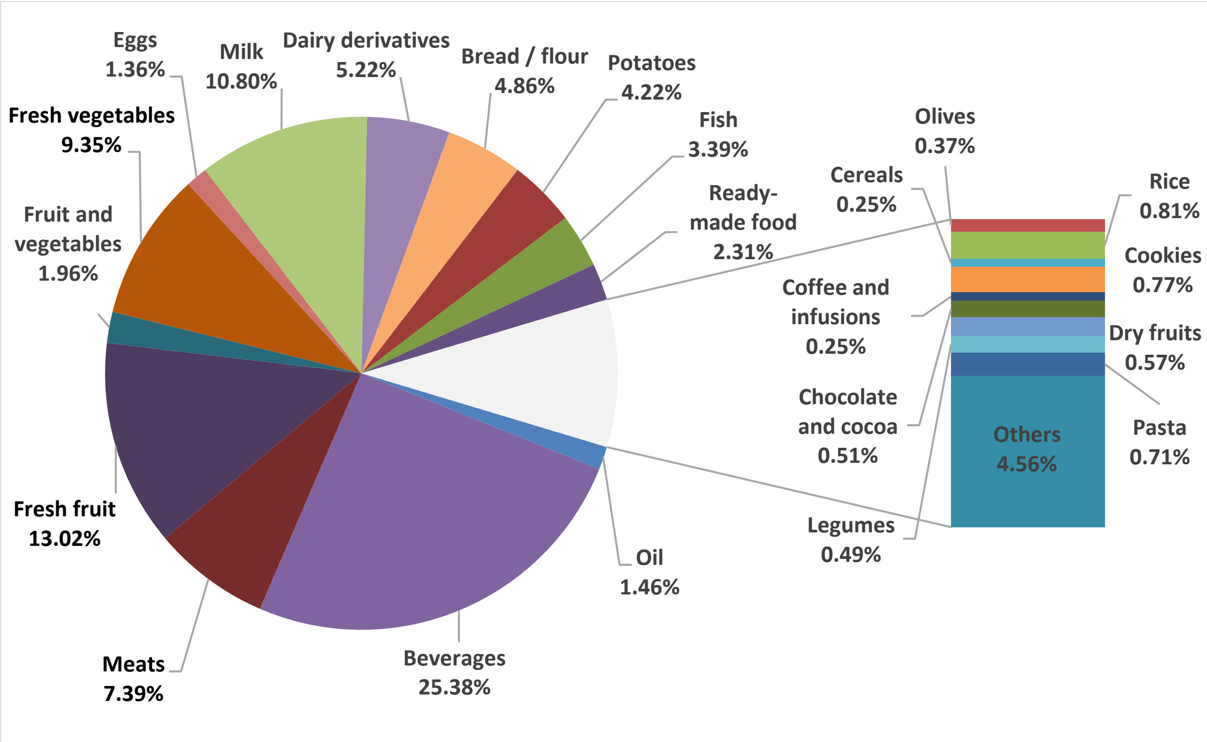


Figure 26. Average of food consumed in the Valencian Community (2018)

Each type of food, accounting for its cultivation/care, land use, transport, etc. has a different emission factor. Therefore, the equivalent emission factor calculated will be the result of the following expression:

$$FE_e = \frac{\sum(Kg_i * EF_i)}{Kg\ total}$$

The emission factors used for each type of food (Clune S. et al., 2017) (Segura M.A. and Andrade H.J., 2012) (Jern M., 2019) (Enguidanos Arroyo E. and Soler Rovira J., 2019) are included in table 23 of the Annex. The equivalent emission factor obtained, taking into account all the GHGs emitted during their entire life cycle, is 2.51 $kgCO_2e/kg$. Nevertheless, if only the emitted CO_2 is taken into account, this would represent an average of 41% of the total GHG emissions (Weiss F. and Leip A., 2012) resulting in an equivalent factor of **1.04 $kgCO_2/kg$ of food consumed**.

Considering the total amount of food consumed by each person per year and the population of the city, the carbon dioxide emissions are equivalent to **645,289.13 $tCO_2/year$.**

CARBON INVENTORY: CLOTHING

As with other consumer goods, throughout its life cycle, clothing makes a significant contribution to the city's carbon footprint. For a cotton garment, about 90% of total GHG emissions are indirect, coming from the raw material (36%) and the manufacturing process (57%). The remaining percentage comes from the transport of the final product and its use phase, and varies quite a bit depending on the country to which it is exported and the consumption and use patterns of the product (amount and mode of washing, lifespan, etc.) (Wang C. et al., 2015). As an example, figure 27 shows the GHG emissions resulting from the life cycle analysis for cotton garments.

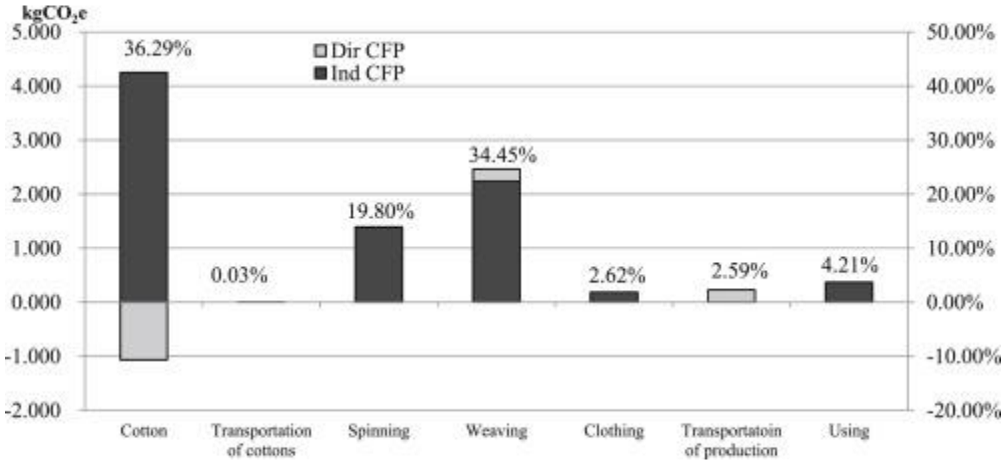


Figure 27. Life cycle assessment and GHG emissions from each process for cotton garments
Source: (Wang C. et al., 2015)

In Spain, textile consumption is estimated at between 12–18 kg of clothing per year and person (Pensupa N., 2020), around 565 euros per person and year, with the Valencian Community being the fourth largest community investing in fashion after Catalonia, Andalusia and Madrid (Ascunce A., 2019).

Similarly to the previous section, the equivalent emission factor is calculated from the emission factors of several types of clothes (Karthik T. and Murugan R., 2017) (Ecotricity, 2018) (Coppini M.V., 2017). These can be found in table 26 of the Annex.

The equivalent emission factor obtained, counting all the GHGs emitted during their entire life cycle, is 19.26 kgCO_2e/kg. If only carbon emissions are considered, they represent between 20 and 50% of total emissions depending on the type of garment (Karthik T. and Murugan R., 2017), giving an equivalent emission factor of **7.71 kgCO_2/kg of clothing**.

Since no data have been found on the average textile consumption of the Community of Valencia, and despite knowing that the Community of Valencia is the fourth Spanish Community that spends the most on clothing, the Spanish average will be used, even if emissions in this area are underestimated.

Thereby, by multiplying the average textile consumption by the number of inhabitants and the equivalent emission factor previously obtained, a quantity of **91,471.28 tCO_2/year is obtained**.

3.2.6. Expansion of the inventory: buildings and new constructions

The construction sector is often not included in carbon inventories. Nonetheless, its activity is one of the principal areas of environmental pollution. This growing impact is due to the consumption of non-renewable natural resources and energy consumption both for the extraction of these resources and for the transformation processes. The problem is further increased by the fact that only 10% of the waste generated in conventional construction is recycled or reused. In Spain, the construction and use of buildings can account for around 32% of non-renewable energy consumption, 30% of the generation of emissions from CO_2 and between 30 and 40% of the generation of solid waste (Wadel G. et al., 2010.). It is also important to monitor emissions in construction in order to propose and implement strategies to reduce their impact, whether through the use of sustainable materials with a lower ecological impact during their life cycle, materials with the possibility of reuse or passive air-conditioning and shading techniques to reduce the energy demand of buildings (Baño Nieva A. and Vigil-Escalera del Pozo A., 2005).

In order to account for emissions from the construction of buildings, several reports and studies calculated the equivalent emission factor per square metre built from the emission factors of the various materials used in the works. According to (Mercader M.P. et al., 2012), the estimated emission factor for the construction of conventional buildings is **694.16 kg CO_2/m²**.

For this study, two types of emissions by construction will be differentiated. This difference will be mainly between large buildings that need several months or years to be built, and which cause large amounts of direct and indirect emissions in the process, and smaller reforms that are less important in terms of pollution and emissions, but which are carried out more quickly and frequently:

a) Emissions from large buildings:

This first category encompasses all existing or newly constructed buildings characterized by varying altitudes with several floors and employees for residential, commercial, and service use mostly. The useful life of these buildings is considered to be about 50 years before the building is renovated or demolished and rebuilt.

According to other studies carried out in Spain on the carbon footprint, mainly in the university field, such as those mentioned in previous sections, the great impact produced at the time of construction will be distributed equally among all the years of its useful life.

The number of buildings constructed on urban land in the city of Valencia can be found in the Valencian Cadastre (Ayuntamiento de Valencia, 2019). Table 9 shows the number of buildings classified by type of activity, where the residential properties represent a 60.3% of the total properties registered in the city. The total built area of real estate in the city of Valencia on urban land amounts to 56,245,872 m².

Properties type use	Nº	%
Residential	410,159	60.33 %
Warehouse/Parking	213,987	31.47 %
Commercial	34,817	5.12 %
Offices	7,556	1.11 %
Industrial	5,218	0.77 %
Others (cultural, health, catering, religious, sports, etc.)	8,151	1.20 %
TOTAL	**679,888**	**100 %**

Table 9. Properties in the city of Valencia, classified by type of activity
Source: Catastro de bienes inmuebles de naturaleza urbana (junio 2019), Ayto. de Valencia

Considering the estimated emission factor per square meter for buildings and knowing the amount of square meters built in the city, if all the buildings had been built in the same year, there would have been produced an amount of carbon emissions equivalent to 39 million tons of CO_2, in other words, about 14.5% of the carbon emissions generated in Spain each year. Following the methodology of the studies mentioned above, this amount is divided into 50 years of useful life which is considered for the buildings, obtaining annual emissions of **780,872.68 tCO_2 for each year**.

b) Emissions of new reform:

This second category includes both public construction (repair of public roads and highways, repairs, etc.) and minor private reforms that do not alter the structure or composition of the buildings. These constructions are characterised by their small size compared to large buildings and by their sporadic nature (no specific lifetime has been established, ranging from 2 to 15 years, as these repairs and alterations are usually carried out every few years when the work in question requires maintenance). Therefore, emissions from this type will be accounted for in the same year in which they occur instead of taking into account their useful life.

Since the emission factor mentioned above is associated with the construction of large buildings, a different equivalent factor will be used for this type of constructionss in terms of the amount of money invested in it. According to (MITECO, 2018), the emission factor associated with this category is **0.136 kg CO_2/€ invested**.

According to Valencia City Council's Municipal Budget for 2018 (Ayuntamiento de Valencia, 2018), the Housing and Town Planning section has a total of 41.04 million Euros, of which 30.76 million Euros are for Town Planning, 4.61 for Public Roads and 5.43 for Housing.

If the emission factor for these constructions is applied based on the budget established for the Housing and Urban Development section of Valencia, the emissions obtained for 2018 for this type of work amount to **5,581.44 tCO_2**.

3.3. EXPANDED CARBON INVENTORY

The main objective of this work is to calculate the carbon footprint of the city of Valencia in the most detailed way possible. Therefore, it is necessary to carry out a previous carbon inventory, disaggregated by sectors, and with as much information as possible. The result sought is consequently the **extended carbon inventory**, calculated for the year 2018.

The extended carbon inventory is the update of the SECAP inventory for the year 2018 as well as adding the different proposals for improvements described in this study, which include updating the methodology of some areas, adding new areas such as the port or airport and classifying emissions by scope of emission.

Figures 28–31 show the total emissions of the municipality of Valencia broken down into fields, areas dependent on the City Council, scope of emission and emission sources, respectively.

For more information, the table with the complete results can be found in the Annex.

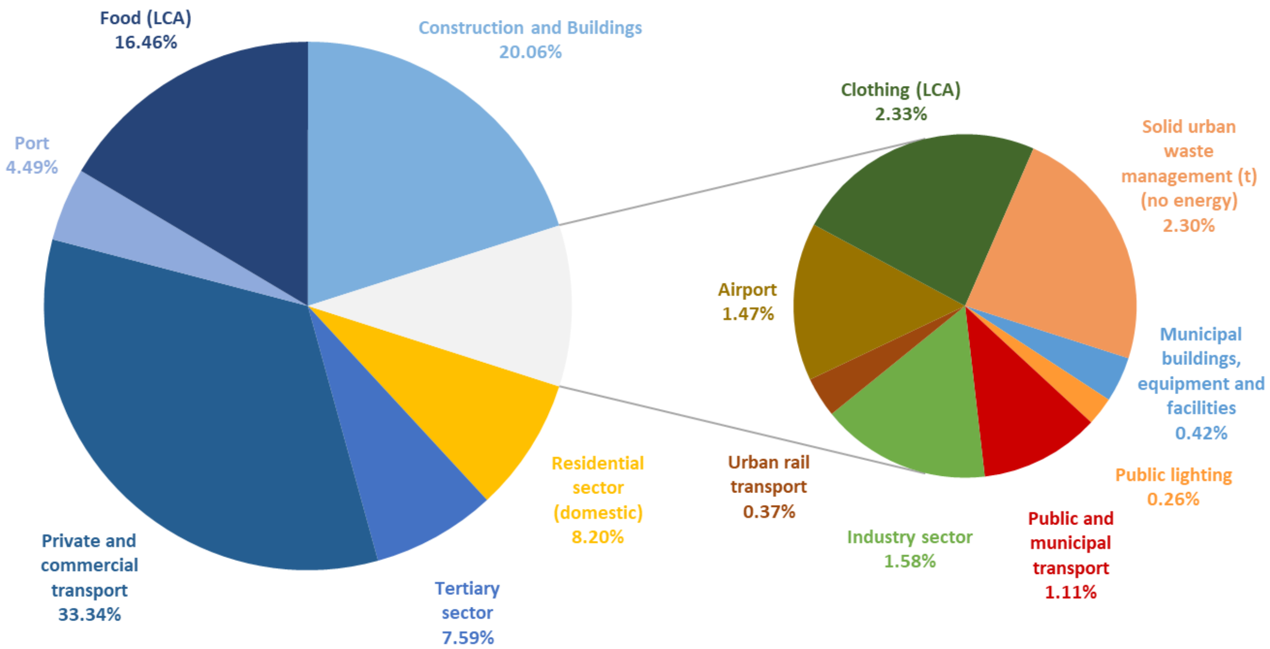


Figure 28. Distribution of CO_2 emissions by fields, municipality of Valencia (2018)

Figure 28 shows that one third of the city's emissions come from transport fuel consumption. The next most influential fields are the impact produced by the building construction and the food consumption. The residential and service sectors account for 8.2% and 7.6% respectively, while the industrial sector is not very influential, as discussed above. It should also be noted that the areas dependent on the City Council (public lighting, public and municipal transport, and municipal buildings) only represent 1.8% of total emissions (figure 29).

