UNIVERSITAT POLITÈCNICA DE VALÈNCIA

School of Industrial Engineering

Neighborhood Decarbonization in Benicalap, Valencia, Spain: A Methodological Approach to Estimating Scope 1 and 2 Emissions and Mitigation Measures.

Master's Thesis

Master's Degree in Energy Technologies for Sustainable Development

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"Happiness is only real when shared."
-Alexander Supertramp-

ABSTRACT

This study addresses Valencia's commitment to the Sustainable Development Goals and the 2030 Agenda, focusing on the transformation of the Benicalap neighborhood towards carbon neutrality. Through a multidisciplinary approach, previous proposals are analyzed and new strategies to mitigate CO_2 emissions are sought, with the objective of reducing emissions in scopes 1 and 2 in the Benicalap neighborhood through effective mitigation measures.

To achieve this end, tools such as Excel for calculations and estimations, Google Maps for area identification, and Datadis that is a tool used to know the electricity consumption of users by creating a data gateway that accesses the databases of distribution companies. The methodology adopted includes a review of the state of the art, background analysis, definition of objectives, analysis of the urban area, analysis of emissions, definition of scopes, selection of decarbonization measures, economic considerations, and contemplates future studies.

Innovative measures proposed include the reduction of parking spaces to encourage public transport and cleaner alternatives, and the retrofitting of old buildings to improve energy efficiency. These actions are designed to complement the nine existing mitigation measures, such as photovoltaic energy systems, storage, heat pumps, induction stoves, nature-based solutions (NBS), street lighting improvements, sustainable transportation, and the parking reduction and building retrofitting.

It is expected that, with the implementation of these measures, a 10% increase in the reduction of CO2 emissions in the Benicalap neighborhood will be achieved, exceeding the initial target. In total, a reduction of 33.330,2 tCO_2 is projected, representing 65% of the emissions considered in Scopes 1 and 2.

In conclusion, this study proposes a comprehensive approach to the decarbonization of the Benicalap neighborhood, combining detailed analysis, innovation in mitigation measures, and a realistic approach to costs and implementation times. The implementation of these strategies will not only contribute significantly to Valencia's sustainability goals but will also serve as a model for other urban carbon reduction initiatives.

RESUMEN

Este estudio aborda el compromiso de Valencia con los Objetivos de Desarrollo Sostenible y la Agenda 2030, enfocándose en la transformación del barrio de Benicalap hacia la neutralidad de carbono. A través de un enfoque multidisciplinario, se analizan propuestas anteriores y se buscan nuevas estrategias para mitigar las emisiones de CO_2, con el objetivo de reducir las emisiones en los alcances 1 y 2 en el barrio de Benicalap mediante medidas de mitigación efectivas.

Para alcanzar este fin, se utilizaron herramientas como Excel para cálculos y estimaciones, Google Maps para la identificación del área, y Datadis que es una herramienta que sirve para conocer los consumos eléctricos de los usuarios, ofreciendo una pasarela de datos que accede a las bases de datos de las empresas distribuidoras. La metodología adoptada incluye una revisión del estado del arte, análisis de antecedentes, definición de objetivos, análisis del área urbana, análisis de emisiones, definición de scopes, selección de medidas de decarbonización, consideraciones económicas, y contempla futuros estudios.

Entre las medidas innovadoras propuestas se incluye la reducción de espacios de estacionamiento para fomentar el transporte público y alternativas menos contaminantes, y la rehabilitación de edificios antiguos para mejorar la eficiencia energética. Estas acciones están diseñadas para complementar las nueve medidas de mitigación existentes, como sistemas de energía fotovoltaica, almacenamiento, bombas de calor, estufas de inducción, soluciones basadas en la naturaleza (NBS), mejoras en el alumbrado público, transporte sostenible, y la mencionada reducción de aparcamientos y rehabilitación de edificios.

Se espera que, con la implementación de estas medidas, se logre un aumento del 10% en la reducción de emisiones de CO2 en el barrio de Benicalap, superando el objetivo inicial. En total, se proyecta una reducción de 33.330,2 tCO_2, lo que representa el 65% de las emisiones consideradas en los alcances 1 y 2.

En conclusión, este estudio propone un enfoque integral para la decarbonización del barrio de Benicalap, combinando análisis detallados, innovación en las medidas de mitigación, y un enfoque realista en cuanto a costos y tiempos de ejecución. La implementación de estas estrategias no solo contribuirá significativamente a los objetivos de sostenibilidad de Valencia, sino que también servirá como modelo para otras iniciativas urbanas de reducción de carbono.

RESUM

Este estudi aborda el compromís de València amb els Objectius de Desenvolupament Sostenible i l'Agenda 2030, enfocant-se en la transformació del barri de Benicalap cap a la neutralitat de carboni. A través d'un enfocament multidisciplinari, s'analitzen propostes anteriors i es busquen noves estratègies per a mitigar les emissions de CO_2, amb l'objectiu de reduir les emissions en els abastos 1 i 2 en el barri de Benicalap mitjançant mesures de mitigació efectives.

Per a aconseguir esta fi, es van utilitzar eines com Excel per a càlculs i estimacions, Google Maps per a la identificació de l'àrea, i Datadis per a l'anàlisi de dades de consum elèctric. La metodologia adoptada inclou una revisió de l'estat de l'art, anàlisi d'antecedents, definició d'objectius, anàlisis de l'àrea urbana, anàlisi d'emissions, definició de scopes, selecció de mesures de decarbonización, consideracions econòmiques, i contempla futurs estudis.

Entre les mesures innovadores proposades s'inclou la reducció d'espais d'estacionament per a fomentar el transport públic i alternatives menys contaminants, i la rehabilitació d'edificis antics per a millorar l'eficiència energètica. Estes accions estan dissenyades per a complementar les nou mesures de mitigació existents, com a sistemes d'energia fotovoltaica, emmagatzematge, bombes de calor, estufes d'inducció, solucions basades en la naturalesa (NBS), millores en l'enllumenat públic, transport sostenible, i l'esmentada reducció d'aparcaments i rehabilitació d'edificis.

S'espera que, amb la implementació d'estes mesures, s'aconseguisca un augment del 10% en la reducció d'emissions de CO_2 en el barri de Benicalap, superant l'objectiu inicial. En total, es projecta una reducció de 33.330,2 tCO_2, la qual cosa representa el 65% de les emissions considerades en els Àmbits 1 i 2.

En conclusió, este estudi proposa un enfocament integral per a la decarbonización del barri de Benicalap, combinant anàlisis detallades, innovació en les mesures de mitigació, i un enfocament realista quant a costos i temps d'execució. La implementació d'estes estratègies no sols contribuirà significativament als objectius de sostenibilitat de València, sinó que també servirà com a model per a altres iniciatives urbanes de reducció de carboni.

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ACRONYMS

GHG	Greenhouse gas emissions
RE	Renewable energies
EE	Energy efficiency
NBS	Natural Based Solutions
SHW	Sanitary Hot Water
HP	Heat Pumps
SDGS	Sustainable Development Goals
tCO_2	Tons of carbon dioxide
MWh	Megawatt hour
kWh	Kilowatt-hour
PV	Photovoltaic systems
PINEC	National Integrated Energy and Climate Plan
ETJ	Just transition strategy

1 INTRODUCTION

1.1 Background

The global urgency to cut down on greenhouse gas emissions to prevent irreversible harm to the Earth's ecosystems in the next few decades has led to a widespread emergency. In response, governments are reassessing their energy strategies to accelerate the widespread adoption of renewable-based electricity production technologies. [1]

In Spain, there is a heightened awareness of the need for a swift transition towards renewable energy sources. This shift is driven by the recognition of the urgent climate situation, compelling the Spanish government to reevaluate and expedite the adoption of renewable technologies for electricity generation.

The national electricity generation in Spain reflects a diversified landscape in 2022. Wind energy maintains its prominent position in the generation mix, accounting for 22,1% of the total production and experiencing a 1,1% growth compared to 2021. Despite ranking second in the generation structure, surpassing nuclear power, wind energy set a new historical record by generating 61.176 GWh. On the other hand, photovoltaic energy emerged as the fastest-growing technology, adding 4.498 MW to the national installed capacity, a 29,4% increase from the previous year. Photovoltaic production reached 27,864 GWh, marking an annual record and representing 10,1% of the national mix. [2]

International and European initiatives emphasize the urgency of reducing greenhouse gas (GHG) emissions to avoid severe and irreversible climate impacts. The European Commission's European Green Deal sets ambitious targets, including a 50-55% reduction in GHG emissions by 2030 compared to 1990. Monitoring progress involves annual reporting of GHG inventories by signatories of the United Nations Framework Convention on Climate Change. While national efforts are crucial, local and regional authorities contribute significantly to these targets. Cities participating in the Covenant of Mayors commit to supporting a 40% GHG reduction target by 2030, adopting a comprehensive approach to mitigation and adaptation measures, and submitting Sustainable Energy and Climate Action Plans to outline their key actions for emissions reduction. This collective effort underscores the importance of coordinated action at various governance levels to address climate change effectively. [3]

In this sense, the city of Valencia is adopting best practices in the adaptation and mitigation of greenhouse gases, defining ambitious but realistic goals framed in the phases of the Valencia 2030 Urban Strategy.

1.2 Motivation and Justification

Various urban concepts have also been introduced in response to the climate change debate, such as low-carbon, carbon-neutral, zero-carbon, and negative-carbon cities. According to reviews, these are considered subsets of the sustainable city concept [4].

Many cities have introduced objectives to address climate change and joined international initiatives such as the Covenant of Mayors for Climate & Energy; these cities have already published their carbon neutrality targets, and the carbon neutrality concept is becoming increasingly central in policy discourse, analyzed the concept only partially, focusing on specific issues such as city carbon accounting methods, environmental urban governance, cities' climate plans or a single city sector. [5]

Following the guidelines set by the EU, Spain has taken significant actions to address this problem, implementing changes and policies to reduce greenhouse gas emissions. In this context, this research is important to seek concrete and effective proposals for reducing emissions in the neighborhood of Benicalap, Valencia, and contributing with a clear methodology for compliance with the reduction of CO_2 emissions and the fight against climate change at the local level, aligning these measures with global efforts.

1.3 Definition of the scopes

The scope framework allows cities to comprehensively report all GHG emissions attributable to activities taking place within the geographic boundary of the town by categorizing the emission sources into boundary sources (scope 1, or “territorial”), grid-supplied energy sources (scope 2), and out-of-boundary sources (scope 3). Scope 1 allows for a territorial approach to aggregating multiple cities’ inventories, consistent with national-level GHG reporting [6], Table 1 shows a clear definition of the scopes.

Table 1 Scope definition [7]

Emission type	Scope	Definition	Examples
Direct emissions	Scope 1	Emissions from operations that are owned or controlled by the reporting party	Reporting party facilities Reporting party vehicles
Indirect emissions	Scope 2	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting party	Purchase electricity
Indirect emissions	Scope 3	All indirect emissions not represented in Scope 2 that are a consequence of the activities of the reporting party but occur from sources not owned or controlled by the company.	Purchase foods and services Travels outside of the district

1.4 Objectives

The main objective of this research is to evaluate greenhouse gas emissions in the neighborhood of Benicalap, Valencia, Spain, focusing on Scopes 1 and 2, and, on this basis, to develop a set of concrete and effective measures for their mitigation, thus contributing to the decarbonization of the neighborhood.

Specific objectives

- Carry out an inventory of GHG in the Benicalap neighborhood.
- Evaluate the effectiveness of the climate change mitigation measures proposed in previous studies for Benicalap, determining their real impact on reducing he GHG.
- Identify the barriers and obstacles that have hindered the implementation of mitigation measures in Benicalap, including economic, political, and social factors.
- Provide recommendations for the implementation of climate change mitigation measures in Benicalap.

Structure

This study is structured by 10 chapters, to guarantee the quality, reliability, and efficacy of a study, the structure of this research work is as follows:

Chapter 1: Introduction. This first chapter will provide a concise study overview, highlighting its significance and relevance to the field. It will also introduce the research objectives or questions, setting the stage for the study's context and purpose. Additionally, it may briefly mention the methodology employed and offer a glimpse into the expected contributions and findings.

Chapter 2: State-of-the-Art. This part of the investigation will review current research and initiatives concerning the utilization of renewable energies in neighborhood decarbonization. This will entail analyzing this domain's latest developments, technologies, and policies while identifying areas where further investigation or innovation is needed.

Chapter 3: Methodology. This chapter will describe the methods and procedures used in this study, explaining how the data was collected and analyzed to address the research questions and objectives.

Chapter 4: Analysis of Benicalap, Valencia. This chapter provides an economic and energy analysis of the Benicalap neighborhood to determine which mitigation measures could have more significant influence and which are the most appropriate proposals.

Chapter 5: Emissions Inventory for Scopes 1 and 2. This chapter mentions the changes made in the emissions inventory carried out in previous studies and the current situation of scopes 1 and 2 in the neighborhood. Finally, a comparison of the methodologies used in these studies is made.

Chapter 6: Actions to approach Carbon Neutrality. Mention is made of the mitigation measures proposed to be carried out in the Benicalap neighborhood, where their scope and influence are mentioned.

Chapter 7: Results. This chapter presents the findings and outcomes of the present study realized in Benicalap, analyzing the strategies and actions to achieve carbon neutrality in the neighborhood.

Chapter 8: Economic analysis. This chapter is the economic analysis of implementing the measures proposed to achieve decarbonization in Benicalap, identifying the barriers, political regulations, and economic-social implications in their inclusion towards this change.

Chapter 9: Challenge barriers. It will provide an in-depth examination of the various impediments that could pose significant challenges to effectively executing the decarbonization plan in the Benicalap area. This chapter will comprehensively analyze these barriers, ranging from technical and logistical challenges to potential resistance from stakeholders or community members.

Chapter 10: Conclusions. This chapter serves as the culmination of this project, where the research findings, key takeaways, and their broader implications for the decarbonization efforts in the studied area will be presented and discussed.

Chapter 11: Bibliography. Provides a list of all the sources, studies, and materials cited throughout the research, ensuring transparency and academic rigor in the work.

Chapter 12: Annexes. This last chapter contains supplementary materials such as additional data, charts, graphs, or other relevant information supporting and enriching the main research content.

2 STATE OF THE ART

2.1 Renewable Energy Growth in Spain

Spain has made significant progress in decarbonizing its energy sector by increasing its share of renewable energy sources. Wind, solar, and hydroelectric power investments have played a crucial role in reducing carbon emissions.

The current Spanish framework for energy and climate is based on the 2050 objectives of national climate neutrality, 100% renewable energy in the electricity mix, and 97% renewable energy in the total energy mix. As such, it is centered on the massive development of renewable energy, particularly solar and wind, energy efficiency, electrification, and renewable hydrogen. Spain is progressing toward its 2030 targets, notably in the electricity sector. The future trajectory of its power mix warrants careful consideration to ensure a smooth transition, especially as Spain plans to phase out coal and nuclear power generation. Plans include storage expansion, demand side management, digitalization, and international interconnections. [8]

Nowadays, Spain is only behind Germany in the leadership of renewable energies in the European Union, mainly in solar and wind production technologies.

The energy environment in Spain in 2022 has continued to advance in its growth, with a 9,1 % increase in installed renewable power capacity compared to the previous year, representing an increase of 5.899 MW. Renewable energy installations represent 59,2 % of electricity generation in Spain. This increase in renewable installed capacity was mainly due to the increase in photovoltaic solar power, which contributed 4.498 MW, 76,3 % of the new capacity, representing the largest historical increase in this technology and has managed to overtake hydroelectric power, currently ranking as the third most powerful source of generation, accounting for 16,6 % of the total national installed capacity. Wind power has contributed an additional 1.400 MW to the new renewable capacity and remains the leading technology, representing 25,2 % of the national generating park. The contribution of renewable energies to the national electricity generation in 2022 has reached a share of 42,2 % of the national energy mix. [9]

However, despite progress in renewable energy, Spain still relies heavily on fossil fuels in its overall energy production. Particularly, the transportation, industrial, and building sectors face significant challenges in meeting the country's goals for incorporating more renewable sources and reducing carbon emissions.

2.2 Energy Transition Plans

Spain has developed comprehensive energy transition plans aimed at phasing out fossil fuels and promoting clean energy. The Integrated National Energy and Climate Plan outlines specific targets for reducing greenhouse gas emissions and increasing the use of renewable energy.

The structure of the strategic framework for Spain's decarbonization is based on three main pillars: the draft Climate Change Law, the National Integrated Energy and Climate Plan (PNIEC), and the Just Transition Strategy (ETJ). The draft bill offers an efficient roadmap for the coming decades; the PNIEC lays the foundations for decarbonization during the period 2021-2030 and in coherence to achieve emissions neutrality by 2050; and the Just Transition Strategy is a strategy of solidarity-based accompaniment to ensure that people and territories make the most of the opportunities of this ecological transition without anyone being left behind. [10]

The measures outlined in the PNIEC will lead to significant outcomes by 2030. These include a 23% reduction in GHG compared to 1990, a substantial increase with 42% of renewables in the final energy consumption, a noteworthy 39,5% improvement in energy efficiency, and a remarkable 74% of renewable energy in electricity generation. These ambitious goals demonstrate Spain's commitment to a sustainable and clean energy transition, aligning with international efforts to combat climate change and reduce carbon emissions [11].

These strategies are aligned with those proposed by the EU, allowing to meet the objectives set for the neutrality of GHG emissions in 2050, reducing 90% of gross emissions, this reduction of emissions is estimated to change from 319,3 MtCO2-eq projected for 2020 to 221,8 MtCO2-eq in 2030, where it is also intended to achieve an electricity system that is 100% renewable.

2.3 Transport sector

Road traffic is the greatest contributor to the transport sector's carbon footprint. Global warming has been one of the main concerns in recent transportation policies, and its reduction has become one of the main objectives of sustainable transport policies. An analysis of the main factors influencing energy consumption and GHG emissions is essential for designing new energy- and environmentally efficient strategies in the road transport mode [12].

To achieve the objective of climate neutrality agreed by the European Union for 2050, a 90% reduction of greenhouse gas emissions related to transportation is required, where the aim is to reduce at least 55% in the course of 2030, for which there are proposals to implement an infrastructure for vehicles with alternative sources of consumption and provide alternative sources of energy supply. The clear trend is the decarbonization of transport, promoting alternative fuels to reduce carbon emissions efficiently [13].

The decarbonization of transport and its digitalization will mean a significant mobility transformation. The PNIEC estimates that 35% of passenger kilometers currently driven in conventional vehicles will be shifted to non-emitting modes and that there will be 5 million units of electric vehicles, including cars, trucks, buses, and coaches to non-emitting modes, and that there will be 5 million units of electric vehicles, including cars, vans, motorcycles and motorbikes, vans, motorcycles, and buses. Achieving these targets requires urban planning and design that favors accessibility and sustainable mobility, the minimization of transport needs, the promotion of pedestrian areas and collective transport, and the use of bicycles. The delimitation of low-emission zones in cities with more than 50,000 inhabitants, together with the Sustainable Urban Mobility Plans, will drive this change, improving air quality and the health of city dwellers [10].

2.4 Net-Zero Energy Neighborhood

One of the more important concepts to reach the goals lined for the transition plans is the Net-zero neighborhood and the carbon-neutral neighborhood, the first one is defined as a district with zero energy consumption, meaning the total amount of energy used by the neighborhood on an annual basis is equal to the amount of renewable energy created on the site or in other definitions by renewable energy [14]

In 2040, neighborhood energy consumption is expected to decrease by around 5,69% compared to 2012. This reduction can be attributed to several factors: a 20% decrease in travel distances, 6,48% due to climate change initiatives, 12,95% because of increased annual building renovations, 18,76% to the adoption of 100% electric cars, 22,26% when doubling the rate of building renovations, and 31,62% to a light renovation and 63,25% to a heavy renovation of all buildings. Additionally, solar panels on residential building rooftops could generate renewable energy equivalent to 6,53% of global energy consumption. Combining heavy building renovations, electric vehicles, and photovoltaic panels can reduce over 90% of current energy consumption, leading to nearly zero-energy neighborhoods. [15]

Under Spain's decentralized system of government, the implementation of several efficiency measures for transport, buildings, and industry will fall on regional and local governments, making coordination between the central government and regional/local administrations as well as skills capacity at all levels of government essential to success [8]

2.5 Economic implications for climate change mitigation.

Consideration of the economic implications of the energy transition plays an important role in accelerating or slowing down the adoption of new cleaner technologies and stimulating investment to reduce greenhouse gas emissions. In this context, economic, political, and financial decisions are paramount to achieving these objectives.

Decarbonizing the energy system by 2050 is a formidable challenge for the Spanish economy and society. In thirty years, there will have to be a qualitative transformation of how the different actors save, generate, and consume energy. This will have a direct impact on the traditional business model of the electricity sector, on the mobility of people and the transport of goods, on the air conditioning of homes, on the type of energy that moves people, and on the use of energy in commerce, services, and the industrial and primary sectors, among others. [10]

The energy transition is part of a broader context in which other trends, such as the circular economy, the collaborative economy, and social innovation, are gaining ground among citizens and businesses alike. Internationally, the reallocation of investment funds from fossil fuels to renewables reflects a clear trend favoring the new energy model and facilitates access to the financing needed to carry out this transition, advances in critical areas such as power generation, sustainable mobility, and energy efficiency in construction support this shift. While energy generation has advanced considerably, sustainable mobility and building retrofitting are in the early stages, and each of these areas will require transition plans tailored to their specific economic and institutional realities [10].

3 Methodology

This section describes in detail all the methods and procedures used to analyze the decarbonization of Benicalap, explaining the process and the tools used to carry out the study.

Due to climate change problems and the energy shortage crisis, many countries, municipalities, and corporations have made carbon neutrality initiatives or net-zero commitments. Generally, decarbonization transition pathways can be classified into energy-saving techniques, renewable energy deployment, and carbon capture. [16]

To achieve decarbonization the use of renewable energies is essential, deployment of different resources like wind, solar, geothermal, and solar, production, these technologies had to be integrated with other methods to improve the decarbonization in cities, like the utilization of heat pumps in the rehabilitation of buildings, reaching a reduction of 8,43% of the emissions in Spain [17]. Other measures considered essential to decarbonization are reducing transport vehicles or using new technologies and alternatives to common fossil fuels.

In Europe, the transport sector is responsible for about a third of total energy use and a quarter of total greenhouse gas emissions. The largest amount of these emissions is coming from road transport, especially passenger cars. Fuel cell buses could also reduce up to 93% less CO_2 emissions in comparison to diesel buses [18]

Other considerations planted in this study are the capacity of PV panels in the buildings in Benicalap and the rehabilitation of buildings. Previous studies on rehabilitation in educational buildings show an average reduction of more than 66% in non-renewable primary energy consumption and more than 71% in CO_2 emissions. [19]

3.1 Decarbonizing Benicalap.

Aligned with the purposes signed in the Paris Agreement (COP 21), the signatory countries have committed to reducing GHG greenhouse gas emissions, with each country responsible for setting its targets to achieve this reduction. This is how the government of Spain presented its National Integrated Energy and Climate Plan (PINIEC) in 2019.

At the regional level, the Regional Ministry of Agriculture, Environment, Climate Change and Rural Development and the Regional Ministry of Sustainable Economy, Productive Sectors, Trade and Labor, with competencies in the matters of climate change and energy, have worked in the same line elaborating and approving in October 2018 the ''Valencian Climate Change and Energy Strategy'' [20], this strategy is based on the reduction of energy consumption, using the growth of renewable energies to promote their use, as well as energy self-consumption and the use of cleaner transport.

At the local level in Valencia, the Action Plan for Climate and Sustainable Energy (Paces) was approved in 2019, and the purpose is to reduce CO_2 emissions by 40% by 2030, taking 2007 as a reference. Thus, for large cities such as Valencia, the European Union considers the concept of "city" not as a whole, but interpreted at the level of neighborhoods, districts, or areas of special interest that meet a series of conditions and requirements [20]. In this sense, the city council of Valencia has approved the strategy "Mission Valencia Neutral City" to achieve three climate-neutral neighborhoods by 2030.

This strategy bases its public policies on acting on the following key points in the impact of emissions:

- Mobility and Transportation
- Energy
- Economy and Industry
- Re-naturalization and Biodiversity
- Housing and buildings
- Urbanism and Habitat

Table 2 shows the impact domains, the strategy to which they belong, and the urban action considered for Valencia in the **"Misión Climática Valencia."**

Table 2 Actions in "Misión Climatica Valencia 2030", modified from [16]

Impact	Urban Strategic of Valencia 2030	Action program
Mobility and transportation	- Sustainable urban and metropolitan mobility, inclusive and efficient urban and metropolitan mobility.	- Public transportation - Non-motorized mobility - Shared mobility - Electric mobility
Energy	- Just and inclusive energy transition and inclusive.	- Local energy production - Energy efficiency - Energy culture - Agri-food
Economy and industry	- Sustainable food and proximity - Inclusive and sustainable and sustainable economic development. - Innovation, culture, and sustainable tourism	- Proximity consumption - Strengthening of the Valencia Orchard - Innovation and knowledge - Reuse, recycling, recovery reduction
Biodiversity and re-naturalization	- Climate resilience territory and re-naturalization of the city.	- New materials and services - Re-naturalization and Biodiversity - Water management - Adaptation to extreme events - Prevention of pests and infections - Resilience
Housing and buildings	- Affordable and sustainable housing	- Housing rehabilitation - Rehabilitation of public buildings
Urbanism and Habitat	- Inclusive and proximity. - Urban regeneration based on social cohesion, accessibility, and sustainability.	- New Construction - City 15 minutes

Decarbonization potential estimation is critical to calculate and measure a specific area's actual greenhouse gas reduction capacity. However, it is often challenging to estimate decarbonization potential, especially when dealing with large and diverse urban areas [21]. In this sense, this study proposes a review of previous studies conducted in Benicalap, performing a comparison of the methods used to calculate their potential decarbonization, as well as comparing the methodology, the tools used, and the results of the studies conducted at the city council level, in comparison with those carried out by the Polytechnic University of Valencia (*Cátedra de Transición Energética Urbana*).

3.2 General procedure

Figure 1 presents an overview of the procedure to be carried out in this study, each of these steps is described below.

