Measuring to Evaluate Alternatives: The Carbon Footprint Calculator for Urban Planning of the Community of Madrid

Alexandra Delgado, Roberto Álvarez and Fernando Beltrán

Abstract

This work is oriented to analyse the carbon footprint calculator for urban planning developed by the authors funded by the Community of Madrid. The starting point is the evolution of urban planning related to environmental problems that have resulted in current situation. Now it is needed to plan cities in a context of climate crisis. Planning with climate change criteria is especially important in the Community of Madrid, a hotspot of urban growth at the European level with a very unique dynamic, near doubling the artificial surfaces from 1990 to 2018, in less than 30 years, and without regional planning. The carbon footprint calculator consists of an assessment of the uses and activities to be developed in future planning that generate greenhouse gas emissions, as well as changes in land use that affect the soil's sink capacity. Mitigation strategies (as self-generation capacity by renewable energies) are analysed for assessment and quantification where data is available. The carbon footprint calculator includes the derived and influential activities that should be included in the application for the approval of urban planning instruments, within the ordinary or simplified strategic environmental assessment procedures, in relation to the potential environmental impacts in terms of climate change. The carbon footprint calculator could help to measure different urban planning alternatives (alternative 0, no transformation and others) for the urban development or transformation, as in the application of a planning proposal is shown. Consequently, thanks to carbon footprint calculator it is possible to choose the lowest carbon emissions alternative among several and to make visible the crucial aspects that generate the most emissions at an early stage of urban development as it is a masterplan.

Keywords

Carbon footprint · Calculator · Urban planning · Community of Madrid · Alternatives

1 Introduction

This research introduces the tool for calculating greenhouse gas (GHG) emissions generated by urban planning in the Community of Madrid with the aim of establishing itself as a comprehensive and synthetic instrument for quantifying these emissions. This tool has been developed at the request of the Subdirectorate General for Strategic Environmental Assessment and Sustainable Development of the Community of Madrid. The calculator is an example of the incorporation of measurable scientific criteria in decision-making in the current context of climate crisis (Álvarez et al., 2022).

This instrument includes the derived and influential activities that should be included in the application for the initiation of urban planning instruments, within the ordinary strategic environmental assessment procedure, in relation to the potential environmental impacts in terms of climate change, in accordance with Article 18 of Law 21/2013, of 9 December, on environmental assessment.

It also involves a proposal of the information to be included in the application for the initiation of urban planning instruments subject to ordinary strategic environmental assessment, for masterplans for the entire municipality, or simplified, for masterplans for a specific area of the

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municipality that includes urban design, in terms of climate change.

In simple words, carbon footprint is defined as the environmental indicator that aims to reflect all greenhouse gases emitted by direct or indirect effects of human actions, events or products. The calculator concept is a tool that allows the users to estimate the greenhouse gas emissions associated with the activities of humans in a country, a region, an organisation, etc., considering both direct and indirect greenhouse gas emissions from electricity consumption.

A wide spectrum of environmental urban planning calculation tools currently exists, tools that help their users to address GHG emission and climate change mitigation. But the one here presented is specifically developed for calculation of GHG in the territorial reality of the region of Madrid, just from urban planning stage, and it has the capacity to work simultaneously at both the regional and local scale levels, or to capture both building performance and transportation impacts.

In practice, this means providing scientific and technical advice on the assessment of climate change in urban planning administrative processing in the Community of Madrid.

This scientific research shows the purpose and justification of the tool by showing the singularities of the development model of the geographical area of the Community of Madrid, where the calculation is circumscribed.

It also specifies the methodological aspects of the calculation both in its general approach to energy consumption, mobility, water consumption and waste treatment, the sink effect of soils that varies with changes in land use resulting from planning and, finally, the strategies for mitigating greenhouse gas emissions and their valuation.

In this way, the role of the tool is analysed with several alternatives of a masterplan in order to assess planning and to be able to select the most suitable one with the lowest carbon footprint. But also in making visible which planning decisions have the greatest effect on reducing greenhouse gas emissions and are therefore the most suitable way to plan and transform to the goal of a low-carbon city. Measuring development in such important aspects as the carbon footprint helps us to make decisions of particular relevance in urban planning, the effects of which are very long term if not irreversible.

2 The Specificity of the Case of the Community of Madrid

The Metropolitan Region of Madrid has been a hotspot of urban growth at European level with a very unique dynamic. As a result, the Community of Madrid has almost doubled the artificial surfaces from 1990 to 2018 in less than 30 years (Fig. 1), so the processes of urban expansion have been very important for the region. It must be underlined that the region has got no land-use planning, only plans for municipalities.

The Community of Madrid is the only region in Spain that does not have spatial planning tools approved, i.e., a plan for the entire region or at the subregional level.

This means that territorial transformations, such as the creation of a new neighbourhood, are decided in each municipal plan or modifications to it, without a regional framework, although the impact in such a conurbation region is regional, especially in topics as mobility.

Therefore, the transformation of the region has been decided on a plan-by-plan basis (sectoral, such as communications and municipal infrastructures) and not with a vision of the whole and of the interrelationships between areas, which in practice means a lack of control over the development as a whole. This also influences climate change in a specific way through induced mobility and through the occupation of the territory and the sealing of soils caused by artificialisation.

Added to this is the territorial impact of the development model and the specific weight of metropolitan mobility in the Madrid Region as a whole, which is much greater than in other Spanish regions (Fig. 2). It has a very important centre-periphery mobility, which has varied through the different conformations of the metropolitan fabric, in a first wave during the developmentalist period and (1940–1975) in a second wave in recent decades (especially during the “prodigious decade” 1997–2008). This configuration and development pattern implies high levels of energy consumption and greenhouse gas emissions for the region (Delgado, 2012).

In the Spanish context, there are currently some tools for calculating greenhouse gas emissions in urban planning in different regions (Sobrino, 2017; Iraegui and González, 2017; Gobierno Vasco, 2017). These tools are of great interest but need to be adapted and adjusted to the Madrid context in order to estimate or weight key aspects for the reality of the Community of Madrid, such as the aforementioned, metropolitan mobility and the loss of land due to urban development. These mentioned aspects (mobility and the loss of land) have been improved in the methodology of the tool is presented and the justification for the development of a calculator is its specificity for the region of Madrid, with the biggest metropolitan area of the country including Madrid the second city in Europe, after Berlin, in one municipality.

This tool aims to offer an instrument for measuring the carbon footprint with a tool to assess urban planning adapted as close as possible to the reality of Madrid. This is of interest so that any plan that will be presented, of growth, of transformation, can be evaluated in order to make a

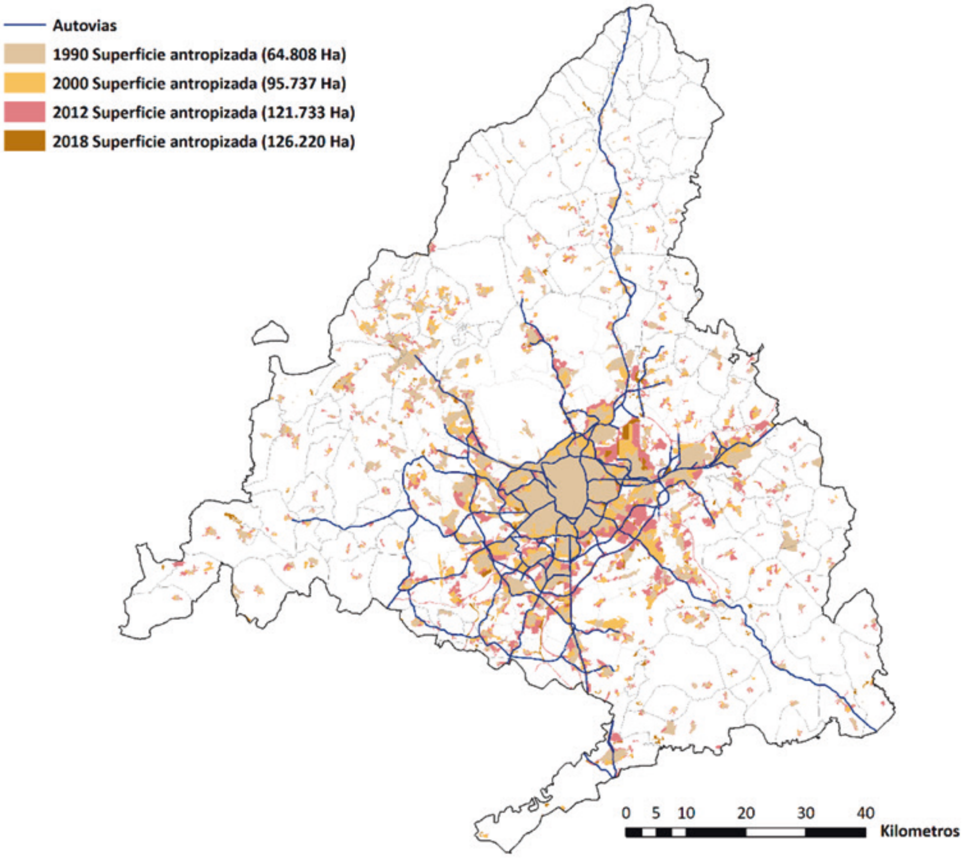

Fig. 1 Evolution of anthropisation in the Autonomous Community of Madrid (Córdoba and Álvarez, 2020, p. 23) based on CORINE Land Cover data (1990, 2000, 2012, and 2018)

better decision, in terms of its position, in terms of its density, in terms of its parameters in relation to its impact on climate change.

In this way, although there is still a lack of regional planning, it is possible to analyse an impact that affects the whole (and globally), such as climate change. It is possible to visualise how urban transformation decisions in one area or municipality are related to the whole and can influence the urban model and, therefore, the development model. Specifically measuring the carbon footprint of an area or territory involves characterising it in terms of its energy consumption and land use.