Regarding the scope of emissions, figure 30 shows that scope 3 emissions are responsible for more than half of the total annual emissions in Valencia, while scope 1 emissions represent about one third of the total emissions. When observing scope 1 in detail, this importance comes mainly from two emission sources: fuel consumption within municipal limits and natural gas consumption in air conditioning systems in the different sectors. On the other hand, scope 3 emissions include a greater number of sources: consumption of food and clothing, transport of goods to and from the city of Valencia or emissions due to the construction of buildings (including the extraction of materials, transformation processes, etc.), among others.

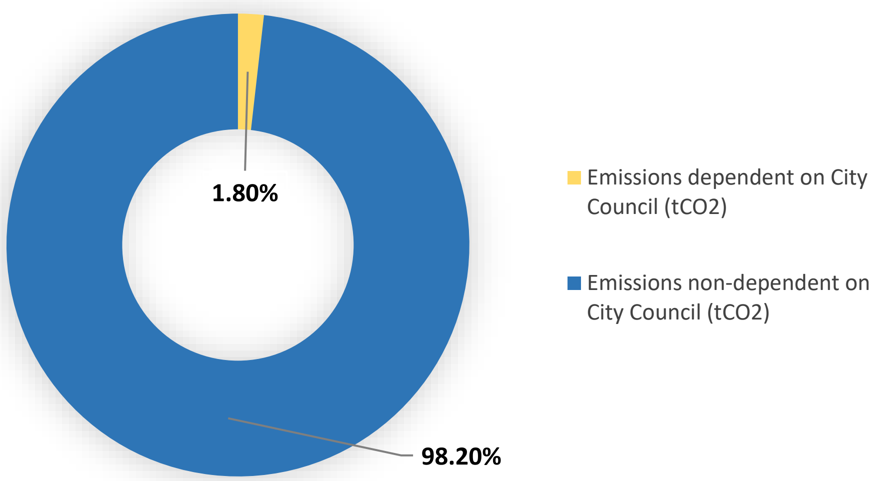


Figure 29. Distribution of CO_2 emissions by dependent and non-dependent areas of the City Council, municipality of Valencia (2018)

In terms of energy, electricity consumption in all sectors (indirect scope 2 emissions) represents 13.65% of total emissions. This fact shows one of the key points where a sustainable energy transition must focus its actions and efforts, mainly by increasing the renewable contribution to the electricity mix, and extending its use in all areas with the aim of reducing the large consumption of fossil fuels that predominates today in most cities and developed countries.

Finally, it is important to highlight the importance of incorporating the life cycle analysis in all sectors, since, as can be seen in figure 31, when all improvement proposals are included in the inventory the categories of food, clothing and building construction represent a 39% of the total emission in the city of Valencia, which are too important to be left out of the inventory.

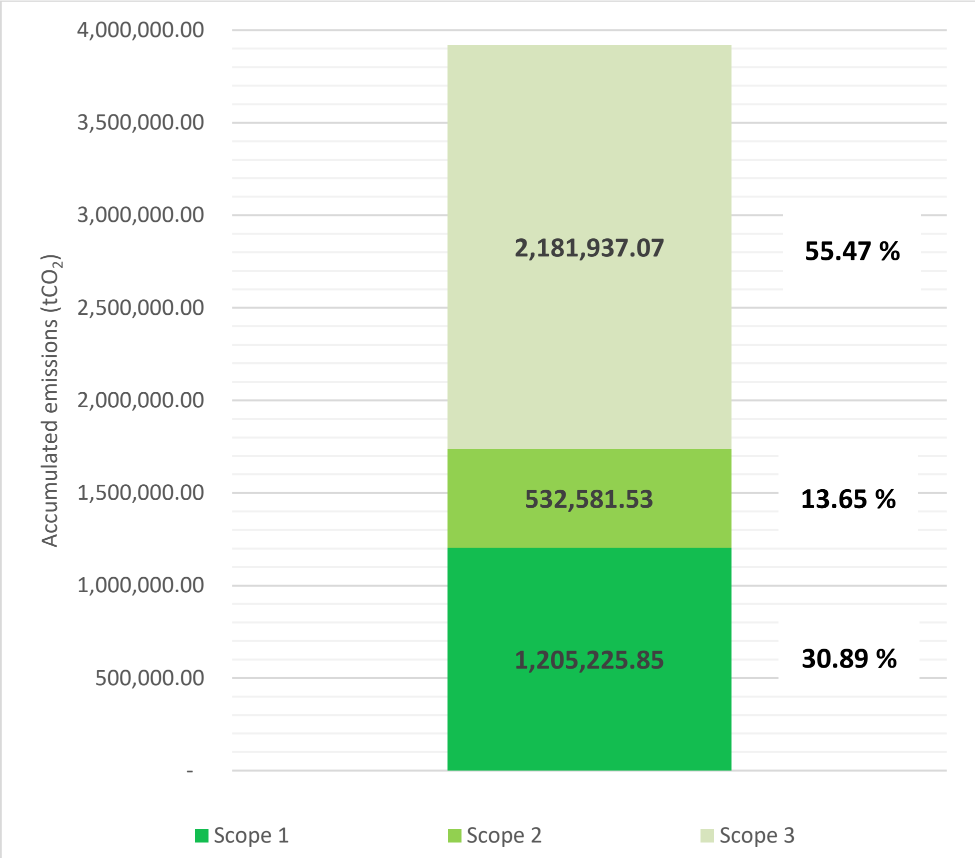


Figure 30. Accumulated CO_2 emissions by scope, municipality of Valencia (2018)

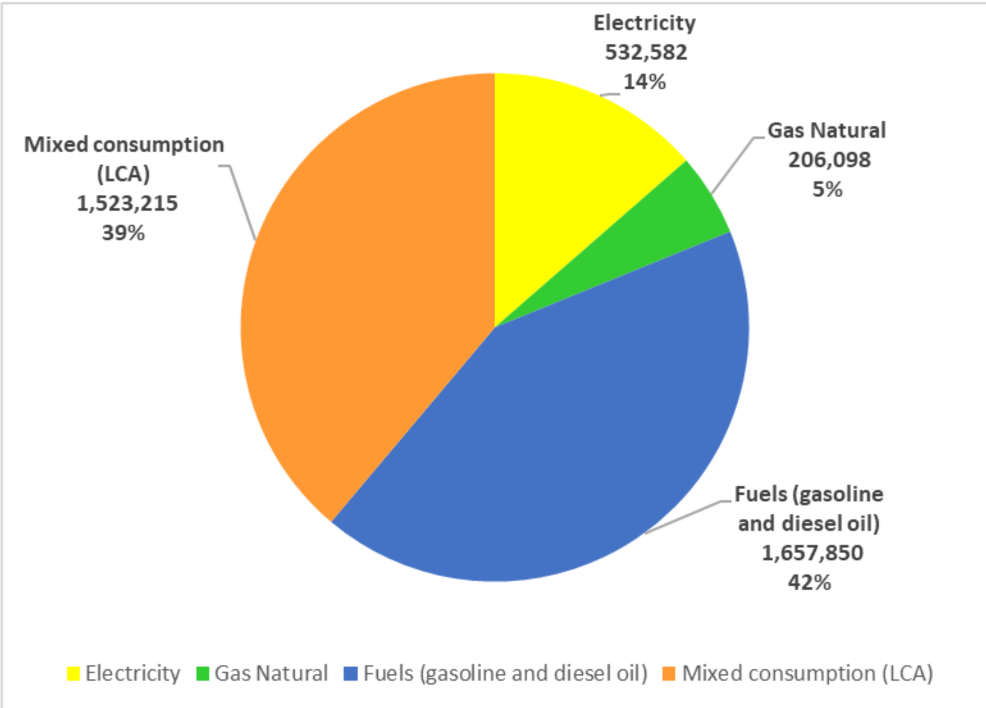


Figure 31. Distribution of CO_2 emissions by energy sources, municipality of Valencia (2018)

3.4. BENCHMARKING

Once the extended carbon inventory has been carried out, it will be compared with the original SECAP inventory of 2016 and its update for 2018, in order to know the changes that would imply incorporating the improvement proposals of this study in future updates of this energy plan.

Firstly, figure 32 shows an increase of 13% in carbon emissions in 2018 compared to 2016, just by updating the data without including any improvement proposal. The SECAP methodology was kept for the fields whose data come from the City Council's yearbook, so the emissions data are the same updated for 2018. Nevertheless, once the proposals to improve the extended inventory are included, it can be seen how the city's emissions increase considerably (105% compared to 2016 and 81% compared to 2018).

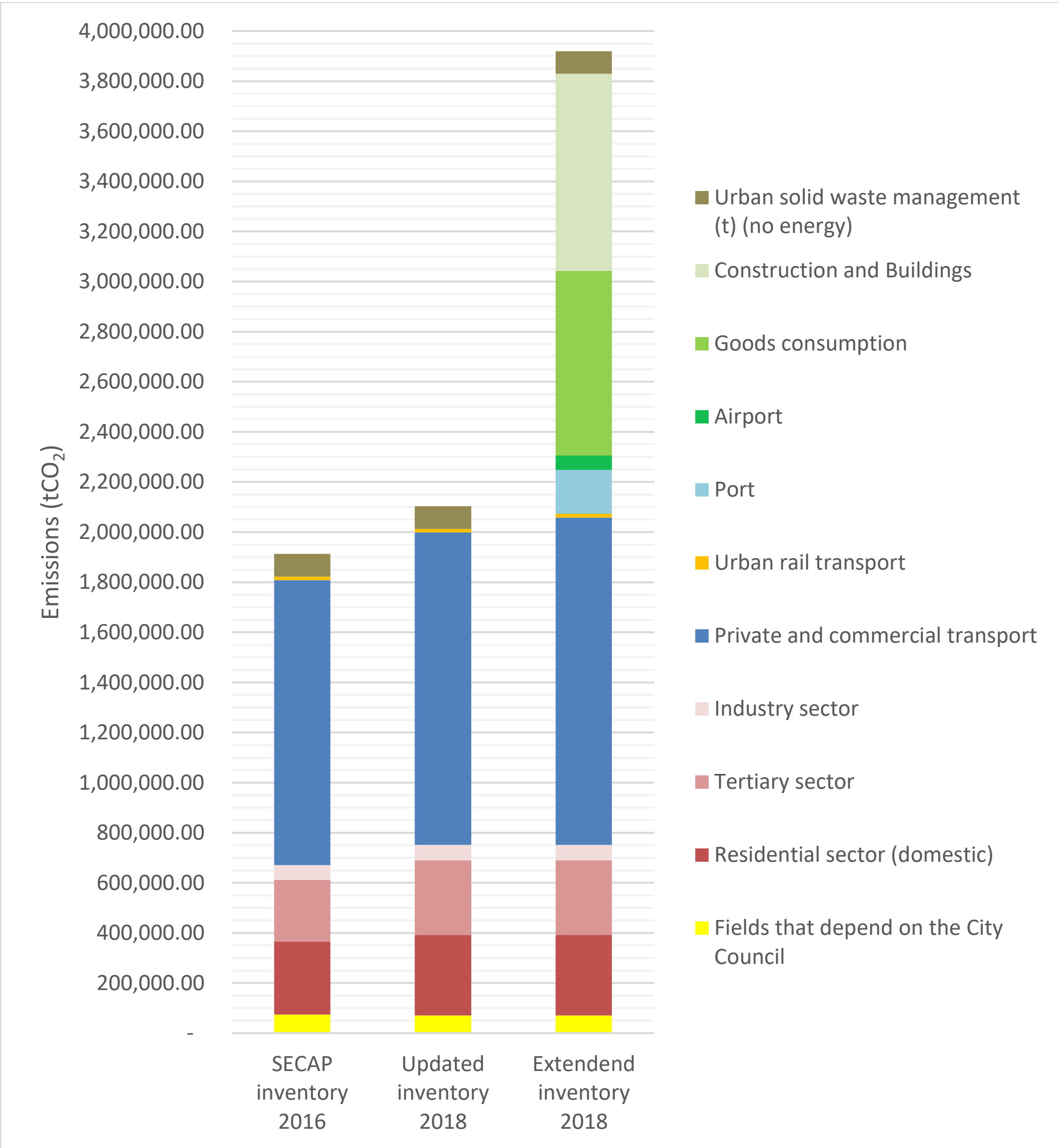


Figure 32. Accumulated CO_2 emissions of the municipality of Valencia. Comparison between SECAP inventory (2016), updated inventory (2018) and own extended inventory (2018)

Regarding the areas under the responsibility of the City Council, figure 33 shows that CO_2 emissions have been reduced by 6% compared to 2016, mainly driven by measures to replace conventional street lighting with high efficiency LED lighting during this period of time.

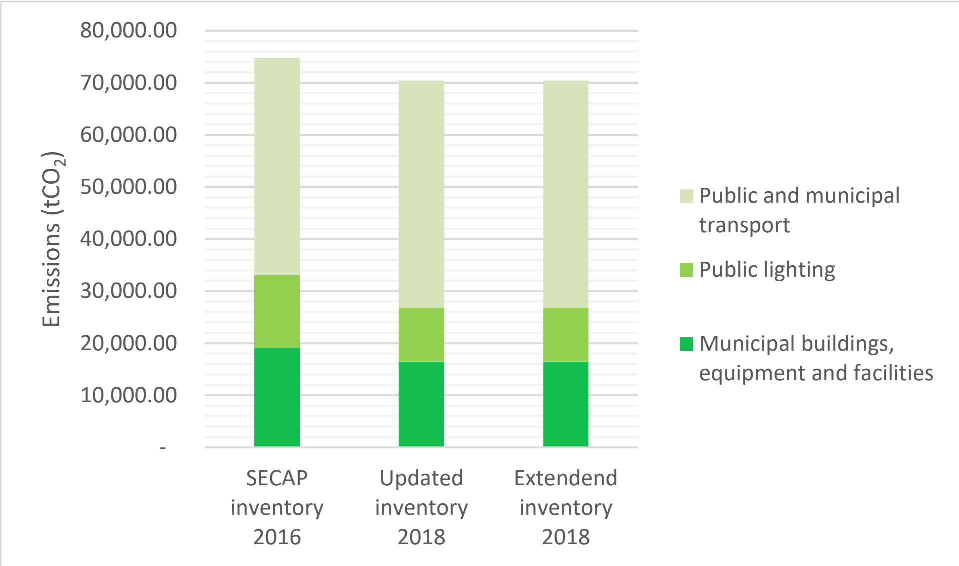


Figure 33. Accumulated CO_2 emissions, dependent on the City Council. Comparison between SECAP inventory (2016), updated inventory (2018) and own extended inventory (2018)

In addition, the residential, service and industrial sectors have increased their emissions by 9.5%, 17.5% and 3.5% respectively compared to year 2016, due to the increase in activity in these years, reversing the downward trend that had occurred in 2015 and 2016.