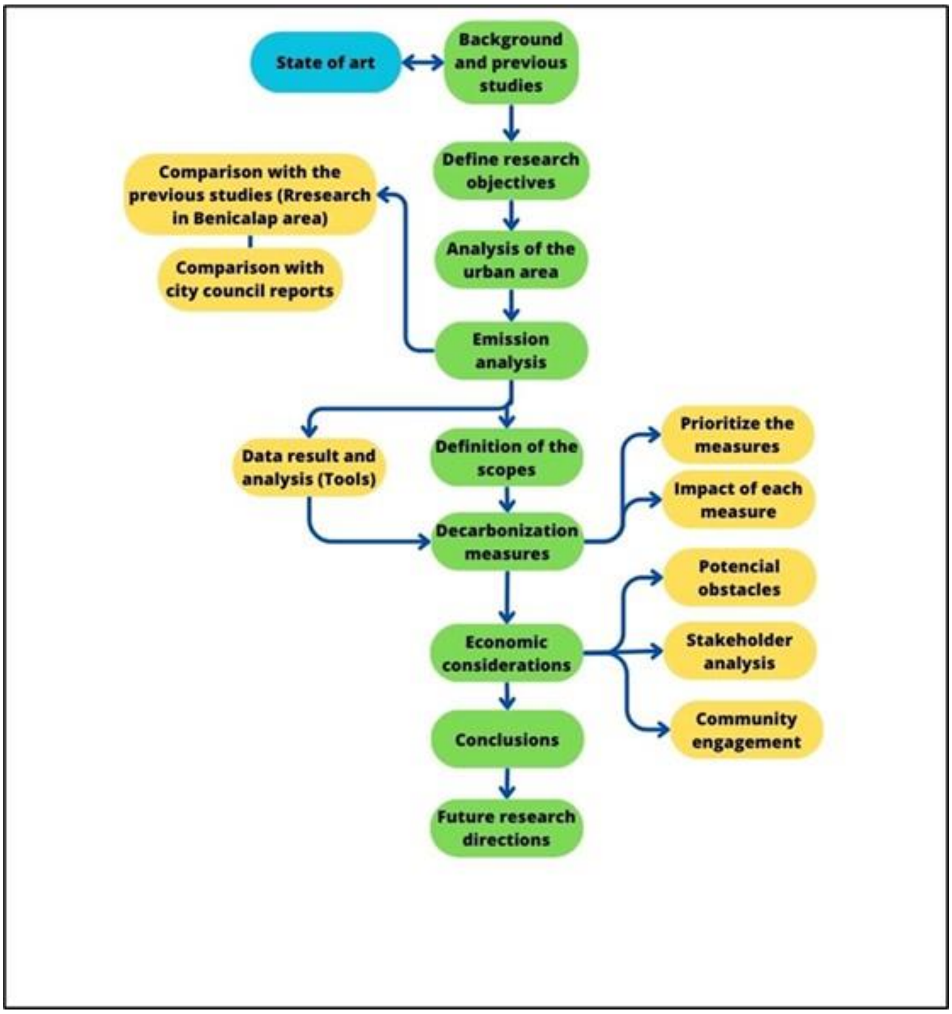


Figure 1 General procedure scheme

<u>Background and Previous Studies</u>

Many cities see in these three areas—renewable energy, energy efficiency, and flexibility options to stabilize the energy systems— opportunities for modernizing their economies, initiating new business models, and profiting from the municipal value-added effects. As a result, several cities have developed their climate protection concepts in recent years and adopted ambitious greenhouse gas reduction targets, ranging from climate neutrality [22]

This is the preliminary analysis of the studies realized by the council level in Valencia, compared with the studies realized by the UPV; this part also considers the state of the art, which would help to identify gaps in the existing research, allowing to find key points of improvement in the study. These previous studies were focused on the Benicalap area, with the main interest in implementing renewable energies and the adequate elaboration of an inventory of emissions in the neighborhood caused by scopes 1 and 2.

Define research objectives.

The definition of the research objectives represents the delimitation and the scope of the study, intending to improve the previous mitigation measures proposed in the earlier studies for Benicalap through the evaluation and the effectiveness of these proposals. Figure 2 shows a representation of these scopes.

These proposals are evaluated in three principal indicators:

- Energy: MWh/year saved.
- Emission: tCO_2/year saved, tCO_2/MWh.
- Economic Analysis: €/kWh, €/tCO_2.

This study will be focused only on the emission considered in scopes 1 and 2, Figure 2 shows a representation of these scopes.

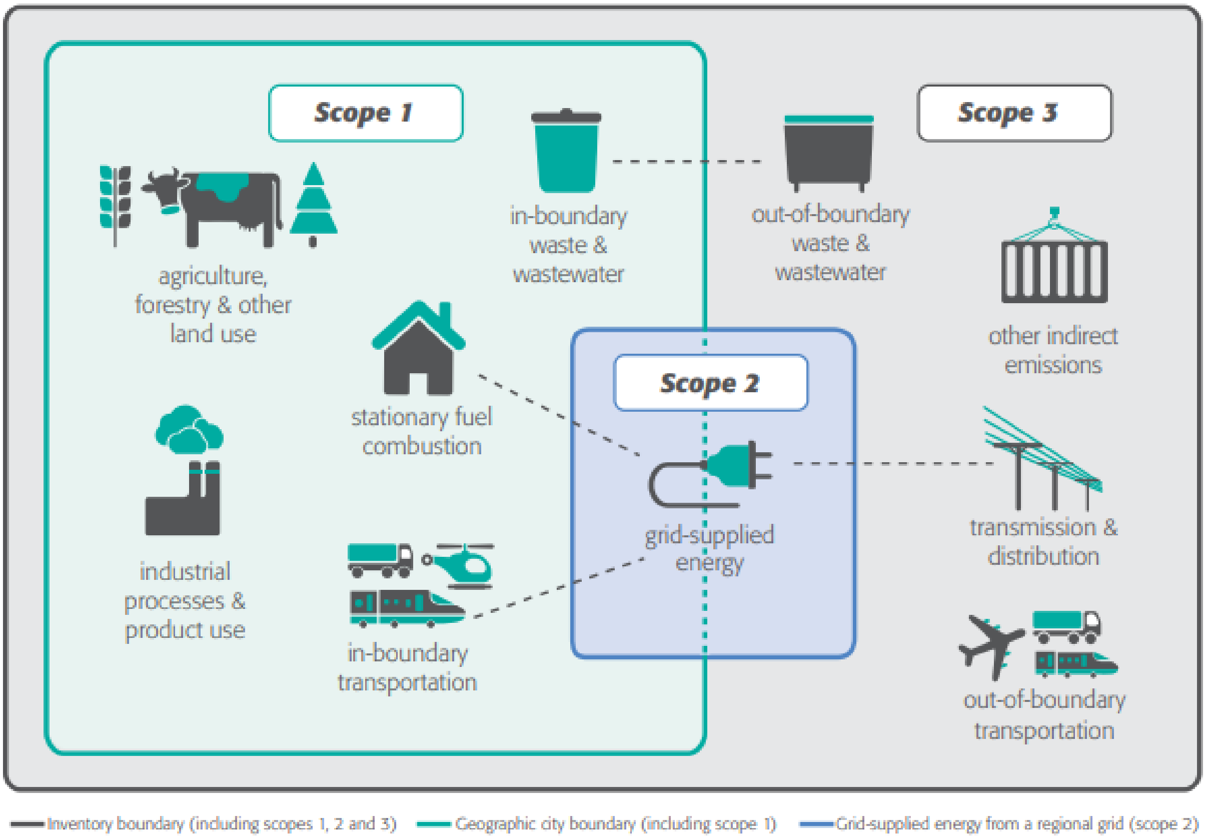


Figure 2 Scopes definition,adapted from [23].

The present study will also analyze the different perspectives of the stakeholders involved in developing a carbon-neutral neighborhood in Benicalap.

Analysis of the urban area

The neighborhood´s design process is crucial for archiving sustainability, Typically, infrastructure systems are independently designed by specialists in the individual areas after the master plan design, ignoring or overlooking the mutual interactions between the infrastructures and the urban layout. Nature sustainability requires engineers and urban designers to work together adopting a holistic perspective, including interactions between the neighborhood and the greater urban region [22], In this way it is crucial to analyze the area of Benicalap, taking into account the principal factors that influenced the CO_2 emissions of the area, which are the follows:

- Land use
- Demography
- Energy Resources
- Mobility (transport)
- Other activities

Towards the sustainability of the district, the main goal principally focuses on lowering urban carbon footprints and reducing greenhouse gas emissions by targeting resource and energy consumption in the construction, operation, and maintenance of the urban built environment. Implicitly, the goals informed practical measures in energy conservation, energy efficiency, and renewable energy generation; incidentally the same three aspects for 100% renewability [24]. One way to achieve this decarbonization goal is to consider the following principles:

- Green building design to reduce operational consumption and optimize building orientation for solar generation.
- Compact development to minimize gray energy use.
- Medium- to low-rise building construction to conserve materials and energy.
- Building renovation and reuse to increase efficiency and material conservation.
- Mixed uses to reduce distances to services and conserve fuels.
- Urban greening to save energy in the cooling of urban heat islands.
- Networked public transport for increased modalities and lowered dependence on private motor vehicles.
- Connected public spaces to save energy in the daily movements through the city.

Emission analysis

In this part of the study, an analysis of the emissions produced in the Benicalap area will be made, making a comparison with previous studies conducted in the neighborhood, analyzing the methodology followed by each of these studies which the UPV and the city council have conducted, as well as making a comparison and review of the inventories of emissions previously made, to generate improvements to the proposals for mitigation of emissions.

As mentioned before the emissions analyzed in this study will be focused only considering the ones produced in scopes 1 and 2, In the same way, an analysis of the tools used to calculate emissions will be carried out.

Definition of scopes

According to the GHG protocol, GHG emissions are studied by grouping them into three scopes. In this context, Scope 1 considers direct GHG emissions, Scope 2 refers to indirect emissions from the production of electricity, heating, steam, or cooling consumed by the reporting entity, and finally, Scope 3 deals with all other indirect GHG emissions, including waste disposal, outsourced activities, vehicles not owned or under the reporting entity's control, and the extraction and production of purchased materials and fuels. [25] The correct definition of the scopes in this part of the study will provide clarity on the direction of the decarbonization of the Benicalap district, setting the specific reduction targets, facilitating the data collection, and the technological choices to achieve the decarbonizing goals

Decarbonization Measures

The proposals will be based on and aligned with the emissions study previously carried out, focused on scopes 1 and 2, this proposal will be made based on the proposals previously made in the studies of the Benicalap neighborhood, opening the possibility of improving them and proposing new measures. Previous studies carried out by the UPV show interest in the following measures:

- Energy efficiency and building reimbursement.
- Renewable generation based on PV generation.
- Evolution of the transport fleet both for private and public transport to sustainable transport.
- Implementation of natural-based solutions.
- Energy efficiency measures in public lighting.
- Reduction of waste production and improve its management.

This study aims to assess the effectiveness and significance of each proposed measure, examining their impact on reducing the carbon footprint of the initial situation. The prioritization of measures with more influence will facilitate the achievement of decarbonization goals by analyzing the data results and the tools used to obtain them.

Economic Considerations

Generating renewable electricity and storing it usually requires an investment three times greater than producing an equivalent kWh from burning carbon. Although renewable energy eliminates the cost of carbon fuel, this saving may be diminished by the higher cost of writing off the investment in renewable energy and paying associated interest charges. [26]

This work will analyze from an economic point of view, different considerations such as potential obstacles and stakeholder analysis in the implementation of the proposed measures, through the realization of an accurate estimate for the implementation of each proposed measure, based on the previous studies and the consideration of new proposals.

Conclusions

Based on the analysis carried out in the Benicalap neighborhood, which will be elaborated considering the emissions generated, their mitigation measures, and their economic implications for their implementation, a series of conclusions will be drawn, consolidating the key results of the study, guiding decision making to offer solutions in the process of decarbonization of the Benicalap neighborhood. Serving as a guide for those responsible for urban planning, as well as for the implementation of greenhouse gas mitigation measures.

Future research directions

In conclusion, this part of the study will analyze what may be the new scope of upcoming projects in the Benicalap neighborhood, as well as point out what other areas concerning carbon mitigation can be analyzed and developed.

3.3 Estimation methodology by sub-sectors

The use of subsectors allows the use of more disaggregated data and improves the detail of the inventory, which is crucial for a more accurate and deeper understanding of the sources of GHG emissions in a city. In addition, this disaggregation facilitates the identification of specific activities and mitigation policies targeting sectors, which is essential for the development of effective emission reduction strategies and informed climate change decision-making [6].

The methodology followed for the estimation of the GHG of the Benicalap neighborhood, focuses on an analysis of various subsectors which have been considered as key within the neighborhood, these include Private Transport, Residential, Industrial and Electrical Services Sectors, Gas use, Solid Waste management, Public Transportation, Municipal Buildings and Equipment, Public Lighting, and Consumption of Goods, each subsector considered in the emissions inventory is addressed individually, using specific data as relevant emission factors to calculate their contribution to total emissions. This approach allows for the identification of the areas with the greatest potential for emission reductions along with the development of effective mitigation strategies. The results are shown in Table 20 which is the representation of the GHG inventory in Benicalap, Valencia. The methodology followed for the estimation of emissions for each subsector is as follows:

Private Transportation: Emissions were estimated based on the number of vehicles, type of fuel, average mileage, and specific emission factors for each vehicle type.

Residential Electric Sector: Emissions were calculated based on household electricity consumption, using emission factors from the local electric grid.

Industrial Electric Sector: Similar to residential, but focused on the electricity consumption of industries, considering a variety of industrial processes.

Service Electric Sector: The electricity consumption of service buildings (offices, schools, hospitals) was analyzed, and emission factors were applied.

Gas consumption: Emissions were accounted for based on natural gas consumption by sector, using specific emission factors.

Solid Waste: Emissions were estimated based on the quantity of generated and treated waste, with emission factors for each treatment method (landfill, incineration, composting).

Public Transportation: Emissions were calculated based on the type of transportation (bus, tram, metro), number of trips, and emission factors for fuel type and vehicle.

Municipal Buildings and Equipment: The energy consumption of these buildings was evaluated, and emission factors for electricity and gas were applied.

Public Lighting: Emissions were estimated based on the electricity consumption of public lighting, considering operating hours and device efficiency.

Consumption of Goods: Emissions associated with the production, transportation, and disposal of consumed goods were calculated, requiring a life cycle analysis for different product categories.

This methodology integrated sector-specific data with relevant emission factors, allowing for a detailed assessment tailored to the characteristics of each subsector.

3.4 Mitigation measures methodology

The urban landscape and environmental quality within neighborhoods are significantly impacted by infrastructural and policy measures, particularly those aimed at mitigating climate change and reducing carbon emissions. Two notable measures that exemplify this approach are the Parking Lots Reduction Measure and the Refurbishment of Houses in Benicalap Measure. The former focuses on the strategic reduction of parking spaces to encourage public transport usage, thereby decreasing private vehicle emissions. This approach not only aims to cut down carbon emissions but also seeks to replace these spaces with green areas, enhancing urban greenery and sustainability. The methodology involves a comprehensive review of related studies, emissions approximation per parking space, and a detailed economic analysis to ensure the proposal's viability. On the other hand, the Refurbishment of Houses in Benicalap Measure addresses the issue of energy inefficiency in older buildings. By focusing on buildings constructed before the 1980, this measure aims to significantly reduce energy losses through targeted rehabilitation, factoring in the buildings' thermal insulation needs against current standards. The process includes a methodical analysis of the buildings' construction years, thermal demands, and an economic evaluation to ascertain the feasibility and impact of the proposed energy savings. Both measures highlight a holistic approach to urban planning, emphasizing sustainability, economic viability, and the reduction of carbon footprints, showcasing innovative strategies to combat climate change at the neighborhood level.

Parking lots reduction measure

Figure 3 shows the general procedure followed to prepare this mitigation proposal, where initially a review of other methodologies and studies related to the administration of parking spaces and its direct influence on the use of transport vehicles was made. Subsequently, an approximation of the emissions considered per parking space was made, taking into account the emissions caused by users when changing private vehicles for public transport, considering that for this study each parking space represents a tourist vehicle in the neighborhood, with capacity for 4 people, with this it is possible to establish a relationship of reduction of parking spaces wit the emissions caused by private vehicles in the neighborhood, considering the spaces available in the neighborhood to be reduced with this proposal.

As part of the final procedure of this proposal, an economic analysis is carried out to determine the scope and costs of said proposal showed in 9.1 , and it is also intended to replace the parking spaces with green areas (NBS) to justify the replacement of said spaces in the neighborhood.

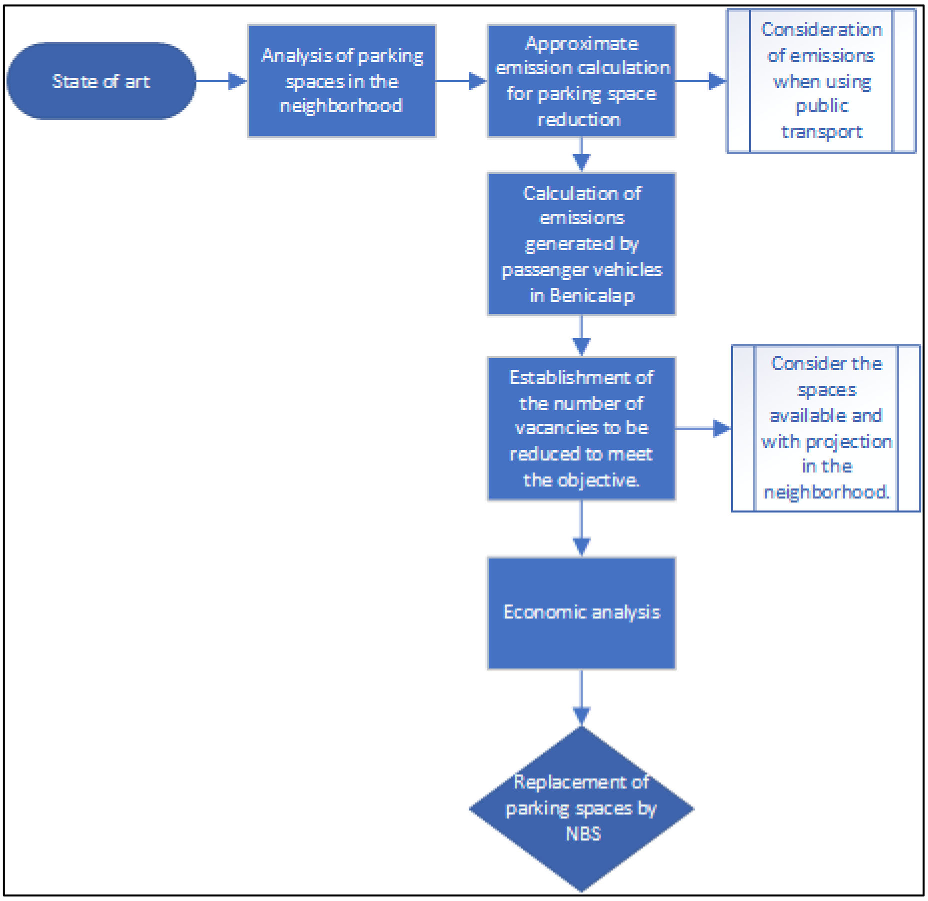


Figure 3 General methodology for parking reduction mitigation measure

The emission calculations for the parking lot reduction measure are based on the specific formulas showed in Table 3, the specific results together with the factors used are shown in section 7.2.1. All formula considerations are annual and can then be adapted to the requirements of the scope of the proposed mitigation measure.

Table 3 Equations Parking reduction measure

Term	Equation	*Definition*	*Variables*
CO_2 savings estimations	$\boldsymbol{CO_2\ Savings\ estimated = NVR * SVE}$	*Equation used to determine the total tons of CO_2 reduced by the reduction of parking spaces in the Benicalap neighborhood, considering the reduction in the use of combustion vehicles and the estimated savings.*	***NVR** = number of vehicles reduced per parking spots elimination.* ***SVE** = Savings per Vehicles reduced*
Number of vehicles reduced per parking sports	$\boldsymbol{NVR = TP * OS}$	*This equation is used to calculate the number of vehicles reduced by the elimination of parking spaces, taking into account the total number of existing parking spaces in Benicalap, and the average occupancy of vehicles per parking space.*	***TP** = Total parking spots in Benicalap* ***OS** = Occupation estimation of vehicles per parking spot*
Savings estimation per vehicles reduction	$\boldsymbol{SVE = Annual\ tCO_{2\ turismo} - (ATU * CU)}$	*This equation determines the estimated tCO_2 reduction by reducing the use of vehicles, considering the annual average tCO2 of passenger cars, and the annual emissions of a public transport user in the Benicalap neighborhood, considering also the change of user from private to public transport.*	***ATU** = annual emissions considered per metro- tram user.* ***Annual $tCO_{2Trurismo}$** = annual tons of CO_2 per car considered* ***CU** = users considered per turismo vehicle*

Refurbishment of houses in Benicalap measure methodology

Figure 4 shows the general procedure followed for the preparation of the proposal for the rehabilitation of buildings in the Benicalap neighborhood, to reduce energy losses, generated by the poor insulation of buildings built before the 80s, which was the time when the regulations for the thermal conditions of buildings came into force.

Different methodologies and studies related to the rehabilitation of buildings for energy savings and their relationship with carbon emissions were reviewed. To develop an appropriate proposal for this study, an analysis of the residential buildings in the Benicalap neighborhood was carried out, establishing a relation to its year of construction and the current thermal construction criteria in Spain, subsequently, it is necessary to know the thermal demand in the neighborhood, taking into account the differences in consumption for heating the homes and cooling them, since the demand is usually much greater during the winter months. Once this demand is established, it is possible to prepare a building rehabilitation proposal to estimate the energy savings. As a final part of the development of this proposal, it is necessary to consider an economic analysis that considers the costs of implementation of the measure and its scope, as well as future improvements to the proposal and rehabilitation plans.

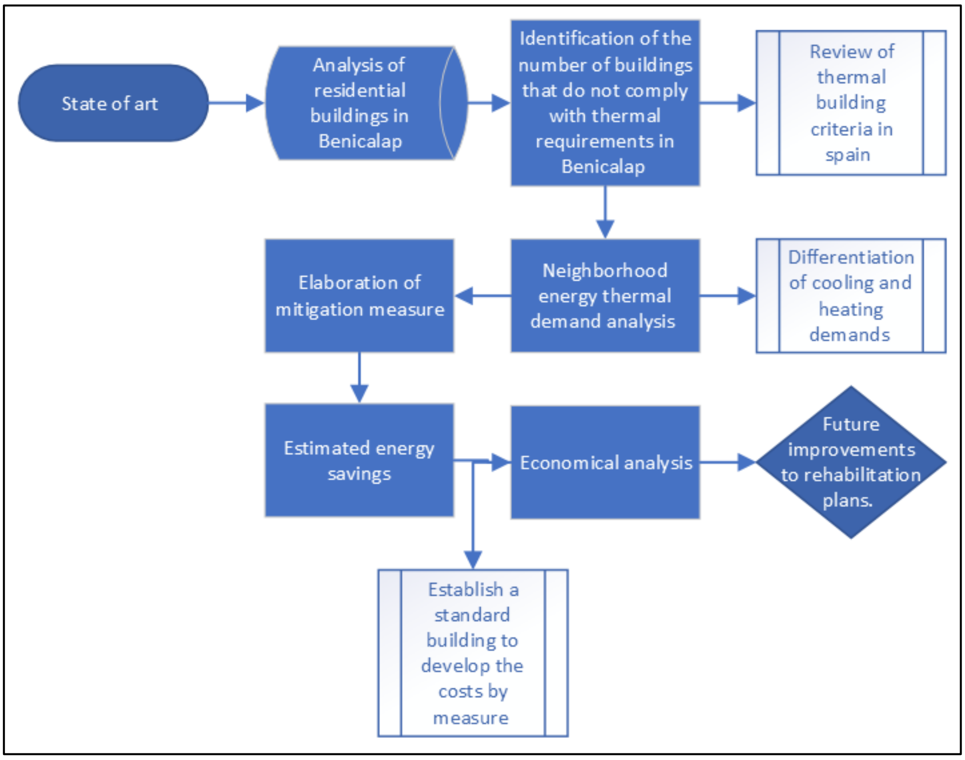


Figure 4 General methodology for Benicalap Buildings rehabilitation measure

The GHG emissions savings estimation for the refurbishment of the buildings measure are based on the specific formulas showed in Table 4 the specific results together with the factors used are shown in section 7.2.2. All formula considerations are annual and can then be adapted to the requirements of the scope of the proposed mitigation measure.

Table 4 Refurbishment measures equations

Term	**Equation**	***Definition***	***Variables***
Annual energy savings *($AE_{Savings}$)*	$\boldsymbol{AE_{Savings} = AE_{Demand} * PAE_{savings}}$	*This equation is used to obtain the estimate of energy saved annually with the Benicalap building refurbishment measure, considering the annual demand of the neighborhood and the percentage of savings considered after the refurbishment of the buildings.*	$\boldsymbol{AE_{demand}}$ = Annual energy demand $\boldsymbol{PAE_{SAVINGS}}$ = Percent of annual energy savings of the building rehabilitation
CO_2 Savings	$\boldsymbol{\text{CO2 Savings} = AE_{Savings} * Esmission\ factor_{Electricity}}$	*This equation is used to calculate the estimated CO2 savings from the refurbishment of the buildings in Benicalap, considering the energy savings and the CO2 emission factor for electricity consumption.*	$\boldsymbol{AE_{Savings}}$ = Annual energy savings ***Emission factor*** $_{\boldsymbol{Electricity}}$ = emission factor of the electricity consumption
Annual consumption (AC)	$\boldsymbol{AC = AC_{Vlc} * \frac{properties_{Vlc}}{properties_{benicalap}}}$	*This Equation used to estimate the annual consumption of Benicalap by extrapolating the data for the city of Valencia*	$\boldsymbol{AC_{Vlc}}$= Annual consumption of the Valencia city (MWh) $\boldsymbol{Propierties_{Vlc}}$= Number of properties in Valencia city $\boldsymbol{Propierties_{Benicalap}}$= Number of properties in Benicalap neighbourhood

3.5 Roadmap methodology

Decarbonizing urban areas is an ambitious yet critical endeavor in the fight against climate change, requiring meticulously planned and strategically implemented measures. The Decarbonizing Benicalap Roadmap proposed in this study in the section 8.1 exemplifies a comprehensive strategy aimed at reducing carbon emissions within the Benicalap neighborhood through a series of targeted interventions spanning from 2024 to 2030. This roadmap integrates a multi-faceted approach, focusing on residential measures, the implementation of photovoltaic (PV) systems, Nature-Based Solutions (NBS), sustainable transport and parking solutions, and the enhancement of public lighting. By setting clear milestones and leveraging a phased implementation strategy, the roadmap aims to transform Benicalap into a model of urban sustainability, demonstrating the potential for neighborhoods to contribute to broader climate goals through localized actions. Figure 5 shows the general procedure of the implementation methodology for the road map.