The need for the application of sustainable urban planning in the Community of Madrid is crucial because of the scale and population of the region and the fact that it has become a centre of accumulation and consumption (Méndez, 2007) which, through its development model, has had an impact on climate change.

3 Method

The main stumbling block in establishing a methodology for calculating the emissions associated with urban planning at such an early stage is undoubtedly the lack of information or certainty. The main stumbling block in establishing a methodology for calculating the emissions associated with urban planning, such an early stage, is undoubtedly the lack of information or certainty.

In planning at this level, the detail is not known, but only the allocation and areas assigned land to certain uses, but only that. The implications of this for the calculation are first to recognise that only an approximation will be possible and secondly that it will be necessary to use sources of statistical information.

The methodology here explained is a continuation of previous research works released between the years 2015 and 2019 by Roberto Álvarez Fernández and Sergio Zubelzu Mínguez (Zubelzu and Álvarez, 2015; Zubelzu et al., 2015; Álvarez et al., 2017; Álvarez, 2019; Álvarez and Giménez, 2019) which have led to the development of a tool for calculating greenhouse gas emissions specific to the Community of Madrid. There is no any other existing assessment methods for calculating carbon footprint from urban planning stage applied to Madrid region.

These previous reference works established the pillars on which the methodology applied in this new research are based and expanded them to include some more aspects.

The methodology followed for the development of this tool consists of analysing the uses and activities to be

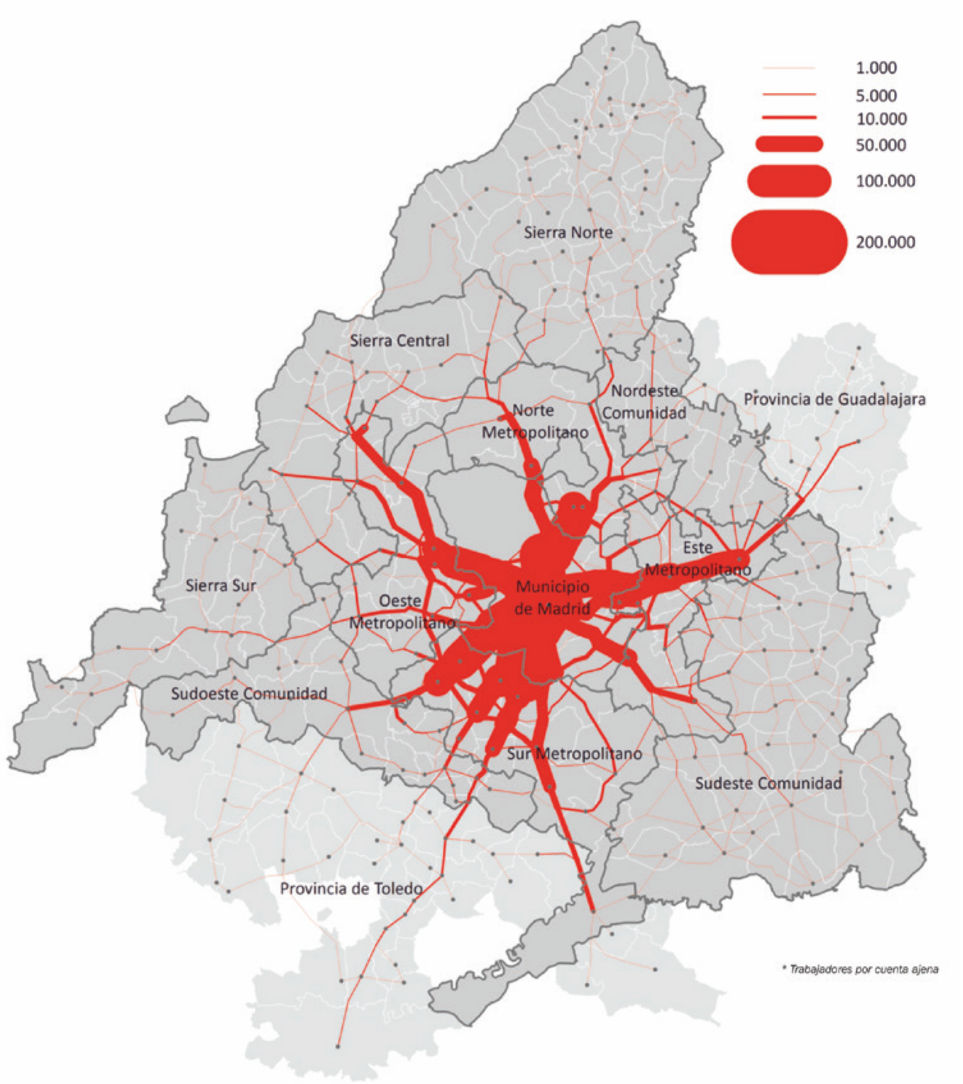

Fig. 2 Inter-municipal flow of workers in the Community of Madrid (2016) (Community of Madrid, 2017a)

developed in future planning that generates emissions, as well as changes in land use that affect the soil's sink capacity. Finally, mitigation strategies are analysed for assessment and quantification where data is available.

In terms of greenhouse gas emissions from energy consumption, emission sources are characterised, consumption is quantified and emission factors are obtained in order to calculate greenhouse gas emissions.

The general theoretical framework for calculation involves defining the cause of emissions around which to orient the calculation process. Thus, making appropriate simplifications, planning should define the land-use pattern and the associated GHG emissions. This requires characterising the emission sources, quantifying consumptions and emission factors and finally calculating the emissions. See an example of emissions from drinking water consumption (Fig. 3).

In the case of calculating the carbon sink of soils, the difference in tCO_2eq capture between the initial and final situation due to the urban transformation under review is calculated. Emissions saved by mitigation are also calculated, when data are available and depending on the type of strategy followed, with this aspect being treated differently.

To sum up, the methodology focuses on the following main stages:

- The land-use distribution, including a preliminary assessment.
- Structuring the calculation of greenhouse gas emissions based on land use.
- The definition of the key factors that affect the calculation of greenhouse gas emissions for each type of land use.
- The relevant aspects of mitigation, adaptation and carbon sequestration.

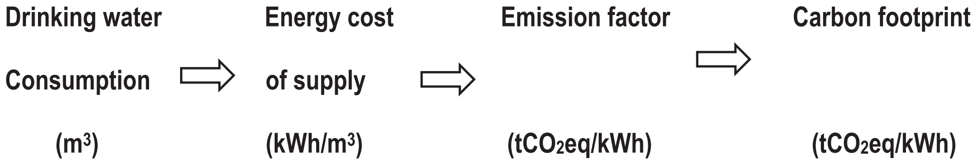

Fig. 3 Emissions from drinking water consumption

3.1 Land-Use Distribution: Initial Balance

This represents the starting point and a key action for GHG calculation. It is an overview, a first approach that allows to know the magnitude of the problem to be analysed and a preliminary approach for the evaluators to obtain an overall idea of the urban planning foreseen for a geographical area. At this stage of the study, the general data of the urban development to be analysed are defined. One of them is, for example, the household size for the planned development [average household size 2.5 persons by the source: Instituto Nacional de Estadística (INE),[1] the figure has remained constant since 2018]. On the other hand, the geographical location of the municipality where the land is situated, the definition of the current and future (planned) land uses must be detailed at this stage, specifying the type of use foreseen, together with the assigned surface areas. It is worth highlighting the introduction of the concept undeveloped land for those soils that do not have pre-existence or that are not going to be developed.

3.2 Structure for GHG Calculation

The general structure for calculating the carbon footprint derives from the distribution of the land according to the different possible uses. These possible uses of the land and buildings with reference to the National Classification of Economic Activities (CNAE) are the following: residential, tertiary, facilities and industrial use.

In addition, GHG emissions from street lighting and irrigation of public green areas and landscaped open spaces should be included. A distinction must be made between the two categories, even if they have vegetation cover, since public green areas are public and constitute their own plots, while landscaped open spaces are private and occur on plots with other uses.

3.3 Key Factors of GHG Generation for Each Type of Land Use

Efforts to calculate GHG emissions depend on understanding the sources and quantities of these gases. The proposed calculation method is based on two previous research works:

- Zubelzu, S., Álvarez, R., & Hernández, A. (2015). Methodology to calculate the carbon footprint of household land use in the urban planning stage. *Land Use Policy*, 48, 223–235
- Zubelzu, S., & Álvarez, R. (2015). Urban planning and industry in Spain: A novel methodology for calculating industrial carbon footprints. *Energy Policy*, 83, 57–68.

The tool represents a simplified representation of collecting data for analysing that tries to encompass all emissions generated by human activity into four emission factors. This consumption-based activities cause a carbon footprint that is persistent over time, being possible to evaluated and quantified and their evolution over time or after the application of mitigation measures can be seen.

For each one of the aforementioned land uses, the greenhouse gas emissions are calculated on the basis that they are generated by energy consumption as a result of different actors:

- Air-conditioning and domestic hot water (DHW) and the rest of the activities.
- Consumption derived from the water cycle.
- Solid waste treatment.
- Mobility.

In the following sections, they will be addressed each of them separately. The four key factors are equally important. The applied methodology evaluates and aggregates the emissions from the different sources and the weight of the key factors contribute differently in every alternative depending of the features, but their weight on the total does not need to be weighted.

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[1] Available at: https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176952&menu=ultiDatos&idp=1254735572981.

3.3.1 Energy Consumption: Air-Conditioning and DHW and the Rest of Activities

Energy consumption can be calculated according to the particularities of each land use. A distinction can be made between a first level of influence that corresponds to the consumption and energy for air-conditioning and domestic hot water and the second level of influence that represents the energy consumption for the performance of other activities. In the first level, energy consumption can be established by means of the energy certification label of the projected building, taking into account the particularities of each land use (Fernández-Herguedas, 2016; Zabalza et al., 2010) established by the Spanish Institute for Energy Diversification and Savings (IDAE). In turn, it is considered that the electrical energy network serves household appliances, lighting and air-conditioning, while heating and hot water are supplied by natural gas. On the other hand, the calculation can also be carried out by applying the technical building code, allowing the percentages of gas and electricity to be distributed in different ways.