Figure 34. Accumulated CO_2 emissions by sectors: residential, services and industry. Comparison between SECAP inventory (2016), updated inventory (2018) and own extended inventory (2018)

Continuing with private and commercial transport, a significant difference in results was to be expected when employing a different calculation methodology. In terms of total emissions, the difference in results can be justified by the increase in daily journeys between these two years and, by extension, the consumption of petrol and diesel, so in the first instance both methodologies offer similar results and can be compared with each other. However, by means of the new methodology based on the circulating fleet, it was obtained that the consumption of diesel and petrol are similar, while, for 2016, the results indicate that the predominant fuel is diesel, with petrol consumption being several times lower. The reason for this may be the methodology used for the SECAP inventory which, as mentioned in previous sections, it is possible that a large number of the petrol vehicles that circulate in Valencia day by day refuel outside the limits of the inventory and are therefore not included in the carbon inventory.

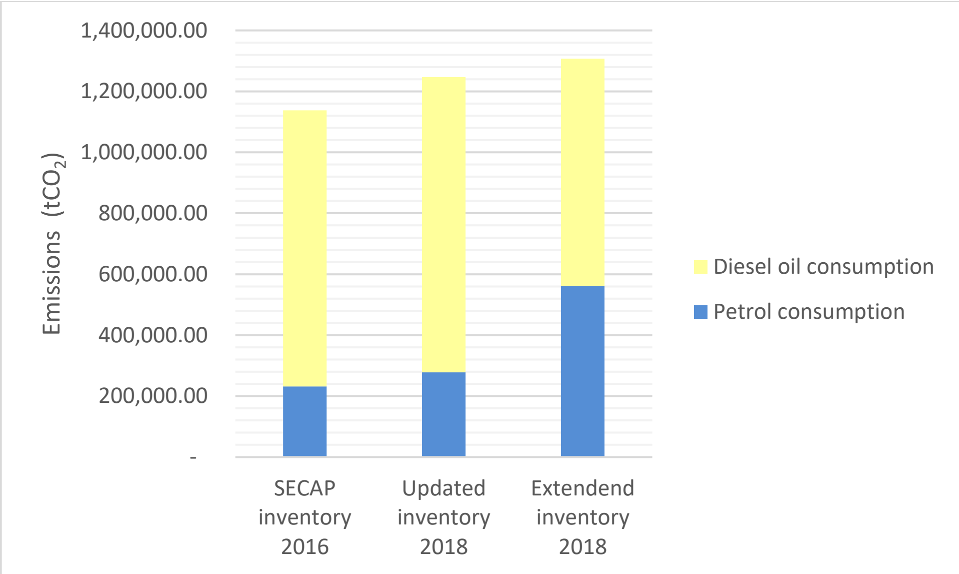


Figure 35. Accumulated CO_2 emissions, derived from the consumption of fuel in transport, from the municipality of Valencia. Comparison between SECAP inventory (2016), updated inventory (2018) and own extended inventory (2018)

Another aspect to highlight of the extended inventory is the classification of emissions by scope, differentiating which emissions are produced every day in the city and which come from external services or actions. This can be a good tool in decision-making since it is generally easier to act in areas that generate emissions in the city itself.

Finally, it should be noted that by year 2018, the extension of the inventory with those fields which are not included in the SECAP represents **an increase of 81% in the city's total emissions, as it reaches 3.92 million tonnes of CO_2 per year**, half of which comes from outside the city limits, but is the consequence of activities, services or travel required by the city of Valencia (scope 3).

CHAPTER 4. CARBON FOOTPRINT AND OVERSHOOT DAY

4.1. CARBON FOOTPRINT

4.1.1. Methodology

The **Bottom Up methodology** described in the methodology section of this document will be used to calculate the carbon footprint, i.e. based on the sum of the emissions from different sources. This method is the most widespread in Spain, specifically in other studies carried out in various universities in the country, including the Polytechnic University of Valencia (UPV) and the University of Valencia (UV), previously mentioned in section 2.2.

Taking advantage of the extended carbon inventory made in the prior section, these emissions will be used to calculate the following carbon footprint indicators: **local hectares (ha), local hectares per inhabitant (ha/hab), global hectares (gha) and global hectares per inhabitant (gha/hab).**

The carbon footprint expressed in **local hectares of forest** indicates the area of forest, in this case Mediterranean forest, that would be needed to capture the total CO_2 emitted each year by the city. The Mediterranean forest fixing capacity coefficient will be used in order to convert the tons of CO_2 obtained in the inventory into local hectares.

The fixing capacity varies according to the vegetation characteristics of the area. Different coefficients have been found in the literature, such as the Leonese forest (4.04 tCO_2/ha and year) (Hernández et al., 2014) and the Mediterranean forest (3.7 tCO_2/ha and year) (Tello E., 1999). Given that Valencia surroundings are considered Mediterranean, the latter will be used to calculate the carbon footprint.

The carbon footprint expressed in global hectares is another similar indicator that, unlike local hectares, considers the carbon sequestration capacity of all the world's forests, not just the local one. This indicator is interesting when comparing the results with other studies from other cities around the world. The conversion coefficient 1.29 $gha/ha_{local\ forest}$ provided by the Global Footprint Network (Lin D. et al., 2019, p55) is used to obtain the global hectares needed to capture the CO_2 emitted by the city.

The Valencia municipally census population is used for each year in order to calculate the corresponding indicators per inhabitant (INE, 2020).

On the other hand, the amount of green areas available in the city and the natural potential for carbon absorption they represent will be studied and compared with carbon footprint indicators.

4.1.2. Carbon Dioxide Capture of the city of Valencia

According to the document '*Estrategia frente al Cambio Climático 2020*' developed by the Valencia City Council (2011), the municipality of Valencia has six large green areas in the city which, together with the Albufera of Valencia, constitute the main green areas of the municipality. The Albufera Natural Park is made up of various habitats (meadows, scrubland, dunes, ponds, coastal lagoons, etc.), so only the equivalent area similar to the green areas found in the city will be considered.

According to (Domínguez Madrid A. Y., 2016) and (Chaparro L. and Terradas J., 2009), the green areas of a city can be divided by the type of use made of each area, differentiating between parks (urban forests), vegetation in residential areas, universities, etc. This differentiation is made because each area has specific tree species and a different vegetation density. On the other hand, it should also be considered that the amount of net CO_2 absorbed by urban vegetation is lower due to the death and frequent pruning of the vegetation.

Bearing all this in mind, the average fixing capacity of urban woodland has been calculated for several cities, specifically for the city of Barcelona, whose climate and vegetation are similar to that of Valencia, so the fixing capacity coefficient of urban woodland calculated for Barcelona will be used for this study, this being 0.2208 kg CO_2/m^2 per year (2.21 tCO_2/ha per year).

According to the Valencia City Council's statistical office, in the green spaces municipality section (Ayuntamiento de Valencia, 2018-B), Valencia has a total of 149,447 trees on public land, with the orange tree being the predominant species with a total of 12,300 specimens (8.2%). This vegetation is equivalent to 500 hectares of green areas, 25% of which correspond to the river Turia. In addition, the area of the Albufera, which is located within the municipality of Valencia is 5880 hectares. Table 10 shows these areas and their extension by type of area.

The extension of the municipality of Valencia is 13,908 ha (139.08 km^2), which means that all these green areas would represent approximately 9% of the total territory. Also considering the lake of the Albufera, the percentage of natural areas regarding to the municipal total amounts to 46%. However, for the calculation of CO_2 absorption only vegetation areas have been considered, so only the hectares corresponding to vegetation will be considered.

Keeping in mind this area of urban vegetation and the fixing capacity calculated for the city of Barcelona, it is estimated that **1,104 tCO_2 are absorbed naturally in the city annually (8,715 tCO_2 if the vegetation areas of the Albufera are considered)**.

Green areas	Extension (ha)	Green areas	Extension (ha)
Valencia	499.95	The Albufera	5,880
Urban forestry	352.39	The Albufera Lake (89,4% water and 10,6% bushes and reeds)	2,721 (2433 and 288)
Turia river	123.36	Meadow of the Albufera	870
Public universities	19.93	Rice field / Marshland	1,703
Cemeteries	4.27	Orchard crops and others	586

Table 10. Extension (in hectares) of green areas in the municipality of Valencia (2018)

4.1.3. Results

Before talking about the carbon footprint, it should be noted that, although the city of Valencia has many green spaces, these are clearly insufficient to directly absorb the large amount of emissions caused by its activity. Nevertheless, these results do not indicate that the emission reduction potential of vegetation is negligible, as vegetation can help reduce emissions and combat climate change indirectly, such as, for example, residential consumption through shading, evaporative cooling in parks, etc.

With reference to the carbon footprint, for the extended carbon inventory for year 2018, the result was **1,059,390.39 ha**, in other words, the area of Mediterranean forest needed per person to absorb all the CO_2 emitted each year. In terms of global hectares, the city's carbon footprint amounts to **1,366,613.60 gha**. This carbon footprint expressed per inhabitant is **1.34 ha/hab per year** and **1.73 gha/hab per year**.

Since carbon indicators are strongly related to each other, the results will only be analysed using the indicator '*global hectare per person (gha/hab)*'. Complete results with all indicators can be found in the Annex.

Figure 36 shows the historical evolution of the carbon footprint according to the SECAP carbon inventory between the reference year 2007 and 2016. As noted in previous sections, the difference in results between SECAP inventories and the extended inventory is significant because there are some sectors that were not included. However, the reduction in the carbon footprint over the last decade can be noticed, with a 25% reduction in 2016 compared to the reference year. This reduction was largely marked by the suspension of activities as a result of the financial crisis from 2008, so, as noted in the data from the '*Anuario Estadístico del Ayuntamiento*' (Statistical Yearbook of Valencia City Council) for the years 2017 and 2018, the carbon footprint has increased slightly in recent years given the economic recovery.

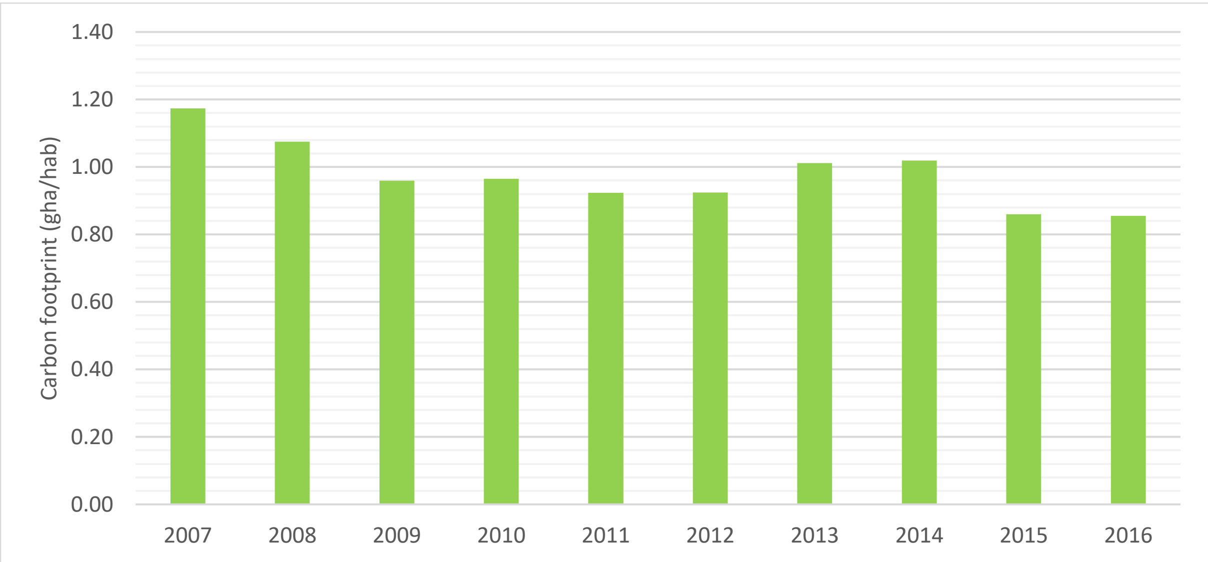


Figure 36. Historical evolution of the carbon footprint in Valencia (data from SECAP 2007–2016)

Once the values of the indicators are obtained, two comparisons will be made and analysed: the first one is a graphic comparison between the carbon footprint obtained with its equivalent area of territory and the second one is given between indicators with the results of other similar studies.

On the one hand, the area of Mediterranean forest necessary to absorb all the CO_2 emitted by the city of Valencia (1,059,390 ha) is equivalent to 98% of the Valencian province extension (1,076,300 ha), in other words, **only the city of Valencia and the activities linked to it generate an amount of CO_2 emissions that, in the case of seeking a zero-emission economy, would require a Mediterranean forest of the same size as the entire province in order to absorb all the emissions in a natural way**. This statement shows the seriousness of the current situation and the need for an urgently implementation of sustainability policies.

On the other hand, table 11 includes a summary of some studies that were found in the literature and which calculate the carbon footprint for certain universities/cities:

Study	Year	Methodology	Carbon Footprint
Extended carbon footprint analysis – VALENCIA	**2018**	**Bottom-Up**	**1.34 ha / hab** **1.73 gha / hab**
Polytechnic University of Valencia (2009)	2009	Bottom-Up	0.59 ha / student 0.81 gha / student
University of Valencia (2011)	2010	Bottom-Up	0.24 ha / student 0.32 gha / student
University of Valladolid (2014)	2014	Bottom-Up	0.25 ha / student 0.34 gha /student
Valencia (Baabou W. et al., 2017)	2015	Top-Down	1.34 ha / hab 1.84 gha / hab
Barcelona (Baabou W. et al., 2017)	2015	Top-Down	1.46 ha / hab 2 gha / hab
Almada (Galli A. et al., 2020)	2016	Top-Down	2.68 gha / hab
Braganza (Galli A. et al., 2020)	2016	Top-Down	2.56 gha / hab
Beijing (Chen S. et al., 2020)	2012	Top-Down	3.87 gha / hab
Vancouver (Isman M. et al., 2018)	2015	Top-Down	2.45 gha / hab
Ottawa (Isman M. et al., 2018)	2015	Top-Down	2.5 gha / hab

Table 11. Comparative summary of the carbon footprint in various studies

The studies that calculated the carbon footprint for universities share the calculation methodology (Bottom-Up) and the categories included: electricity consumption, water, paper and waste, buildings, mobility, and fuel consumption. In addition, the study by the Polytechnic University of Valencia has also included food, which may explain why the carbon footprint obtained is greater than the rest of them. These results considered the number of students and staff registered at each university for the year of the calculation.