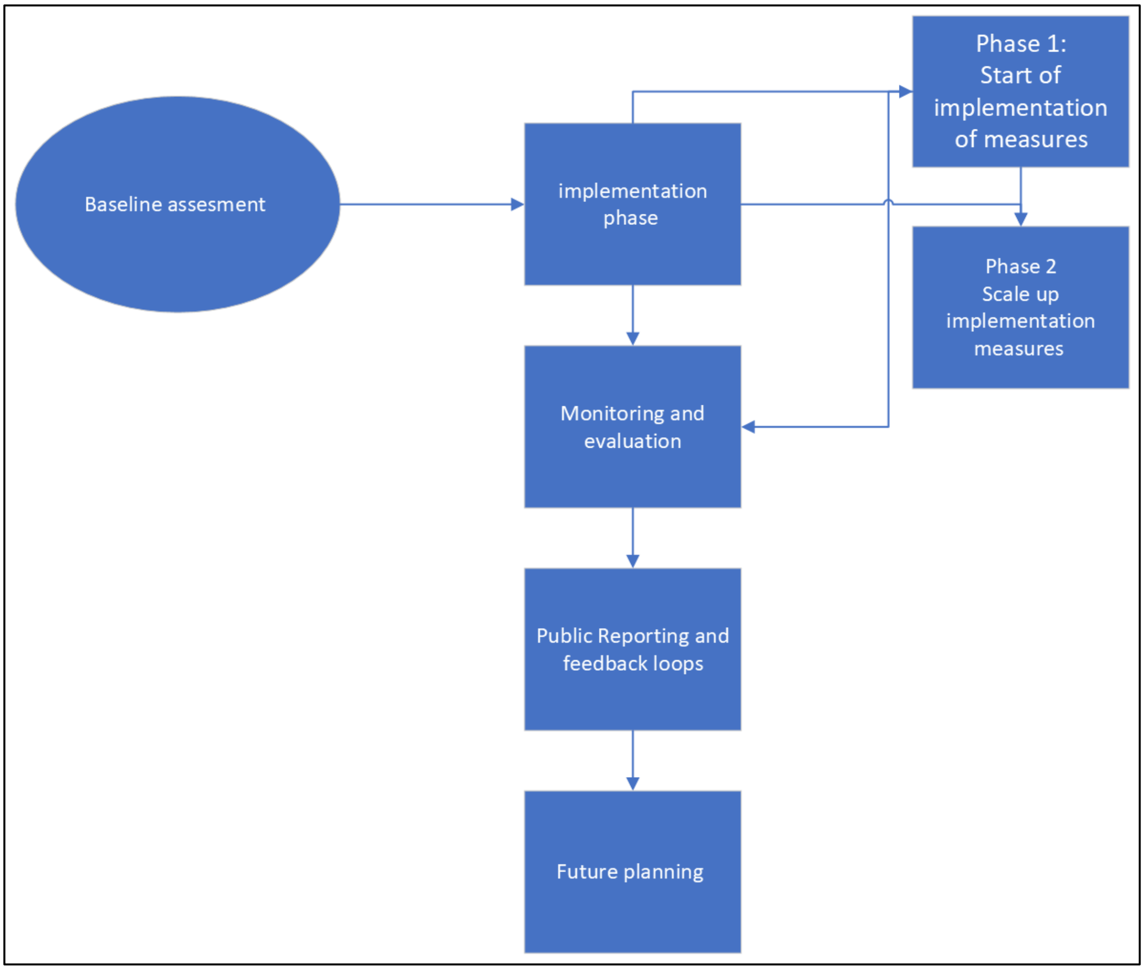


Figure 5 General methodology of the road map implementation

4 Analysis of Benicalap, Valencia

The city of Valencia is subdivided into 19 neighborhoods, as shown in Figure 6; this study focuses on the Benicalap neighborhood, a Benicalap neighborhood map is shown in Figure 7.

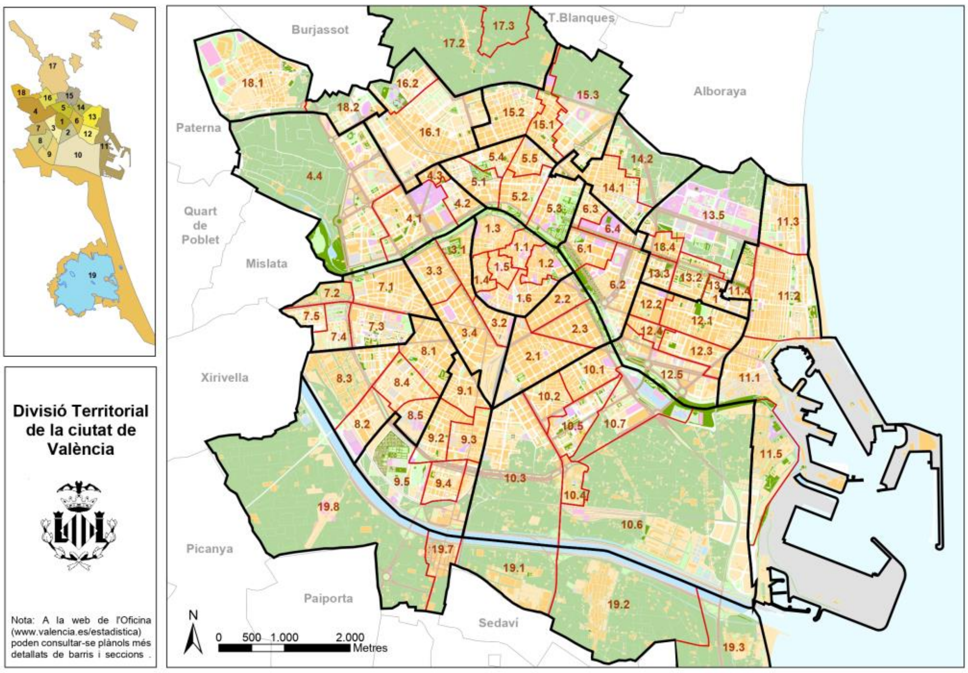


Figure 6 Territorial subdivision of Valencia City

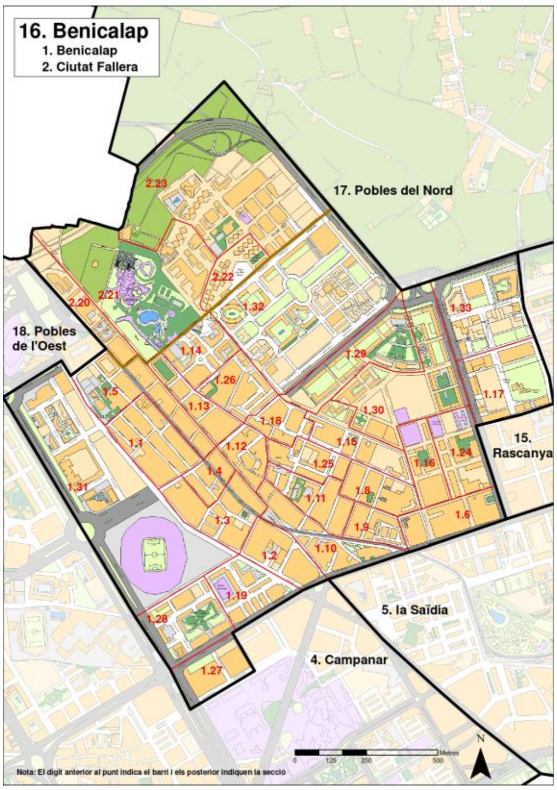


Figure 7 Benicalap District map

Population (number of inhabitants)	**41868**
Surface (km²)	1.719
Density of population (inhab/km²)	24332

Figure 8 Basic data of Benicalap [27]

Evaluating the starting point of various neighborhoods is vital for turning them into carbon-neutral areas. Suggesting customized measures that suit each neighborhood's unique features and observing how the initial situation develops is essential. This involves thoroughly examining the social, economic, and energy aspects and providing a concise summary.

4.1 The economic situation in Benicalap

Understanding the economic situation and existing activities in a neighborhood is fundamental when considering mitigation measures, as these variables are crucial for designing effective and socially inclusive strategies. The economic reality and activities influence consumption patterns, mobility, and available resources.

According to the cadastral data 2022 of the Benicalap [27] neighborhood, the economic activities of the neighborhood are subdivided into 3 industrial activities: commercial and service activities by type, and finally professional activities by type.

Figure 9 shows the industrial activities by type developed in the Benicalap neighborhood.

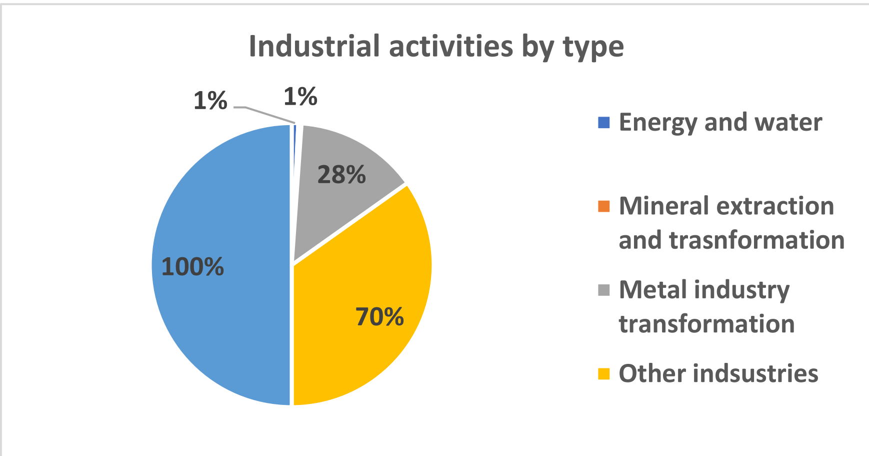


Figure 9 Industrial activities by type, adapted from [27]

Figure 10 shows the presence of stores and services in the neighborhood by type.

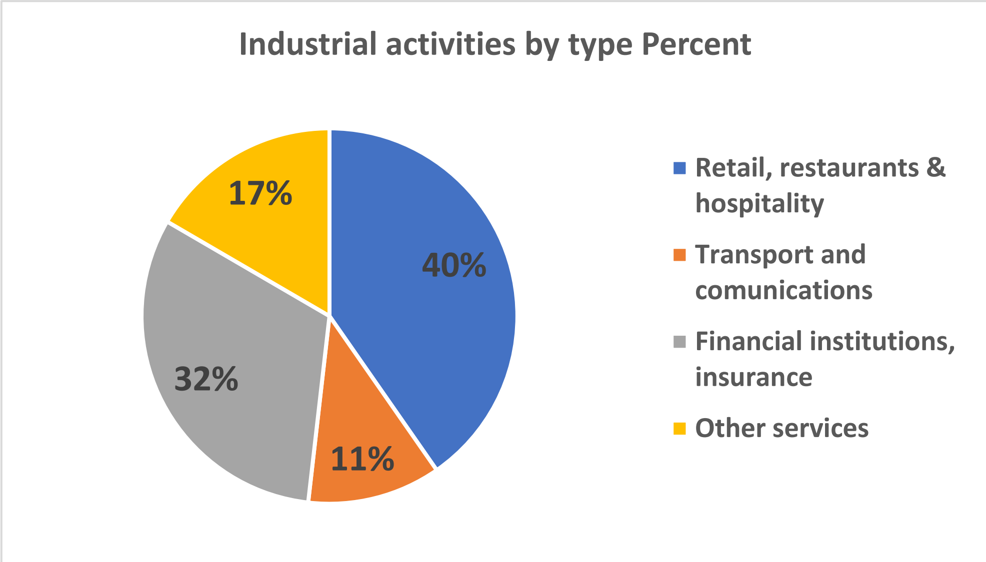


Figure 10 Commercial & services by type, adapted from [27]

Figure 11 shows the professional activities by type carried out in the neighborhood.

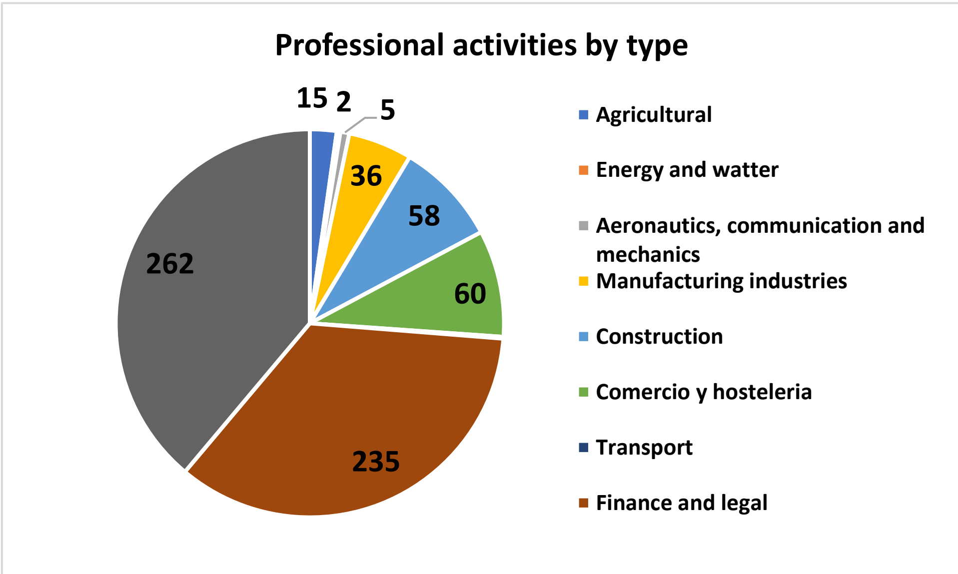


Figure 11 Professional activities by type, adapted from [27]

4.2 Energy situation

To develop GHG mitigation measures in the neighborhood of Benicalap, in addition to knowing the activities carried out, it is essential to know the energy situation of the neighborhood since understanding both aspects will allow us to focus the measures on the most vulnerable areas.

Figure 12 and Table 5 illustrate the total consumption in the neighborhood of Benicalap, subdivided into three sectors: Residential, industry, and services, as can be seen in the graph the residential sector is the one that demands more electricity consumption, which means 59% of the total electricity consumption of the neighborhood. [28]

Table 5 Benicalap Electricity consumption by sector [29]

Sector	Total (kWh/year)	Percent
Residential	45.604,25	59%
Industry	1.136,71	1%
Services	30.344,38	39%
Total	77.085,33	100%

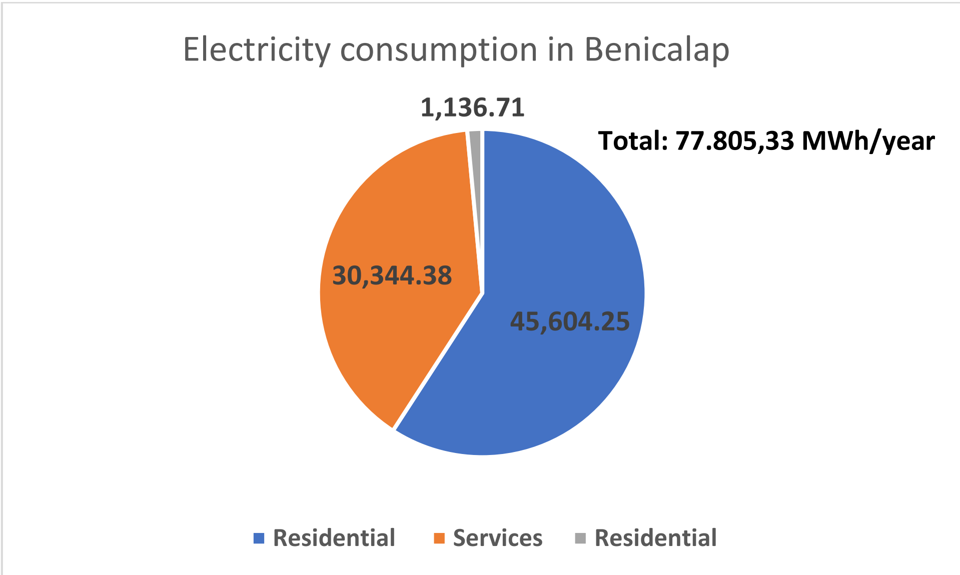


Figure 12 Electricity consumption in Benicalap [29]

Since residential consumption is the largest percentage of total energy demand, the consumption within this sector is further subdivided and studied in Current situation of the buildings in the neighborhood of Benicalap 7.2.2.1 and illustrated in Figure 37.

5 Emissions Inventory for Scopes 1 and 2.

An inventory identifies the gases, emission sources, geographic area, and period covered by a GHG inventory. This inventory within the boundary is designed to provide a city with a comprehensive understanding of where emissions are coming from and an indication of where it can act or influence change. [6]

As mentioned before, this study will focus on the emissions related to scopes 1 and 2 of Benicalap, reclassifying some of the emissions that were taken as part of scope 3. Also, this chapter will present the comparative of the previous studies realized in Benicalap, comparing the methodology and the tools, used to conduct these studies.

Cities shall account for emissions of the seven gases currently required for most national GHG inventory reporting under the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). [6].

Following this requirement for the elaboration of the GHG inventory, the Green House Protocol proposes to classify the activities into six main sectors:

- Stationary energy
- Transportation
- Waste
- Industrial processes and product use
- Agriculture, forestry, and other land use
- Any other emissions occurring outside the geographic boundary as a result of city activities (collectively referred to as Other Scope 3).

To specify the origin of the emissions the sectors shall be also subdivided into sub-sectors Table 6 shows the subdivision proposed for the GPC (Greenhouse protocol for cities).

Table 6 Sectors and sub-sectors

Sectors	Subsectors
STATIONARY ENERGY	• Residential buildings • Commercial and institutional buildings and facilities • Manufacturing industries and construction • Energy industries • Agriculture, forestry, and fishing activities with non-specified sources • Fugitive emissions from mining, processing, storage, and transportation of coal • Fugitive emissions from oil and natural gas system
TRANSPORTATION	• On-road • Railways • Waterborne navigation • Aviation • Off-road
WASTE	• Solid waste disposal • Biological treatment of waste • Incineration and open burning • Wastewater treatment and discharge
INDUSTRIAL PROCESSES AND PRODUCT USE	• Industrial processes • Product use
AGRICULTURE, FORESTRY, AND OTHER LAND USE	• Livestock • Land • Aggregate sources and non-CO2 emission sources on land
OTHER SCOPE 3	• All other GHG emissions that occur outside the city boundary result from activities taking place within the city boundary.

5.1 Scope emission current situation in Benicalap

In previous studies carried out in the Benicalap neighborhood by the *CÁTEDRA DE TRANSICIÓN ENERGÉTICA*, an organization that is part of the UPV, the emissions calculations were made in the Benicalap neighborhood. The results show that the higher contributor to these emissions is the consumption of goods; the goods considered in this inventory are food, clothes, and other manufactured products. [7], The results of considering the CO2 emissions factors for each of these items are shown in Table 7.

The other sources of emissions in Benicalap are the energy consumption in the buildings (considering different sectors) and the emissions caused using different transportation (public transportation, private and pass-through traffic).

Table 7 Benicalap emission estimation

Source of emissions	Emission estimations	Methodology estimations
Building	77.085,3 tCO_2	• Considering the consumption of electricity and gas on different sectors (residential, industry, services, gas, municipal building equipment and facilities
Transport vehicles (private transport and pass-through traffic)	34.221,1 tCO_2	• Kilometers travelled er type of vehicle and year. • Emissions per kilometer depending on the type and year of the vehicle.
Public transport	3.367,6 tCO_2	• Considering the number of kilometers of different kinds of vehicles
Consumption of goods	122.415,1 tCO_2	• Considering the number of people living in Benicalap • Emissions per consumption of goods
Waste	2.786 tCO_2	• Considering the emissions for the generation and management of waste generation
Public Lighting	269,7 tCO_2	• Considering the points of light and the consumption of energy
	Total: 184.379,7 tCO_2	

To analyze future proposals, it is important to know the contribution of emissions by sector, Figure 13 shows the contribution of the total emissions by each sector considered in this study, in addition to the contributions and their scope classification, Figure 14 shows this relation, as well as the contribution in tCO_2e to the emissions considered from Benicalap.

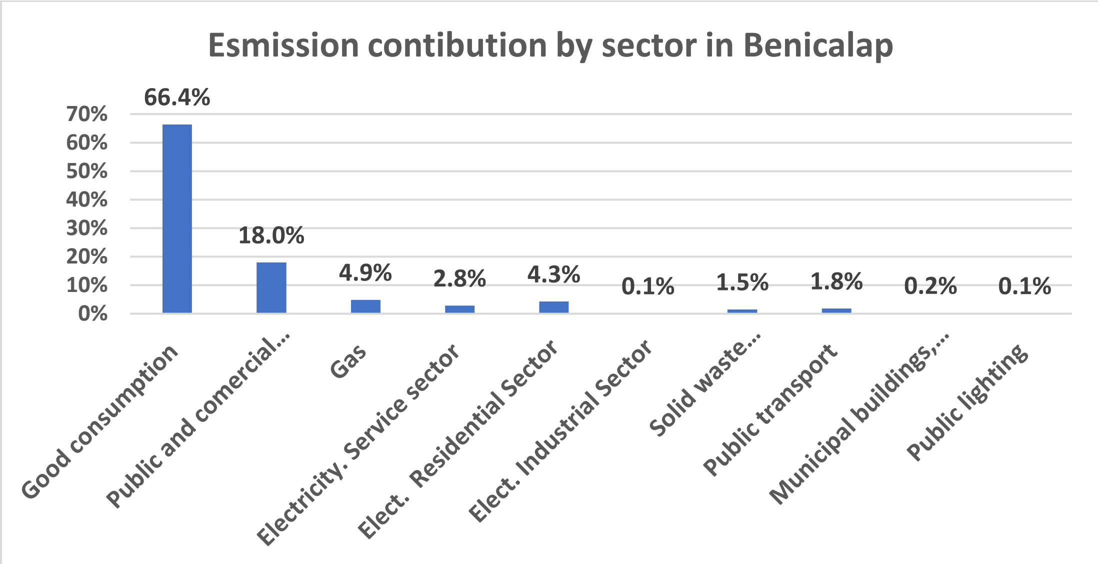


Figure 13 Emission contribution by sector in Benicalap, adapted from [7]

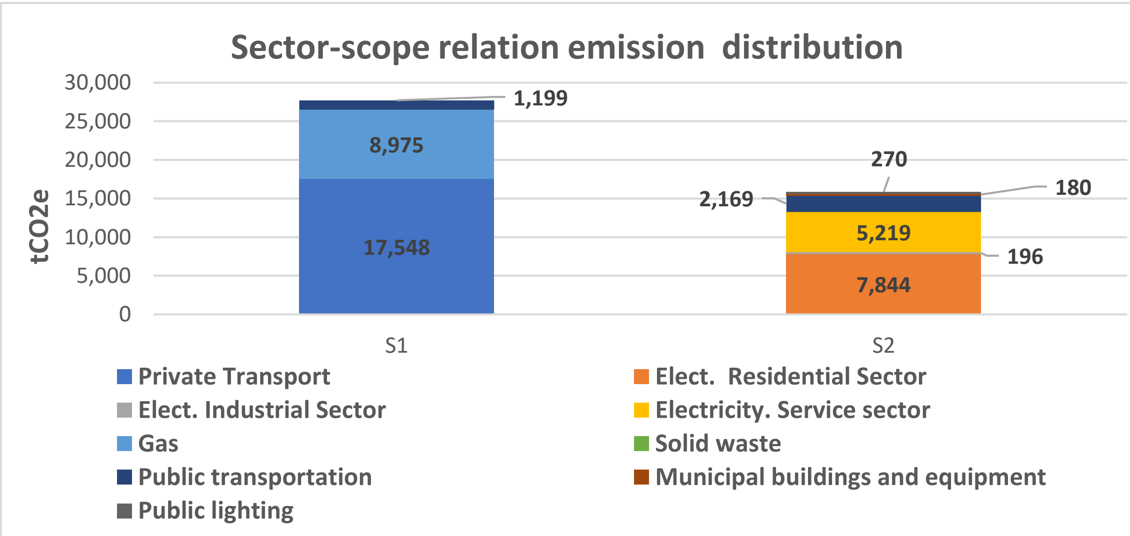


Figure 14 Sector-scope relation emission distribution, adapted from [7]

Figure 15 shows the percentage of emissions attributed to scopes 1, 2, and 3 in the Benicalap neighborhood, it is important to mention that in these previous studies realized in Benicalap, some emissions related to the transport and vehicles classified as passing-through were considered as part of the scope 3, Forward in this study they will be considered as part of scopes 1, 2 according to the group they belong to (electric vehicles or fossil fuel vehicles).