On the second level, energy consumption must be estimated for the performance of the activities carried out in each land use, which will be different in each one, both in terms of the quantities and the type of fuel used. The values for the consumption of energy of this second level in the residential, industrial, tertiary and facilities (schools, medical centres, etc.) sectors are obtained from various sources (Sech-Spahousec, 2011; Hernández Sánchez, 2012; Mertens, 2013; Zubelzu and Álvarez, 2015, 2016; INE—National Statistical Institute, 2017; Díaz Martín, 2018).

3.3.2 Consumptions Derived From the Water Cycle

The average annual water consumption for different land uses can be obtained from several sources of information (Community of Madrid, 1984; INE—National Statistical Institute, 2006, 2016; IDAE, 2010; López-Jiménez et al., 2017; Ferrer et al., 2017), either on the basis of square metres built or per inhabitant. Once these consumptions are known, the relationship with emissions is obtained through the energy cost that represents the energy of the water cycle. This will include the processes of adduction, distribution, sewerage, purification and regeneration. This factor relates to the energy required in kWh per cubic metre of water supplied (IDAE, 2010) and, together with the emission factor of the electricity mix in Spain averaged over the last 5 years (Oficina Catalana del Cambio Climático, 2013) makes it possible to calculate the carbon footprint of water consumption.

3.3.3 Solid Waste Treatment

Municipal waste includes waste from the cleaning of public roads, green areas, recreational areas and beaches; furniture, electrical and electronic equipment, clothing, batteries, household goods and abandoned vehicles; waste and rubble from minor works and home repairs. It also includes commercial waste, defined as waste generated by retail and wholesale trade, hotels and restaurants, bars, markets, offices and services. In addition, for management purposes, waste generated by industry, which is considered to be similar to municipal waste, has been considered to be comparable to this waste.

Direct and indirect emissions from the complete management process are included: collection and transport, transfer plants, pre-treatment plants, final treatment plants and final disposal of the waste. In addition, a differentiation is made between the possibility of selective collection and non-separate collection.

The generation of the different types of waste by each land use and the corresponding greenhouse gas emissions can be calculated from data obtained from various sources (Zubelzu et al., 2015; INE—National Statistical Institute, 2016, 2017; Community of Madrid, 2016, 2017b).

3.3.4 Mobility

In order to determine the carbon emissions associated with the mobility, it would be necessary to know the data related with the number of trips (journeys) generated as a result of the activities in each land use planned in that area. A part of this information can be extracted from surveys, as the Community of Madrid Mobility Survey (Community of Madrid, 2018) and other publications (Hernández et al., 2008; Tejada, 2018; Martínez Palencia et al., 2016; Álvarez and Giménez, 2019; Álvarez, 2019; Community of Madrid, 2020), but it will therefore be necessary to combine the available statistical data with additional research techniques in order to complete the estimation of emissions. The information is complemented with the application of the Theory of Gravitational Modelling (Zubelzu et al., 2011; Zubelzu et al., 2015; Álvarez et al., 2017). It has been applied with the objective of estimating the distribution of movements and the distances travelled, which allow estimating the distribution of trips from a population (origin-i) to a set of destinations-j by weighting different alternatives and establishing the so-called degree of attraction (DoA). This is a factor that depends on the mass (inhabitants) of the different destinations (Mj) and the corresponding distances separating them from the origin, which in turn represent the distances to be travelled (dij). This information makes it is possible to estimate the distribution of the number of outbound vehicle journeys from a starting town (i) to the different destinations (j), and thus the total mileage travelled.

In the case of private vehicles, the statistical analysis of the percentage composition of the vehicle fleet (diesel and petrol) in the Community of Madrid is obtained from the General Directorate of Traffic (DGT) and the estimated fossil fuel consumption of the different vehicle models is provided (Zubelzu et al., 2015; Álvarez, 2019; Álvarez and Giménez, 2019). This makes it is possible to estimate both, fuel consumption and greenhouse gas emissions.

At the same time, the emissions of public transport journeys are evaluated using the emission factors of these vehicles, means of transport per kilometre and passenger (Oficina Catalana del Cambio Climático, 2013). Mobility of heavy-duty vehicles and vans in the industrial and tertiary sectors is estimated through the number of such vehicles (trucks and vans) per surface area and averaged number of kilometres travelled (Oficina Catalana del Cambio Climático, 2013; Community of Madrid, 2019, 2020).

Residential Land Use: Degree of Attraction Calculation

To determine this parameter as a property of a destination town, it is necessary to apply the Theory of Gravitational Modelling that, in its maximum simplification, considers that the number of movements generated at an origin (point being studied) and attracted to a set of destinations are directly proportional to population of destination and inversely proportional to the distance between both points (origin and destination). This simplification is necessary when exists a large number of municipalities (179 in the Community of Madrid), each of which could be either origin and/or a destination. The steps to be followed to make this calculation are summarised as follows:

Step 1: Construction of distance matrix (D): This is a square matrix with a number of rows and columns equal to the destination towns. Each element dij represents the distance from origin (i) to destination (j),

Step 2: Construction of the mass matrix (M): This matrix is composed by the number of inhabitants of each municipality. It is a single column matrix where each element (M1j) represents (for j = 1–179) the population (mass) of each municipality.

Step 3: Determination of the force of attraction (FoA) and construction of the matrix of forces of attractions (F). It is a square matrix. Each element (Fij) is obtained as a result of the application of the Gravitational Law Equation (Eq. 1), where K is a value that allows to emphasise the importance of a destiny for different (work, commercial, or recreational among others) reasons. In the case of existing a decentralised model where densely populated areas coexist with larger, less populated areas, the force of attraction depends mostly on population and distance factors and the value of the parameter "K" is considered equal to all the municipalities.

$$FoA_{ij=}K * \frac{Mj}{d_{ij}^2} \tag{1}$$

Step 4: Calculation of the percentage of trips of each destination. Once constructed the FoA matrix, it is easy to see that elements of each file represents the capacity of attraction of each destination j to the origin I. By summing up all the values in a row and using that value as a divisor for the elements in that row, it can obtained the different percentages of trips that each destination j attracts from each origin.

This procedure needs to know the total number of trips leaving the municipality under study. This information is obtained through the mobility surveys. In the case of Community of Madrid, it is estimated that, for a residential use, a value of 0.46 motor vehicle trips per resident (Community of Madrid, 2018).

This information allows to determine how many vehicles are driven from each origin to the 178 possible destinies. As the information of the distances is compiled in matrix D, it is possible to calculate the number of kilometres driven. Besides it is necessary to establish a set of representative vehicle models to extract the GHG emissions per km driven. Statistics from Spanish Directorate General of Traffic (DGT) allow knowing the percentage of petrol and diesel cars (10.939.069 patrol and 1.3510.143 diesel in Spain). Once it has been established the distance and it is determined the fuel, it is a final calculation left: determine the GHG emissions per km of the different types of vehicles. In this sense, three representative consumption values for patrol and three for diesel are selected by using statistical procedures (Álvarez, 2019; Álvarez and Giménez, 2019) and it is possible to construct the procedure for determining the emissions.

There is an additional variable to consider in the model, and it is represented by domestic traffic. In municipalities as the one considered here the interior movements have much less importance than the exterior ones, and that is why the outer movements can be considered of an estimated of 5% of the traffic for each of the sections of the road network (Mínguez, 2011).

Mobility in Tertiary, Industrial and Facilities Uses

In the case of emissions by trucks and vans including heavy duty for the different land uses. The first step is to determine the number of trips per built area. In the case of Community of Madrid and under normal conditions, this information is based on empirical studies (Community of Madrid, 2020); frequently generation rates used in traffic are:

Commercial (tertiary): 0.04 trips/built m^2 (15% heavy-duty vehicles);
Industrial: 0.014 trips/built m^2 (80% heavy-duty vehicles);
Facilities: 0.016 trips/built m^2;

3.4 Key Factors for GHG Mitigation and Capture

The second issue is to take into account permeable soil, CO_2 fixation in the initial and final state. It is known that soil is a scarce and non-renewable resource. Preserving permeable soil, especially with vegetation cover, improves the CO_2 sink function. In this way, it is possible to prioritise whether an alternative is more rigorous and maintains areas with trees with a certain function as a sink, compared to another that does not take this into account.

It also includes a section on measures that are not quantified but which it was important to evaluate positively in a carbon footprint report that will accompany urban planning in its environmental processing. To this end, there are free fields for introducing mitigation and adaptation measures beyond those that can be quantitatively assessed today. Also for new measures that may emerge in future.

Such free texts can be recharging points, inclusion of a heat network, or self-generation capacity by renewable energies, among others.

Then it is in this very positive and currently so often quoted concept of the 15-min city (Moreno et al., 2021). In the event that these mitigation and adaptation measures can be measured, these values are introduced and reduce the carbon footprint. In any case, even if the reduction is not known, it is important to the action and the effort that is being made, for example, to choose between two alternatives, is positively valued.

In the case of the alternatives shown as case studies, self-sufficiency has been assessed, which implies significant variations on business-as-usual case study.

Finally, it is important to underline that at this stage of the urban planning the uncertainty is total, as only the distribution of land according to its use has been carried out with its key factors and the mitigation and captures measures proposed. Therefore, the tool serves to make approximations that will have the usefulness of allowing a comparison between two or more urban development solutions.

4 Results: Application for Selection Alternatives in a Case Study in Sector 11B, Alcalá de Henares, Community of Madrid

For testing the tool, a number of alternatives for the development of a sector that has already been developed, Sector 11B in Alcalá de Henares (Madri) are set out below, changing some criteria to look at the impact they have on the generation of GHG emissions (Fig. 4).