While a university carbon footprint cannot be directly compared to the city' s footprint, if all the other activities that a student undertakes outside the university were added to it, the personal carbon footprint could be obtained. In other words, in the case of a student at the Polytechnic University of Valencia, 45% of the carbon footprint is produced at the university, whereas the remaining 55% is generated outside the university (electricity, gas and water consumption at home, food, etc.).

Regarding the rest of the studies for cities, all of them use a Top-Down methodology to calculate the ecological footprint. Given that this study has only considered carbon and buildings, the results shown in table 11 are only the part corresponding to these two categories instead of the total result that has been calculated in each study.

All cities show results between 1.5 and 4 global hectares per inhabitant, being the city of Beijing (China) the one with the highest carbon footprint, which makes sense since China is one of the most polluting countries in the planet nowadays. For the rest of the cities there is no specific pattern, as the results of the carbon footprint depend on many variables such as the size and development of the city, number, and density of inhabitants in the area, etc. Nevertheless, the carbon footprint is the main component of the ecological footprint in developed cities, where mobility is the main source of GHG emissions.

Finally, it should be noted that the study (Baabou W. et al., 2017) shows a carbon footprint per inhabitant for the city of Valencia in 2015 almost equal to the one calculated in this study, so it can be seen that both methodologies are comparable.

4.2. OVERSHOOT DAY

4.2.1. Methodology

The Overshoot Day environmental indicator is usually linked to a region's ecological footprint and biocapacity, and is calculated using the following equation:

$$Overshoot\ Day = \frac{Biocapacity\ (gha)}{Ecological\ footprint\ (gha)} * 365$$

The result of the equation determines the day in a natural year when the demand for natural resources exceeds its production in a given region and forces the use of resources from other areas of the planet.

However, this study cannot apply the above formula in a conventional way for two main reasons:

- Firstly, this indicator is usually calculated for large areas of land. In Spain, for example, the biocapacity and ecological footprint have been calculated by autonomous communities (Gullón Muñoz-Repiso N. et al., 2007). Since this study focuses on the municipality of Valencia, the biocapacity of a city is minor while consumption and emissions are very large, so the results would not provide relevant information (as shown in section 4.1.2. which compares the city's natural CO_2 absorption against total emissions).
- Secondly, this study only takes into account carbon emissions, so only the forest biocapacity in charge of absorbing the CO_2 emitted should be considered and not all types of land (fishing, agriculture, etc.)

Keeping this in mind, an alternative methodology is proposed to estimate the Overshoot Day based on the ecological footprint and biocapacity of Spain, whose data can be obtained from the Global Footprint Network website (2019).

This data is updated until year 2016, so, first of all, data must be extrapolated to 2018 following the trend of slight increase observed in recent years.

Based on the carbon emissions obtained in this study, the ecological footprint of Valencia will be estimated, if we assume that the percentage of carbon in the ecological footprint of Spain is the same for Valencia. Finally, the biocapacity of Valencia will be estimated from the national biocapacity by two ways:

a) Through the population of Valencia in relation to the population of Spain.

b) By the extension of the (1) municipality of Valencia, (2) metropolitan area of Valencia and (3) the province of Valencia with respect to the national extension.

4.2.2. Results

Table 12 shows the different environmental indicators recorded in Spain from 2010 to 2016. The values for 2018 have been estimated, obtaining an **ecological footprint per inhabitant of 4.12 gha/hab, a biocapacity of 1.32 gha/hab and a carbon footprint of 2.27 gha/hab**.

Year	2010	2011	2012	2013	2014	2015	2016
Ecological footprint (gha)	208,966,535.93	198,533,002.63	177,778,762.39	185,911,524.93	175,241,542.27	184,866,618.42	187,277,145.35
Carbon footprint (gha)	126,313,303.52	117,868,169.07	109,736,692.85	101,754,608.13	102,428,732.35	104,755,301.66	105,079,942.84
Carbon footprint (% to EF)	60.45%	59.37%	61.73%	54.73%	58.45%	56.67%	56.11%
Biocapacity (gha)	63,692,234.24	61,438,099.07	61,101,212.26	70,338,942.17	54,780,697.32	65,966,696.72	64,496,804.03
Population	46,490,000	46,670,000	46,820,000	46,730,000	46,510,000	46,450,000	46,440,000
Ecological footprint (gha/hab)	4.49	4.25	3.80	3.98	3.77	3.98	4.03
Carbon footprint (gha)	2.72	2.53	2.34	2.18	2.20	2.26	2.26
Biocapacity (gha/hab)	1.37	1.32	1.31	1.51	1.18	1.42	1.39

Table 12. Environmental indicators registered for Spain (from 2010 to 2016)
Source: Global Footprint Network, 2019

In 2018, the carbon footprint would represent 55.04% of Spain's total ecological footprint. In this study, it has been obtained that the carbon footprint of Valencia is 1,366,613.60 gha by 2018, so if the same percentage as in Spain is assumed, the **ecological footprint of Valencia would amount to 2,482,984.36 gha**, and would represent a 1.29% of the national ecological footprint (3.14 gha/hab in terms of global hectares per inhabitant of which 1.73 gha/hab correspond to carbon).

Finally, the biocapacity and Overshoot Day have been calculated according to:

a) The population residing in Valencia. Assuming the average biocapacity per inhabitant of Spain (1.32 gha/hab), the population of Valencia corresponds to a biocapacity of **1,044,085.40 gha**. Therefore, the **Overshoot Day for Valencia is the day 153 or 1st June**.

b) The relative size (in hectares), according to table 13:

	Extension (ha)		Biocapacity (gha)	Overshoot Day	
Spain	50,599,000		61,557,018.65		
B1: City of Valencia	13,908	0.03%	16,920.00	**2.49**	**2nd January**
B2: Metropolitan area of Valencia	116,100	0.23%	141,243.30	**20.76**	**20th January**
B3: Valencia province	1,076,300	2.13%	1,309,389.89	**192.48**	**10th July**

Table 13. Overshoot Day depending on the bioproductive area to be considered (2018)

From considerations B1 and B2, it can be seen that in 'small' areas the production of natural resources is exceeded too early (in January).

As mentioned above, urban centres concentrate a large part of the population and the activities that they perform quickly consume the resources that the area naturally provides. Consequently, in order to compensate for the ecological footprint that occurs these urban centres, it is necessary to include extensive surrounding natural areas.

If considering the province of Valencia as the resource area corresponding to the city, the resulting Overshoot Day would be 10th July (half of a natural year). In other words, to cover the demand for resources in the city of Valencia in a natural and sustainable way, two areas equivalent to the size of the province of Valencia would be needed.

Finally, as seen in figure 37, the Overshoot Day for Spain according to Global Footprint Network (Overshootday, 2020), is 27th May. Nonetheless, to obtain this result, the global average biocapacity of 1.63 gha/hab was used. If the biocapacity defined for Spain is used, Overshoot Day would be moved forward to26th April.

Since the Overshoot Day for Valencia according to option A is 1st June, it can be concluded that **the ecological footprint representing the population of Valencia is more sustainable than that of Spain as a whole**.

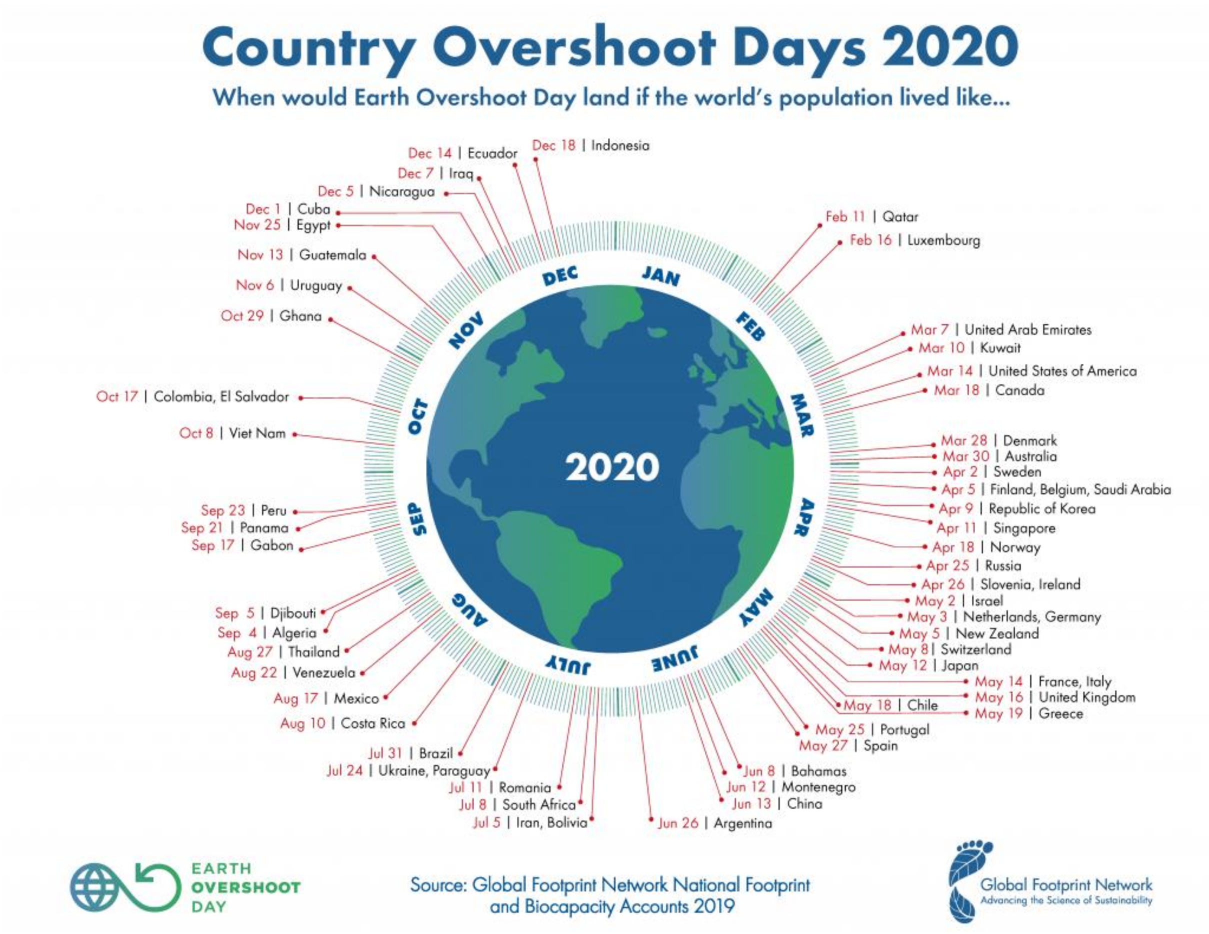


Figure 37. Overshoot Day for several countries of the planet
Source: Overshootday.org

CHAPTER 5. SIMULATION OF TREND SCENARIOS 2030

The purpose of this chapter is to analyse different scenarios for the year 2030 by studying how certain CO_2 reduction measures would affect the different indicators discussed in this work. These measures will be the main issues to achieve, or even exceed, the decarbonisation objectives defined by the European Union, also increasing the sustainability of the city and helping to achieve the objectives proposed by the Valencia City Council in terms of energy poverty and energy democracy.

5.1. DEFINITION OF SCENARIOS

This section will define the different scenarios in which sustainable measures will be considered to reduce emissions in several of the most polluting areas in the city of Valencia, as these are considered to be the essential points on which public and private administrations should work and improve.

Before analysing each scenario, the criteria shared by all the scenarios will be defined:

- According to the document '*Proyecciones de Población 2018-2033*' of the Conselleria de Economía Sostenible, Sectores Productivos, Comercio y Trabajo (Regional Department of Sustainable Economy, Productive Sectors, Trade and Labour) (Ayuntamiento de Valencia, 2020), it is estimated that by 2030 there will be an increase of 3% in population, mainly marked by ageing (the number of people over 65 will increase by 15% while the number of people under 20 will decrease by 5%).
- Concerning the other areas that will not be analysed in depth, most sectors have shared the same trend in the last decade, marked by a decrease in the number of emissions until 2015 as a result of the financial crisis and a subsequent change in trend and slight increase in emissions due to the economic recovery and the increase in labour and commercial activity. Given the global pandemic that began in early 2020, this year is set to be a key point for a return to a trend of reducing emissions (inevitably due to the worldwide cessation of activity and the coming financial crisis). A slight emission reduction trend will be considered, even though the effect of the new crisis may be underestimated.
- Although within a decade the emission factors may change due to technological improvements, increased production of renewable energy, etc., the same factors will be used as for 2018, allowing direct comparison of the number of net emissions without being affected by improvements in the factors.

5.1.1. Scenario 1: Decarbonisation of private transport

The first scenario will study the evolution of emissions in private and commercial transport, as this is the sector with the highest number of CO_2 emissions in the city of Valencia and, currently, one of the most problematic sectors where the inclusion of the hybrid/electric car and the oil economy are the order of the day.

For the next decade, the automotive sector has predicted the greatest changes in all its history, largely, due to new environmental policies and changes in the habits of new generations. Hybrid and electric vehicles are therefore expected to dominate the market in the next few years to the detriment of conventional petrol and diesel vehicles, particularly in the field of private transport. The change in habits also influences the sector, since a few years ago the priority when reaching the legal age was to obtain a driving licence and a private vehicle to move around. Now, the sustainable micromobility alternative has appeared, opening the way for the bicycle or the electric scooters for short/medium distance journeys (Yoldi M., 2019).

Hence, the scenario outlined is a combination of all these changes:

- The number of journeys by private car increases by 3% in 2020 compared to 2018. By 2030, this number of trips will be expected to be maintained.
- Two independent scenarios will be proposed. In the first one, a classic renovation of the vehicle fleet will be considered, without including renewable alternatives, nor hybrid or electric vehicles. The number of renewed cars is estimated according to the average age of the fleet, keeping this around 8-10 years, so it is expected that vehicles older than this will be almost completely renewed (models from Euro 1 to Euro 5).
- In the second one, the great change in mobility previously mentioned will be considered, changing the classic renovation for a more sustainable one, so that:
    - The number of people using public transport increase (20% of private vehicles are stopped).
    - 50% of renewed cars are hybrid models (electric–petrol).
    - 10% of renewed cars are electric models.
    - 10% of renewed cars are replaced by the electric car-sharing alternative.
    - 3% of renewed cars are replaced by micro-mobility alternatives (approximately 14,000 cars and motorcycles are replaced by bicycles and/or electric scooters).
    - The remaining percentage is renewed by conventional petrol (or diesel to a lesser extent) Euro 6 +2020 models.
    - 25% of the motorcycles are replaced by electric models.
    - The light transport fleet is renewed in the classic way, keeping the diesel engines because they are still the most optimal engines for covering long distances and electric vehicles are not mature enough to replace this technology in a sustainable and safe way.