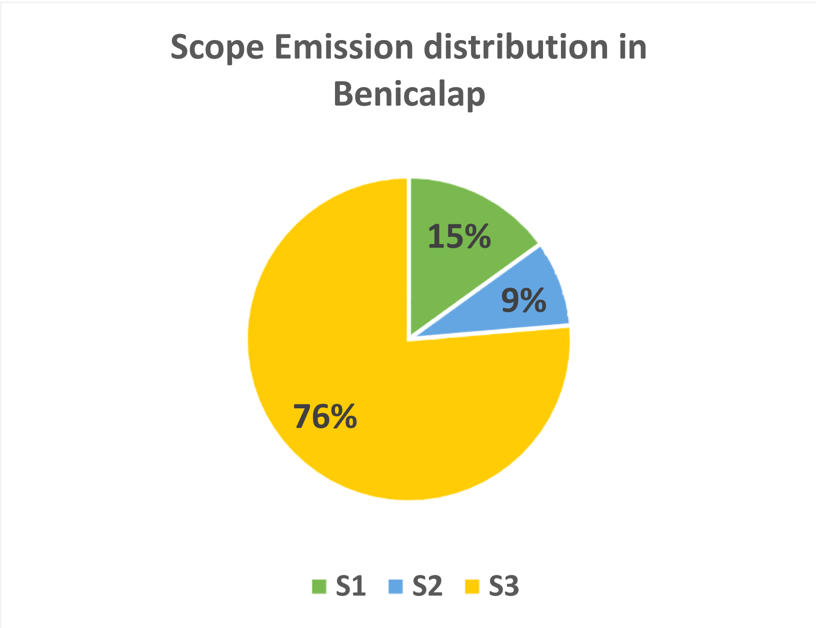


Figure 15 Scope emission distribution in Benicalap, adapted from [7]

Since this study is focused on the scopes 1 & and 2 produced in Benicalap, Figure 16 shows the contributions related to those scopes,

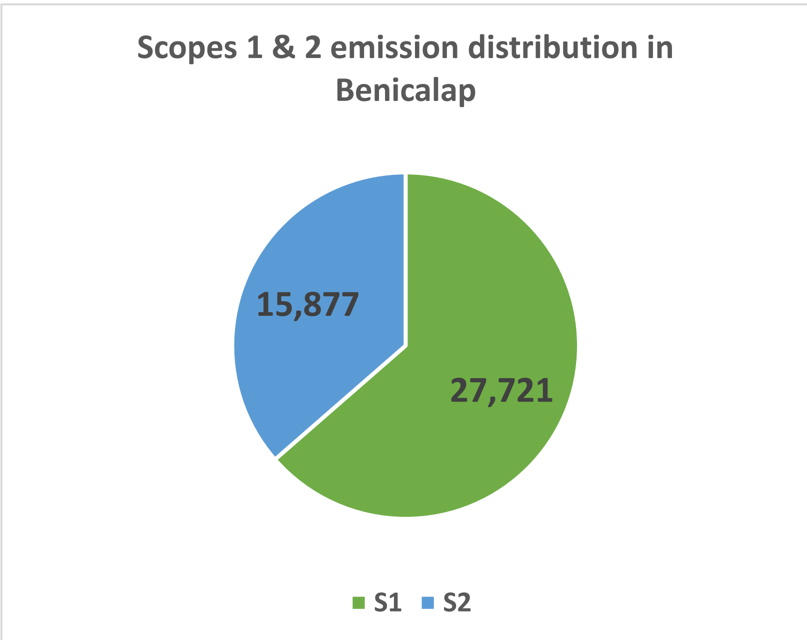


Figure 16 Scopes 1 & 2 emission distribution in Benicalap

The total emissions related to scopes 1 & and 2 are 43.598 tCO_2, and the percent corresponding to each scope is 36% to scope 1 and 64% to scope 2, ¡Error! No se encuentra el origen de la referencia. shows the 1 & 2 Sector-scope relation emission distribution in Benicalap**,** corresponding to each sector considered in these scopes.

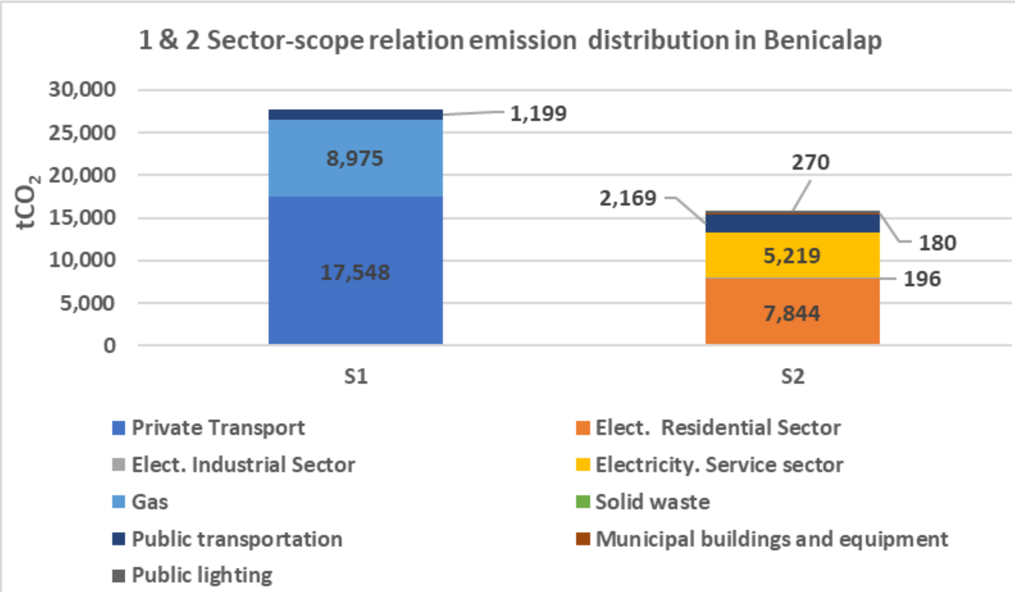


Figure 17. 1 & 2 Sector-scope relation emission distribution in Benicalap

5.2 Comparative of the previous studies conducted in Benicalap

This study is conducted to analyze the results of previous studies and measures realized in Valencia and Benicalap, and to improve these results and proposals. Table 8 shows a short comparative analysis of 3 previous studies, two of them conducted in the Benicalap area, and the third one is considered because of the similitude of the proposal and the location of the study, compared with the other, this third study was conducted for a large sample of multi-story buildings in Valencia, and then apply in the Maritim area of the city by the project named "*mapa solar del district dels poblats marítims"*

Table 8 shows 5 sections considered in this short comparative, the **methodology** that illustrates each procedure adopted by each study, the **tools** section that shows the programs, databases, and other instruments used to analyze the relevant data, the section **measures proposed shows** the proposals analyzed in each of the studies to achieve CO_2 mitigation, the following section shows the **savings estimated per measure by 2030 (tCO2)**, this section does not apply to the "*mapa solar del district dels poblats marítims"* because the specific considerations of this study, later in this section it will be analyzed in detail. The last section shows the **Economic cost** of each measure proposed in the different studies, as the same as the previous section the economic considerations for the "*mapa solar del district dels poblats marítims"* will be analyzed separately.

Table 8 Comparative previous studies on the decarbonization district in Valencia, Spain.

Studies	Methodology	Tools	GHG mitigation Measures proposed	Savings estimated per measure by 2030 (tCO_2)	Energy Savings (MWh)	Economic cost of application (M€) (Initial investment)
Methodology to estimate the decarbonization potential at the neighborhood level. case study: Benicalap and l'illa perduda in Valencia, Spain	• Energetic initial situation analysis of Benicalap and l'illa perduda. • Simulation of the proposed GHG mitigation measures • Sensitivity analysis of variables considered as a big impact on the measure's implementation. • CO_2 Balance considering the reduction based on the reduction measures • Economic scenario of the measure's implementation	• **QGIS** (Estimation of building surface available to implement PV installations) • **EXCEL** (Analysis, organization, and visualization of numerical data) • **Google Earth** (Distance estimation of transportation routes) • **Datadis (**Obtaining daily electricity consumption data) • **PVGIS** (Obtaining the solar resource database) • **Homer** (to dimension and evaluate the neighborhood's photovoltaic potential)	1. NBS 2. PV generation 3. Public lighting 4. Sustainable transport	1. 59,5 2. 9.754 3. 110,0 4. 9.961 **Total: 19.884,6**	1. N/A (Due to the nature of the measure) 2. 90.315 3. 1018,8 4. N/A (due to the electricity consumption of the measure) **Total: 91.333,8**	1. 5,83 2. 56,7 3. 0,048 4. 146,6 **Total: 209,2**
Neighborhood decarbonization based on electrification and implementation of renewable energies. case to study: Benicalap, Spain			1. HP 2. Induction stoves 3. PV with storage system	1. 7.386,63 2. 407,4 3. 5.931 Total: **13.725,1**	1. 36,730.18 2. 1.636,05 3. 34.482,70 **Total: 72.868,93**	1. 35,7 2. 6,7 3. 12,2 **Total: 54,6**
Council level *"Mapa solar* IMPACTE"	• Skyline and surrounding analysis • Irradiation calculation • Electrical PV yield calculation • Energy demand estimation (Per building) • Economic estimations • Environmental impact of the measures	• 3D building modeling (PV potential) • LIDAR and cadastral data (Shadows projection analysis) • EnergyPlus (Irradiation database) • Multilinear regression model to calculate the economic feasibility • SAM	• PV panels to cover the building energy demand	N/A	N/A	N/A

Figure 18 shows the cost implementation of each measure proposed by the previous studies conducted for Benicalap, it is important to mention that this cost considered only the initial investment of each measure implementation, and does not take into account the O&M cost during the years considered for this study, as is showed in **Figure 18** the measure named as sustainable transportation is the one that requires the largest investment representing the 56% of the total cost of the measures proposed, followed by the PV Measure that represents the 21% as is showed in **Figure 19**

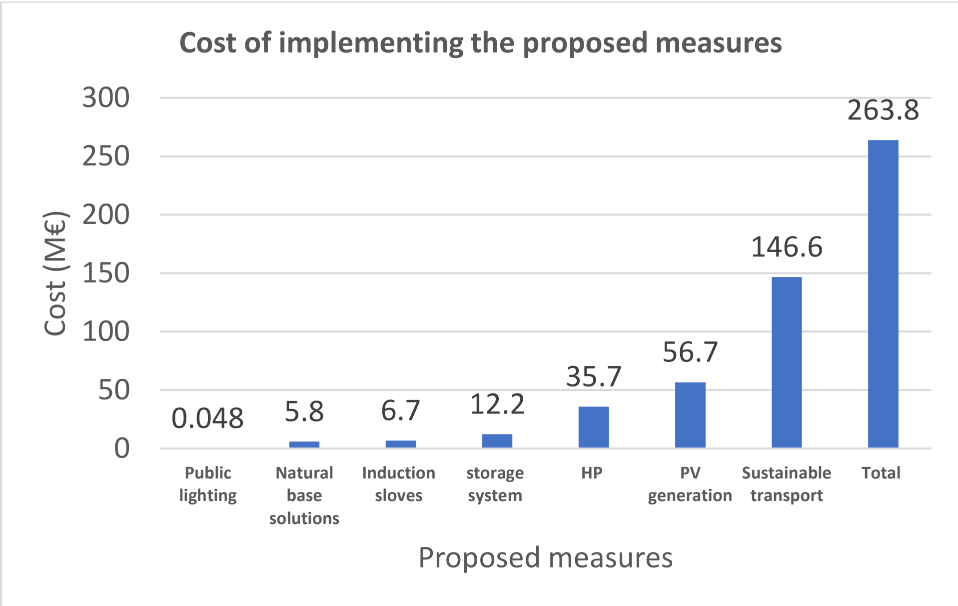


Figure 18. The implementation cost of the proposed measures

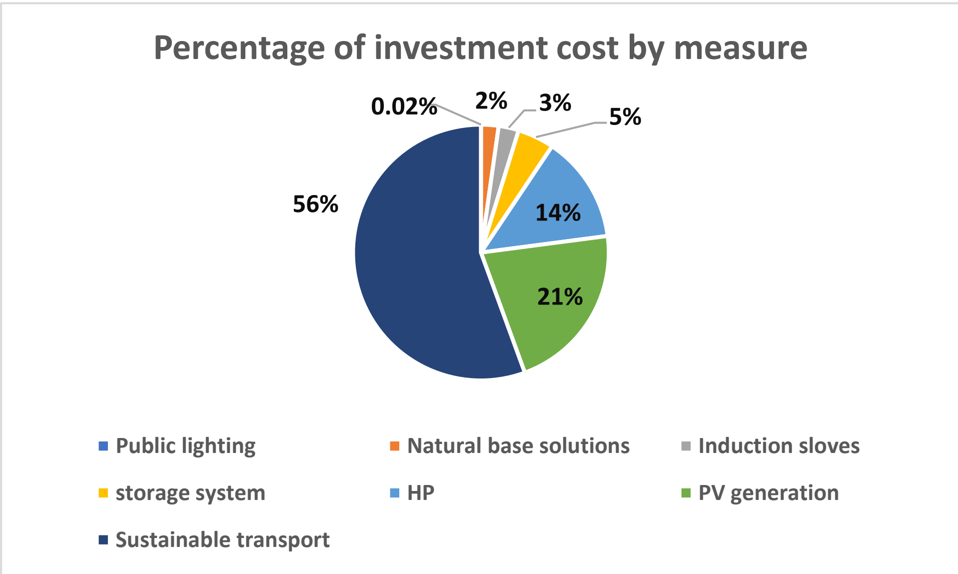


Figure 19 Percentage of investment cost by measure

Figure **20** shows a summary of the tCO_2 estimates related to each of the measures proposed in the previous studies in Benicalap, with an estimated total of 27.678,53 tCO_2, this savings represents 15% of the total emissions considered for Benicalap, it is important to take into account that these measures are not focused on the reduction of emissions caused by the consumption of goods and that it represents 66% of the total emissions calculated for Benicalap.

As shown in **Figure 20,** the mitigation measures are ordered from lowest to highest contribution to emissions reduction, with PV power generation making the most significant contribution, representing 36% of the estimated emissions reductions for the scopes 1 & and 2, and 35% represented by the sustainable transportation measure.

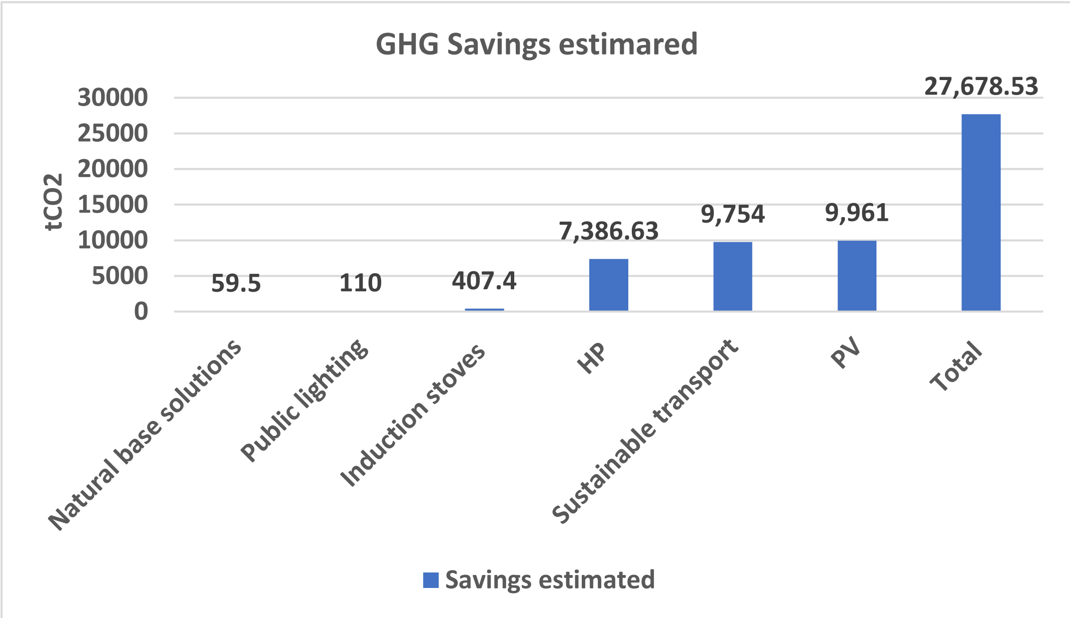


Figure 20 GHG Savings estimated by measure

As mentioned before the cost of the measure proposed by the ***"mapa solar del district dels poblats marítims"*** is illustrated in **Table 9**, the assumed investment costs depend on the installed power as indicated in **Table 9**. Additionally, a yearly operation and maintenance cost has been considered, as well as a yearly inflation rate and discount rate, all the economic considerations in this study are displayed in **Table 11**.

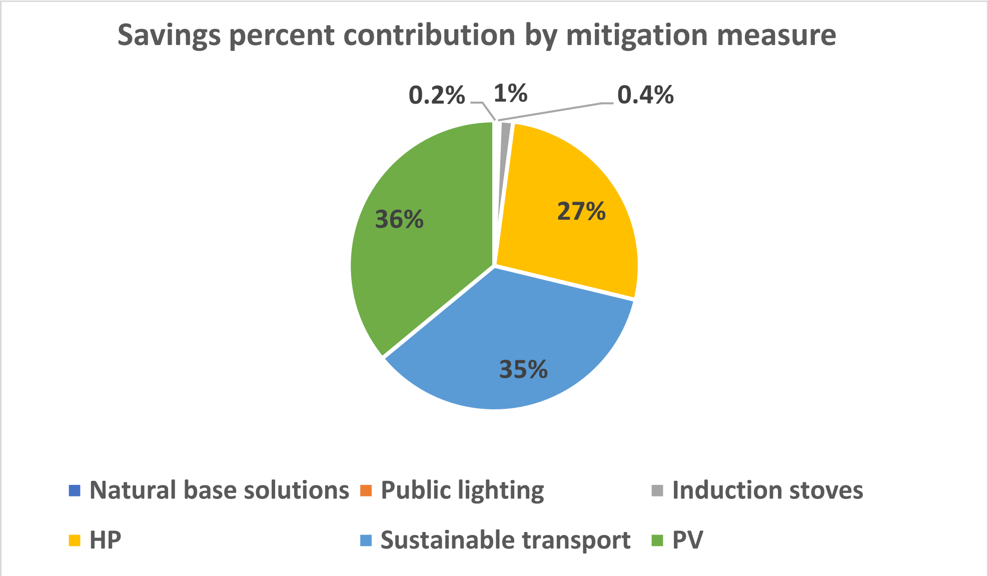


Figure 21 Savings percent contribution by mitigation measure

Table 9 Unit power costs as a function of the installed power, considered for "*mapa solar del district dels poblats marítims*" [30]

Power range, P (kW_p)	Power unit cost (€/kW_p)
P ≤ 10	1.600
10 ≤ P ≤ 20	1.600
20 ≤ P ≤ 50	1.566
50 ≤ P ≤ 500	1.178
P > 500	900

Other specific considerations in the simulation of the PV measures on this comparative are shown in **Table 10,** the considerations exposed in this table are a direct comparative with the previous studies conducted by the Chair of Urban Energy Transition in Benicalap, other specific considerations were taken into account for the simulation carried out in the project "***Mapa solar* IMPACTE"**, these have not been considered for this comparison due to their differences, all the specific considerations for the simulation on this study are shown in **Table 11.**

Some considerations are similar in both studies, as the similitude of the module angle considered and the lifetime, however, it is possible to observe a notorious difference in other considerations, such as the exclusion of the derating factor and ground reflectance in the "***Mapa solar* IMPACTE"** project, this can result as a big variation in the results, however due the inclusion of more variables in the "***Mapa solar* IMPACTE"** project it can be considered as a more complex approach.

Table 10 Different considerations on the simulation of the PV measures

Study	**Simulation program**	**Irradiation base data**	**Considerations on the simulation**	**Value**	**Unit**
Chair of Urban Energy Transition	HOMER	PVGIS	Module tilt angle	15 and 35	◦
			Azimud tilt angle	0	◦
			Temperature coeff. of power	-0,34	%/◦C
			Derating factor	90	%
			Ground reflectance	20	%
			NOCT	43	◦C
			Efficiency at std. test conditions	21,3	%
			Lifetime	25	Years
			O&M	30	€/year
Impacte “mapa solar “	SAM	EnergyPlus	Module tilt angle	30	◦
			Azimud tilt angle	0	◦
			Temperature coeff. of power	-0,4	%/◦C
			Derating factor	-	-
			Ground reflectance	-	-
			NOCT	45	%
			Efficiency at std. test conditions	15	%
			Lifetime	25	Years
			O&M	9,35	€/W_P

Table 11. Inputs on Mapa solar simulation [30]

Parameter	Value	Units
Default module tilt angle	30	◦
Default azimuth tilt angle	0	◦
Latitude	39,4697	◦
Soiling losses	5	%
Albedo coefficient	0,2	-
The efficiency of the module	15	%
The power temperature coefficient of the module	-0,4	%/◦C
NOCT	45	◦C
Performance ratio	0,8	-
Useful area ratio	0,7	-
Area/power ratio	10	m^2
Module degradation rate	2	%/year
Electrical demand per dwelling	3500	kWh/year
Electrical demand in commerces	300	kWh/ m^2year
Electrical demand in offices	137,75	€/kWh
Electric tariff (mean)	0,12,335	€/kWh
Surplus remuneration	0,046,584	€/W_p
O&M costs	9,35	€/Wp
Inflation rate	1,30	%
Discount rate	7	%
CO_2 grid emission factor	0,267,262	kgCO_2/ kWh
CO_2 transport emission factor	0,151	kgCO2/ t·km
CO_2 manufacturing emission factor	932	kgCO2/ kW_p
Module weight/power ratio	0,07047	t/kW_p
The life cycle of the facility	25	years

5.3 Methodology comparison

The figures show the general methodologies followed by the previous studies carried out in Benicalap and Valencia. As mentioned above, the methodologies of [7] and [31] are very similar; their main differences are the elaboration of the emissions inventory and the different mitigation measures taken into account for each of the studies.

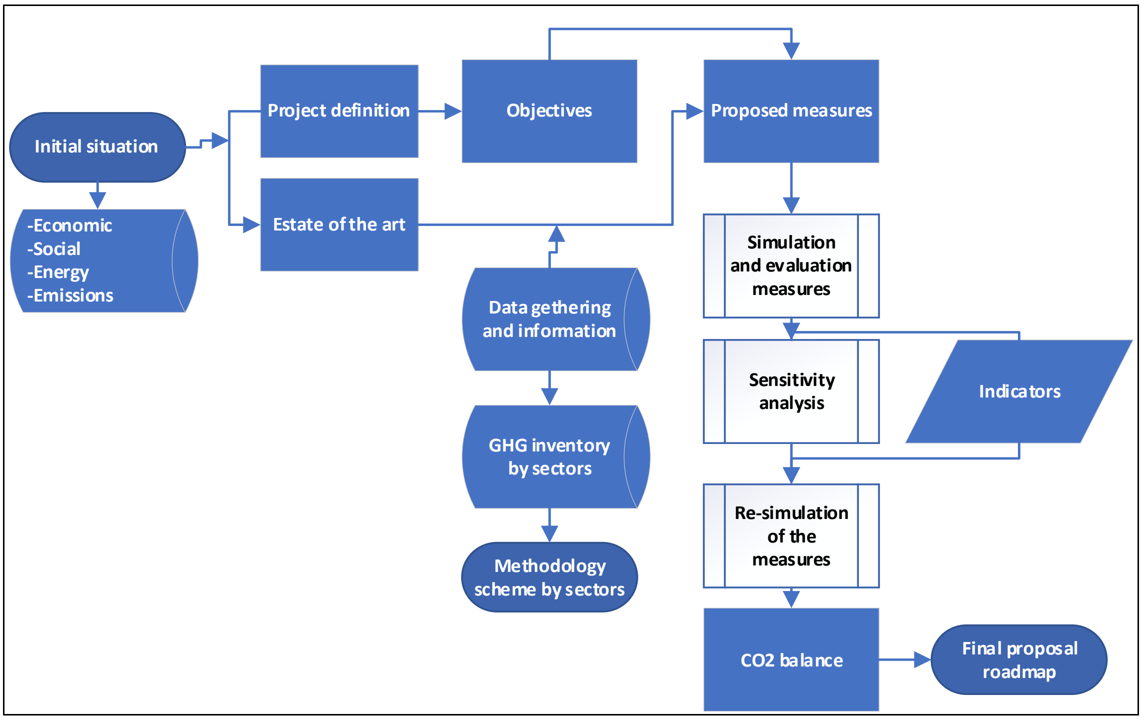


Figure 22 Scheme of general procedure methodology adapted from [7]

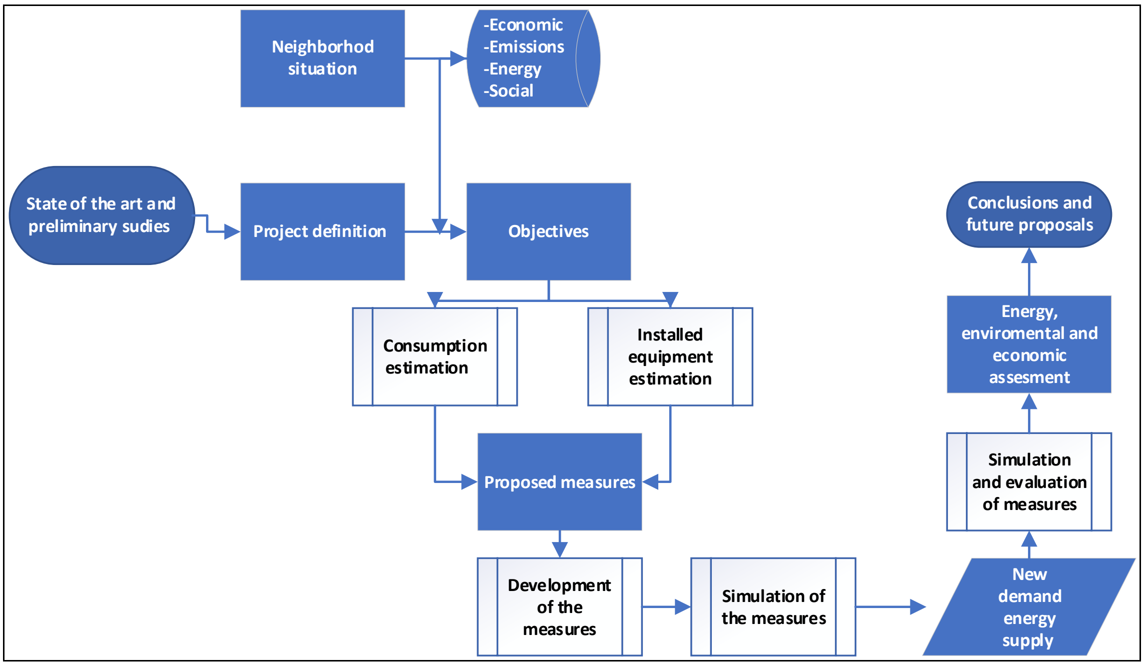


Figure 23 Scheme of general procedure methodology, adapted from [31]

Figure 24 shows the general workflow of the methodology proposed in [30]. The techno-economic model has been developed in the R programming code to estimate the PV electricity generation and to calculate the energy, economic, and environmental impact. The calculations are carried out with an hourly time step. The approach only requires as main input the rooftop coordinates of the building under study [30]; the economic model estimates the costs, cash flows, and energy savings. Finally, the emissions model is used to quantify the environmental impact of the facility [30]

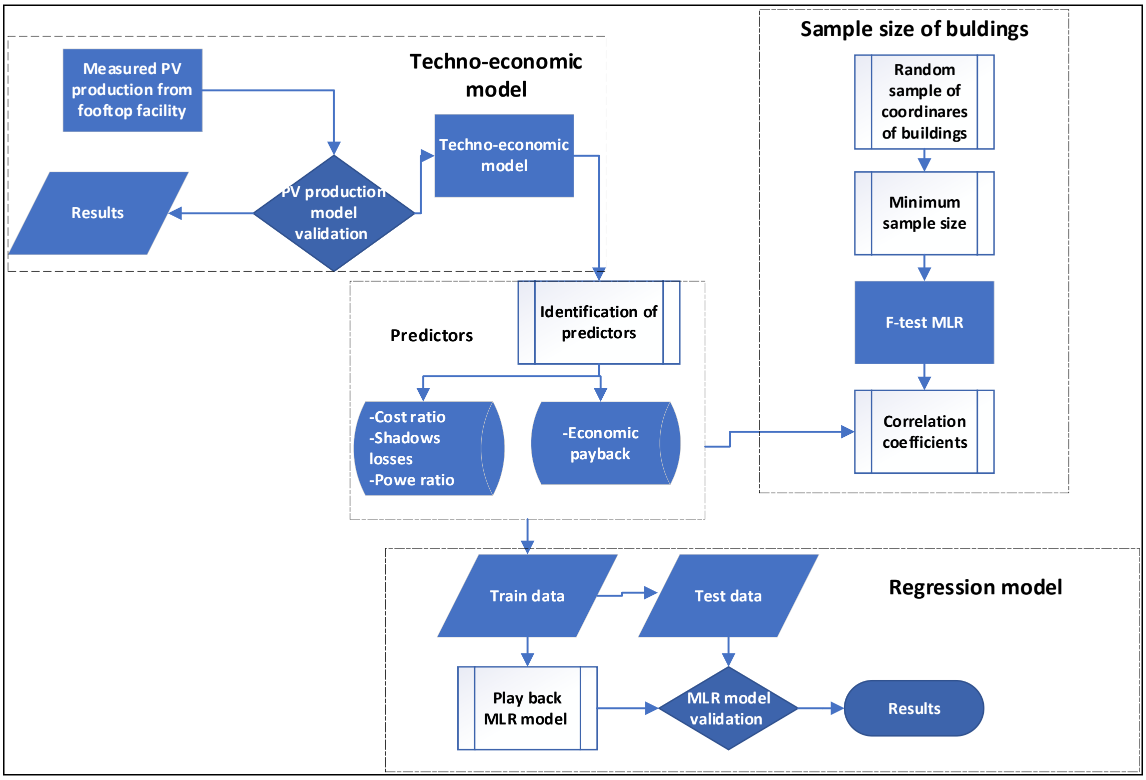


Figure 24. Workflow of the proposal methodology "mapa solar by impacte", adapted from [30]

6 Actions to approach Carbon Neutrality in Benicalap (Scopes 1 and 2).

Decarbonization potential estimation is critical for measuring a specific area's greenhouse gas reduction capacity. However, it is often challenging to estimate decarbonization potential, especially when dealing with large and diverse urban areas. Therefore, it is necessary to study the carbon footprint in the study area before evaluating decarbonization potential [21], in this way the elaboration of a general procedure provides a clear strategic plan for the city's decarbonization efforts, outlining the necessary steps, goals, and timelines. Furthermore, through defined indicators and key performance indicators, a roadmap facilitates effective progress tracking and allows for necessary adjustments.