4.1 Alternative 1: Business-as-Usual

A sector of 27.27 ha located in Alcalá de Henares (Community of Madrid), 193,751 of inhabitants and 87.99 km^2. This is a neighbourhood already developed, and its features have been considered. In this case with energy certification B for buildings, as a minimum for new buildings (Fig. 5).

This alternative has got 6.774 tCO_2eq, and the majority of emissions from the planned urban development by sources and uses of Alternative 1 belong to Residential Use (53%), but with less intensity that the built-up surface that represents (71%). Mobility stands out, being the highest of all the emissions generated, because 59% of GHG emissions corresponds to the mobility generated, without considering emissions from land-use change.

In the case of this location (the original one), the average distance of trips is set at 5.28 km and the percentage of trips for the sector being 53.81%.

The second biggest source is energy consumption (without considering air-conditioning and DHW, the third source) with 19%. The land cover changes suppose the emission of 110 tCO_2eq.

4.2 Alternative 2.1: Masterplan with Energy Certification a for Buildings

This alternative is equal to the first one but considering an energy certification A for buildings.

This alternative has got 6.312 tCO_2eq, 7% less than alternative 1. In alternative 2.1, the residential use is the source of the majority of emissions, with 50.47%. The most significant emission in this use belongs to mobility, with 63%, and energy consumption increases up 21% (Fig. 6).

4.3 Alternative 2.2: Masterplan with 0 Emissions for Air-Conditioning and Domestic Hot Water (DHW)

This alternative is equal to the first one but considering no energy consumption for air-conditioning and domestic hot water (DHW).

This alternative has got 6.063 tCO_2eq, 11% less than alternative 1. In alternative 2.2, it can be seen some changes. The predominant emissions are still from residential use but with a lower percentage of total emissions, 49.32%. By far the highest emission within this use belongs to mobility (67%), followed by energy consumption.

In alternative 2.2, the air-conditioning and DHW emissions are 0 while in alternative 2.1, 193 tCO_2eq, approximately 6% of the total emissions (Fig. 7).

Fig. 4 Municipalities for location in alternatives 1, 2, 3, 4 (Alcalá de Henares), 5 (Madrid) and 6 (San Martín de Valdeiglesias) for showing the weight of location by population size and size of the municipality in the generation of GHG

4.4 Alternative 3: Masterplan with 100% Renewable or Self-Production

This alternative includes self-consumption emissions (consumption of energy with other uses of electricity) that suppose a cut of 1,278 tCO_2eq, without energy consumption, that are 19% of total emissions, with a total of 5.496 tCO_2eq, as seen in Fig. 8.

In case it is considered to be zero emissions, then the values for air-conditioning and DHW, energy consumption, public lighting and irrigation of green and public areas would be zero.

If we also include air-conditioning and DHW, public lighting and irrigation of green and public areas the emissions avoided are 2,079 tCO_2eq, 30% of total.

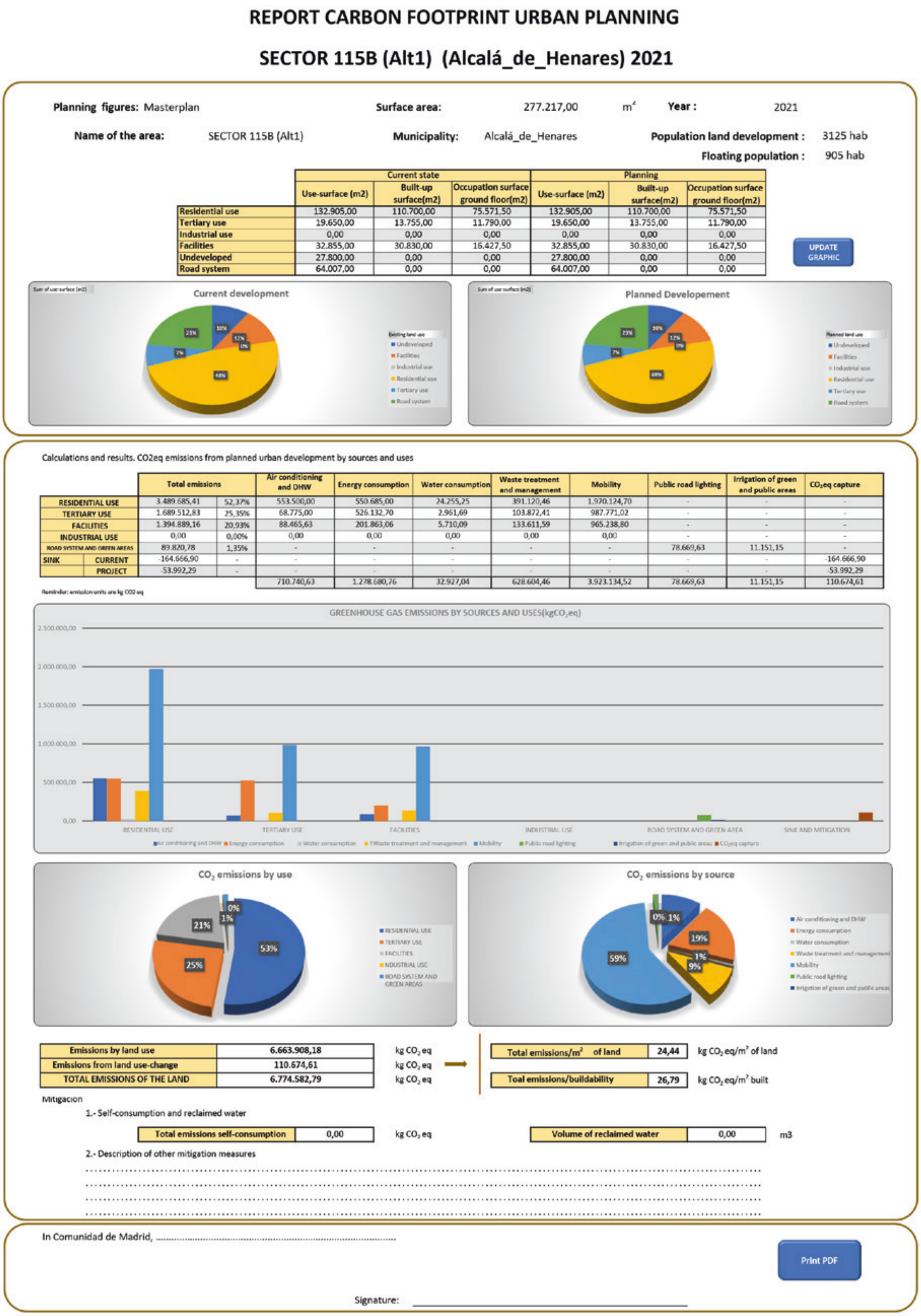
If it could prove this self-consumption energy emissions are really with 100% renewable energy without emissions, the cut of emissions is very important. Between one in five or one in three emissions could be avoided with 100% renewable emissions, depending on the emissions cut. Mobility, water consumption and waste treatment and management are not included in any case.

4.5 Alternative 4: Masterplan with Tertiary Use Instead Residential Use

This alternative is equal to the first one but considering there is no residential use, and the use surface for residential in alternative 1 is considered as tertiary.

This alternative has got 16.146 tCO_2eq, 238% more than alternative 1, and the alternative with the highest amount of emissions (Fig. 9).

In this case, the tertiary sector is the source of the majority of emissions, with 90% of total emissions. The most significant emissions in this use are mobility with 52% followed by energy consumption with 37%.



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B (Alt1) (Alcalá_de_Henares) 2021

Planning figures: Masterplan **Surface area:** 277.217,00 m^2 **Year :** 2021

Name of the area: SECTOR 115B (Alt1) **Municipality:** Alcalá_de_Henares **Population land development :** 3125 hab

Floating population : 905 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	132.905,00	110.700,00	75.571,50
Tertiary use	19.650,00	13.755,00	11.790,00	19.650,00	13.755,00	11.790,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Air conditioning and DHW	Energy consumption	Water consumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO_2eq capture
RESIDENTIAL USE		3.489.685,41	52,37%	553.500,00	550.685,00	24.255,25	391.120,46	1.970.124,70	-	-	-
TERTIARY USE		1.689.512,83	25,35%	68.775,00	526.132,70	2.961,69	103.872,41	987.771,02	-	-	-
FACILITIES		1.394.889,16	20,93%	88.465,63	201.863,06	5.710,09	133.611,59	965.238,80	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		89.820,78	1,35%	-	-	-	-	-	78.669,63	11.151,15	-
SINK	**CURRENT**	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-53.992,29	-	-	-	-	-	-	-	-	-53.992,29
				710.740,63	1.278.680,76	32.927,04	628.604,46	3.923.134,52	78.669,63	11.151,15	110.674,61

Reminder: emission units are kg CO2 eq

Emissions by land use	6.663.908,18	kg CO_2 eq
Emissions from land use-change	110.674,61	kg CO_2 eq
TOTAL EMISSIONS OF THE LAND	6.774.582,79	kg CO_2 eq

Total emissions/m^2 of land	24,44	kg CO_2 eq/m^2 of land
Toal emissions/buildability	26,79	kg CO_2 eq/m^2 built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption 0,00 kg CO_2 eq **Volume of reclaimed water** 0,00 m3