Figure 38 shows the composition of the fleet for each alternative. From these compositions, the emissions have been calculated using COPERT 5.2 software.

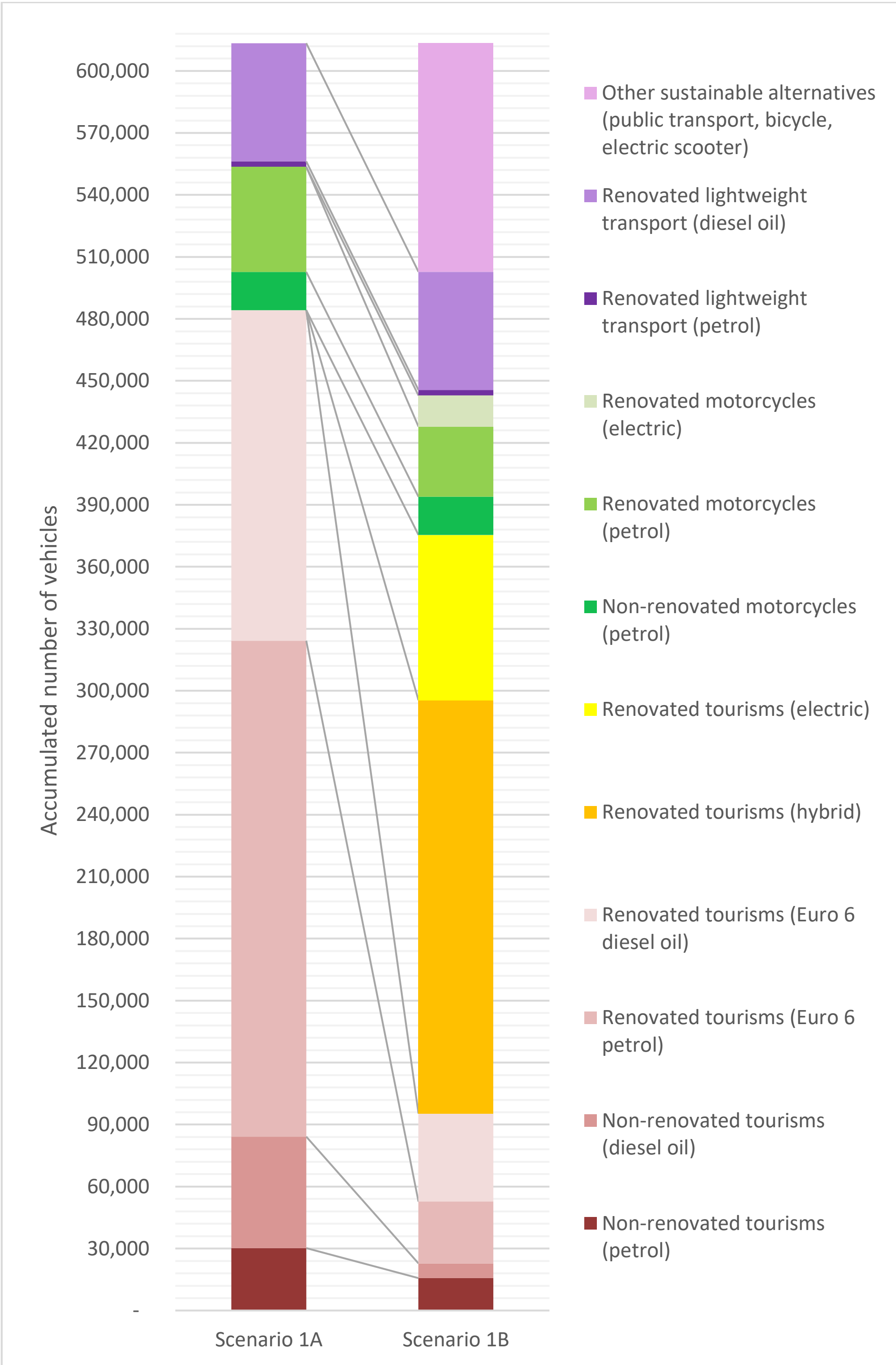


Figure 38. Composition of Valencia's vehicle fleet: scenario 1 (2030 without a change in trend) and scenario 2 (2030 with a trend towards sustainable renewal)

5.1.2. Scenario 2: Improving the energy efficiency of buildings

As described in section 3.2.6., the main problem in the building sector is that in Spain only about 10% of building materials are recycled. Therefore, if the amount of recycled materials is increased or replaced by more environmentally friendly materials, the amount of CO_2 emissions generated in building construction could be greatly reduced.

Another problem that the construction sector faces is the rehabilitation of housing. In particular, in 2009 Spain employed only 19% of total construction investment in housing rehabilitation compared to the European Union average of 43% (WWF/Adena, 2010), opting for a new housing construction model.

In the case of Valencia, this problem of renovation is notable in older houses whose thermal insulation is, in most cases, not enough, which causes an increase in the annual heating and cooling demands. Consequently, this means that a large part of these dwellings lacks the minimum requirements established by the Technical Building Code in terms of limiting energy demands.

According to the data collected by the National Statistics Institute (2011), there are 419,930 dwellings registered in Valencia, of which 328,980 are habitual residences (non-abandoned dwellings or second homes). Approximately 11% of these habitual residences are classified as poor/deficient, with no facilities for air conditioning or insulation.

To make a practical case, it is proposed to renew this number of houses in the period of 10 years (until 2030), plus the possible houses that suffer from wear and tear during this period, until reaching a total renovation of 15% of the houses (approximately 5,000 houses per year).

To insulate these homes thermally, the SATE insulation (thermal insulation on the outside) is chosen, which, although it depends on the availability of the facade to be insulated, it is one of the optimal options to achieve good thermal insulation while having other advantages such as not requiring interior works in the building and does not reduce the useful living area of homes. The current price of SATE insulation is around 65 €/m^2 depending on its thickness (Cype Ingenieros, 2020).

With all this, the following considerations will be taken into account to calculate the scenario:

- The average built area of houses in Valencia is 109.8 m^2, so an exterior facade area of 31.50 m^2 will be considered for each (equivalent to 9 m of facade length and 3.50 m of height between floors).
- The percentage of reduction in energy consumption and CO_2 emissions in non-refurbished houses is 56.9% and 55.3% respectively (WWF/Adena, 2010).
- It is considered that these houses in poor conditions and lacking heating use portable heating appliances such as stoves, so the reduction of energy and emissions will affect electricity consumption in the residential sector.

5.1.3. Scenario 3: Change in eating habits

As discussed in section 3.2.5, the emission factor for food consumption can be calculated based on the amount of food consumed of each type and the emission factor attributed to each of these food groups. Thus, fresh plant products (fruits, vegetables, legumes, potatoes, etc.) have the lowest emission factors while meat products, especially those of bovine and sheep origin, have the highest emission factors.

In 2018, the Valencian Community consumed on average 785.75 kg of food per capita, of which approximately 30% are products from vegetable origin, 25% drinks of all types and 17.4% dairy products and their derivatives and eggs. The remaining percentage is divided between meat and fish, pre-cooked products, flour, pasta, rice, etc.

Considering that this food consumption remains constant until 2030, there are two possible ways that could help to reduce greenhouse gas emissions in this area:

- The first way would be to reduce the carbon footprint of food, without changing consumption habits. In this way, manufacturing and food-producing companies would contribute to reducing the carbon footprint of their products by using more sustainable packaging than plastics and/or by preferably consuming local products, avoiding the long distances involved in transporting the products and the emissions they generate. On the other hand, the final consumer would also contribute to the reduction of emissions by supporting the local ecological trade, preferably consuming these fresh foods which would save industrial pre-treatments.
- The second way would be to change eating habits by substituting packaged products with fresh products and consuming more vegetable products (with low emission factors) instead of animal and pre-cooked products (with high emission factors).

Since the first way requires an exhaustive life cycle analysis for each type of food, this scenario will only simulate the effect of the second way, modifying the consumption of certain food groups to favour an increase in the consumption of low-carbon products. Table 14 shows the amount of food consumed by type and its emission factors for the years 2018 and 2030, assuming this proposed evolution in food consumption habits.

Finally, another sustainable measure applicable to both routes is the consumption of drinking water straight from the tap at home, which means a significant reduction in the number of plastic bottles used. In this scenario, it will be considered that 20% of total liquid consumption is non-bottled water (either consumed straight from the tap or with a specific purifying and filtering device).

Net consumption: 785,75 kg / hab and year	2018		2030	
Food category	% consumption	Emission Factor ($kgCO_{2-eq}$ / kg)	% consumption	Emission Factor ($kgCO_{2-eq}$ / kg)
Vegetable products	29.60%	0.621	34.63%	0.598
Dairy & Eggs	17.37%	3.790	17.37%	3.790
Flours and cereals, pasta, and rice	7.40%	1.197	7.78%	1.252
Meats	7.39%	9.292	6.00%	9.292
Fish	3.39%	6.498	3.00%	6.498
Drinks	25.38%	1.434	25.38%	1.289
Other food	9.46%	3.216	5.83%	3.057
TOTAL	**100%**	**2.506**	**100%**	**2.221**

Table 14. Food consumption by categories and emission factors (2018 and 2030)

5.2. RESULTS

When analysing the results for the first trend scenario (table 15), it is evident that if the population increases and sustainable transport alternatives are not introduced, despite the evolution of technology, emissions in this sector will inevitably increase. On the contrary, in the renewable scenario it can be seen that the inclusion of the hybrid vehicle (and the electric one to a lesser extent), as well as the rest of the public or micro-mobility alternatives, contributes to achieving an important reduction in CO_2 emissions.

	tCO_2	Δ emissions
Extended inventory emissions (2018)	1,306,993.28	-
Scenario 1A: classic renovation emissions (2030)	1,489,669.73	13.98%
Scenario 1B: sustainable renovation emissions (2030)	906,559.57	-30.64%

Table 15. Results of scenario 1 (1A: classic renovation scenario, 1B: sustainable scenario)

This scenario is not easy to accomplish, as it requires the participation of many agents: vehicle manufacturers have to adapt their models to new environmental policies and to the sector demands, public institutions have to promote sustainable culture and change of habits, as well as offer plans and help to guarantee access to these new technologies for everyone, and end consumers must have the capacity and willingness to acquire them.

Thus, even though the renovation of private transport is showing good results in terms of climate change, it is not as profitable nor efficient in economic terms. Taking into account the current prices of electricity, fuels and hybrid/electric models for sale, achieving the proposed sustainable renovation of the vehicle fleet would entail an **extra cost of 1,242 million euros** which would have to be provided by private capital, if public entities do not intervene by means of funding and aid. Under these conditions, scenario 1B presents an average **fuel saving of 42.4 million euros** per year, so the payback period would be around **29 years**.

Given these unfavourable results, the main reasons why the electric vehicle is still not economically profitable will be further analysed:

- First of all, electric vehicles still lie ahead a technological development that allows to obtain more efficient batteries, that provide more autonomy to the vehicle and make the costs decrease regarding to the current costs. The increase in the production of electric vehicles is also a key point for reducing the price of this technology. Nevertheless, it should not be forgotten that the materials used to manufacture the batteries are not renewable, so a large increase in the car batteries production could lead to an increase in price rather than a decrease.
- Furthermore, an electric vehicle is currently becoming profitable after 20,000 km per year (55 km per day), so it is not recommended to use this technology for intra-city mobility. For this reason, micro-mobility alternatives such as the electric scooter or bicycle are highly recommended for short distance journeys, as the energy required for individual journey is much lower.
- Another important factor to take into account is that this scenario considers the emissions from vehicles that move within the city and part of those that move from Valencia to its metropolitan area and vice versa, thus, and with reference to the previous point, a large part of these journeys do not reach the average of 55 km per day.
- Finally, the price of electricity and fuels has a strong influence on the profitability of the investment. For instance, if the price of petrol and diesel increases by 20% while the price of electricity remains constant, the return on investment would be 19 years (10 years earlier than previously mentioned). If the price of fuel increases at the same time the price of electricity decreases by 20%, the payback time would decrease to 15 years (half the original payback time).

In the second scenario, it is suggested the option to increase the rate of building renovations, especially of the worst condition buildings which are more vulnerable to climate change and extreme temperatures. The investment costs over the ten years amount to **101 million euros**. As the number of refurbished homes increases every year until reaching 15% of homes in use in Valencia in 2030, the energy savings produced an increase progressively during these years until reaching **13.2 million euros** in 2030, achieving a return on investment in **12 years from the start of the refurbishments**.

Although the emissions avoided in this area are not as significant compared to the measures of the first scenario, the payback time is very profitable as buildings have a longer life than vehicles. Furthermore, these rehabilitation measures help to reduce energy poverty, which is another of the objectives of Valencia City Council.

The third scenario shows that with a small change in diet, significant reductions in greenhouse gas emissions can be achieved as, by replacing a small portion of meat, fish and precooked food (equivalent to 5% of the food consumed annually) for fresh vegetable food, rice and pasta, emissions in this area are reduced by around 8% compared with the emissions obtained in 2018.

In terms of economics, the food price varies constantly. While foods that are intended to be consumed preferentially to reduce the carbon footprint are generally less expensive today, no extra investment nor savings are to be considered in this area.

In the end, table 16 shows the emissions avoided annually in each scenario and the necessary investment costs. **All three scenarios together would achieve a 12.26% reduction in CO_2 emissions compared to the extended inventory for 2018, reducing the carbon footprint to 1.46 gha/inhabitant and delaying Overshoot Day to 23th June (22 days compared to 2018).**

SCENARIOS 2030	Δ CO_2 emissions (from 2018 extended inventory)		Investment costs (million euros)	
	tCO_2	%	Public	Private
Scenario 1	-400,433.71	10.22%	35.12	1,242.71
Scenario 2	-26,742.19	0.68%	60.62	40.41
Scenario 3	-53,454.38	1.36%	-	-
Scenarios 1+2+3	-480,630.28	12.26%	95.74	1,283.12

Table 16. Summary table of results obtained for the trend scenarios (2030)

CHAPTER 6. CONCLUSION

With the aim of achieving a zero greenhouse gas emissions economy, carbon inventories become very important. These inventories facilitate the task of identifying the most polluting fields and help public and private entities to make decisions and propose improvements to achieve the globally agreed sustainable energy transition.

This study has shown that it is not enough to carry out a carbon inventory limited to certain areas, since the more complete and detailed it is, the closer it will get to reality and, therefore, it will be more useful as a tool for decision-making.

In the case of Valencia, including all the areas proposed in this study, for the year 2018, the emissions obtained are twice (3,92 million tons of CO_2) those obtained in the SECAP, which shows how critical the situation is and the long road remaining to achieve the objectives of zero emissions in 2050 that were signed in the Paris agreement.