The following measures were proposed in previous studies carried out in the Benicalap neighborhood [31] & [7]

1. Green Solutions: Increase of 0.058 km2 of existing green areas in the neighborhood.
2. Public Lighting: Progressive replacement of public lighting with LED lights and intelligent control systems.
3. Induction Stoves: Replacement of combustion stoves with induction stoves to cover an annual demand of 8,616 MWh.
4. Heat Pumps: Replacement of inefficient equipment with high-efficiency heat pumps to cover an annual demand of 21,829.75 MWh in the neighborhood.
5. Sustainable Transport: Increase the use of electric vehicles in Benicalap by replacing fossil fuel vehicles, estimating an increase of 3413 cars, 747 motorcycles, and 209 small trucks. Also, replace 50% of public vehicles with hybrid or electric ones and increase the number of public bicycles by 350 for different users.
6. Photovoltaic Production: Production of 90,315 MWh by installing photovoltaic panels in the neighborhood.

Figure 25 shows the evolution of the measures proposed in the previous studies realized in Benicalap, considering the proposed evolution for the years 2022, 2025, and 2030.

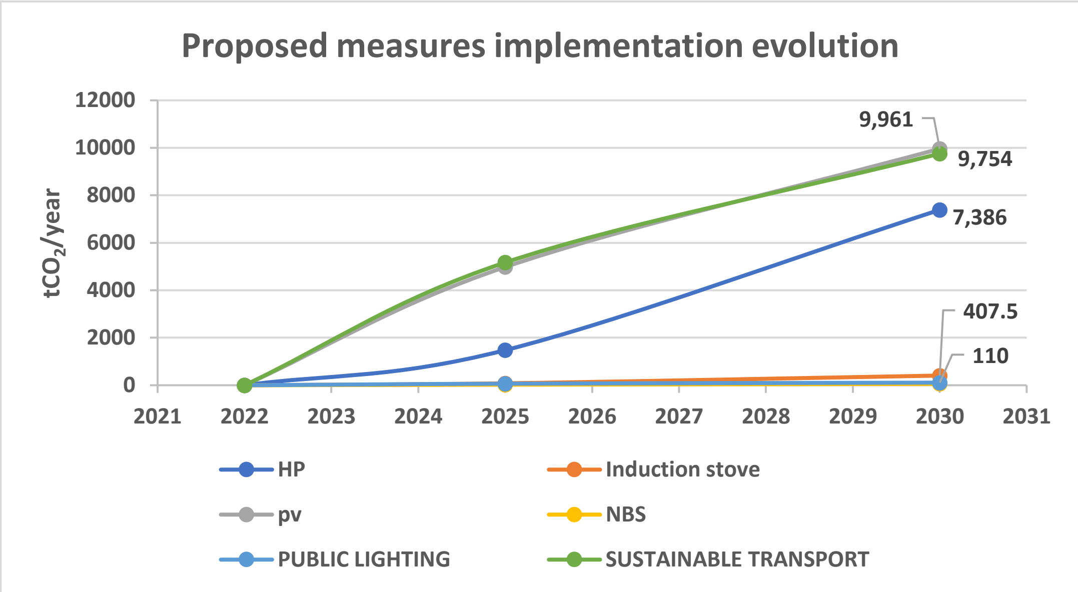


Figure 25 Proposed measures implementation evolution. Adapted from [31]

Table 12 shows the data illustrated in Figure 25, providing a clear view of the data included for 2025 and 2022, this table shows the total tCO2 mitigation estimates for all measures as well as the individual estimates.

Table 12 Proposed measures implementation evolution. Adapted from [31]

	2022 (tCO_2e)	2025 (tCO_2e)	2030 (tCO_2e)
HP		1.477	7.386
INDUCTION STOVE		81	407,5
PV		4.980,5	9.961
NBS	22.37	23,82	59,5
PUBLIC LIGHTING		66,02	110
SUSTAINABLE TRANSPORT		5.170,00	9.754
TOTAL	***22.37***	***11.799,02***	***27.678,02***

7 Results

As mentioned before, this study aims to improve and update the actual data on the measures proposed in the previous ones realized in Benicalap; this section will show the updates of the measures considered in previous studies, as well as the new measures considered to improve the GHG mitigation in Benicalap.

7.1 Emissions Inventory for Scopes 1 and 2.

Previous studies realized in Benicalap [7], considered the emissions related to the passing through vehicles as part of scope 3 in the GHG inventory; section 7.1.1 shows the new considerations and the actualization of the data evaluated in the previous studies.

7.1.1 Transport considerations for Scope 1 & 2

As mentioned before, the previous GHG inventory considered in [7] part of the transport emissions was considered as part of scope 3; these emissions were the ones related to the vehicles denominated as "passing through vehicles.", these emissions are highly significative in the GHG inventory since the contribution of the transport considered in this section represents the 18% of the total emissions considered in Benicalap. The emissions attributed to the passing through vehicles (15.580 tCO_2) represent 47% of the total emissions related to private and commercial transport, as shown in Table 13.

Table 13 shows only one part of the GHG inventory to represent the contribution of private and commercial transport to the total amount of tCO_2 estimated in Benicalap.

Table 13 Previous private and commercial transport emissions in Benicalap, Adapted from [7]

	Scope 1	Scope 2	Scope 3	Total (tCO_2)	%
Private and commercial transport	17.548		15.580	33.128	18,0%
Total emissions in Benicalap	28.691	13.708	141.980	184.380	100%
%	15,6%	7,4%	77,0%		

To improve the previous emission calculation of the passing-through vehicles, this study considered a different approach to estimating the emissions contribution of these vehicles in Benicalap.

The previous study proposed a calculation of these emissions based on a daily average index of the streets with the most traffic in Benicalap, taking into account an average emission factor for the vehicles (**0,00035 tCO_2e/km)** [7], since there was no specific information on the models of the vehicles that traveled these streets, to make a calculation that was closer to reality, this study proposes the consideration of the models of these vehicles, taking into account the data provided by the Emission Inventory System, considering the emissions related to passenger cars, light vehicles, and motorcycles to estimate a new average emission factor for these vehicles.

Estimating a new average emissions factor **(0.000222482 tCO_2/km) is 36% lower than the previous emission factor**.

This new consideration of emissions for transit vehicles considers only emissions from combustion vehicles, to include them within scope 1, as they had previously been considered within scope 3 in the previous emissions inventory.

In the same way, emissions related to electric vehicles were calculated and relocated within scope 2, just as combustion emissions were previously being considered in scope 3.
These changes are shown in Table 13, the new considerations show the diminution considered in the emission factor and the new tCO_2 estimation for the passing-through vehicles, the difference between the new considerations is 991,05 tCO_2 concerning the previous calculations.

Table 14 Passing-trough vehicles emission new consideration for Benicalap

Study	External emissions passing through vehicles (tCO_2)	Factor emission tCO_2e/km
Previous GHG inventory	15.580,17	0,00035
Actual study	14.589,12	0,00022

Another consideration for the recalculation of emissions in the private transport sector, considered in the emissions inventory, is the modification of the emissions factors previously considered in the inventory carried out in the studies preceding the current one, which are based on the reports provided on the emissions calculated for combustion vehicles by the emissions inventory system.

This change was made taking into account their regulation and the type of fuel used. As a comparative Table 14 shows the new estimation of CO_2 emissions generated by passing vehicles in the neighborhood, with comparison with the previous estimated, this estimation takes into account the daily kilometers traveled by passing vehicles in the neighborhood of Benicalap and the emissions factor (0.000222482 tCO2/km) mentioned above, as shown in Table 15.

Table 15 External emissions formula estimation

Term	Formula	Variable
External emissions passing through vehicles (tCO_2)	$D_{km} * E_f * 365\ Days$	$D_{km} = \text{Daily km traveled}$ $E_f = \text{Emission factor}$

Table 16 Previous Emission factors (tCO2/km) [7]

Regulation	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	0,000419	0,000368	0,000225	0,000313	0,00035
Euro 1	0,000403	0,000356	0,000225	0,000313	0,000366
Euro 2	0,000387	0,000344	0,000225	0,000313	0,000322
Euro 3	0,000371	0,000332	0,000225	0,000313	0,000308
Euro 4	0,000355	0,00032	0,000225	0,000313	0,000294
Euro 5	0,000342	0,000313	0,000225	0,000313	0,000285
Euro 6	0,000329	0,000306	0,000225	0,000313	0,000276

Table 17 New emission factors estimation (tCO2/km), adapted from [7] .

Regulation	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	0,000211947	0,00020453	n/data	0,0001825	n/data
Euro 1	0,000212178	0,00019996	n/data	0,00018339	n/data
Euro 2	0,000209547	0,00018899	n/data	0,00018495	n/data
Euro 3	0,000207448	0,00017738	n/data	0,00020762	n/data
Euro 4	0,000208742	0,00017437	n/data	0,00018481	n/data
Euro 5	0,00020254	0,00017579	n/data	0,00018533	0,00019872
Euro 6	0,000203151	0,00017295	n/data	0,00018748	0,00021723

Table 18 Percentage of reduction of factors concerning previous studies, adapted from [7] .

Regulation	Petrol	Diesel oil	Electricity	LPG	CNG
Pre Euro	51%	56%	n/data	58%	n/data
Euro 1	53%	56%	n/data	59%	n/data
Euro 2	54%	55%	n/data	59%	n/data
Euro 3	56%	53%	n/data	66%	n/data
Euro 4	59%	54%	n/data	59%	n/data
Euro 5	59%	56%	n/data	59%	70%
Euro 6	62%	57%	n/data	60%	79%

Obtaining the new emission factors one by one with the data provided by the Spanish Emission Inventory System [32], the percentage reduction concerning the emission factors previously considered is 40% for truism vehicles, Table 19 shows this reduction considered in the GHG inventory of the present study.

Table 19. Private transport vehicles emission, own elaboration.

Study	Private transport vehicles emissions (tCO_2/km)
Previous GHG inventory	17.547,71
Actual study	10.524,40

7.1.2 Benicalap GHG Inventory

Table 20 shows the CO2 emissions considered for the Benicalap neighborhood in this study. Although this study focuses on scopes 1 and 2, also shows the emissions considered in scope 3. This inventory considers the changes in the emissions caused by passing vehicles in the neighborhood, previously considered in scope 3 and now integrated in scopes 1 and 2. Considering the percentage reduction of the emission factors, based on the data of the Spanish emission inventory system [32] the total emissions of Benicalap decreased by 5% compared to the previous proposal, which is equivalent to 8000 tCO_2 in total emissions.

Table 20 shows the percentage of total emissions contribution of each sector subdivided by scope.

Table 20. GHG inventory in Benicalap, Valencia, adapted from [7] and [31].

Sector	Benicalap (tCO_2)				
	S1	S2	S3	Total	%
Private Transport	25.114	7,04		**25.121**	14%
Elect. Residential Sector		7.844		**7.844**	4%
Elect. Industrial Sector		196		**196**	0%
Electricity. Service sector		5.219		**5.219**	3%
Gas	8.975			**8.975**	5%
Solid waste			2.786	**2.786**	2%
Public transportation	1.199	2.169		**3.368**	2%
Municipal buildings and equipment		180		**180**	0%
Public lighting		270		**270**	0%
Good consumption			122.415,13	**122.415,13**	69%
Total	**35.287**	**15.884**	**125.201,11**	**176.372,39**	
Percent	20,0%	9,0%	71,0%		

A transparent GHG inventory helps document the current situation of an entity and helps decision-makers clarify priorities to reduce carbon emissions, the results of an emissions inventory help municipalities create a pathway to proceed, assisting state policies, and creating city action plans to ensure greenhouse gas reductions, which contributes to achieving a low carbon city. [33].

The total contributions considered in this study for scopes 1 and 2 are shown in Figure 27, where you can see the new considerations in scopes 1 and 2 as well as their percentage of contribution in the total tCO_2 considered in the neighborhood of Benicalap.

Table 21 Scopes 1,2 Benicalap

	S1	S2	Total tCO_2
Total	35.287	15.884	51.171
Percent	69%	31%	100%

The changes in the distribution of the scopes in the Benicalap neighborhood considered in the emissions inventory can be observed in Figure 26 in comparison with its previous consideration observed in Figure 15 [31],

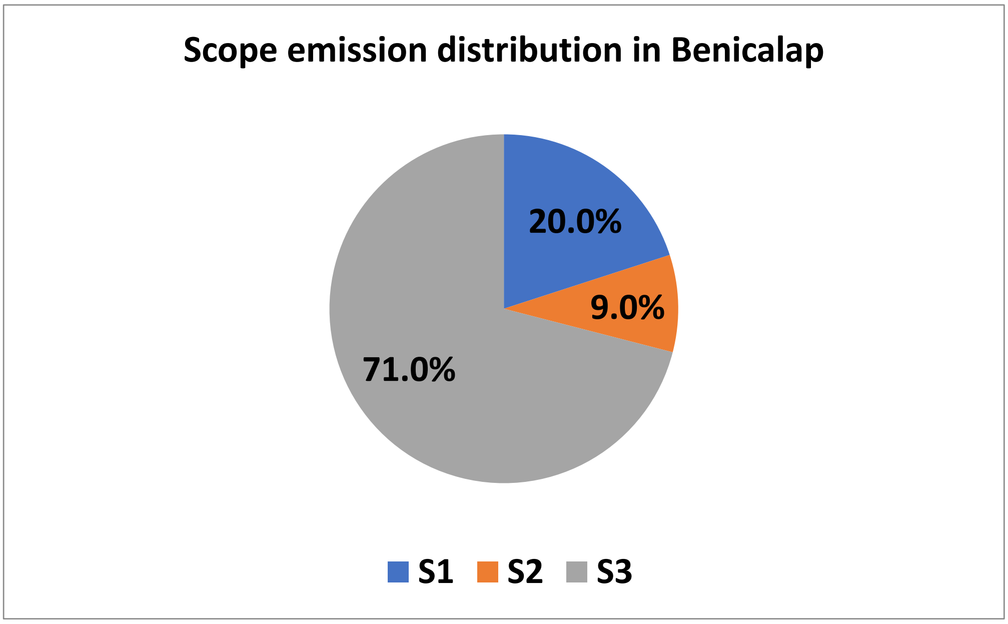


Figure 26 Scope emission distribution in Benicalap

In the same way, the new considerations in the contributions of scopes 1 and 2 can be seen in Figure 27 in comparison with their previous consideration in Figure 16.

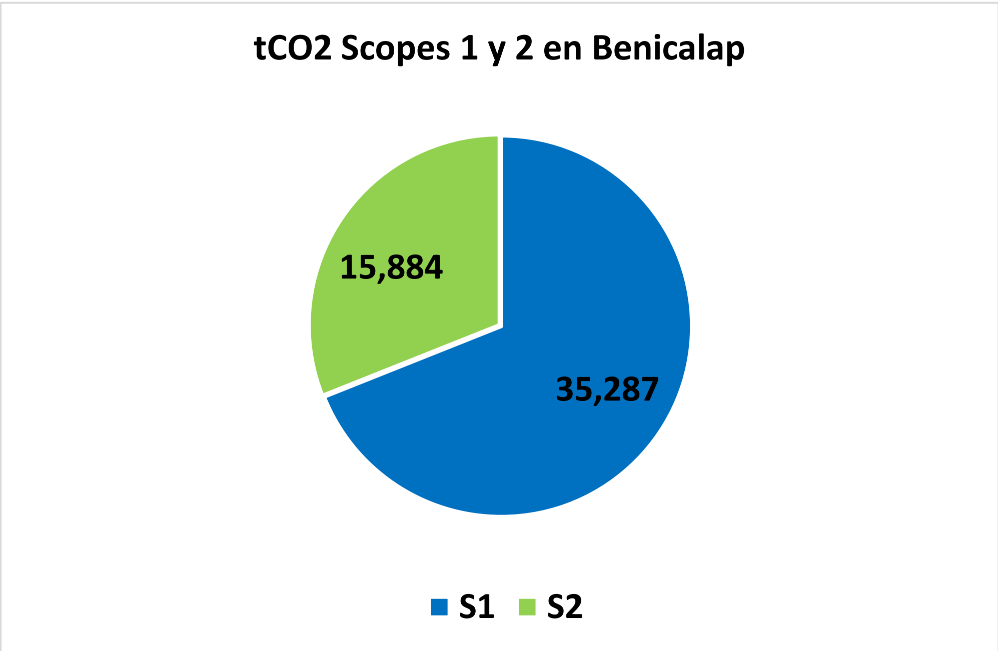


Figure 27 Scopes 1 & 2 new emission distribution in Benicalap

7.2 Mitigation measures to achieve Carbon Neutrality in Benicalap Scopes 1 and 2

As mentioned in section 6, a series of GHG mitigation measures focused on the Benicalap neighborhood have been developed. These measures include the expansion of green spaces, the transition to LED public lighting and intelligent control systems, the adoption of induction stoves and high-efficiency heat pumps to meet energy demands, the promotion of sustainable transport through an increase in the use of electric vehicles, and the harnessing of solar energy through photovoltaic panels. These initiatives have laid a foundation for further developing new measures to enhance the environmental resilience and sustainability of the area even more.

Following the path outlined by these measures, two measures are proposed to complement and expand the decarbonization efforts in Benicalap. The first focuses on the reduction of parking spaces, a policy aligned with global trends to mitigate traffic congestion and pollution through the encouragement of public transport and carpooling. This approach aims not only to alleviate traffic-related issues but also serves as a catalyst for increasing the use of public transportation, thus contributing to a reduction in carbon emissions.

The second measure targets the construction sector, emphasizing the significant potential for energy efficiency improvements through building renovation. Recognizing that existing buildings are a major source of energy loss and carbon emissions, this initiative advocates for the adoption of modern insulation techniques, window replacements, and other renovations to improve thermal efficiency. Such renovations are crucial for reducing CO_2 emissions and increasing the integration of renewable energy sources, marking a critical step towards achieving a more sustainable and energy-efficient urban environment.

The total CO_2 reduction estimated by measure and the set of them is detailed in Section 7.3, showing the total of each result ach of GHG savings contributions per measure, as well as the evolution of each of these measures.

7.2.1 Reduction of parking spaces in Benicalap.

A growing number of governments have begun to implement policies that seek to reduce the use of private cars by encouraging the use of public transport and carpooling, having as the main motivation the decongestion of traffic associated with polluting emissions. [34]

Vehicle restrictions are considered an immediate and effective measure to mitigate traffic demand and have been adopted by many high-growth cities around the world, as well as helping to control traffic and traffic pollution, such policies affect various modes of transportation by encouraging and promoting the use of public transportation, increased public transportation ridership in different cities by 5 % to 25%. [35]. The fast increase in the number of trips made by car causes complications in the air pollution problem and energy consumption. Simultaneously, it participates in the rise of social problems such as traffic congestion and a decline in quality of life. Consequently, national and international transportation and territorial planning policies aim to shift travel demand from private cars to public transit systems. [36]

Implementing regulatory measures in the field of public parking plays a crucial role in reducing congestion in urban areas. These measures promote a higher turnover of parked vehicles, improving road safety and the area's environmental quality. However, it is important to keep in mind that the creation of regulated parking zones can lead to a relocation of parking pressure to nearby free parking streets. To address this issue more effectively, it is essential to promote comprehensive parking management at the metropolitan level that considers uniform regulatory and management aspects and common parking pricing criteria at urban destinations. This strategy becomes a key instrument to promote the use of public transport. [37]

7.2.1.1 Actual situation of Benicalap parking spaces

In line with the proposals of the basic mobility plan in the metropolitan area of Valencia [37], one of the proposals elaborated in this work is the reduction of parking spaces in the neighborhood of Benicalap, to promote the use of public transport and non-polluting transport such as bicycles.

There are currently 8.142 total public parking spaces in the Benicalap neighborhood, taking into account the different parking space classifications, Table 22 shows the distribution of parking spaces taking into account this classification.

Table 22 Unregulated parking spaces by district 2021

Unregulated parking spaces by district 2021					
Parallel to the sidewalk (*Cordón*)	Perpendicular to the sidewalk (*Batería*)	Loading and unloading	Motorcycles	functional diversity	Total
4.491	3.651	85	260	130	8.142

Table 23 shows the total surface area for parking spaces in m^2 in Benicalap, taking into account the spaces of private dwellings.

Table 23. The surface area of parking lots in Benicalap [38]

The total surface area of parking lots and surface area per property and tourism.		
Total surface area of parking lots (m^2)	Total parking area per dwelling (m^2)	Total parking area per tourist (m^2)
297.467	13,6	14,71

It is important to mention that although in Valencia there is a regulation of paid parking spaces, the neighborhood of Benicalap does not have any of these regulated zones, Figure 28 and Table 24 show the distribution by district of the regulated paid parking spaces around Valencia.

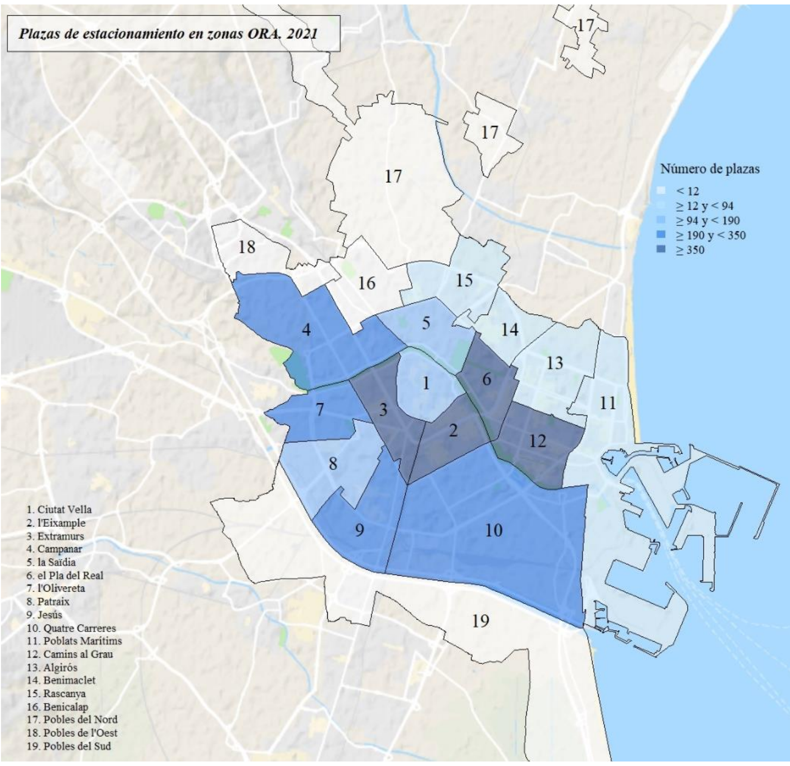


Figure 28. Regulated parking spaces in Valencia.

Table 24. Regulated parking spaces by district

Regulated parking spaces by district 2021		
16. Benicalap	**Zona ORA Azul**	**Zona ORA Naranja**
	0	0

Parking management in Valencia has been carried out at the municipal level by analyzing regulatory aspects as well as destination parking pricing criteria, which is a key instrument to encourage the use of public transport, these criteria are established according to the size of the municipality and the availability of public transport. [37]

These paid parking spaces have been used as an incentive for the use of public transport, aiming at better mobility management and the reduction of the inefficient use of private vehicles, however, smaller municipalities have a higher dependence on private motorized vehicles. [39]

An inflated supply of parking spaces can create more congestion, degrade the urban environment, increase development costs, and reduce the availability of affordable housing [40]

To consider the total number of parking spaces, it is necessary to estimate how many private car parking spaces exist in the neighborhood, this consideration was made based on the official measurements of parking spaces in Valencia. [38] The dimensions of the parking spaces are shown in Table 25.