2.- Description of other mitigation measures

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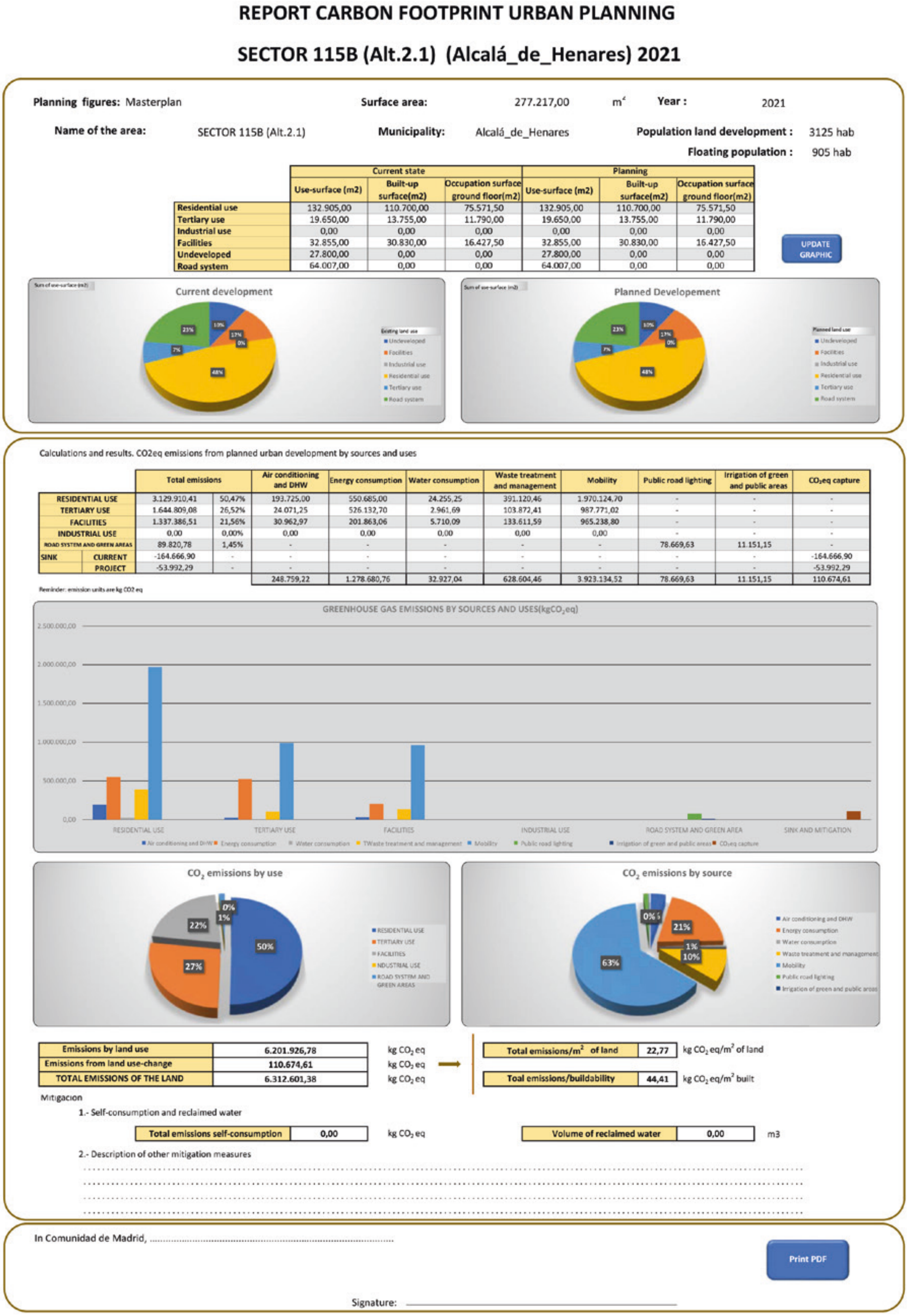
Fig. 5 Sector 11B Alcalá de Henares Alternative 1: report carbon footprint urban planning



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B (Alt.2.1) (Alcalá_de_Henares) 2021

Planning figures: Masterplan **Surface area:** 277.217,00 m² **Year :** 2021

Name of the area: SECTOR 115B (Alt.2.1) **Municipality:** Alcalá_de_Henares **Population land development :** 3125 hab

Floating population : 905 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	132.905,00	110.700,00	75.571,50
Tertiary use	19.650,00	13.755,00	11.790,00	19.650,00	13.755,00	11.790,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

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Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Air conditioning and DHW	Energy consumption	Water consumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO_2eq capture
RESIDENTIAL USE		3.129.910,41	50,47%	193.725,00	550.685,00	24.255,25	391.120,46	1.970.124,70	-	-	-
TERTIARY USE		1.644.809,08	26,52%	24.071,25	526.132,70	2.961,69	103.872,41	987.771,02	-	-	-
FACILITIES		1.337.386,51	21,56%	30.962,97	201.863,06	5.710,09	133.611,59	965.238,80	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		89.820,78	1,45%	-	-	-	-	-	78.669,63	11.151,15	-
SINK	**CURRENT**	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-53.992,29	-	-	-	-	-	-	-	-	-53.992,29
				248.759,22	1.278.680,76	32.927,04	628.604,46	3.923.134,52	78.669,63	11.151,15	110.674,61

Reminder: emission units are kg CO2 eq

Emissions by land use	6.201.926,78	kg CO_2 eq
Emissions from land use-change	110.674,61	kg CO_2 eq
TOTAL EMISSIONS OF THE LAND	6.312.601,38	kg CO_2 eq

Total emissions/m² of land	22,77	kg CO_2 eq/m² of land
Toal emissions/buildability	44,41	kg CO_2 eq/m² built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption 0,00 kg CO_2 eq

Volume of reclaimed water 0,00 m3

2.- Description of other mitigation measures

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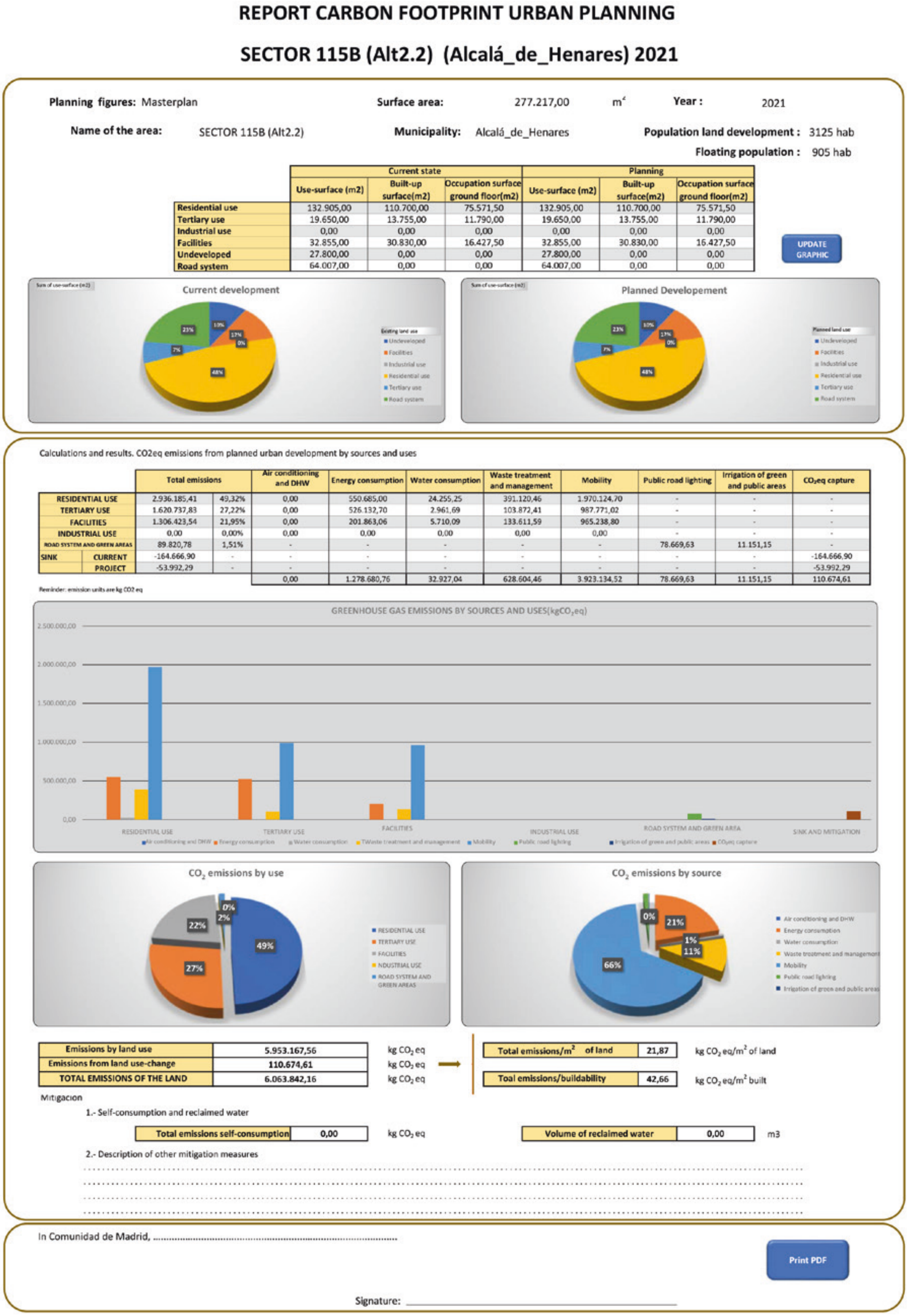
Fig. 6 Sector 11B Alcalá de Henares Alternative 2.1: report carbon footprint urban planning



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B (Alt2.2) (Alcalá_de_Henares) 2021

Planning figures: Masterplan

Surface area: 277.217,00 m²

Year : 2021

Name of the area: SECTOR 115B (Alt2.2)

Municipality: Alcalá_de_Henares

Population land development : 3125 hab

Floating population : 905 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	132.905,00	110.700,00	75.571,50
Tertiary use	19.650,00	13.755,00	11.790,00	19.650,00	13.755,00	11.790,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Air conditioning and DHW	Energy consumption	Water consumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO$_2$eq capture
RESIDENTIAL USE		2.936.185,41	49,32%	0,00	550.685,00	24.255,25	391.120,46	1.970.124,70	-	-	-
TERTIARY USE		1.620.737,83	27,22%	0,00	526.132,70	2.961,69	103.872,41	987.771,02	-	-	-
FACILITIES		1.306.423,54	21,95%	0,00	201.863,06	5.710,09	133.611,59	965.238,80	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		89.820,78	1,51%	-	-	-	-	-	78.669,63	11.151,15	-
SINK	**CURRENT**	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-53.992,29	-	-	-	-	-	-	-	-	-53.992,29
				0,00	1.278.680,76	32.927,04	628.604,46	3.923.134,52	78.669,63	11.151,15	110.674,61