According to the results obtained, the most polluting areas in the city of Valencia are private transport (33.3%), construction (20%), and food (16.5%), followed by consumption in the residential and services sectors, and port activities (8.2%, 7.6% and 4.5%, respectively). These are, thus, the areas on which the sustainable policies and measures of the City Council should focus in the future.

In terms of carbon footprint, it was noted that a large population centre such as the city of Valencia (the third most important city in Spain after Madrid and Barcelona), monopolises large areas of bioproductive land to develop its activities. In the case of this study, the obtained carbon footprint per inhabitant in the city of Valencia is 1.34 ha/hab (or in the case of global hectares, 1.73 gha/hab). In other words, the carbon footprint is 1.06 million hectares, which is almost the same extension of the whole province of Valencia.

The Overshoot Day is another environmental indicator to be considered. In 2018, the city of Valencia exhausted its natural resources before the middle of the year (1st June), requiring resources from other areas of the planet. This indicator again reflects the critical environmental situation that exists today and the necessity of making a sustainable transition to guarantee the future use of the available resources in the long term.

Finally, it should be noted that the suggested trend scenarios contribute considerably to the sustainability of the city. Although the reduction of emissions in the three areas considered is only 12%, the results can serve as a roadmap for further improvements in all areas.

CHAPTER 7. BIBLIOGRAPHY

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ANNEX

1. LIST OF ACRONYMS

APV/PAV	Autoridad Portuaria de Valencia (Port Authority of Valencia)	**IPCC**	Intergovernmental Panel on Climate Change
CLUM	Consumption land-use matrix	**IVACE**	Institute of Business Competitiveness
CO_2	Carbon Dioxide	**LCA**	Life Cycle Assessment
CORES	Corporación de Reservas Estratégicas de Productos Petrolíferos	**MITECO**	Ministry for the Ecological Transition and the Demographic challenge
DGT	Dirección General de Tráfico (Directorate-General for Traffic)	**MRIO**	Multirregional input–output
EEA	European Environmental Agency	**OCCC**	Oficina Catalana del Canvi Climàtic
EF	Emission Factor	**PEQC**	Pla d'energia, canvi climàtic i qualitat de l'aire de Barcelona
ERI	Emissions Reference Inventory	**PMoME**	Plan de movilidad metropolitana de Valencia (Valencia Metropolitan Mobility Plan)
FGV	Ferrocarrils de la Generalitat Valenciana	**PMUS**	Plan de movilidad urbana sostenible (Sustainable urban mobility plan)
gha	Global hectare	**REE**	Red Eléctrica de España (Spanish Electricity Grid)
gha/hab	Global hectare per person	**SEAP**	Sustainable Energy Action Plan
		SECAP	Sustainable Energy and Climate Action Plan
GHG	Greenhouse gases	**EU**	European Union
GHGP	Greenhouse Gas Protocol	**UPV**	Universidad Politécnica de Valencia (Polytechnic University of Valencia)
GWP	Global warming potential	**UV**	Universidad de Valencia (University of Valencia)
ha	Local hectare	**WRI**	World Resources Institute
INE	Instituto Nacional de Estadística (National Statistics Institute)		

2. EMISSION FACTORS

Category	Emission Factor	Units	Source
Water (from the network)	0.367	$kgCO_2 / m^3$	OCCC
Food	1.038	$kgCO_2 / kg$	Own source
Construction of buildings	694.16	$kgCO_2 / m^2$	Mercader M.P. et al., 2012
Electricity in the C.V.	0.188	tCO_2 / MWh	SECAP (IVACE)
Petrol	0.242	tCO_2 / MWh	SECAP (IVACE)
Petrol (average vehicle fleet Valencia)	0.260	tCO_2 / MWh	COPERT 5.2
Diesel oil	0.265	tCO_2 / MWh	SECAP (IVACE)
Diesel oil (average vehicle fleet Valencia)	0.269	tCO_2 / MWh	COPERT 5.2
GLP (butane, propane)	0.225	tCO_2 / MWh	SECAP (IVACE)
Natural Gas	0.201	tCO_2 / MWh	SECAP (IVACE)
Minor works	0.136	$kgCO_2$ / €	MITECO
Clothing	7.71	$kgCO_2 / kg$	Own source
MSW (solid wastes)	0.305	tCO_2 / MWh	SECAP (IVACE)

Table 17. Emission factors employed

3. CALCULATION AND RESULTS TABLES

Regulations	Entry into force	Assignment
ECE 15/…	previous	Before 1992
Euro 1	July 1992	1992-1995
Euro 2	January 1996	1996-1999
Euro 3	January 2000	2000-2004
Euro 4	January 2005	2005-2009
Euro 5	September 2009	2010-2014
Euro 6	September 2014	=> 2015

Table 18. European regulations on emissions, applied to vehicles

Vehicle type	Fuel	Age	City											TOTAL by...	
			Valencia	Paterna	Burjassot	Torrent	Mislata	Alboraya	Xirivella	Manises	Moncada	Paiporta	Aldaia	Age	Fuel
Tourisms	Petrol	Before 1990	38374	2341	1175	2614	1245	579	792	1192	574	521	897	50304	250434
		1990 - 2000	27107	2238	1287	2529	1382	690	1045	1100	628	672	969	39647	
		2001 - 2005	35984	2996	1714	3605	1873	1112	1403	1457	966	1107	1518	53735	
		2006 - 2010	31527	2863	1403	2969	1598	996	1080	1106	887	909	1179	46517	
		2011 - 2015	22525	2204	889	2125	1188	734	714	739	596	729	842	33285	
		2016	8334	876	346	891	433	301	293	278	252	285	313	12602	
		2017	9563	1044	359	966	491	376	331	273	244	313	384	14344	
	Diesel oil	Before 1990	3070	210	102	270	117	72	82	100	61	60	67	4211	290149
		1990 - 2000	19963	1936	1285	2506	1234	569	979	1048	728	700	946	31894	
		2001 - 2005	52757	5517	3161	6487	3246	1705	2492	2906	1969	2139	2554	84933	
		2006 - 2010	58266	6477	3052	6463	3373	1954	2409	2851	1962	2186	2790	91783	
		2011 - 2015	35049	4052	1628	3704	1773	1293	1263	1574	1090	1248	1549	54223	
		2016	8270	952	403	1031	390	317	280	340	258	307	377	12925	
		2017	6534	764	269	868	313	295	212	267	196	210	252	10180	
	Electric	Before 2016	30	28	2	5	0	0	1	0	0	1	0	67	181
		2016	20	2	0	0	0	1	1	0	1	0	0	25	
		2017	70	7	0	2	3	2	0	2	0	1	2	89	
	LPG	Before 2016	42	4	1	0	5	2	1	2	1	2	0	60	135
		2016	7	1	2	1	0	0	0	0	0	0	0	11	
		2017	44	5	2	2	1	2	1	1	1	5	0	64	
	Othes		75	6	5	3	3	0	1	1	0	2	1	97	97
		Total by cities	357611	34523	17085	37041	18668	11000	13380	15237	10414	11397	14640	540996	
Motorcycles	Petrol	Before 1990	12368	654	400	845	367	355	233	298	259	188	214	16181	87238
		1990 - 2000	8257	609	346	674	361	313	250	255	195	192	224	11676	
		2001 - 2005	8645	689	383	738	408	313	322	274	206	224	288	12490	
		2006 - 2010	17480	1491	789	1583	827	675	631	558	478	538	596	25646	
		2011 - 2015	9875	749	335	642	448	363	229	292	272	229	304	13738	
		2016	2720	231	94	182	132	113	85	76	73	73	77	3856	
		2017	2615	185	97	201	121	104	79	61	80	37	71	3651	
	Diesel oil	All	39	4	1	4	0	2	0	1	0	0	0	51	51
	Electric	Before 2016	50	6	3	1	0	2	2	0	3	6	1	74	170
		2016	2	0	0	0	0	0	0	0	0	0	0	2	
		2017	93	0	1	0	0	0	0	0	0	0	0	94	
		Total by cities	62144	4618	2449	4870	2664	2240	1831	1815	1566	1487	1775	87459	
Mopeds	Petrol	Before 2000	6540	700	382	893	343	279	293	354	292	215	331	10622	33784
		2001 - 2005	10088	930	591	1010	485	346	359	407	370	247	333	15166	
		2006 - 2010	4002	301	232	308	169	135	146	119	147	122	158	5839	
		2011 - 2015	1001	90	65	73	35	30	35	21	36	24	22	1432	
		2016	212	17	10	12	9	7	7	8	15	7	6	310	
		2017	308	20	17	12	11	11	3	5	15	6	7	415	
	Diesel oil	Before 2016	324	52	24	60	13	8	20	23	38	13	35	610	656
		2016	8	1	0	1	0	1	1	2	3	0	2	19	
		2017	13	2	3	2	2	0	0	1	2	2	0	27	
	Electric	Before 2016	69	7	0	2	0	1	0	0	1	0	0	80	92
		2016	3	0	0	0	1	0	0	0	0	0	0	4	
		2017	6	0	0	1	0	0	0	0	1	0	0	8	
		Total by cities	22574	2120	1324	2374	1068	818	864	940	920	636	894	34532	
Vans	Petrol	Before 1990	3375	221	131	224	99	60	72	134	54	45	89	4504	7652
		1990 - 2000	1140	86	50	84	51	40	33	42	20	21	38	1605	
		2001 - 2005	565	53	16	52	11	15	12	10	10	8	16	768	
		2006 - 2010	376	35	6	28	11	22	7	10	6	9	10	520	
		2011 - 2015	104	6	2	7	3	1	1	2	2	0	2	130	
		2016	40	6	2	2	1	3	0	0	1	0	2	57	
		2017	46	5	2	3	2	1	1	5	3	0	0	68	
	Diesel oil	Before 1990	2385	224	133	267	69	66	89	94	70	37	86	3520	26383
		1990 - 2000	3405	331	175	324	156	92	132	167	103	94	121	5100	
		2001 - 2005	3042	311	153	350	152	119	105	157	103	116	141	4749	
		2006 - 2010	3605	448	150	341	130	142	141	190	108	158	158	5571	
		2011 - 2015	2965	414	78	296	107	104	113	165	101	112	184	4639	
		2016	827	212	34	75	27	37	37	35	25	23	36	1368	
		2017	930	141	24	84	42	33	37	45	25	38	37	1436	
	Electric	Before 2016	12	2	0	0	3	1	0	0	0	1	0	19	45
		2016	7	1	0	1	0	0	0	0	0	1	0	10	
		2017	9	3	0	2	0	1	0	1	0	0	0	16	
		Total by cities	22833	2499	956	2140	864	737	780	1057	631	663	920	34080	

Table 19. Census of vehicles in the metropolitan area of Valencia (2017) (part 1)

Vehicle type	Fuel	Age	City											TOTAL by...	
			Valencia	Paterna	Burjassot	Torrent	Mislata	Alboraya	Xirivella	Manises	Moncada	Paiporta	Aldaia	Age	Fuel
Trucks < 3500 kg	Petrol	Before 1990	131	18	3	4	4	4	2	5	0	2	1	174	1246
		1990 - 2000	302	19	27	33	13	9	12	14	7	7	14	457	
		2001 - 2005	200	19	23	22	5	9	7	7	7	11	5	315	
		2006 - 2010	154	12	8	10	4	11	3	12	8	4	3	229	
		2011 - 2015	25	2	1	1	0	2	0	2	0	0	1	34	
		2016	12	0	0	1	0	0	1	0	1	0	1	16	
		2017	19	2	0	0	0	0	0	0	0	0	0	21	
	Diesel oil	Before 1990	2282	182	86	213	61	48	92	80	55	52	80	3231	38696
		1990 - 2000	4973	644	361	818	246	169	265	330	194	209	321	8530	
		2001 - 2005	7144	953	510	1102	354	267	386	485	355	318	431	12305	
		2006 - 2010	6077	861	398	850	340	276	324	449	338	331	397	10641	
		2011 - 2015	1560	277	71	244	69	61	58	88	60	88	101	2677	
		2016	365	134	12	46	10	7	9	22	12	20	22	659	
		2017	359	114	17	50	19	15	15	24	8	17	15	653	
		Total by cities	23603	3237	1517	3394	1125	878	1174	1518	1045	1059	1392	39942	
Trucks > 3500 kg	Diesel	Before 1990	1211	52	19	83	49	21	29	36	15	38	50	1603	5462
		1990 - 2000	558	80	22	69	35	24	65	43	18	42	49	1005	
		2001 - 2005	584	140	19	104	26	26	55	50	12	34	54	1104	
		2006 - 2010	555	132	17	106	33	17	60	23	30	45	62	1080	
		2011 - 2015	183	43	1	28	7	14	28	12	12	11	22	361	
		2016	47	26	1	10	2	6	14	4	2	6	5	123	
		2017	84	26	1	27	2	4	29	3	0	4	6	186	
	Others		90	1	0	5	3	0	6	4	3	3	2	117	117
		Total by cities	3312	500	80	432	157	112	286	175	92	183	250	5579	
Buses	Diesel	Before 1990	216	8	2	4	1	2	1	8	1	3	3	249	1358
		1990 - 2000	234	3	0	6	1	4	2	2	2	1	2	257	
		2001 - 2005	283	13	9	3	11	7	3	6	13	5	32	385	
		2006 - 2010	188	7	4	7	7	5	3	3	8	12	32	276	
		2011 - 2015	67	4	1	0	2	5	2	1	6	7	5	100	
		2016	33	1	1	1	1	3	1	2	2	2	5	52	
		2017	19	0	0	0	2	2	0	1	4	4	7	39	
	Others		47	1	0	0	0	0	0	0	0	0	0	48	48
		Total by cities	1087	37	17	21	25	28	12	23	36	34	86	1406	
Tractors	Diesel	Before 1990	417	19	8	13	13	4	14	11	8	3	2	512	4986
		1990 - 2000	311	24	4	27	21	2	16	13	5	5	9	437	
		2001 - 2005	611	54	16	49	34	11	28	26	12	19	25	885	
		2006 - 2010	928	122	13	89	28	15	49	30	27	29	46	1376	
		2011 - 2015	633	146	11	109	24	10	27	25	34	29	48	1096	
		2016	264	60	2	27	4	1	6	13	9	7	12	405	
		2017	138	53	11	23	4	0	15	5	5	6	15	275	
		Total by cities	3302	478	65	337	128	43	155	123	100	98	157	4986	
Others	Petrol	Unknown	758	67	40	94	35	18	38	37	17	23	42	1169	1169
	Diesel oil	Unknown	1782	381	72	192	244	70	62	83	143	170	114	3313	3313
	Electric	Unknown	39	28	5	1	1	7	0	5	4	7	8	105	105
	Others	Unknown	5973	896	167	703	237	137	293	238	201	204	367	9416	9416
		Total by cities	8552	1372	284	990	517	232	393	363	365	404	531	14003	
TOTAL PER CITY			505018	49384	23777	51599	25216	16088	18875	21251	15169	15961	20645	762983	
TOTAL PER CITY (WITHOUT UNKNOWN VEHICLES)			496466	48012	23493	50609	24699	15856	18482	20888	14804	15557	20114	748980	