Table 25 Parking space dimensions in Benicalap

Parking space dimensions					
	Battery Parking	**Curb Parking**	**Moto bicycles**	**Functional diversity**	**Unit**
Width	2.40	2.60	1.5	3	m
Long	4,8	5	2,4	3,6	m
Area	11,52	13	3,6	10,8	m^2

These dimensions were considered to calculate the total number of private parking spaces in the neighborhood with a total of 194.684,5 m^2 remaining in the neighborhood after considering the m^2 of public spaces, considering that 94% of the private parking spaces are for battery spaces, 3% for motorcycles, 2% for functional diversity, and 1% for others. Approximations of parking spaces were made as shown in

Table 26 Private parking approximation

Private parking spaces approximation					
	Total	**Battery Parking 95%.**	**Moto bicycles 3 %**	**Functional diversity 2%**	**Others 1%**
m^2	194.684,5	183.003,41	5.840,53	3.893,69	1.946,84
Parking spots	-	15.885,71	1.622,37	360,53	n/a

Together with the public parking spaces, a total of 24,028 parking spaces for tourism vehicles are considered in the neighborhood.

7.2.1.2 Parking reduction measured description for Benicalap.

This study proposes the reduction of parking spaces in Benicalap, as a measure to mitigate emissions related to the use of combustion vehicles in the neighborhood, to reduce the use of such vehicles by eliminating some parking spaces and promoting the increased use of public transport. Table 27 shows the 10.524 tCO_2 emited by the private transport vehicles in Benicalap, that is the tCO_2 target to be reduced.

Table 27 Table Combustion vehicles emissions in Benicalap

Combustion vehicle emissions in Benicalap		
Private transport vehicles emissions in Benicalap	10.524,40	tCO_2

Considering that these emissions are generated only by cars in the Benicalap neighborhood, an estimate of tCO_2/year per car can be made, taking into account the number of passenger cars in Benicalap 20,218 and the emissions considered to be related to these vehicles emitted within the neighborhood 10,524.40 tCO2, which would mean an approximate of 2,385 tCO_2/ year per Vehicle.

To make the closest approximation of what the reduction of these parking spaces represents in annual tCO2 savings, the contribution of emissions that a person makes when using public transport is considered, in this case, lines 1 and 2 of the metro that pass through the Benicalap neighborhood, considering the annual user demand on these lines in Valencia versus the District/neighborhood ratio [7], previously considered in the previous studies carried out for the Benicalap neighborhood.

Table 28. Annual demand users Districts/ Neighborhood (Persons)

Nivel	Annual users L2	Annual users L1	Annual users L4
Valencia	8.457.006	8.451.798	4.585.940
Benicalap	444.222	443.949	240.886

This estimation of user demand in Benicalap in conjunction with the 2168,60 tCO_2 annual estimates for emissions [7] caused by the metro and tramp lines inside of the neighborhood, serves to estimate 0.0019 tCO_2 annual per user in Benicalap.

Taking into account that one car carries up to 4 potential metro users, it is estimated that one less car in circulation in the neighborhood represents 2,377 tCO_2.year/car.

To establish a relationship with parking spaces, some studies carried out in cities such as Barcelona and Berlin [41], mention that regulated public parking spaces and those provided maintain an average occupancy rate of 85%, considering that they have higher and lower occupancy rates depending on the time and day, as well as establishing that a parking space can be occupied daily by between 2-5 automobiles.

This study considers a ratio of 0.2 vehicles per parking spot, considering the occupancy of the spaces mentioned above for [41], so a reduced parking spot could be considered as 0.4753 tCO2.year.

Table 29 and Figure 29 illustrate the different scenarios, considering different percentages of reduction in parking spaces in the neighborhood, showing their scope about the vehicles and the emissions.

Table 29 Parking spot reduction

Parking spot reduction								
Percent of reduced parking spaces	2%	5%	10%	20%	30%	40%	50%	100%
Parking spots	163	407	814	1.628	2.443	3.257	4.071	8.142
Vehicles	33	81	163	326	489	651	814	1.628
tCO_2	77	194	387	774	1.161	1.548	1.935	3.870

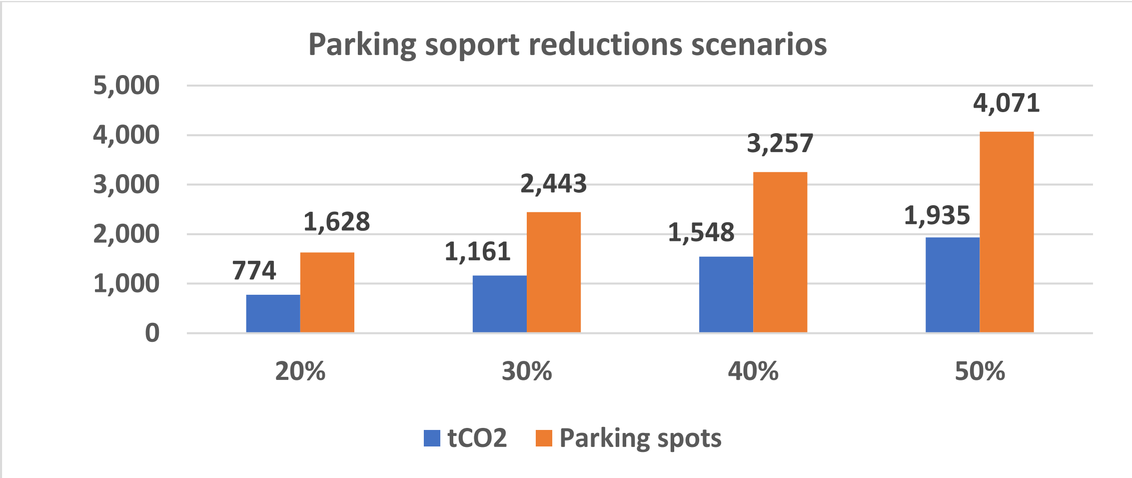
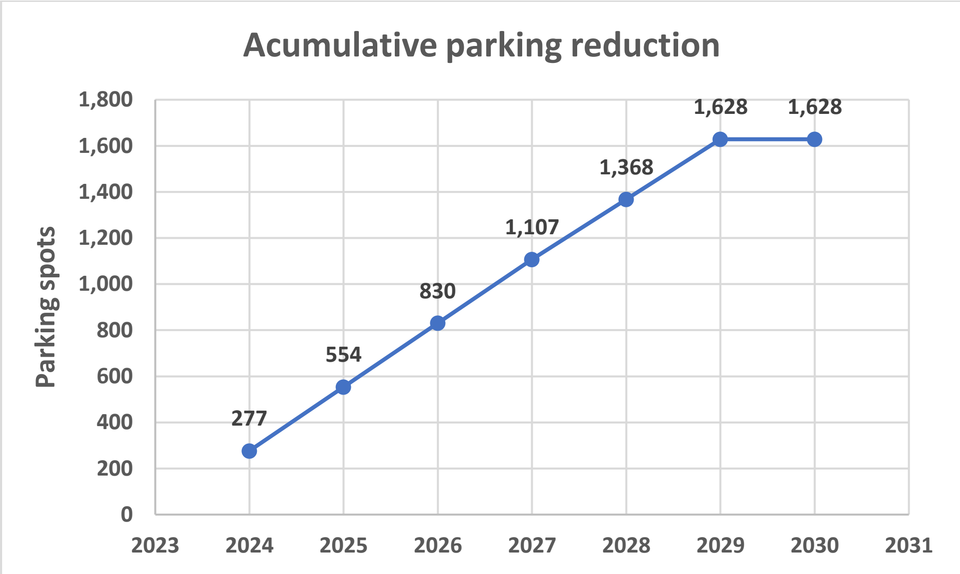


Figure 29 Parking space reductions

As shown in Figure 29 analyzing the different possible scenarios when considering a reduction of parking spaces, the one selected for this study is the 20% reduction of public parking spaces in Benicalap. This would result in a reduction of 1,628 parking spaces from 2024 to 2030, generating a cumulative emission reduction of 2,211.7 tCO_2 by 2030. As can be seen in Figure 32. On other hand
Figure 30 shows the reduction plan for the years 2024 to 2023.

Figure 30 Accumulative parking reduction



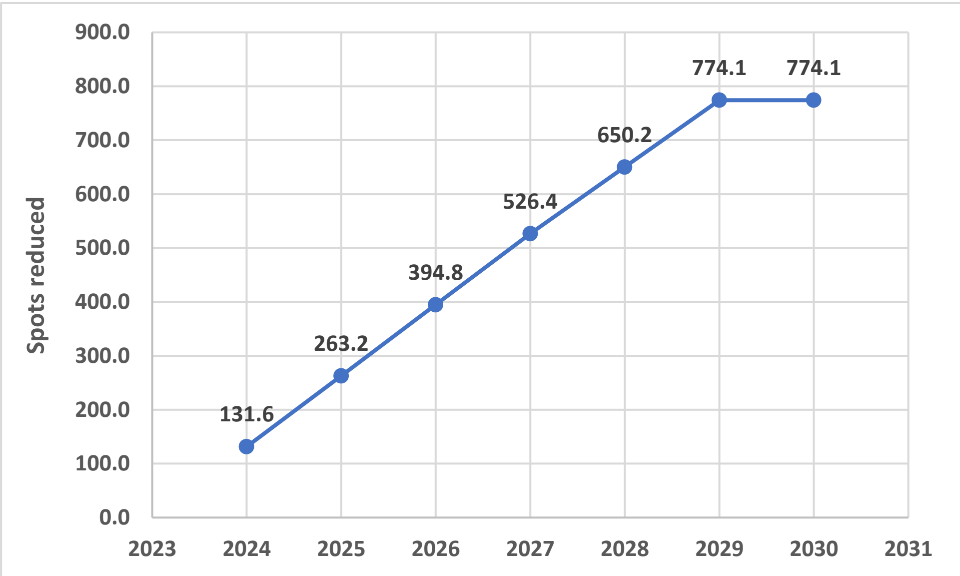


Figure 31 tCO_2 by year for parking reduction measure

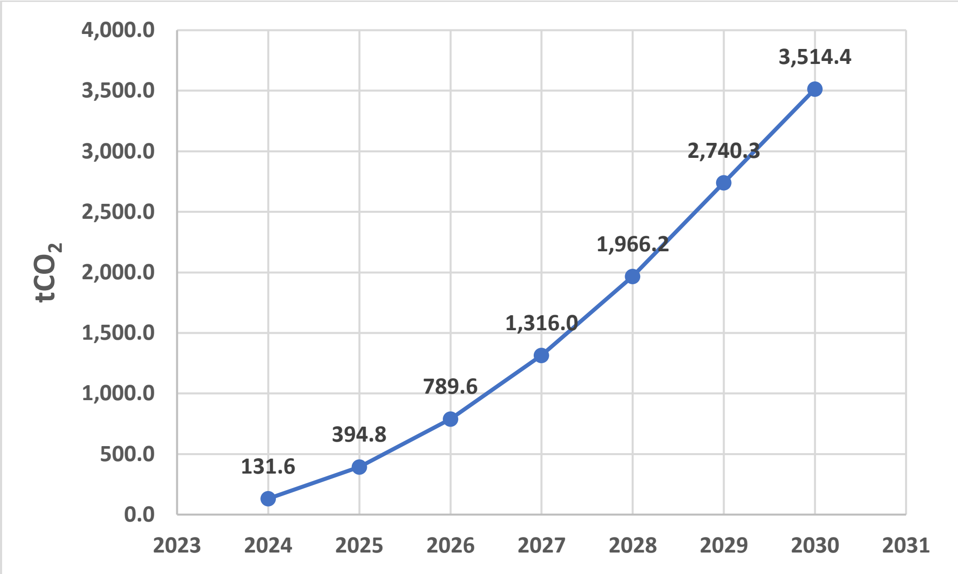


Figure 32 tCO2 accumulative by parking spot reduction

7.2.1.3 Alternatives to justify the elimination of parking spaces

To reduce these public parking spaces, it was necessary to analyze the public streets in the neighborhood and consider the squares that could be replaced, justifying their replacement with something that would be acceptable to the stakeholders, in this sense, the replacement of these parking spaces with green areas was proposed. Some studies suggested that urban green space as an essential part of the urban ecosystem, can optimize the urban landscape pattern to reduce GHG emissions concentration. [42]

Figure 33 shows the Benicalap district subdivided into sections to analyze its streets and its potential to reduce public parking spaces, in this sense between sections 32 and 29, on Av. Levante Ud. There are parking spaces in the middle of the avenue, which have more side parking, and that makes it an attractive area to implement green areas and reuse such space. The vegetation in green spaces could adsorb and stagnate the pollutant emissions through leaf surface, reducing concentration and playing a role in environment purification [42]

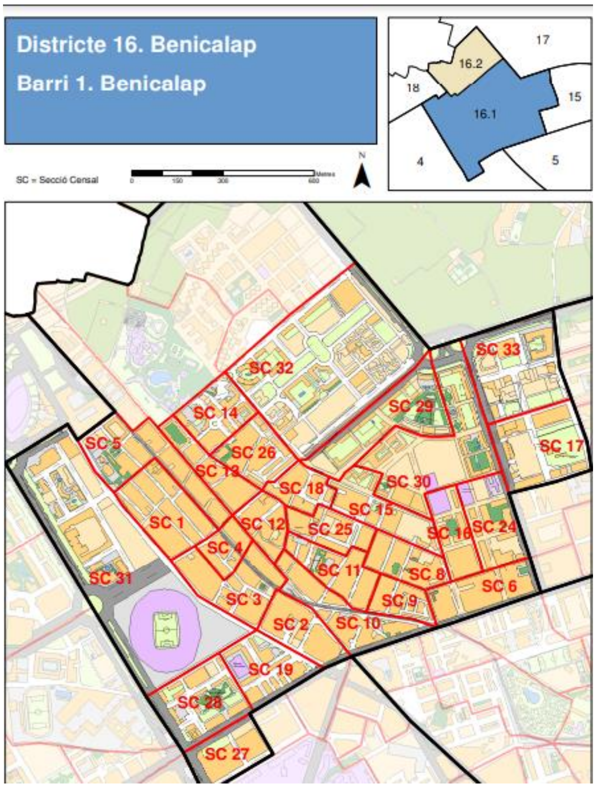


Figure 33 Benicalap district distribution

Figure 34 shows the delimitation of the Benicalap neighborhood area, together with f Figure 35 which shows Levante Avenue where the replacement of parking spaces with green areas is proposed, these areas are illustrated in Figure 36.

Figure 34. Benicalap delimited area

Figure 35. Av. Levante Ud. Parking spaces

Figure 36. Green areas proposal

These proposals for replacing parking spaces with green areas represented in Figure 36, are subdivided into two zones, as can be seen in the image, zone 1 of 4,77.93 m2 and zone 2 of 3,448.12 m2, which is equivalent in total to 0.82 ha.

Considering the CO2 absorption factor of green areas taken into account in previous studies is 1,58 tCO2 eq/ha, the absorption estimates of this new green area considered in the Benicalap is 1,29 tCO2 eq/ha. annually, which can be added to the accumulative 59,94 tCO2 emissions mitigation proposed with natural-based solutions in the previous studies carried out in the neighborhood [7]

In Berlin, the maintenance and administration of each parking space reaches an annual cost of 220 euros [43] . Additionally, the underutilization of underground parking, evidenced by occupancy rates of 50% during peak hours and 34% at 6:00 PM in places like Stuttgart, suggests the possibility of reevaluating the distribution of surface parking spaces. There is a need to free up sidewalks and repurpose parking spaces for urban services. A study realized in Austria indicates that the availability of parking spaces influences transportation modes, with 77% commuting by car when parking is available, compared to only 31% when it is not. An innovative approach to addressing this issue is observed in Amsterdam, where 1,100 surface parking spaces were eliminated in 2019. These spaces were diversified for use in children's areas (42%), new housing (17%), bicycle parking (11%), extensions of docks and bridges (8%), new green spaces (6%), and pedestrian crossings (4%). This comprehensive approach aims to optimize the use of urban space, promote sustainable mobility, and enhance the quality of life in urban environments. [43]

One of the measures currently being used in Europe to manage parking spaces in Europe is the PUSH AND PULL initiative, this measure aims to improve urban mobility in European cities by employing parking space management combined with mobility management measures. By introducing paid parking, increasing parking fees, reducing or restraining parking supply, or implementing comparable measures, car drivers will be “pushed” to use more sustainable transport. [44]

Some results of this initiative of reduction of parking spaces in the city of Munich have been a 14% decrease in the use of private vehicles, a 40% reduction in long-term parking (vehicles that owners do not move), a 75% increase in the use of bicycles, and a 61% increase in short-distance walking,   61% increase in walking for short distances, as well as this study indicates that parking management does not have a negative influence on local businesses by reducing parking spaces or establishing charging systems and fees, as has been demonstrated in Barcelona and Amsterdam, in their "Amsterdam Mobility found" program. [45]

7.2.2 Refurbishment of houses in Benicalap for energy savings measure

The energy performance of the building sector has improved significantly over the last decades. However, building renovation has great potential to take advantage of energy efficiency benefits. A study conducted by the European Union shows that the environmental impact of new buildings is negligible compared to that of existing buildings in terms of heating and insulation energy losses. [46]

Objectives such as reducing CO2 emissions in housing and increasing renewable energy quotas are impossible without policies that encourage a process of renovation in existing buildings, most of which do not have updated technologies. [46]

A study conducted for different types of buildings in the European Union analyzing energy efficiency concludes that energy efficiency can be substantially improved by applying higher levels of thermal insulation in building envelope components; among the improvement options identified as the most influential is: the replacement of windows, additional facade insulation, jointing and framing to reduce ventilation losses [47]

7.2.2.1 Current situation of the buildings in the neighborhood of Benicalap

With a total final energy consumption of 80,786 ktep (2013), consumption associated with buildings accounted for nearly 31% in Spain and, specifically, the residential sector accounted for 19% of total consumption, in line with OMS data worldwide, which puts consumption associated with buildings at 18%. Between 50% and 70% of this amount is used for heating and cooling. On the other hand, approximately 54% of the housing units in Spain (14 million) were built in Spain more than 35 years ago, before were built in Spain more than 35 years ago, before the entry into force of the first mandatory energy standard, the first mandatory energy standard came into force. [48]

In this sense, most of the houses built in the Benicalap neighborhood were constructed between the 60s and 80s. Table 30 shows the residential buildings according to their year of construction.

It can be established that dwellings built before 1980 in Spain, in general, have a worse energy performance in the sense that the envelope does not have the normative limitations that were mandatory since 1980 with the approval of the Basic Building Standard on Thermal Conditions (NBE-CT-79). [48]

Table 30 Benicalap residential buildings by year of construction. [27]

1801-1900	1901-20	1921-40	1941-60	1961-80	1981-2000	2001-10	2011-20	Total
32	60	124	1.329	10.864	4.559	3.992	901	21.861

The total number of houses built in the neighborhood before 1980 corresponds to 12409, which do not comply with the standard thermal conditions of construction, these houses correspond to 57% of the total number of houses in the neighborhood, which would have a great potential to be rehabilitated to improve their energy consumption during winter and summer.

7.2.2.2 Neighborhood energy residential consumption.

Since the main objective of the proposed measure for the rehabilitation of buildings is to reduce energy consumption in the residential sector of the neighborhood, it is necessary to analyze the current situation of this sector, and how this measure would affect its behavior.

This study is based on previous analyses carried out in the city of Valencia and specifically for the neighborhood of Benicalap, Table 31 shows the previous analysis of energy consumption in the city of Valencia, from which the analysis at the neighborhood level is shown in Table 32 is extrapolated.

Table 31 Total consumption in MWh in Valencia city, 2019. [28]

Electricity consumption	2,548,179	MWh
Gas Natural consumption	939,008	MWh
Butane Packaged consumption	132,506	MWh
Propane packaged consumption	20,910	MWh

Table 32 Total annual electric consumption (MWh) in Benicalap residential sector. Adapted from [31]

Source	Electricity consumption	Unit	Reference
Datadis	45,604	MWh	[49]
City Council data	45,561	MWh	[28]

Table 32 shows two total consumptions calculated under different methods, the data considered for this study are those adapted from Datadis, which leaves a consideration of 45,604 MWh of annual consumption in the residential sector, which represents 57% of all energy sources consumed in the neighborhood. Table 33 shows residential consumption by energy source in Benicalap.

Table 33 Consumption of the residential sector on Benicalap by energy source, 2021 Adapted from [28] and [31]

Energy Source	Consumption (MWh)	Percentage
Oil products	7,181	9%
Natural gas	25,408	32%
Renewable resources	796	1%
Coal	536	0,7%
Electricity	45,604	57%
Total	79,525	100%

Based on this total consumption, it is of vital importance to know which are the consumptions for heating and cooling the buildings to be rehabilitated, Table 34 shows the consumptions by uses in the residential sector of the neighborhood.

As can be seen in the consumption for heating and cooling, the residential sector represents 37% and 6% respectively of the total residential consumption in Benicalap, so the rehabilitation of buildings would have a direct influence in reducing the amount of energy needed to heat and cool the buildings. Being these two uses the ones that demand more energy in the residential sector. Table 34 and Figure 37 represent these mentioned data.

Table 34 Residential consumption by use in Benicalap. Adapted from [28] and [31]

Residential consumption by use in Benicalap		
Use	**MWh**	**Percent**
Heating	29.576	37%
DHW	17.586	22%
Cooling	4.623	6%
Cooking	5.473	7%
Lighting	4.073	5%
Household appliances	18.291	23%
Total	**79.622**	**100%**

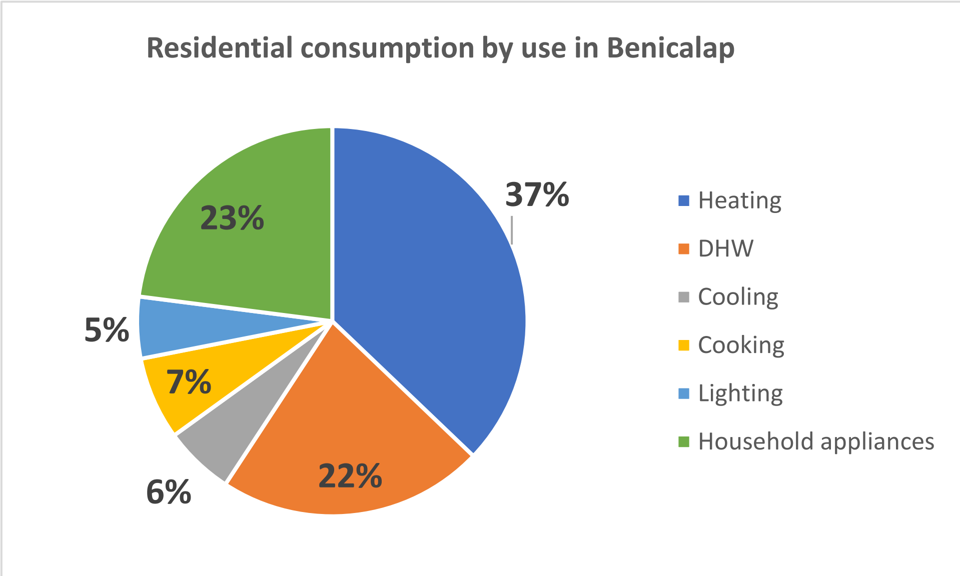


Figure 37 Residential consumption by use in Benicalap

7.2.2.3 Energy saving estimation.

According to studies carried out in Valencia, where prediction models determine that advanced rehabilitation of buildings with an energy deficiency and energy losses can obtain a reduction between 50-80% of energy demand [50], this study contemplates a 40% reduction in energy consumption in the residential sector. These changes contemplated in rehabilitating the buildings are based on the typology of the buildings in the Valencia community made by TABULA. [51] & [52].

Based on the analysis of residential consumption of the neighborhood presented in section 7.2.2.2, different scenarios were estimated and studied, represented in Figure 38, showing the tCO_2 and MWh savings considered in different building retrofit scenarios, which are shown as a percentage of the total buildings in the neighborhood.

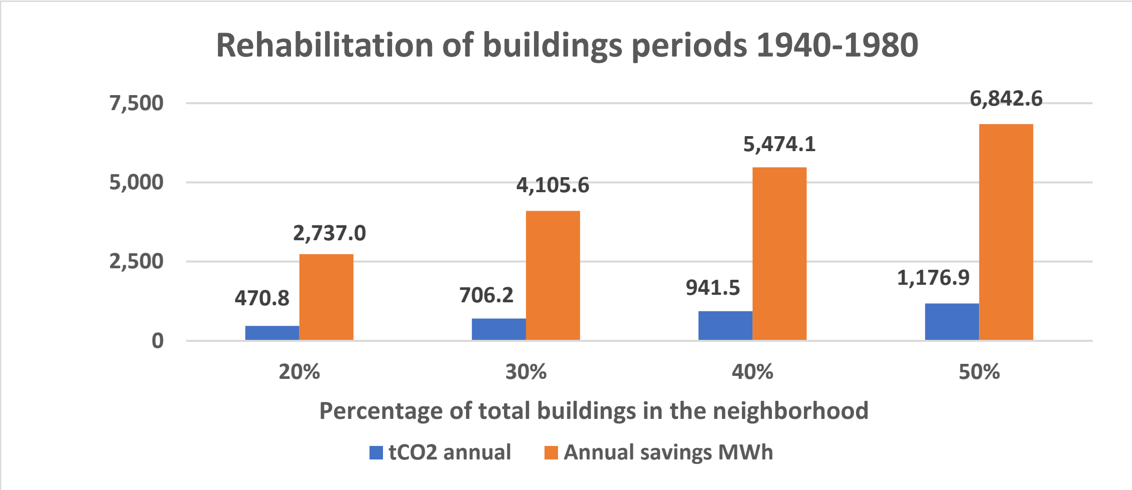


Figure 38 Rehabilitation scenario of buildings periods 1940-1980

After analyzing the scenarios in Figure 39 the present study contemplates the rehabilitation of 30% of the houses in the neighborhood, Figure 39 shows the rehabilitation plan for the buildings covered by this measure, with the action plan for the years 2024-2030.