Reminder: emission units are kg CO2 eq

Emissions by land use	5.953.167,56	kg CO$_2$ eq
Emissions from land use-change	110.674,61	kg CO$_2$ eq
TOTAL EMISSIONS OF THE LAND	6.063.842,16	kg CO$_2$ eq

Total emissions/m^2 of land	21,87	kg CO$_2$ eq/m^2 of land
Toal emissions/buildability	42,66	kg CO$_2$ eq/m^2 built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption 0,00 kg CO$_2$ eq

Volume of reclaimed water 0,00 m3

2.- Description of other mitigation measures

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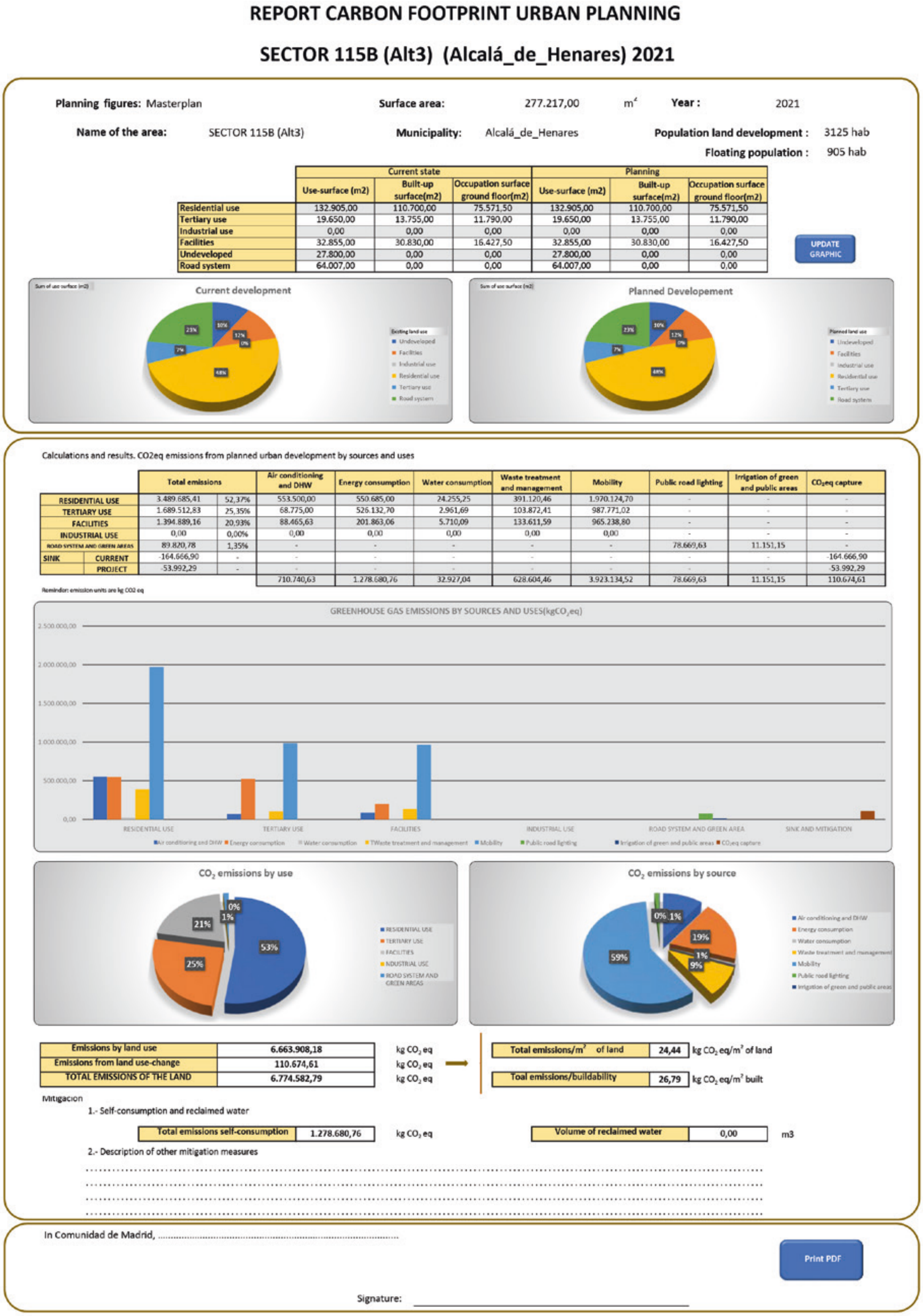
Fig. 7 Sector 11B Alcalá de Henares Alternative 2.2: report carbon footprint urban planning



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B (Alt3) (Alcalá_de_Henares) 2021

Planning figures: Masterplan **Surface area:** 277.217,00 m² **Year :** 2021

Name of the area: SECTOR 115B (Alt3) **Municipality:** Alcalá_de_Henares **Population land development :** 3125 hab

Floating population : 905 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	132.905,00	110.700,00	75.571,50
Tertiary use	19.650,00	13.755,00	11.790,00	19.650,00	13.755,00	11.790,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Air conditioning and DHW	Energy consumption	Water consumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO$_2$eq capture
RESIDENTIAL USE		3.489.685,41	52,37%	553.500,00	550.685,00	24.255,25	391.120,46	1.970.124,70	-	-	-
TERTIARY USE		1.689.512,83	25,35%	68.775,00	526.132,70	2.961,69	103.872,41	987.771,02	-	-	-
FACILITIES		1.394.889,16	20,93%	88.465,63	201.863,06	5.710,09	133.611,59	965.238,80	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		89.820,78	1,35%	-	-	-	-	-	78.669,63	11.151,15	-
SINK	CURRENT	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-53.992,29	-	-	-	-	-	-	-	-	-53.992,29
				710.740,63	1.278.680,76	32.927,04	628.604,46	3.923.134,52	78.669,63	11.151,15	110.674,61

Remindor: emission units are kg CO2 eq

Emissions by land use	6.663.908,18	kg CO$_2$ eq
Emissions from land use-change	110.674,61	kg CO$_2$ eq
TOTAL EMISSIONS OF THE LAND	6.774.582,79	kg CO$_2$ eq

Total emissions/m² of land	24,44	kg CO$_2$ eq/m² of land
Toal emissions/buildability	26,79	kg CO$_2$ eq/m² built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption	1.278.680,76	kg CO$_2$ eq
Volume of reclaimed water	0,00	m3

2.- Description of other mitigation measures

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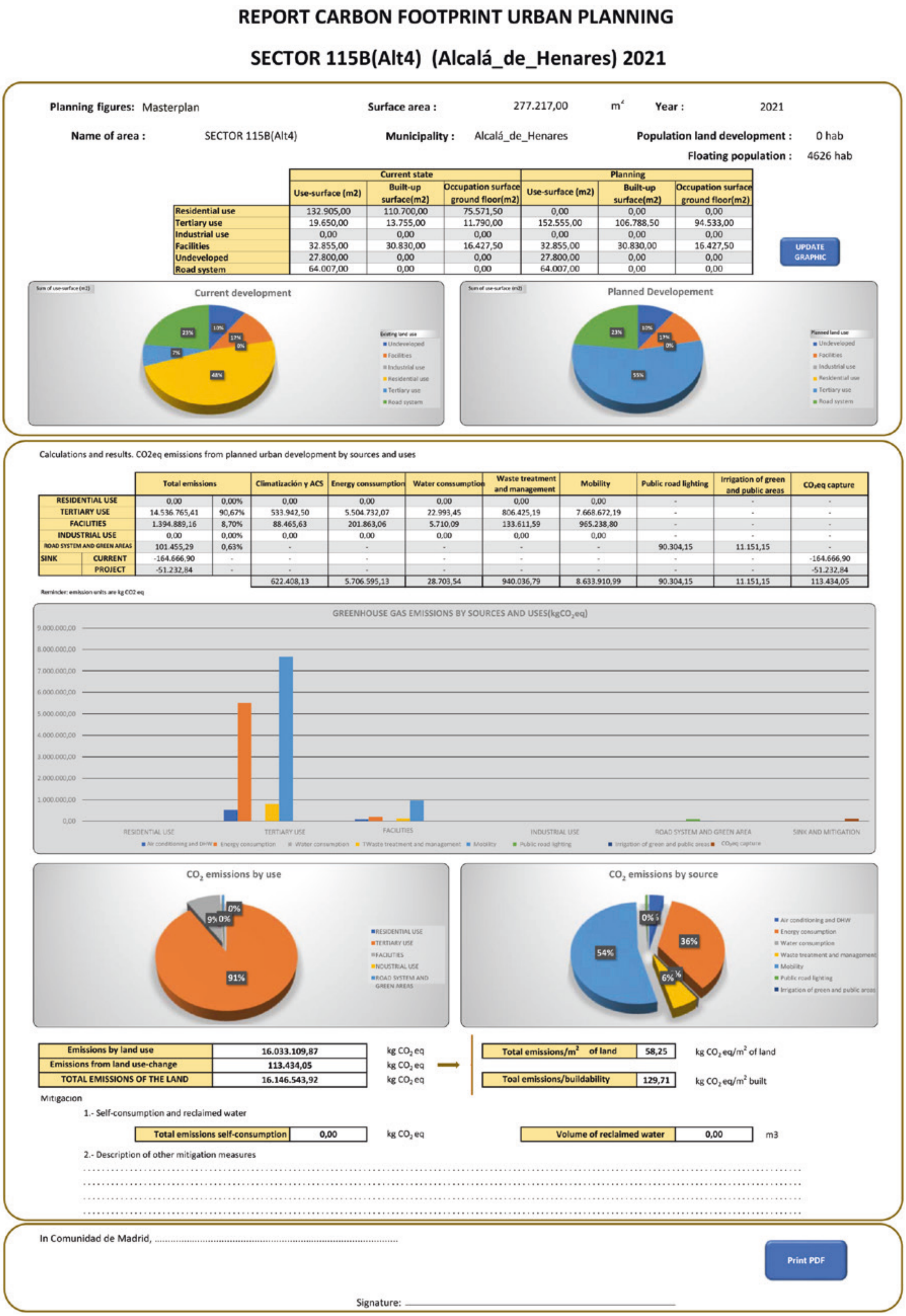
Fig. 8 Sector 11B Alcalá de Henares Alternative 3: report carbon footprint urban planning