Table 20. Census of vehicles in the metropolitan area of Valencia (2017) (part 2)

Census fleet Metropolitan area of Valencia		
Tourisms	540,996	72.23%
Motorcycles	87,459	11.68%
Mopeds	34,532	4.61%
Vans	34,080	4.55%
Trucks < 3500 kg	39,942	5.33%
Trucks > 3500 kg	5,579	0.74%
Buses	1,406	0.19%
Tractors	4,986	0.67%
	748,980	100.00%

Table 21. Census fleet of the Metropolitan area of Valencia (2017)

Census fleet city of Valencia		
Tourisms	357,611	72.03%
Motorcycles	62,144	12.52%
Mopeds	22,574	4.55%
Vans	22,833	4.60%
Trucks < 3500 kg	23,603	4.75%
Trucks > 3500 kg	3,312	0.67%
Buses	1,087	0.22%
Tractors	3,302	0.67%
	496,466	100.00%

Table 22. Census fleet of the city of Valencia (2017)

	Census fleet		Active fleet	
Regulation	**Passenger cars**			
Pre Euro	44,579	11.93%	0	0.00%
Euro 1	7,646	2.05%	1,101	0.36%
Euro 2	24,534	6.56%	12,512	4.11%
Euro 3	77,813	20.82%	73,922	24.30%
Euro 4	98,660	26.39%	96,687	31.78%
Euro 5	56,401	15.09%	55,837	18.35%
Euro 6	64,153	17.16%	64,153	21.09%
	373,786		**304,213**	
	Census fleet		**Active fleet**	
Regulation	**Motorcycle**			
Pre Euro	18,784	20.91%	0	0.00%
Euro I	16,565	18.44%	0	0.00%
Euro II	10,441	11.62%	4,281	9.19%
Euro III	35,284	39.27%	33,520	71.98%
Euro IV	8,769	9.76%	8,769	18.83%
Euro V	0	0.00%	0	0.00%
	89,843		**46,570**	
	Census fleet		**Active fleet**	
Regulation	**Lightweight transport vehicles**			
Pre Euro	10,666	22.42%	693	1.84%
Euro 1	3,415	7.18%	3,415	9.08%
Euro 2	3,415	7.18%	3,415	9.08%
Euro 3	11,253	23.65%	11,253	29.92%
Euro 4	10,208	21.45%	10,208	27.14%
Euro 5	4,692	9.86%	4,692	12.48%
Euro 6	3,930	8.26%	3,930	10.45%
	47,579		**37,606**	

Table 23. Estimate of the census and the real active fleet for the city of Valencia (2018), by type of vehicle and regulations to which they belong (age)

Consumption per person (kg / hab and year)				Emission Factor $kgCO_{2e}$ / kg
Spain		**629.70**		
Valencian Community		**646.85**		
Mix of consumed food (at home) (kg / hab and year)				
1	Oil	9.42	1.46%	2.20
2	Olives	2.41	0.37%	6.01
3	Rice	5.24	0.81%	2.66
4	Beverages	164.18	25.38%	1.43
5	Cereals	1.64	0.25%	0.53
6	Cookies	4.99	0.77%	0.53
7	Coffee and infusions	1.61	0.25%	1.39
8	Meats	47.82	7.39%	9.29
9	Chocolate and cocoa	3.27	0.51%	2.30
10	Fresh fruit	84.2	13.02%	0.50
11	Fruit and vegetables	12.68	1.96%	2.81
12	Fresh vegetables	60.45	9.35%	0.47
13	Dry fruits	3.68	0.57%	1.42
14	Eggs	8.8	1.36%	3.39
15	Milk	69.83	10.80%	1.39
16	Dairy derivatives	33.76	5.22%	8.86
17	Legumes	3.16	0.49%	0.66
18	Bread / flour	31.43	4.86%	0.98
19	Pasta	4.58	0.71%	1.98
20	Potatoes	27.28	4.22%	0.20
21	Fish	21.94	3.39%	6.50
22	Ready-made food	14.97	2.31%	-
23	Others	29.51	4.56%	-
TOTAL CONSUMED (AT HOME)		**646.85**		
TOTAL CONSUMED (AWAY FROM HOME)		**138.90**		**2.51**
TOTAL		**785.75**		

Table 24. Mix of food consumed per person in the Community of Valencia and average emission factors by food category
Source: Report on food consumption in Spain (2018)

Type of meat	Consumption (%)	Emission factor ($kgCO_{2e}$ / kg)
Chicken	38.56 %	4.12
Pork	30.64 %	5.60
Beef	15.03 %	26.05
Turkey	8.62 %	6.04
Lamb	4.17 %	33.84
Rabbit	2.98 %	4.70
TOTAL		**9.29**

Table 25. Emission factor: meat food mix

Type of beverage	Consumption (%)	Emission factor ($kgCO_{2e}$ / kg)
Wine derivatives	1.12 %	2.20
Wines	5.65 %	2.00
Beers	12.98 %	0.64
Ciders	0.25 %	0.77
Spirits	0.52 %	0.77
Juices and nectars	6.15 %	0.68
Bottled water	44.91 %	0.30
Soft drinks	28.42 %	0.63
TOTAL		**0.59**

Table 26. Emission factor: beverage mix

Type of clothing	Average mass (kg)	Emission factor ($kgCO_{2e}$ / piece)
Shoes (sneakers or boots, synthetic materials)	0.80	14.00
Pants (jeans)	0.70	33.40
Underwear	0.10	8.77
T-shirt (cotton)	0.28	18.00
Jacket (polystyrene)	0.80	1.90
TOTAL	**2.68**	**76.07**
FE average ($kgCO_{2e}$ / kg)		**19.26**

Table 27. Emission factor: clothing mix

	2007		2008		2009		2010		2011		2012	
	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)
Fields that depend on the City Council	**330,882.80**	**91,084.76**	**329,378.29**	**82,737.99**	**339,947.29**	**76,477.45**	**304,747.29**	**65,212.59**	**339,337.94**	**80,561.50**	**330,076.79**	**66,640.72**
Municipal buildings, equipment and facilities	95,241.09	28,010.44	97,068.13	24,518.73	95,997.83	20,079.11	99,588.00	19,998.11	99,710.12	25,060.99	93,688.97	17,831.86
Electricity consumption	88,892.00	26,734.28	90,505.13	23,199.57	89,077.83	18,688.19	92,022.00	18,477.34	90,400.00	23,189.65	83,494.00	15,782.67
Natural Gas consumption	6,349.09	1,276.17	6,563.00	1,319.16	6,920.00	1,390.92	7,566.00	1,520.77	9,310.12	1,871.33	10,194.97	2,049.19
Diesel oil consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Public lighting	84,745.00	25,487.07	86,282.87	22,117.26	84,922.17	17,816.35	74,932.00	15,045.79	87,170.00	22,361.09	84,730.00	16,016.31
Public and municipal transport	150,896.71	37,587.25	146,027.29	36,101.99	159,027.29	38,581.99	130,227.29	30,168.69	152,457.82	33,139.43	151,657.82	32,792.56
Petrol consumption	72.22	17.48	72.23	17.48	72.23	17.48	72.23	17.48	72.22	17.48	72.22	17.48
Diesel oil consumption	103,030.41	27,303.06	96,055.43	25,454.69	74,055.43	19,624.69	16,055.43	4,254.69	16,055.41	4,254.68	19,605.41	5,195.43
Natural Gas consumption	30,191.30	6,068.45	33,899.63	6,813.83	34,899.63	7,014.83	35,099.63	7,055.03	35,238.52	7,082.94	36,377.41	7,311.86
Biodiesel consumption (10%)	17,602.78	4,198.26	16,000.00	3,816.00	50,000.00	11,925.00	79,000.00	18,841.50	13,316.67	3,176.03	0.00	0.00
Biodiesel consumption (20%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87,775.00	18,608.30	95,602.78	20,267.79
Fields that not depend on the City Council	**9,366,984.61**	**2,593,039.62**	**9,123,838.34**	**2,406,056.22**	**8,745,662.34**	**2,163,102.46**	**8,378,133.34**	**2,048,760.57**	**8,437,082.14**	**2,218,660.22**	**7,772,199.85**	**1,871,842.57**
Residential sector (domestic)	1,770,237.43	466,260.73	1,783,244.96	422,596.91	1,899,150.04	392,189.83	1,809,062.04	363,390.21	1,816,614.78	427,996.95	1,833,252.42	355,715.43
Electricity consumption	1,107,197.00	332,989.60	1,159,582.00	297,240.66	1,189,230.00	249,495.91	1,115,286.00	223,941.22	1,132,102.00	290,409.88	1,066,475.00	201,593.17
Natural Gas consumption	663,040.43	133,271.13	623,662.96	125,356.25	709,920.04	142,693.93	693,776.04	139,448.98	684,512.78	137,587.07	766,777.42	154,122.26
Tertiary sector	1,641,431.48	481,805.03	1,688,040.04	426,060.09	1,685,221.96	352,352.09	1,642,352.96	329,800.09	1,501,844.76	378,597.51	1,438,596.50	273,545.84
Electricity consumption	1,522,578.00	457,915.48	1,567,997.00	401,931.43	1,548,681.00	324,907.35	1,508,764.00	302,948.71	1,381,897.66	354,488.15	1,304,000.14	246,491.97
Natural Gas consumption	118,853.48	23,889.55	120,043.04	24,128.65	136,540.96	27,444.73	133,588.96	26,851.38	119,947.10	24,109.37	134,596.36	27,053.87
Industry sector	577,585.00	132,349.96	556,976.00	121,734.62	473,799.00	96,453.32	455,984.00	91,626.78	402,893.00	87,566.65	184,395.38	35,764.61
Electricity consumption	162,961.00	49,010.54	176,788.00	45,316.83	138,665.00	29,091.39	125,392.00	25,177.79	118,603.00	30,424.36	108,488.00	20,507.22
Natural Gas consumption	414,624.00	83,339.42	380,188.00	76,417.79	335,134.00	67,361.93	330,592.00	66,448.99	284,290.00	57,142.29	75,907.38	15,257.38
Private and commercial transport	5,377,730.70	1,397,513.07	5,095,577.34	1,324,065.24	4,687,491.34	1,217,312.78	4,470,734.34	1,161,674.69	4,633,261.25	1,203,207.17	4,237,980.70	1,100,286.52
Petrol consumption	1,199,372.22	290,248.08	1,141,858.77	276,329.82	1,081,409.77	261,701.16	1,003,039.77	242,735.62	1,069,872.22	258,909.08	990,363.89	239,668.06
Diesel oil consumption	4,178,358.48	1,107,265.00	3,953,718.57	1,047,735.42	3,606,081.57	955,611.62	3,467,694.57	918,939.06	3,563,389.03	944,298.09	3,247,616.81	860,618.45
Urban rail transport	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82,468.34	21,155.00	77,974.86	14,739.40
Electricity consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82,468.34	21,155.00	77,974.86	14,739.40
Urban solid waste management (t) (no energy)	413,808.00	115,110.83	405,228.50	111,599.36	381,389.53	104,794.44	370,939.14	102,268.80	359,699.00	100,136.92	330,438.00	91,790.78
Waste collection (t)	377,545.00	115,110.83	366,027.95	111,599.36	343,708.91	104,794.44	335,425.20	102,268.80	328,433.00	100,136.92	301,059.00	91,790.78
Glass (t)	11,195.00	0.00	12,228.19	0.00	12,051.33	0.00	12,113.90	0.00	12,208.00	0.00	12,329.00	0.00
Paper and cardboard (t)	18,159.00	0.00	19,259.22	0.00	17,446.90	0.00	15,380.19	0.00	11,192.00	0.00	9,705.00	0.00
Plastics (t)	6,909.00	0.00	7,713.14	0.00	8,182.39	0.00	8,019.85	0.00	7,866.00	0.00	7,345.00	0.00
Total in the city	**9,697,867.41**	**2,684,124.38**	**9,453,216.63**	**2,488,794.21**	**9,085,609.63**	**2,239,579.91**	**8,682,880.63**	**2,113,973.16**	**8,776,420.08**	**2,299,221.72**	**8,102,276.65**	**1,938,483.30**
Variation from the reference year (%)	**-**	**-**	**-2.52%**	**-7.28%**	**-6.31%**	**-16.56%**	**-10.47%**	**-21.24%**	**-9.50%**	**-14.34%**	**-16.45%**	**-27.78%**
Energy from renewable sources	**31,711.94**		**31,711.94**		**31,711.94**		**31,711.94**		**37,583.69**		**40,982.25**	
Local electricity emission factor	**0.301**		**0.256**		**0.210**		**0.201**		**0.257**		**0.189**	

Table 28. Complete data: evolution of the CO_2 emissions inventory (2007–2012)
Source: SECAP 2016