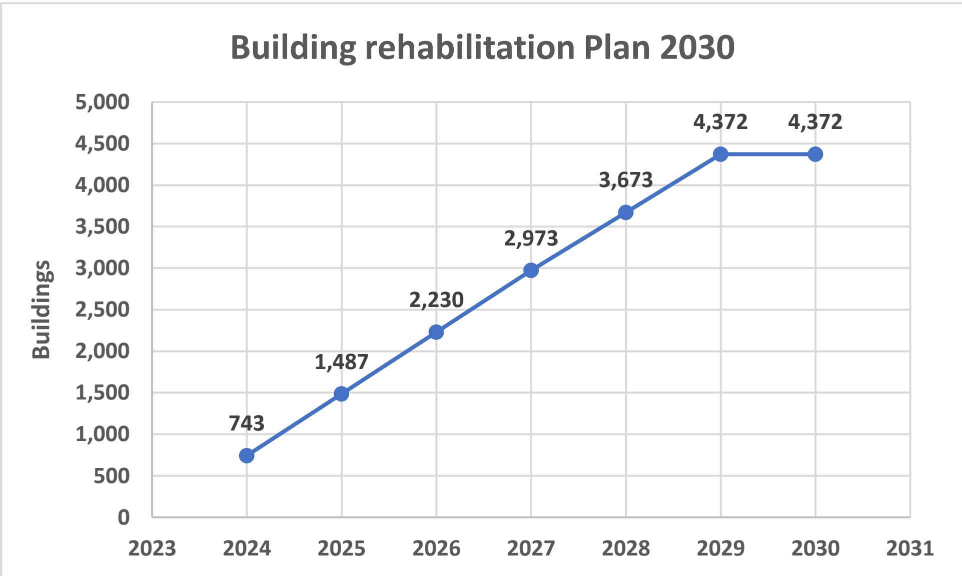


Figure 39 Building rehabilitation plan 2030

Figure 40 shows the tCO_2 contemplated per year when retrofitting the buildings in the neighborhood, and Figure 41 shows the cumulative over the years when implementing this measure. This represents a rehabilitation of 4.372 buildings and a cumulative 2.137,3 tCO2 by 2030, which is linked to the reduction of electricity consumption for heating and cooling buildings.

Figure 40 tCO_2 by year

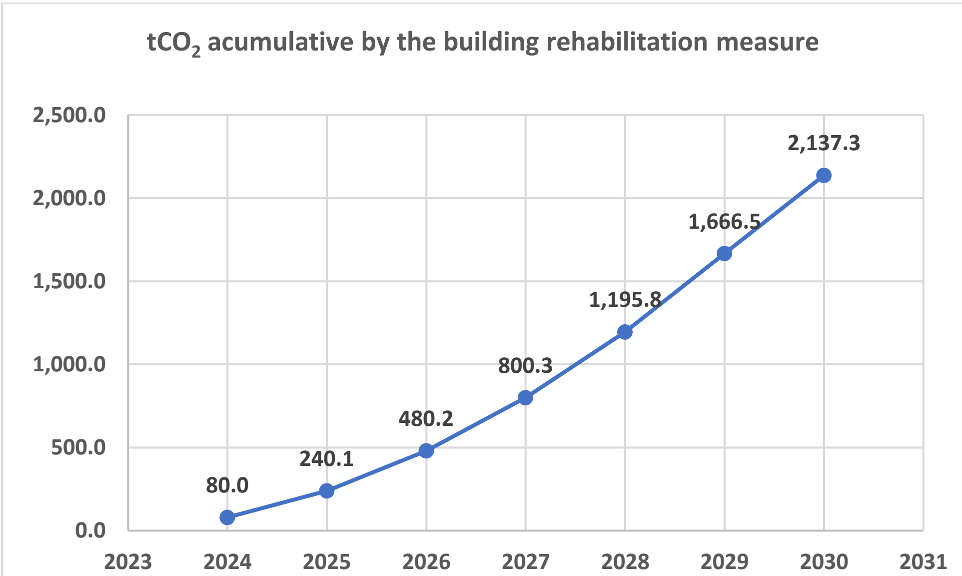


Figure 41 tCO_2 accumulative by the building rehabilitation measure

7.3 Comparison of the previous studies in Benicalap

The mitigation measures proposed in this study are a complement to other studies conducted in the Benicalap neighborhood; these studies contemplate different measures to mitigate CO2 emissions in the neighborhood, these measures as can be seen in Table 35 including the implementation of HP and induction stoves to reduce the use of fossil fuels, photovoltaic panels to reduce electricity consumption, NBS to increase green areas, the change of public lights for more efficient models, and sustainable transport to reduce the use of combustion vehicles.

As mentioned above, this study proposes two complementary mitigation measures to be implemented in the neighborhood. These two proposals are the elimination of parking spaces and the rehabilitation of buildings constructed in the neighborhood between 1940 and 1980 to decrease the tCO2 emitted in the neighborhood.

Table 35 shows the estimates considered from 2022 onwards, this is because the first considerations were taken into account with these dates, however, they all have 2030 as their implementation deadline. Table 35 shows an estimated total tCO2 of all the mitigation measures proposed for the neighborhood, considering a total figure of 33.329,70

Table 35 Proposed measures implementation evolution.

Measure	2022 (tCO_2e)	2025 (tCO_2e)	2030 (tCO_2e)
HP		1.477,00	7.386,00
INDUCTION STOVE		81,00	407,50
PV		4.980,50	9.961,00
NBS	22.37	23,82	59,50
PUBLIC LIGHTING		66,02	110,00
SUSTAINABLE TRANSPORT		5.170,00	9.754,00
Building Rehabilitation		240,10	2.137,30
Parking Spot reduction		394,80	3.514,40
TOTAL	***22.37***	***12.433,24***	***33.329,70***

In the same way, Figure 42 graphically shows each measure's contributions to the estimated mitigation for 2030, ordered from lowest to highest contribution of tCO_2 savings, as well as the total value considered by all measures.

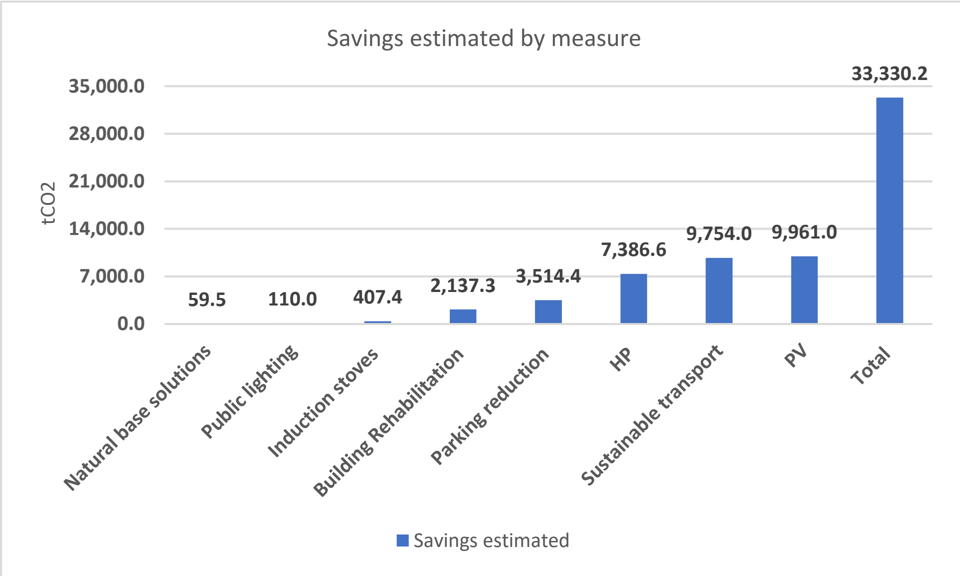


Figure 42 total tCO_2 estimation by measure

Figure 43 shows the evolution of these measures and the savings contribution of each of them for 2030, where it is possible to see how during the project development period the mitigation measures do not have a great contribution to savings of tCO_2, however when the measures are implemented, there is a considerable contribution to saving the tCO_2 emitted in the neighborhood.

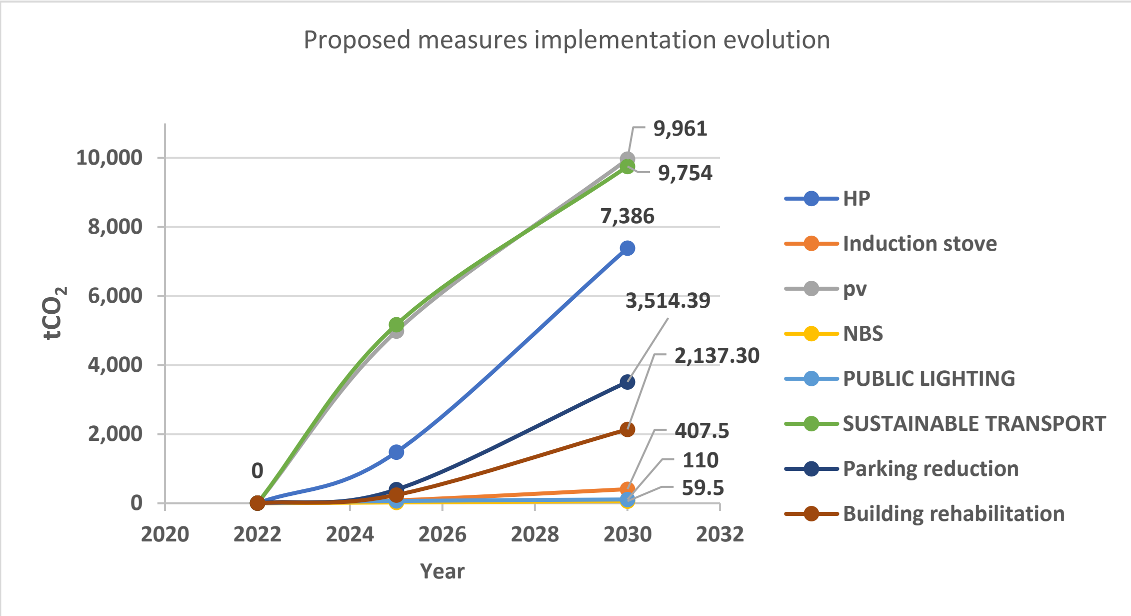


Figure 43 Proposed measures implementation evolution.

The total savings from the measures is 33,330.2 tCO_2 and represents 65% of the total emissions contributed by scopes 1 and 2 in the emissions inventory in the neighborhood, the total estimate of said scopes1 y 2 is 51,171 tCO_2. The total tCO_2 considered by the mitigation Figure 42 measures show a growth of 5,651.65 in consideration of the previous estimation [31] shown in Figure 20, which represents a growth of 17% of the total mitigation emissions.

8 Carbon balance: initial situation vs final situation

In this part of the study, a comparison is made of the initial carbon situation considered in the neighborhood of Benicalap, compared to the one that would be achieved by implementing the proposed mitigation measures.

This figure shows the contributions in tCO_2 of the different sectors considered in the emissions inventory for the Benicalap neighborhood Table 20, this graph considers a linear behavior of the emissions since the period considered is short.

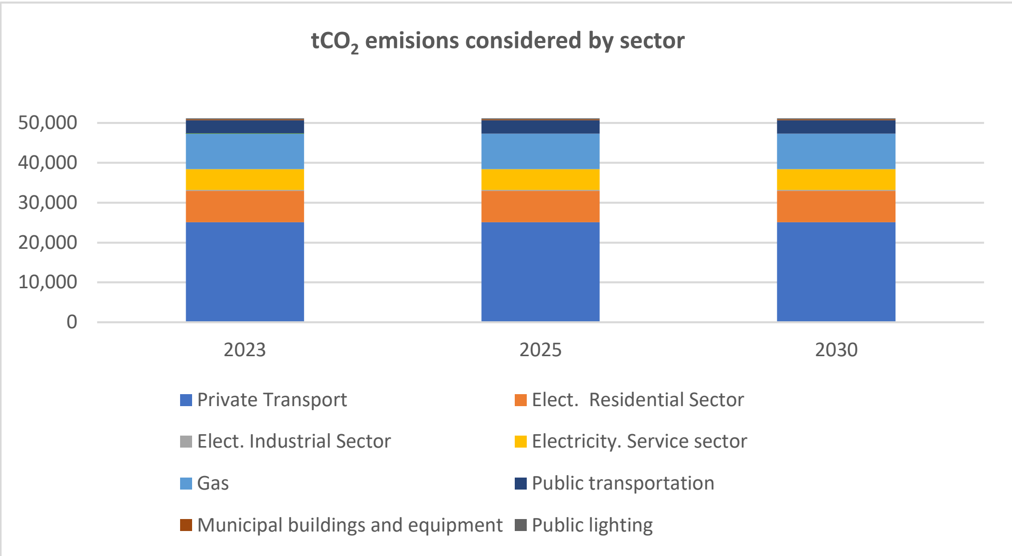


Figure 44 tCO2 emissions considered by sector on the period 2023-2030

Taking into account the tCO_2 reduction contributions of each measure proposed in this study, Figure 45 shows the behavior of the sectors and their reduction in the total contribution of CO_2 in the neighborhood.

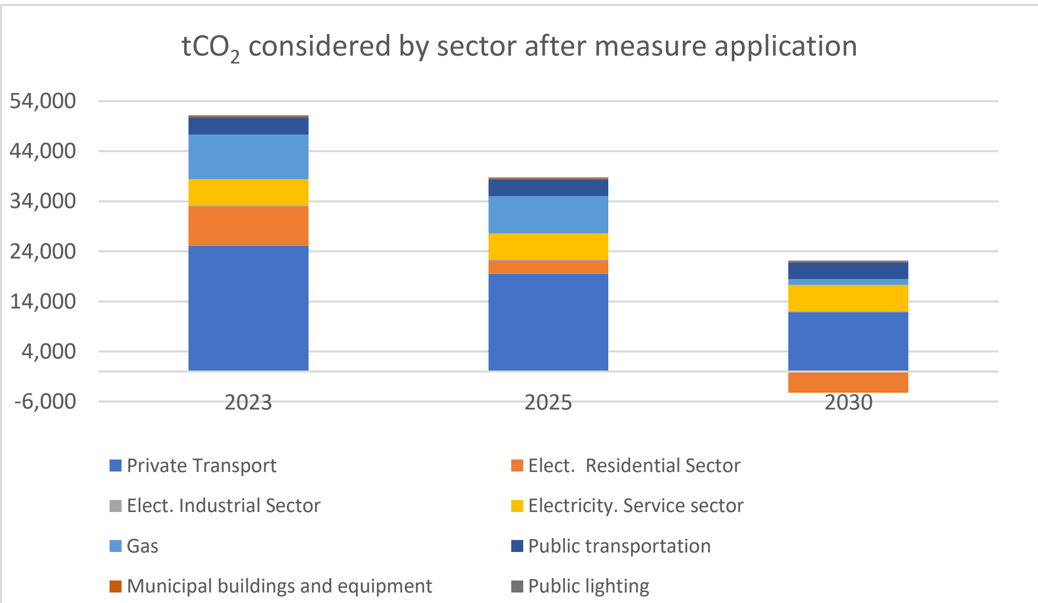


Figure 45 tCO2 reduction considered by sector after measure applications.

8.1 Decarbonizing Benicalap: A Roadmap

The roadmap of this project provides a clear and detailed vision of the goals, milestones, and steps to be taken. The strategic plan facilitates efficient organization and resource allocation, ensuring effective time and workload management. Additionally, it serves as a vital communication tool, ensuring that all team members and stakeholders understand the project's progress and expectations.

Figure 46 adopts mitigation measures considered by previous studies, mentioned in Figure 43, this map takes 2024 as its starting point, since it is the next current year, and adapts the previous considerations of the studies [7] and [31], this road maps put is divided into four measures categories residential measures, PV systems, NBS, Sustainable transport & parking and Public lighting. Two categories consider more than one mitigation measure, which are: "Residential measures" and "sustainable transport & parking", the first one considers the use of heat pumps, the use of induction stoves, and the restoration of buildings, and the second one considers the use of electric vehicles, electric buses, hybrid buses and the reduction of the parking places in the neighbor.

Measure	2024	2025	2030
Residential measures	743 Buildings restored.	20% Heat pumps 20% induction stoves 1428 Buildings restored.	100% heat pumps 100% induction stoves 4378 Buildings restored.
PV systems		50% PV systems installed	100% PV Batteries installed
NBS		40% of NBS solutions implemented	100% of NBS solutions implemented
Sustainable transport & parking	1.3% electric vehicle 3% electric bus 35% hybrid bus 134 less parking places	5% electric vehicles 10% electric bus 41% hybrid bus 554 less parking places	17% of electric vehicles 20% electric bus 51% hybrid bus 1628 less parking places
Public Lighting	30% Led luminaries	60% Led luminaries	100% LED luminaries

Figure 46 Measures Roadmap

9 Economic analysis

9.1 Parking Reduction Measure economic analysis

The economic analysis of the measure of reduction of parking spaces, carried out in this study considers two costs mainly, the first one is the cost of an advertising campaign to communicate the reduction of parking spaces in the neighborhood effectively, and the other is the cost of NBS construction in m2 of reduced spaces.

¡Error! No se encuentra el origen de la referencia. shows the costs of the advertising campaign considered in t his study, based on the costs offered by the OBLICUA advertising agency, this advertising campaign considers advertising in bus stops, billboards, advertising meshes, buses, and subway stations. For this study, a 6 -6-month advertising campaign will be adequate to communicate the reduction of parking spaces effectively, considering a total campaign cost of 0.69 million euros.

Publicity campaign			
Tipo	number	Mensual cost	6 months cost
Bus stops	40	22,400.00	134,400.00
Billboard	3	3,000.00	18,000.00
Advertising meshes	100	17,000.00	102,000.00
Buses	20	26,000.00	156,000.00
Metro	3	47,400.00	284,400.00
Total		0.12	0.69

As mentioned in section 7.2.1.3, the justification for the elimination of parking spaces has to be accompanied by an option of interest for the parties involved, which is why this economic analysis considers the costs of replacing the parking spaces reduced in the neighborhood for NBS.

To give continuity to the studies previously carried out in the Benicalap neighborhood, the price per m^2 of NBS established in previous studies [7], with 18,759 m^2 of parking spaces to be replaced in Benicalap, the approximate cost of this measure is 1,8 million of Euros. These costs are show in Table 36.Table 36 Parking Reduction measure cost

Table 36 Parking Reduction measure cost

Measure	Cost Millions (€)
Campaign	0,69
NBS	1,88
Total	2,57

The total initial investment costs for the parking space reduction measure are 2.57 million Euros.

9.2 Building Rehabilitation Measure economic analysis

Energy efficiency initiatives have become a central theme in national energy policies. This emphasis is well-founded, given that the building and construction industry accounts for a third of global energy consumption and contributes 40% to worldwide GHG emissions. Prioritizing EE projects aligns with national strategic goals and offers direct economic advantages to infrastructure owners, presenting a financially rewarding prospect. [53]

In this sense, it is important to perform a cost analysis of the mitigation measure that aims to rehabilitate the buildings constructed in the 1940-1980 period in the neighborhood of Benicalap.

The following cost analysis is based on the studies carried out by Tabula and the typology of buildings made with the cadastral data of Valencia, for this economic analysis are considered two types of buildings considered in this typology [51], which are: apartment buildings built in the period 1960-1979, and apartment buildings built in 1937-1950.

A comparative analysis of the proposed costs proposed for the rehabilitation of buildings proposed in [49] and the information available on the Internet about the costs per square meter for rehabilitating facades, roofs, and windows in Spain was carried out. Generating an average cost estimate for this study.

Table 37 shows a list of the components of the buildings considered in the typology carried out by [51] . It also mentions the usual rehabilitation proposed for these components and their area in m2 to estimate their costs.

Table 37 Building data apartment Type 1930-1979

Building data Apartment B. Type 1930-1979				
Surface area	**Existing type**	**Type of rehabilitation**	**m²**	**Cost media/ m²**
Roof	flat roof: a one-way framework with prestressed join	Add new waterproof, 20 mm of insulation, and gravel.	132	80
Wall	Masonry of coating bricks	Adding 30 mm of insulation at the inside side of the facade, clad with plasterboard.	576	100
Floor	One-way framework with prestressed joint	Thermal insulation of the cellar ceiling (from the bottom)	175	100
Window	Metal frame, single-glazed, no thermal break	Installing new windows, metal frame with thermal break, double glazed 4-6-4	71	80

Table 38 shows the costs considered in the studies carried out by [51] and information from the Internet that takes an average cost per square meter in the rehabilitation of the different elements that make up the building, obtaining an approximate average cost per building of 40.008 euros, and an approximate cost for the rehabilitation of the 4,372 buildings proposed in the neighborhood of Benicalap of 174 million euros.

Table 38 Cost considerations

Media between Tabula considerations and Internet cost	
Cost per building	**Euros**
Tabula	3523
internet info.	76.493,50
Media cost. Per building	40.008,25
Benicalap Costs building rehabilitation (Millions of Euros)	174,92

The element that most increases costs is the rehabilitation of the facades because the typology considered for this study is apartment buildings, which have a larger extension of m^2 of facade than other types that could be considered smaller, such as single-family houses.

The original typology is shown in section Annexes, it's the original version in Spanish, where heating and DHW elements are also considered for the renovations in the buildings, the improvement considered in this study is the one considered standard, which contemplates only the elements of its construction, as mentioned before.

9.3 Final budget for the measures

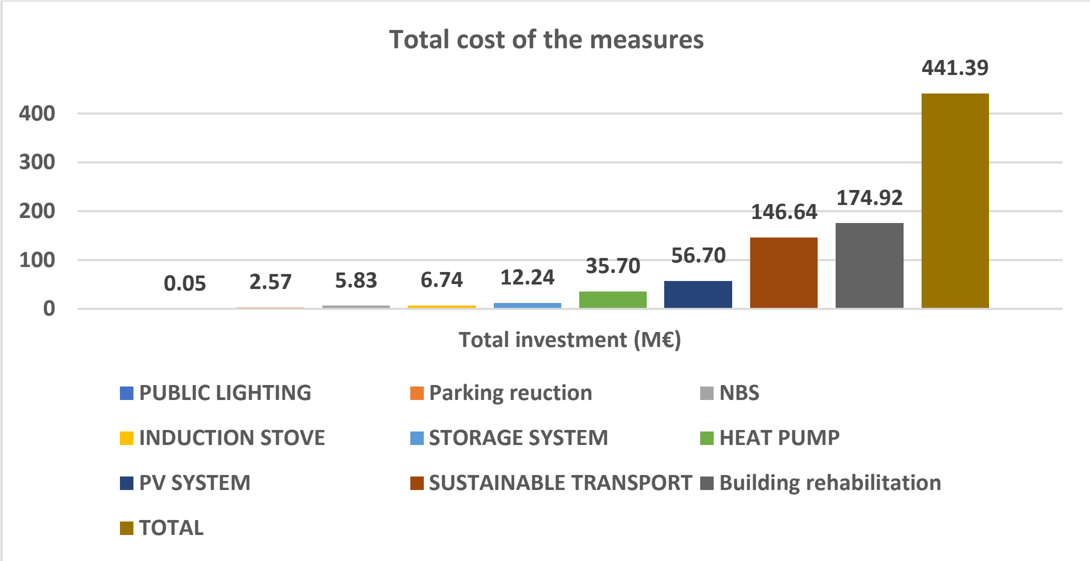
Table 39 shows the costs of the mitigation measures previously considered in the studies [31] & [7], and are complemented by the costs of the two measures proposed in this study, the parking lot redevelopment with a cost of 2,57 million euros and the rehabilitation of the neighborhood buildings with a total of 174.92 million euros, the total cost of all measures is 441 million euros.

Table 39 Total costs of the proposed mitigation measures

Measure	Total investment (M€)	Percent	Estimated emissions savings tCO_2e	€/ tCO_2e
PV SYSTEM	56,70	13%	9.961,00	5.692
HEAT PUMP	35,70	8%	7.386,00	4.833
INDUCTION STOVE	6,74	2%	407,50	16.540
NBS	5,83	1%	59,50	97.983
PUBLIC LIGHTING	0,05	0%	110,00	455
SUSTAINABLE TRANSPORT	146,64	34%	9.754,00	15.034
PARKING REDUCTION	2,57	1%	3.514,40	731
BUILDING REHABILITATION	174,92	41%	2.137,30	81.842
TOTAL	***441,39***	***100%***	***33.329,70***	**223.110**

As in section 5.2, Figure 46 illustrates the total costs of the proposed mitigation measures and the complementary measures contemplated in this study, ordered from lowest to highest cost according to their initial investment. Sustainable transport and building renovation are the two most costly measures, accounting for 33% and 40% of total investment costs.

Figure 47 Total cost of the CO2 reduction measures for Benicalap.



10 Challenge barriers

10.1 Stakeholder analysis

Recognizing and effectively managing stakeholders are imperative for achieving sustainable development and competitiveness. Stakeholders, encompassing individuals or groups impacted by an organization's actions, play a pivotal role in project management and overall success. Organizations are now held accountable to a diverse network of internal and external stakeholders, underscoring the importance of addressing their expectations and concerns. Strategic identification of stakeholders, considering their significance in specific contexts, becomes vital for success. This study delves into analyzing how specific stakeholder qualities shape managerial decisions, examining the correlation between these attributes and stakeholder relevance. [54]

The stakeholders identified as having a presence and influence on the development of the proposals put forward in this study are the following:

<u>Highly importance</u>:

Residents of Benicalap Neighborhood: this group is classified as high Interest because the application of the measures will directly impact their quality of life, and also, they wield significant influence as direct users of the space and voters.

Car owners:

Its importance may vary depending on your dependence on cars and your willingness to adapt to changes in mobility.

Municipal and governmental authorities of Valencia:

They have the power to approve and fund the project and their support is crucial for successful implementation.

Renewable Energy Companies:

Companies specialized in renewable energies could benefit or contribute to the project, especially in the phase of building rehabilitation to improve energy efficiency.

<u>Moderate Importance:</u>

Builders and rehabilitation companies:

They could obtain contracts to implement the proposed measures, as well as their collaboration is important in carrying out the rehabilitation of buildings.

Local merchants:

Because they can be affected by changes in the mobility and consumption patterns of residents, their participation can be key to minimizing negative impacts on their businesses.

Educational institutions:

Schools, universities, or training centers in the area could be interested in educational initiatives on sustainability and could be allies for awareness programs.

Cultural Associations and Historical Heritage:

Since the rehabilitation of historic buildings is proposed, these organizations could have an interest in preserving and promoting the cultural heritage of the neighborhood.

Technology Companies

Companies specialized in technological solutions for energy efficiency or intelligent mobility management could play an important role.

Neighborhood associations:

Its importance will depend on its level of participation and representativeness in the community.

<u>Low importance:</u>

Environmental groups and organizations:

Although they have a high interest, their direct influence could be moderate as they can be strategic allies to generate public support.

Civil Society Organizations (CSO):

Non-governmental groups that work on environmental and community issues. They could advocate for sustainable practices and actively participate in the project.