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B(Alt4) (Alcalá_de_Henares) 2021

Planning figures: Masterplan **Surface area :** 277.217,00 m² **Year :** 2021

Name of area : SECTOR 115B(Alt4) **Municipality :** Alcalá_de_Henares **Population land development :** 0 hab

Floating population : 4626 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	0,00	0,00	0,00
Tertiary use	19.650,00	13.755,00	11.790,00	152.555,00	106.788,50	94.533,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

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Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Climatización y ACS	Energy conssumption	Water conssumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO₂eq capture
RESIDENTIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
TERTIARY USE		14.536.765,41	90,67%	533.942,50	5.504.732,07	22.993,45	806.425,19	7.668.672,19	-	-	-
FACILITIES		1.394.889,16	8,70%	88.465,63	201.863,06	5.710,09	133.611,59	965.238,80	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		101.455,29	0,63%	-	-	-	-	-	90.304,15	11.151,15	-
SINK	CURRENT	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-51.232,84	-	-	-	-	-	-	-	-	-51.232,84
				622.408,13	5.706.595,13	28.703,54	940.036,79	8.633.910,99	90.304,15	11.151,15	113.434,05

Reminder: emission units are kg CO2 eq

Emissions by land use	16.033.109,87	kg CO₂ eq
Emissions from land use-change	113.434,05	kg CO₂ eq
TOTAL EMISSIONS OF THE LAND	16.146.543,92	kg CO₂ eq

Total emissions/m² of land	58,25	kg CO₂ eq/m² of land
Toal emissions/buildability	129,71	kg CO₂ eq/m² built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption 0,00 kg CO₂ eq

Volume of reclaimed water 0,00 m3

2.- Description of other mitigation measures

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Fig. 9 Sector 11B Alcalá de Henares Alternative 4: report carbon footprint urban planning

It is clear that in the tertiary use, the mobility of people going to work is more important as the energy consumption inside the buildings. In any case, energy consumption in this alternative 4 is 446% higher in alternative 1.

4.6 Alternative 5: Business-as-Usual with Location in Madrid City

This alternative is equal to the first one but moving the masterplan to Madrid City, with 3,223 million of inhabitants and 604.3 km^2.

This alternative has got 8.748 tCO$_2$eq, 29% more than alternative 1 (Fig. 10).

It does not have much impact on emissions, with residential use once again being the main part, with 44.94%, where the highest emission belongs to mobility that increases up 68%.

In the case of alternative 5, the average distance of trips is set at 13.88 km and the percentage of trips for the sector being 72.28%. This means that it is a municipality where internal movements are predominant but which, due to its large size, ultimately involves a greater number of emissions than alternative 1.

4.7 Alternative 6: Business-As-Usual with Location in the Municipality of San Martín de Valdeiglesias

This alternative is equal to the first one but moving the masterplan to a municipality in the border of Community of Madrid, with 8.318 inhabitants and 115.5 km^2.

This alternative has got 12,525 tCO$_2$eq, 84% more than alternative 1 (Fig. 11).

In this alternative, the predominant emissions are by far those from residential use, with 77.29%, and mainly by mobility.

In the case of alternative 6, the average distance of trips is set at 6.06 km and the percentage of trips for the sector being 15.17%, which means that there is a strong commuting to other municipalities and its location far from more populated municipalities.

As a conclusion of the results, it can be seen than mobility is the first source of GHG emissions in the alternatives.

Furthermore, it can be seen that the alternative that generates the most mobility of all is alternative 6 because of commuting (9,588 tCO$_2$eq), and after this, alternative 4 with tertiary use (8,633 tCO$_2$eq).

The alternative 4 with mainly tertiary use, is the one with the highest amount of GHG emissions of all, because of the high amount of emissions of mobility, as said, and the greatest weight in other kind of energy consumption (38%).

The use of renewable energy could avoid an important amount of emissions, in the studied alternative 3, between one in five to one in three GHG emissions.

The emissions of land-use change are around 2% in the alternative with more intensity, alternative 3, but they are important for the irreversibility of the process.

5 Conclusions

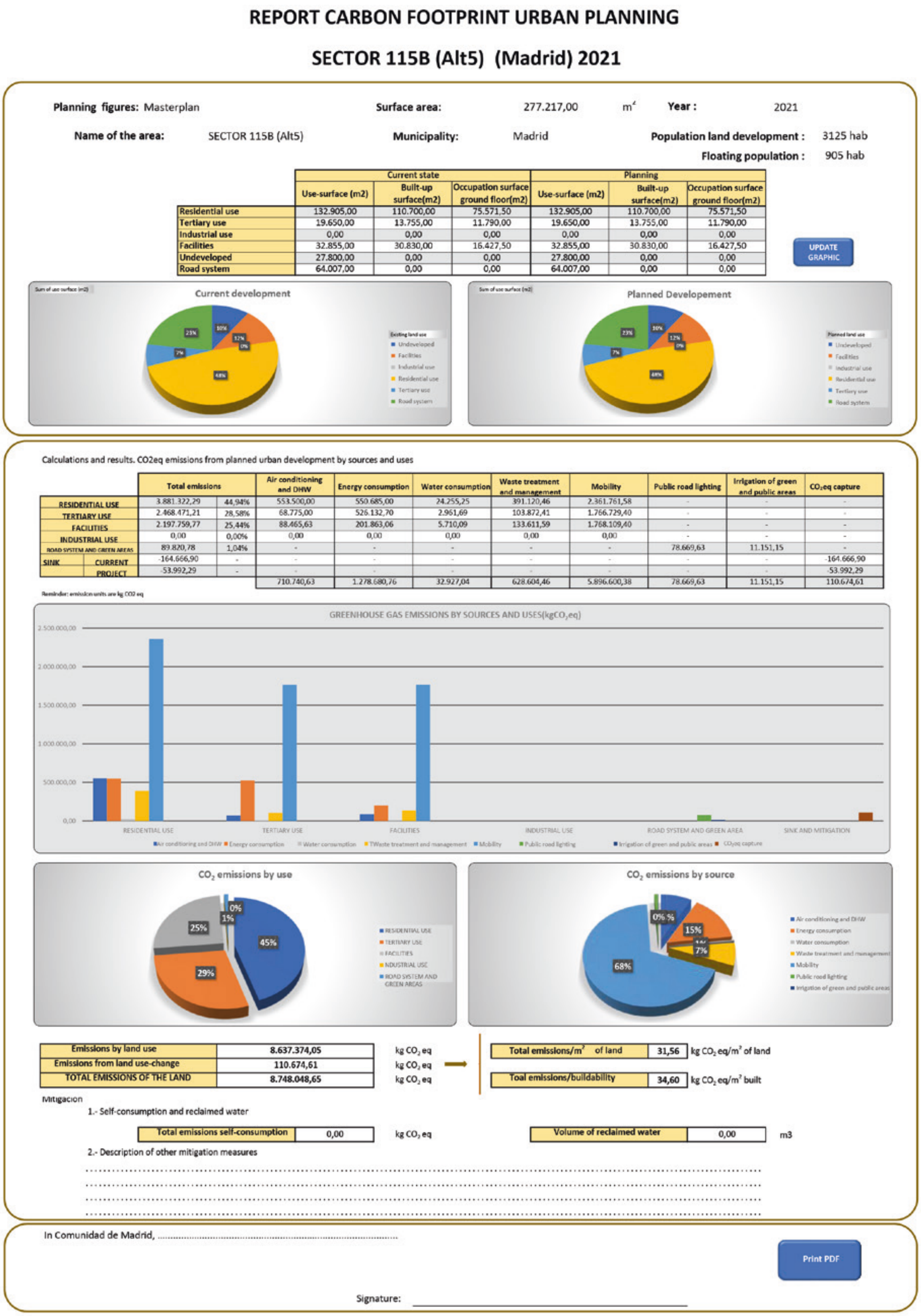
There is a climate crisis which means that all plans and programmes must be measured in terms of how much they will affect climate change, and for then, it is necessary to have tools. Therefore, this environmental awareness, this change in the discipline's criteria, which it has been seen today, responds to the fact that urban planning can be at the service of ecology in the search for impact reduction, such as climate change.

Planning operates between thresholds or maximums. It is not a project that materialises the next day. Planning shows scenarios that are shaped, in the case of development planning with urban design. It has to be understood that with regard to climate change it is needed to quantify the effects, 1.5 or 2 degrees of temperature increase scenario. But the causes are not always quantified, and this quantification does not always help us to make decisions. Then, there is a need to measure in order to evaluate, as in the alternatives showed. And for this, the concept of carbon footprint introduces the set of GHGs emitted as a direct or indirect effects of an activity. In the case of a plan of the activity, it will host when it is in operation.

With the carbon footprint, the impact of climate change is observed and specific data is available to evaluate development alternatives in terms of climate change. It is necessary to understand that instruments that provide better, more rigorous, contrasted and comparable information will help us to make better decisions. This means making data on the carbon footprint impact of urban development plans visible, so that they can be included in the public agenda. With better data and the best data available at any given time, citizens can know and make decisions.

For all these reasons, it is considered the carbon footprint calculator for Community of Madrid could be useful for urban planning decision-making. Its data can be revised when it is updated, new methods could be more realistic for the region or when better data becomes available. But what is also important is the structuring of the factors affecting the carbon footprint and the visibility of the effects.