	2013		2014		2015		2016		2017	2018	
	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)	Consumption (MWh)	Emisssions (t CO_2)		Consumption (MWh)	Emisssions (t CO_2)
Fields that depend on the City Council	**348,394.80**	**72,604.24**	**356,276.62**	**72,334.87**	**342,473.56**	**78,037.98**	**342,288.39**	**74,760.49**		**315,558.31**	**70,433.60**
Municipal buildings, equipment and facilities	108,555.70	19,312.94	111,793.55	18,763.15	105,488.54	22,018.32	100,895.25	19,098.01		86,645.52	16,469.10
Electricity consumption	99,661.19	17,447.60	103,039.11	16,924.80	96,654.18	20,158.64	92,909.54	17,427.60		78,784.47	14,811.48
Natural Gas consumption	7,682.84	1,544.25	7,524.70	1,512.46	7,522.33	1,511.99	6,965.66	1,400.10		6,649.38	1,336.53
Diesel oil consumption	1,211.67	321.09	1,229.74	325.88	1,312.04	347.69	1,020.05	270.31		1,211.67	321.09
Public lighting	84,880.00	14,859.87	85,200.00	13,994.62	74,490.00	15,535.98	74,580.00	13,989.42		54,810.00	10,304.28
Public and municipal transport	154,959.11	38,431.44	159,283.07	39,577.11	162,495.02	40,483.68	166,813.14	41,673.06		174,102.79	43,660.22
Petrol consumption	72.22	17.48	72.22	17.48	72.22	17.48	72.22	17.48		72.22	17.48
Diesel oil consumption	113,776.51	30,150.78	118,097.61	31,295.87	122,175.32	32,376.46	127,197.76	33,707.41		135,353.17	35,868.59
Natural Gas consumption	41,110.37	8,263.19	41,113.24	8,263.76	40,247.48	8,089.74	39,543.16	7,948.17		38,677.40	7,774.16
Biodiesel consumption (10%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
Biodiesel consumption (20%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00
Fields that not depend on the City Council	**7,452,437.62**	**1,770,910.90**	**7,394,718.51**	**1,734,423.59**	**7,681,313.45**	**1,907,908.70**	**7,568,248.04**	**1,838,535.90**		**8,890,623.34**	**2,092,591.19**
Residential sector (domestic)	1,708,299.96	317,775.02	1,588,055.22	282,265.65	1,634,087.00	336,265.64	1,512,474.00	290,784.46		1,666,616.00	321,365.11
Electricity consumption	987,128.98	172,815.79	1,005,263.04	165,120.58	1,032,985.00	215,444.14	985,013.00	184,764.80		1,048,054.00	197,034.15
Natural Gas consumption	721,009.82	144,922.97	582,632.00	117,109.03	601,102.00	120,821.50	527,461.00	106,019.66		618,562.00	124,330.96
Tertiary sector	1,287,641.37	227,177.34	1,363,764.51	229,720.28	1,353,826.22	281,461.76	1,299,962.89	245,409.60		1,572,301.00	297,444.13
Electricity consumption	1,220,111.21	213,603.78	1,208,265.21	198,464.92	1,235,048.55	257,587.45	1,183,174.55	221,935.15	→	1,429,875.00	268,816.50
Natural Gas consumption	67,530.16	13,573.56	155,499.30	31,255.36	118,777.67	23,874.31	116,788.34	23,474.46		142,426.00	28,627.63
Industry sector	171,290.34	31,909.72	165,773.98	29,921.83	300,323.00	61,044.85	302,509.00	59,600.20		313,807.00	61,843.35
Electricity consumption	97,167.34	17,011.00	92,497.98	15,193.36	89,882.00	18,746.21	89,698.00	16,825.19		94,758.00	17,814.50
Natural Gas consumption	74,123.00	14,898.72	73,276.00	14,728.48	210,441.00	42,298.64	212,811.00	42,775.01		219,049.00	44,028.85
Private and commercial transport	4,209,494.15	1,093,828.07	4,200,575.78	1,091,926.91	4,314,997.95	1,122,029.98	4,375,367.24	1,137,458.73		4,930,979.86	1,306,993.25
Petrol consumption	942,951.17	228,194.18	922,855.40	223,331.01	932,368.61	225,633.20	957,112.35	231,621.19		2,160,036.81	561,609.57
Diesel oil consumption	3,266,542.98	865,633.89	3,277,720.39	868,595.90	3,382,629.34	896,396.77	3,418,254.89	905,837.55		2,770,943.05	745,383.68
Urban rail transport	75,711.80	13,254.80	76,549.02	12,573.64	78,079.28	16,284.58	77,934.91	14,618.72		77,646.18	14,597.48
Electricity consumption	75,711.80	13,254.80	76,549.02	12,573.64	78,079.28	16,284.58	77,934.91	14,618.72		77,646.18	14,597.48
Urban solid waste management (t) (no energy)	313,576.37	86,965.94	317,751.17	88,015.28	328,282.40	90,821.89	328,612.70	90,664.18		329,273.30	90,347.87
Waste collection (t)	285,234.29	86,965.94	288,675.95	88,015.28	297,881.20	90,821.89	297,363.93	90,664.18		296,329.39	90,347.87
Glass (t)	12,083.62	0.00	12,079.17	0.00	12,127.23	0.00	12,308.24	0.00		12,670.26	0.00
Paper and cardboard (t)	8,993.86	0.00	9,653.01	0.00	10,602.18	0.00	11,155.84	0.00		12,263.16	0.00
Plastics (t)	7,264.60	0.00	7,343.04	0.00	7,671.79	0.00	7,784.69	0.00		8,010.49	0.00
Total in the city	**7,800,832.42**	**1,843,515.14**	**7,750,995.13**	**1,806,758.46**	**8,023,787.01**	**1,985,946.69**	**7,910,536.43**	**1,913,296.39**		**9,206,181.64**	**2,163,024.80**
Variation from the reference year (%)	**-19.56%**	**-31.32%**	**-20.08%**	**-32.69%**	**-17.26%**	**-26.01%**	**-18.43%**	**-28.72%**		**-5.07%**	**-19.41%**
Energy from renewable sources	**40,982.25**		**40,982.25**		**40,982.25**		**40,982.25**			**40,982.25**	
Local electricity emission factor	**0.175**		**0.164**		**0.209**		**0.188**			**0.188**	

Table 29. Complete data: evolution of the CO_2 emissions inventory (2013–2018)
Source: SECAP 2016

	Scope 1		Scope 2		Scope 3		TOTAL	
	Consumption (MWh)	Emissions (t CO_2)	Consumption (MWh)	Emissions (t CO_2)	Consumption (MWh)	Emissions (t CO_2)	Consumption (MWh)	Emissions (t CO_2)
Fields that depend on the City Council	**181,963.84**	**45,317.84**	**133,594.47**	**25,115.76**	**-**	**-**	**315,558.31**	**70,433.60**
Municipal buildings, equipment and facilities	7,861.05	1,657.62	78,784.47	14,811.48	-	-	86,645.52	16,469.10
Electricity consumption	-	-	78,784.47	14,811.48	-	-	78,784.47	14,811.48
Natural Gas consumption	6,649.38	1,336.53	-	-	-	-	6,649.38	1,336.53
Diesel oil consumption	1,211.67	321.09	-	-	-	-	1,211.67	321.09
Public lighting	-	-	54,810.00	10,304.28	-	-	54,810.00	10,304.28
Electricity consumption			54,810.00	10,304.28			54,810.00	10,304.28
Public and municipal transport	174,102.79	43,660.23	-	-	-	-	174,102.79	43,660.23
Petrol consumption	72.22	17.48	-	-	-	-	72.22	17.48
Diesel oil consumption	135,353.17	35,868.59	-	-	-	-	135,353.17	35,868.59
Natural Gas consumption	38,677.40	7,774.16	-	-	-	-	38,677.40	7,774.16
Biodiesel consumption (10%)	-	-	-	-	-	-	-	-
Biodiesel consumption (20%)	-	-	-	-	-	-	-	-
Fields that not depend on the City Council	**4,604,259.88**	**1,159,908.00**	**2,689,554.86**	**507,465.77**	**2,286,887.85**	**2,181,937.07**	**9,580,702.59**	**3,849,310.84**
Residential sector (domestic)	618,562.00	124,330.96	1,048,054.00	197,034.15	-	-	1,666,616.00	321,365.11
Electricity consumption	-	-	1,048,054.00	197,034.15	-	-	1,048,054.00	197,034.15
Natural Gas consumption	618,562.00	124,330.96	-	-	-	-	618,562.00	124,330.96
Tertiary sector	142,426.00	28,627.63	1,429,875.00	268,816.50	-	-	1,572,301.00	297,444.13
Electricity consumption	-	-	1,429,875.00	268,816.50	-	-	1,429,875.00	268,816.50
Natural Gas consumption	142,426.00	28,627.63	-	-	-	-	142,426.00	28,627.63
Industry sector	219,049.00	44,028.85	94,758.00	17,814.50	-	-	313,807.00	61,843.35
Electricity consumption	-	-	94,758.00	17,814.50	-	-	94,758.00	17,814.50
Natural Gas consumption	219,049.00	44,028.85	-	-	-	-	219,049.00	44,028.85
Private and commercial transport	3,293,357.93	872,217.14	-	-	1,639,107.04	434,776.11	4,932,464.97	1,306,993.25
Petrol consumption	1,485,721.61	386,645.02	-	-	672,000.28	174,964.55	2,157,721.89	561,609.57
Diesel oil consumption	1,807,636.32	485,572.12	-	-	967,106.76	259,811.56	2,774,743.08	745,383.68
Electricity consumption	-	-	-	-	-	-	-	-
Urban rail transport	-	-	77,646.18	14,597.48	-	-	77,646.18	14,597.48
Electricity consumption			77,646.18	14,597.48			77,646.18	14,597.48
Port	711.48	142.56	10,921.68	3,009.60	450,366.84	172,847.84	462,000.00	176,000.00
Electricity consumption	-	-	10,921.68	3,009.60	-	-	10,921.68	3,009.60
Fuel consumption	711.48	142.56	-	-	450,366.84	172,847.84	451,078.32	172,990.40
Airport	880.17	213.00	28,300.00	6,193.53	197,413.97	51,098.59	226,594.14	57,505.12
Electricity consumption	-	-	28,300.00	6,193.53	-	-	28,300.00	6,193.53
Fuel consumption	880.17	213.00	-	-	197,413.97	51,098.59	198,294.14	51,311.59
Goods consumption	-	-	-	-	-	736,760.41	-	736,760.41
Food (LCA)	-	-	-	-	-	645,289.13	-	645,289.13
Clothing (LCA)	-	-	-	-	-	91,471.28	-	91,471.28
Other goods (medicines, technology, etc.)	-	-	-	-	-	-	-	-
Construction and Buildings	-	-	-	-	-	786,454.12	-	786,454.12
Large buildings	-	-	-	-	-	780,872.68	-	780,872.68
New reforms	-	-	-	-	-	5,581.44	-	5,581.44
Urban solid waste management (t) (no energy)	329,273.30	90,347.87	-	-	-	-	329,273.30	90,347.87
Waste collection (t)	296,329.39	90,347.87					296,329.39	90,347.87
Glass (t)	12,670.26	-					12,670.26	-
Paper and cardboard (t)	12,263.16	-					12,263.16	-
Plastics (t)	8,010.49	-					8,010.49	-
Total in the city	**4,786,223.72**	**1,205,225.85**	**2,823,149.33**	**532,581.53**	**2,286,887.85**	**2,181,937.07**	**9,896,260.90**	**3,919,744.45**

Table 30. Complete data: extended carbon inventory (2018)
Source: Self-made

	SECAP inventory 2016	Updated inventory 2018	Extendend inventory 2018
Fields that depend on the City Council	**74,760.49**	**70,433.60**	**70,433.60**
Municipal buildings, equipment and facilities	19,098.01	16,469.10	16,469.10
Electricity consumption	17,427.60	14,811.48	14,811.48
Natural Gas consumption	1,400.10	1,336.53	1,336.53
Diesel oil consumption	270.31	321.09	321.09
Public lighting	13,989.42	10,304.28	10,304.28
Electricity consumption	13,989.42	10,304.28	10,304.28
Public and municipal transport	41,673.06	43,660.22	43,660.23
Petrol consumption	17.48	17.48	17.48
Diesel oil consumption	33,707.41	35,868.59	35,868.59
Natural Gas consumption	7,948.17	7,774.16	7,774.16
Biodiesel consumption (10%)	-	-	-
Biodiesel consumption (20%)	-	-	-
Fields that not depend on the City Council	**1,838,535.90**	**2,032,789.54**	**3,849,310.84**
Residential sector (domestic)	290,784.46	321,365.11	321,365.11
Electricity consumption	184,764.80	197,034.15	197,034.15
Natural Gas consumption	106,019.66	124,330.96	124,330.96
Tertiary sector	245,409.60	297,444.13	297,444.13
Electricity consumption	221,935.15	268,816.50	268,816.50
Natural Gas consumption	23,474.46	28,627.63	28,627.63
Industry sector	59,600.20	61,843.35	61,843.35
Electricity consumption	16,825.19	17,814.50	17,814.50
Natural Gas consumption	42,775.01	44,028.85	44,028.85
Private and commercial transport	1,137,458.73	1,247,191.60	1,306,993.25
Petrol consumption	231,621.19	277,945.43	561,609.57
Diesel oil consumption	905,837.55	969,246.17	745,383.68
Electricity consumption	-	-	-
Urban rail transport	14,618.72	14,597.48	14,597.48
Electricity consumption	14,618.72	14,597.48	14,597.48
Port			176,000.00
Electricity consumption			3,009.60
Fuel consumption			172,990.40
Airport			57,505.12
Electricity consumption			6,193.53
Fuel consumption			51,311.59
Goods consumption			736,760.41
Food (LCA)			645,289.13
Clothing (LCA)			91,471.28
Other goods (medicines, technology, etc.)			-
Construction and Buildings			786,454.12
Large buildings			780,872.68
New reforms			5,581.44
Urban solid waste management (t) (no energy)	90,664.18	90,347.87	90,347.87
Waste collection (t)	90,664.18	90,347.87	90,347.87
Glass (t)	-	-	-
Paper and cardboard (t)	-	-	-
Plastics (t)	-	-	-
Total in the city	**1,913,296.39**	**2,103,223.15**	**3,919,744.45**

Table 31. Complete data: comparison between SECAP carbon inventory (2016), updated SECAP (2018) and extended carbon inventory (2018)
Source: Self-made

Year	2007	2008	2009	2010	2011
Emissions (tCO2)	2,684,124.38	2,488,794.21	2,239,579.91	2,239,579.91	2,113,973.16
Population (hab)	797,654	807,200	814,208	809,267	798,033
Carbon footprint (ha)	725,439.02	672,647.08	605,291.87	605,291.87	571,344.10
Carbon footprint (gha)	935,816.34	867,714.74	780,826.51	780,826.51	737,033.89
Carbon footprint (ha/hab)	0.91	0.83	0.74	0.75	0.72
Carbon footprint (gha/hab)	1.17	1.07	0.96	0.96	0.92

Table 32. Evolution of the carbon footprint from SECAP data (2007–2011)

Year	2012	2013	2014	2015	2016
Emissions (tCO2)	2,113,973.16	2,299,221.72	2,299,221.72	1,938,483.30	1,938,483.30
Population (hab)	797,028	792,303	786,424	786,189	790,201
Carbon footprint (ha)	571,344.10	621,411.28	621,411.28	523,914.40	523,914.40
Carbon footprint (gha)	737,033.89	801,620.55	801,620.55	675,849.58	675,849.58
Carbon footprint (ha/hab)	0.72	0.78	0.79	0.67	0.66
Carbon footprint (gha/hab)	0.92	1.01	1.02	0.86	0.86

Table 33. Evolution of the carbon footprint from SECAP data (2011–2016)

Year	Extentended inventary 2018	Tren Scenarios 2030			
		E1	E2	E3	E1+E2+E3
Emissions (tCO2)	3,919,744.45	3,519,310.74	3,893,002.26	3,866,290.07	3,439,114.17
Population (hab)	791,413	819,112	819,112	819,112	819,112
Carbon footprint (ha)	1,059,390.39	951,165.06	1,052,162.77	1,044,943.26	929,490.32
Carbon footprint (gha)	1,366,613.60	1,227,002.93	1,357,289.98	1,347,976.81	1,199,042.51
Carbon footprint (ha/hab)	1.34	1.16	1.28	1.28	1.13
Carbon footprint (gha/hab)	1.73	1.50	1.66	1.65	1.46

Table 34. Carbon footprint for the extended carbon inventory (2018) and trend scenarios (2030)