The carbon footprint calculator structures, simplifies and makes visible processes and their relative impact on climate change actions when the planning being assessed is under load for the specific case of the Community of Madrid.



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B (Alt5) (Madrid) 2021

Planning figures: Masterplan **Surface area:** 277.217,00 m² **Year :** 2021

Name of the area: SECTOR 115B (Alt5) **Municipality:** Madrid **Population land development :** 3125 hab

Floating population : 905 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	132.905,00	110.700,00	75.571,50
Tertiary use	19.650,00	13.755,00	11.790,00	19.650,00	13.755,00	11.790,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Air conditioning and DHW	Energy consumption	Water consumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO_2eq capture
RESIDENTIAL USE		3.881.322,29	44,94%	553.500,00	550.685,00	24.255,25	391.120,46	2.361.761,58	-	-	-
TERTIARY USE		2.468.471,21	28,58%	68.775,00	526.132,70	2.961,69	103.872,41	1.766.729,40	-	-	-
FACILITIES		2.197.759,77	25,44%	88.465,63	201.863,06	5.710,09	133.611,59	1.768.109,40	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		89.820,78	1,04%	-	-	-	-	-	78.669,63	11.151,15	-
SINK	CURRENT	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-53.992,29	-	-	-	-	-	-	-	-	-53.992,29
				710.740,63	1.278.680,76	32.927,04	628.604,46	5.896.600,38	78.669,63	11.151,15	110.674,61

Reminder: emission units are kg CO2 eq

Emissions by land use	8.637.374,05	kg CO_2 eq
Emissions from land use-change	110.674,61	kg CO_2 eq
TOTAL EMISSIONS OF THE LAND	8.748.048,65	kg CO_2 eq

Total emissions/m² of land	31,56	kg CO_2 eq/m² of land
Toal emissions/buildability	34,60	kg CO_2 eq/m² built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption 0,00 kg CO_2 eq

Volume of reclaimed water 0,00 m3

2.- Description of other mitigation measures

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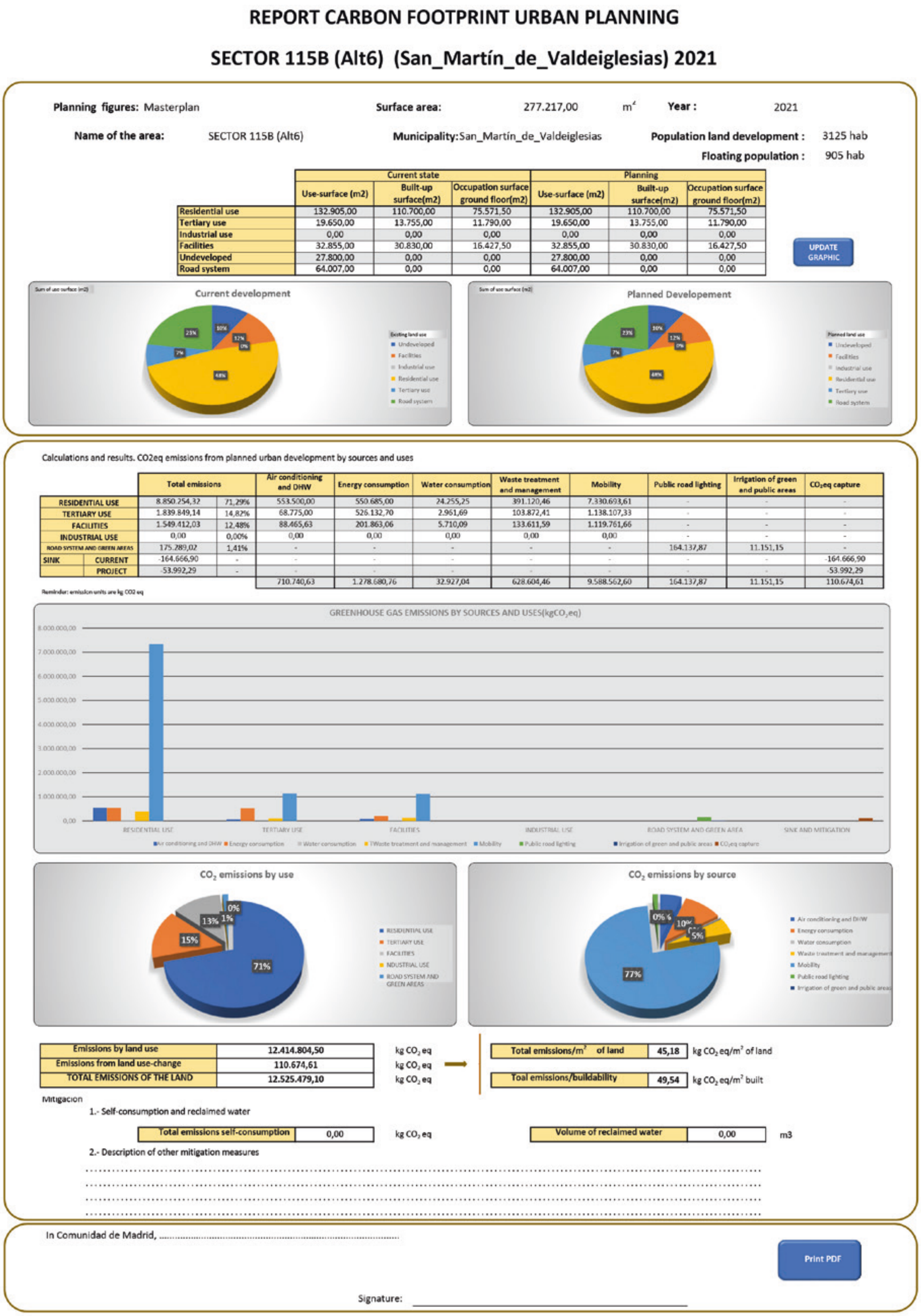
Fig. 10 Sector 11B Alcalá de Henares Alternative 5: report carbon footprint urban planning



REPORT CARBON FOOTPRINT URBAN PLANNING

SECTOR 115B (Alt6) (San_Martín_de_Valdeiglesias) 2021

Planning figures: Masterplan **Surface area:** 277.217,00 m² **Year :** 2021

Name of the area: SECTOR 115B (Alt6) **Municipality:**San_Martín_de_Valdeiglesias **Population land development :** 3125 hab

Floating population : 905 hab

	Current state			Planning		
	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)	Use-surface (m2)	Built-up surface(m2)	Occupation surface ground floor(m2)
Residential use	132.905,00	110.700,00	75.571,50	132.905,00	110.700,00	75.571,50
Tertiary use	19.650,00	13.755,00	11.790,00	19.650,00	13.755,00	11.790,00
Industrial use	0,00	0,00	0,00	0,00	0,00	0,00
Facilities	32.855,00	30.830,00	16.427,50	32.855,00	30.830,00	16.427,50
Undeveloped	27.800,00	0,00	0,00	27.800,00	0,00	0,00
Road system	64.007,00	0,00	0,00	64.007,00	0,00	0,00

Calculations and results. CO2eq emissions from planned urban development by sources and uses

		Total emissions		Air conditioning and DHW	Energy consumption	Water consumption	Waste treatment and management	Mobility	Public road lighting	Irrigation of green and public areas	CO$_2$eq capture
RESIDENTIAL USE		8.850.254,32	71,29%	553.500,00	550.685,00	24.255,25	391.120,46	7.330.693,61	-	-	-
TERTIARY USE		1.839.849,14	14,82%	68.775,00	526.132,70	2.961,69	103.872,41	1.138.107,33	-	-	-
FACILITIES		1.549.412,03	12,48%	88.465,63	201.863,06	5.710,09	133.611,59	1.119.761,66	-	-	-
INDUSTRIAL USE		0,00	0,00%	0,00	0,00	0,00	0,00	0,00	-	-	-
ROAD SYSTEM AND GREEN AREAS		175.289,02	1,41%	-	-	-	-	-	164.137,87	11.151,15	-
SINK	CURRENT	-164.666,90	-	-	-	-	-	-	-	-	-164.666,90
	PROJECT	-53.992,29	-	-	-	-	-	-	-	-	-53.992,29
				710.740,63	1.278.680,76	32.927,04	628.604,46	9.588.562,60	164.137,87	11.151,15	110.674,61

Reminder: emission units are kg CO2 eq

Emissions by land use	12.414.804,50	kg CO$_2$ eq
Emissions from land use-change	110.674,61	kg CO$_2$ eq
TOTAL EMISSIONS OF THE LAND	12.525.479,10	kg CO$_2$ eq

Total emissions/m² of land	45,18	kg CO$_2$ eq/m² of land
Toal emissions/buildability	49,54	kg CO$_2$ eq/m² built

Mitigacion

1.- Self-consumption and reclaimed water

Total emissions self-consumption 0,00 kg CO$_2$ eq

Volume of reclaimed water 0,00 m3

2.- Description of other mitigation measures

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In Comunidad de Madrid, ……………………………………………

Signature: ____________________

Fig. 11 Sector 11B Alcalá de Henares Alternative 6: report carbon footprint urban planning

Therefore, a dynamic region like Community of Madrid has the support of a tool to assess plans whose effects are very long term. In this way, information is provided for discussion, but also for sharing, with the ultimate objective of influencing administrative decisions and the general interest.

It should be stressed that this type of tool does not replace spatial planning, nor does it replace planning itself. Rather, they provide it with information and complement it by showing the factor of the development model in climate change when urban planning is in charge.

The current moment is a time of transition in which there are many uncertainties. Added to this is the fact that planning is an early stage of design in which projects have not yet developed their guidelines and therefore carries with it certain uncertainties.

It must take advantage of this confluence of early design stage so that the urban futures will have the lowest carbon footprint impact.

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Appendix

Alternatives Reports

In this appendix are the full reports of the evaluated alternatives showing the options in relation to the data or variables as well as associated greenhouse gas emissions.

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