Residents of Surrounding Neighborhoods:

Although they do not reside directly in Benicalap, residents of nearby neighborhoods might be interested in how the measures could affect regional mobility and the environment.

Figure 48 shows the map of the interested parties, where they are identified in order of influence and importance as mentioned above. This map represents the actions that must be maintained by these interested parties.

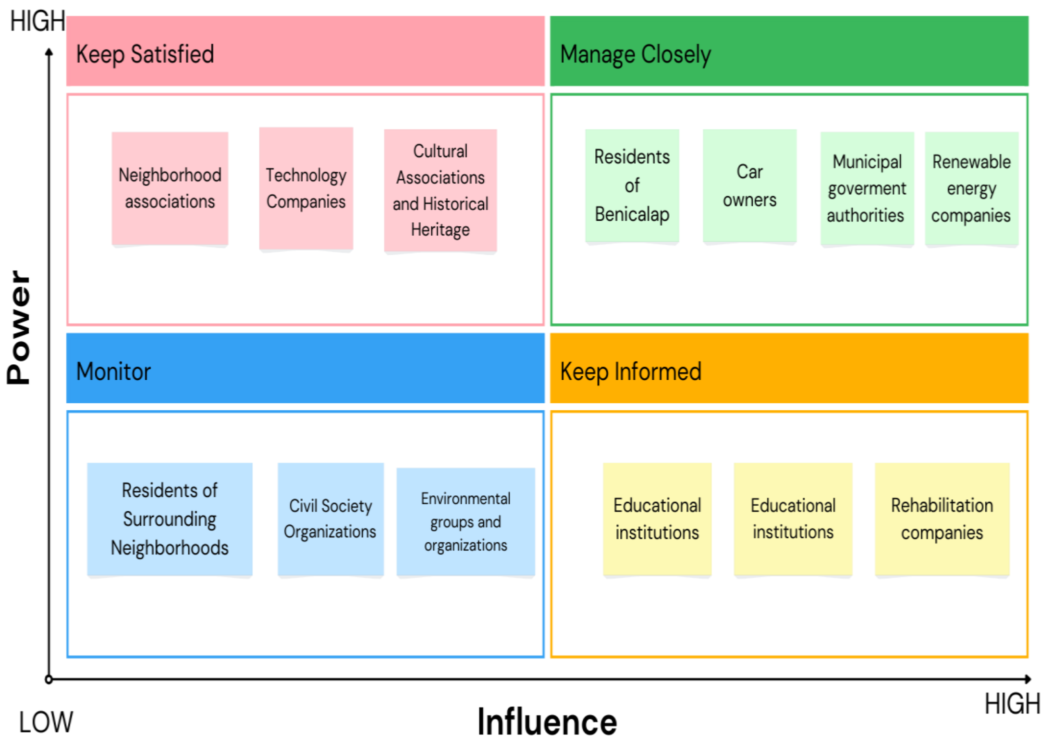


Figure 48 Stakeholder map

11 Conclusions

Today the world is more aware of the positive and negative influence that human activities have on climate change, which has led to an interest in generating proposals and actions at a global level to combat climate change. The international response to climatic threats is categorized as mitigation, which includes a range of activities, initiatives, and interventions by global bodies to minimize the degradation of climate systems [55]

In that sense, this research contributes to urban sustainability, by proposing specific measures adapted to the urban context and that serve as an example, since these local solutions can inspire sustainable approaches at other levels, such as carrying out these projects at the local city level.

The methodology developed in this project complements previous studies focused on the decarbonization potential of the Benicalap neighborhood, adding two emissions mitigation measures, which are the reduction of parking spaces, and the rehabilitation of buildings with poor energy performance in the neighborhood.

The parking space reduction measure contemplates a reduction of 3.514 TCO_2 which represents 10% of the annual emissions estimated for Scope 1 in the emissions inventory, likewise, the building rehabilitation measure contemplates a reduction of 2.137 TCO_2 which represents 13% concerning the emissions calculated in Scope 2.

On the other hand, important changes were also made to the emissions inventory, the main one being the modification of the emission factors for combustion vehicles, where, thanks to this data update, the emissions considered in the neighborhood caused by combustion vehicles were reduced by 40%.

The efficiency comparison in terms of investment-cost ratio per tCO_2 among the proposed mitigation measures, including the parking reduction measure, demonstrates the importance in the environmental investment strategy of the Benicalap neighborhood. Heat pumps lead in efficiency, with a cost of 4.833 €/tCO_2 saved, presenting itself as the most cost-effective intervention in terms of emissions reduction per euro invested. On the other hand, building refurbishment, although essential for energy savings and emissions reduction, represents the highest cost per tCO_2 saved, at 81.842 €/tCO_2, reflecting its lower economic efficiency.

The set of mitigation measures elaborated in previous studies contemplate 9 measures which are PV SYSTEM, STORAGE SYSTEM, HEAT PUMP, INDUCTION STOVE, NBS, PUBLIC LIGHTING, SUSTAINABLE TRANSPORT, PARKING REDUCTION, BUILDING REHABILITATION, which together contemplate a reduction of emissions of 33,330.2 tCO2, which represents 65% of the emissions considered in Scopes 1 and 2.

It is important to mention that the data considered for the development of this work are calculated from the general information of the city of Valencia since this data is usually not available at neighborhood level, which may represent a considerable error when calculating the real emissions of the neighborhood.

11.1 Future lines of research

1- Continue working to have reliable sources of information, especially on the consumption habits of the population, thus reducing uncertainty and allowing us to focus our efforts on the activities that generate the greatest environmental impact.

2- Conduct a more detailed study of the effect of vegetation on the temperature of neighborhoods and analyze the savings produced by re-naturalization measures.

3- Conduct a technical-economic analysis of building renovation, studying the reduction in demand due to renovation measures and the cost.

4- Investment in reliable and updated sources of information, such as consumption data.

5- Conduct an air quality analysis to understand other sources of pollution,

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13 Annexes

A. Relationship of work with the Sustainable Development Goals of the agenda

It is crucial that your project is linked to the Sustainable Development Goals (SDGs) of the 2030 Agenda, as this comprehensive framework addresses not only emissions reduction but also social and economic aspects. By aligning with the SDGs, your initiative contributes to global goals, demonstrates social responsibility, and attracts resources and collaborations that enhance its impact, sustainability, and support at both local and international levels. Table 40 SDGS project shows this relation, between the elaboration of this project and the mitigation measures.

Table 40 SDGS project relation

Sustainable development Goal	HIGH	MEDIUM	LOW	NOT MATCHING
SDGs 1. End of poverty				x
SDGs 2. Zero hunger				x
SDGs 3. Health and wellness		x		
SDGs 4. Quality education				x
SDGs 5. Gender equality				x
SDGs 6. Clearwater and sanity				x
SDGs 7. Affordable and non-polluting energy	x			
SDGs 8. Decent work and economic growth.			x	
SDGs 9. Industry, innovation, and infrastructure.		x		
SDGs 10. Reduction of inequalities.		x		
SDGs 11. Sustainable cities and communities.	x			
SDGs 12. Responsible production and consumption.	x			
SDGs 13. Climate action	x			
SDGs 14. Submarine life				x
SDGs 15. Life of terrestrial ecosystems.		x		
SDGs 16. Peace, justice, and solid institutions.				x
SDGs 17. Alliances to achieve objectives.	x			

The most important relationships of the project and their relationships with the SDGS are briefly described below.

SDG 11: Sustainable cities and communities

Your focus on the rehabilitation of buildings and the reorganization of parking spaces in Benicalap, Valencia, directly contributes to the goal of building inclusive, safe, resilient, and sustainable cities and communities.

SDG 12: Responsible production and consumption

By addressing emissions reduction through efficient parking space management and building rehabilitation, your project promotes responsible production and consumption practices, fostering a more sustainable use of resources.

SDG 13: Climate action

The reduction of emissions targeted by your project directly addresses the challenge of climate change, aligning to take urgent action to combat climate change and its impacts.

SDG 17: Partnerships for the goals

Your project aligns to form partnerships to achieve objectives, as it involves collaboration and coordination among various stakeholders to implement sustainable urban development strategies.

SDG 7: Affordable and non-polluting energy

The emphasis on reducing emissions in your project contributes to the promotion of clean and non-polluting energy sources, aligning to ensure access to affordable, reliable, sustainable, and modern energy for all.

B. Downscaling factors

The sources of information considered for the elaboration of this study generally consider data at the level of the City of Valencia, so it is necessary to consider these downscaling factors to bring them to the level of the Benicalap neighborhood.

Table 41 Downscaling factors.

Downscaling factors Valencia / Benicalap		
	Factor	%
Population	0,052	5,25
Area	0,016	1,62

C. Summary table of studies and measures carried out for Benicalap CO_2 reduction.

Studies	**Mitigation Measures**	**Estimation of mitigated emissions for 2030(tCO2)**	**Energy savings (MWh)**	**Application economic costs (M€) (Initial investment)**
Methodology to estimate the decarbonization potential at the neighborhood level. Case study: Benicalap and l'illa perduda in Valencia, Spain	1. NBS 2. PV 3. Public Lighting. 4. Sustainable Transport	5. 59,5 6. 9.754 7. 110,0 8. 9.961 **Total:** 19.884,6 (tCO2)	1. N/A 2. 90.315 3. 1.018,8 4. N/A **Total:** 91.333,8 (MWh)	1. 5,83 2. 56,7 3. 0,048 4. 146,6 **Total:** 146,6 (M€)
Neighborhood decarbonization based on electrification and implementation of renewable energies. case to study: Benicalap, Spain	1. HP 2. Induction stoves 3. PV & Batteries	4. 7.386,63 5. 407,4 6. 5.931 **Total:** 13.725,1 (tCO2)	1. 3.730,18 2. 1.636.05 3. 34.482.70 **Total:**72.868,93 (MWh)	1. 35,7 2. 6,7 3. 12,2 **Total:** 54,6 (M€)
Neighborhood Decarbonization in Benicalap, Valencia, Spain: A Methodological Approach to Estimating Scope 1 and 2 Emissions and Mitigation Measures.	1. Parking Reduction 2. Rehabilitation of buildings	3. 2.211,7 4. 941,5 **Total:**3153,2 (tCO2)	1. N/A 2. 5.474, **Total**:5.474,1 (MWh)	1. 2,57 2. 174.92

D. Emission factors

The information shown in section 7.1.1 where the updates of the vehicle emission factors and their comparison, are shown in **¡Error! No se encuentra el origen de la referencia.**, Table 17, and Table 18.

The information in these tables is derived from Table 42, which specifies the regulation of the vehicles, the year to which they belong, and their specific emission factor considered in the preparation of this study, which was prepared from the update of the year 2017 to 2021, These data were adapted from the emissions estimation methodology developed by the Ministry of Ecological Transition and Demographic Challenge [56]

Table 42 New data of vehicles emission factors adapted from [56]

Regulation	Age	Factor emissions tCO_2/km				
	Antes 1990	Petrol	Diesel oil	Electricity	LPG	CNG
PRE EURO	1990	0,000211713	0,00020465	n/data	0,00018232	n/data
	1991	0,000212181	0,000204404	n/data	0,00018269	n/data
EURO 1	1992	0,000213489	0,000204778	n/data	0,00018267	n/data
	1993	0,00021349	0,000202483	n/data	0,00018395	n/data
	1994	0,000211385	0,00019797	n/data	0,00018352	n/data
	1995	0,000210347	0,000194616	n/data	0,0001834	n/data
EURO 2	1996	0,000211075	0,000192373	n/data	0,0001848	n/data
	1997	0,000209025	0,000189451	n/data	0,00018436	n/data
	1998	0,000209448	0,000188113	n/data	0,00018509	n/data
	1999	0,000208642	0,000186012	n/data	0,00018525	n/data
EURO 3	2000	0,000207851	0,000180296	n/data	0,00018525	n/data
	2001	0,000208119	0,000178493	n/data	0,00018506	n/data
	2002	0,000207464	0,000176945	n/data	0,00018463	n/data
	2003	0,000206918	0,000175837	n/data	0,00029862	n/data
	2004	0,000206888	0,000175307	n/data	0,00018455	n/data
EURO 4	2005	0,000208397	0,0001753	n/data	0,00018532	n/data
	2006	0,000208417	0,00017442	n/data	0,00018484	n/data
	2007	0,000209148	0,000174591	n/data	0,00018479	n/data
	2008	0,000208805	0,000174387	n/data	0,00018464	n/data
	2009	0,000208946	0,000173168	n/data	0,00018449	n/data
EURO 5	2010	0,000173168	0,000184492	n/data	0,00018527	n/data
	2011	0,000209737	0,000174031	n/data	0,00018501	n/data
	2012	0,000210066	0,000173914	n/data	0,00018535	n/data
	2013	0,000210499	0,000173864	n/data	0,0001858	0,00019893
	2014	0,000209231	0,000172647	n/data	0,00018522	0,0001985
EURO 6	2015	0,000207758	0,000172678	n/data	0,0001985	0,00027423
	2016	0,000205572	0,000172739	n/data	0,00018529	0,00019752
	2017	0,000205422	0,000172745	n/data	0,00018502	0,00019649
EURO 6	2018	0,000205611	0,000173311	n/data	0,00018533	0,00019611
	2019	0,000204792	0,000172993	n/data	0,00018474	0,00019622
	2020	0,000202993	0,000172563	n/data	0,00018423	0,00019561
	2021	0,00019921	0,000172923	n/data	0,00019561	0,00026442

The emission factors used in this report related to electricity use are shown below.

Table 43 Electricity emission factor

Source	(tCO_2/MWh)	Reference
Electricity	0,172	[57]

E. Typology of buildings 1940-1959 and 1960-1970 & rehabilitation measures proposed (Spanish version)

The proposals for improvements as adapted in section 7.2.2.1 and Table 37 are prepared from the typology made by TABULA [58] and [51], in this section the typology is presented originally in Spanish and its proposed improvement elements, it is important to mention that the improvements proposed in this study are based on structural improvements only, as mentioned above, and do not take into account the SHW and heating system components described here in the original typology.

Caracterización energética del tipo:
| Bloque en altura | Período 1937-59 |Clima mediterráneo |

ES.ME.AB.03.Gen

Zona climática	Clima mediterráneo
Periodo de construcción	1937-1959
Tipo de construcción	Bloque en altura

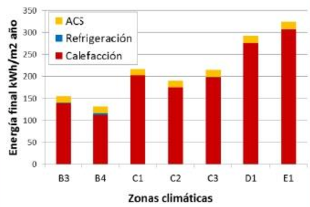
S.Habitable (m^2)	Volumen (m^3)	Compacidad V/S (m)	Nº de plantas	Nº de viviendas
832,0	2787,0	3,69	6	10

ESTADO ORIGINAL

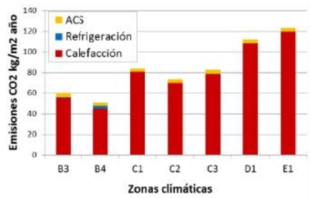
Características: elementos constructivos e instalaciones

Elemento	Descripción	U(W/m²K)
Cubierta plana	Baldosa cerámica Mortero de agarre Impermeabilización Hormigón de pendientes Forjado unidireccional de HA de 200 mm de canto Enlucido de yeso	1,37
Cubierta inclinada	Teja cerámica Cañizo Cámara de aire ventilada Cañizo Enlucido de yeso	4,17
Fachada principal	Enfoscado de cemento Ladrillo perforado de 115mm Enlucido de yeso	2,27
Fachada patio y medianera	Enfoscado de cemento Ladrillo hueco de 70mm Enlucido de yeso	2,63
Suelo	Baldosa de terrazo Mortero de agarre Forjado unidireccional de HA Enlucido de yeso	1,27
Huecos	Carpintería de madera de densidad media alta Vidrio monolítico 4mm Abatible Ajuste malo Sin persiana	4,72
Sistema	**Descripción**	**η**
Calefacción	Radiador eléctrico	1
ACS	Calentador de gas butano Sin acumulador	0,8

Análisis del consumo y las emisiones



Zona climática	Energía final (KWh/m² año)
B3	155,30
B4	131,20
C1	216,70
C2	190,00
C3	214,10
D1	291,50
E1	323,90



Zona climática	Emisiones CO_2 (Kg/m² año)
B3	60,10
B4	51,20
C1	84,10
C2	73,50
C3	82,80
D1	112,10
E1	123,60

Detalle de emisiones de CO_2

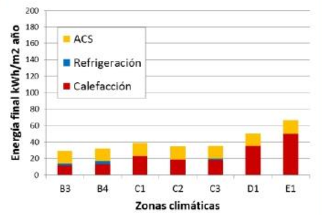
MEJORAS

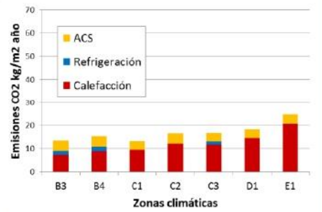
Mejora estándar = instalaciones existentes + mejora de elementos constructivos

Elemento	Descripción	U(W/m²K)
Cubierta — Todas: 50 mm; B, C, E : 0 mm; D : 60 mm	Baldosa filtrante aislante; Baldosa cerámica; Mortero de agarre; Impermeabilización; Hormigón de pendientes; Forjado unidireccional de HA de 200 mm de canto, Enlucido de yeso; Aislante térmico; Placa de yeso laminado	B, C, E: **0,46**; D: **0,21**
Cubierta inclinada — B4: 60 mm; B3, C2: 100 mm; C1,C3, D1,E1: 180 mm	Teja cerámica; Cañizo; Cámara de aire ventilada; Aislante térmico; Placa de yeso laminado	B4: **0,76**; B3, C2: **0,19**; C1,C3 D1,E1: **0,34**
Fachada principal — B4: 60 mm; B3, C2: 100 mm; C1,C3,D1,E1: 120 mm; B3,B4,C2,C3,E1: 0 mm; C1,D1 : 80 mm	Sistema SATE; Enfoscado de cemento; Ladrillo perforado de 115mm; Enlucido de yeso; Cámara de aire 10mm; Aislante térmico; Placa de yeso laminado 15mm	B4: **0,62**; B3,C2: **0,30**; C3, E1: **0,25**; C1, D1: **0,15**
Fachada patio y medianera — B4: 60 mm; B3, C2: 100 mm; C1,C3,D1,E1: 120 mm; B3,B4,C2,C3,E1: 0 mm; C1,D1 : 80 mm	Sistema SATE; Enfoscado de cemento; Ladrillo hueco de 70mm; Enlucido de yeso; Cámara de aire 10mm; Aislante térmico; Placa de yeso laminado 15mm	B4: **0,64**; B3,C2: **0,30**; C3, E1: **0,26**; C1, D1: **0,15**
Ventanas — Corredera — Metálica con rotura de puente térmico	Todas: vidrio doble low-e 4-15-4; C1, C3, D1, E1: Carpintería Clase 4	**1,58**
Mejora avanzada= mejora estándar + mejora instalaciones		
Calefacción+ ACS	Caldera de condensación de gas natural. Sin acumulador. Aporte solar ACS en zonas B3, B4, C2 y C3	COP **1,08**
Refrigeración	B4, B3: Sistema eléctrico; B4, C3: Toldo programable	EER **3,8**

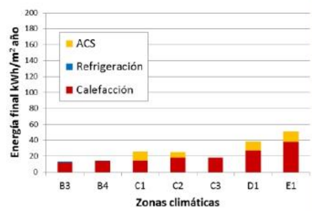
Análisis del consumo y las emisiones

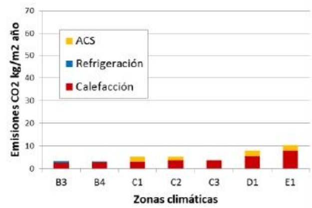
Mejora estándar





Mejora avanzada

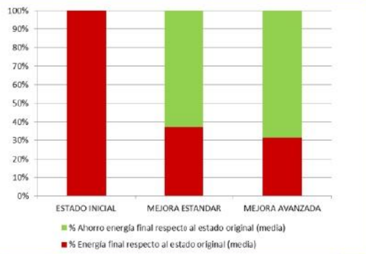




Nota: Conductividades de los aislantes empleados: en cubierta por el exterior 0,035 W/Km, por el interior 0,036 W/Km; en fachada, en sistema SATE 0,034 W/Km y en aislamiento por el interior 0,032 W/Km.

AHORROS

Zona climática	Original	Estándar	Avanzado	Estándar	Avanzado
	Energía final (kWh/m² año)			Ahorros (%)	
B3	155,30	29,30	13,00	81%	92%
B4	131,20	32,00	14,40	76%	89%
C1	216,70	38,50	26,00	82%	88%
C2	190,00	34,40	25,40	82%	87%
C3	214,10	35,30	18,30	84%	91%
D1	291,50	50,30	38,40	83%	87%
E1	323,90	66,50	50,90	79%	84%



Caracterización energética del tipo: | Bloque en altura | Período 1960-79 |Clima mediterráneo |

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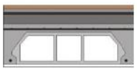
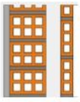
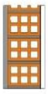
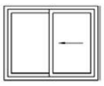
Zona climática	Clima mediterráneo
Periodo de construcción	1960-1979
Tipo de construcción	Bloque en altura

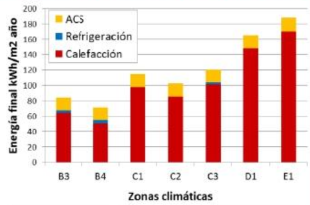
S.Habitable (m^2)	Volumen (m^3)	Compacidad V/S (m)	Nº de plantas	Nº de viviendas
1945,60	5836,80	4,87	10	18

ESTADO ORIGINAL

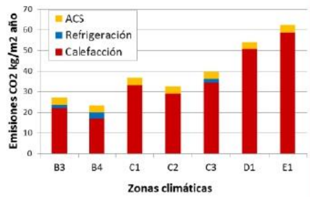
Características: elementos constructivos e instalaciones

Elemento		Descripción	U(W/m²K)
Cubierta		Baldosa cerámica Mortero de agarre Impermeabilización Hormigón de pendientes Forjado unidireccional de HA Enlucido de yeso	1,92
Fachada principal		Enfoscado de cemento Ladrillo hueco de 115mm Cámara 30 mm Ladrillo hueco de 40mm Enlucido de yeso	1,33
Fachada patios		Enfoscado de cemento Ladrillo hueco de 115mm Enlucido de yeso	2,08
Suelo		Baldosa de terrazo Mortero de agarre Forjado unidireccional de HA Enlucido de yeso	1,72
Huecos		Carpintería metálica Corredera Ajuste malo Cajas de persiana sin aislamiento	5,70
Sistema		**Descripción**	**η**
Calefacción y refrigeración		Sistema eléctrico	COP **2,67** EER **2,20**
ACS		Calentador de gas Sin acumulador	0,8

Análisis del consumo y las emisiones



Zona climática	Energía final (KWh/m² año)
B3	27,4
B4	23,5
C1	36,7
C2	32,5
C3	39,7
D1	54,10
E1	62,4



Zona climática	Emisiones CO_2 (Kg/m² año)
B3	84,10
B4	71,40
C1	114,70
C2	102,50
C3	120,50
D1	164,80
E1	188,30

Detalle de emisiones de CO_2

MEJORAS

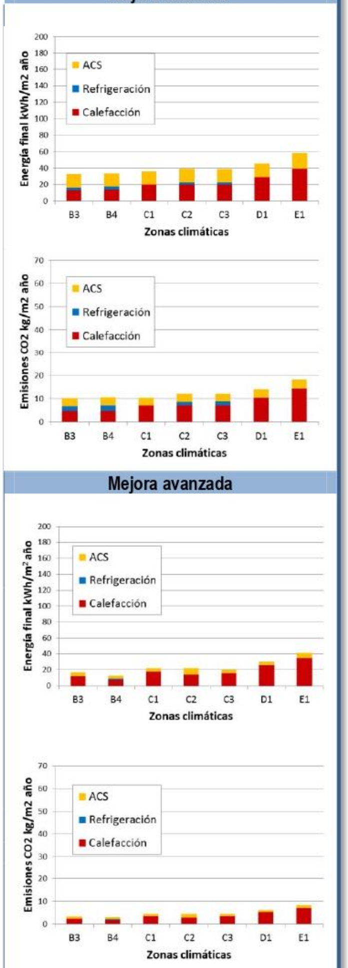
Mejora estándar = instalaciones existentes + mejora de elementos constructivos

Elemento		Descripción	U(W/m²K)
Cubierta (B, C, E: **50 mm**; D: **60 mm**)		Baldosa filtrante aislante Baldosa cerámica Mortero de agarre Impermeabilización Hormigón de pendientes Forjado unidireccional de HA Enlucido de yeso	B, C, E: **0,51** D: **0,36**
Fachada principal (B4: **0 mm**; B3, C2: **60 mm**; C3: **80 mm**; C1, D1, E1: **100 mm** / B, C, E : **0 mm**; D : **100 mm**)		Sistema SATE Enfoscado de cemento Ladrillo hueco de 115mm Aislante inyectado en cámara Ladrillo hueco de 40mm Enlucido de yeso Cámara de aire 10mm Aislante térmico Placa de yeso laminado 15mm	B4: **0,53** B3,C2: **0,27** C3: **0,24** C1, E1: **0,21** D1: **0,14**
Fachada patio (B4: **40 mm**; B3, C2: **60 mm**; C3: **80 mm**; C1, D1, E1: **100 mm** / B, C, E : **0 mm**; D: **60 mm**)		Sistema SATE Enfoscado de cemento Ladrillo hueco de 115mm Enlucido de yeso Cámara de aire 10mm Aislante térmico Placa de yeso laminado 15mm	B4: **0,60** B3, C2: **0,45** C3: **0,35** C1, E1: **0,29** D1: **0,18**
Ventanas – Corredera	Metálica con rotura de puente térmico	B4: vidrio doble 4-15-4 B3: vidrio doble 4-15-4 + aislamiento caja persiana	B3,B4: **2,83** C2: **2,61** C3: **1,66**
Ventanas – Abatible	PVC 3 cámaras	C1,C3,E1: vidrio doble low-e 4-15-4 C2: vidrio doble 4-15-4 D1: vidrio doble low-e 4-20-6 Todos: aislamiento caja persiana	C1,E1: **1,62** D1: **1,44**

Mejora avanzada= mejora estándar + mejora instalaciones

Elemento	Descripción	
Calefacción+ ACS	Caldera de condensación de gas natural. Sin acumulador P calorífica nominal (kW)=24 Rendimiento nominal 100% Aporte solar ACS=60%	COP **1,08**
Refrigeración	B3, C1, D1 y E1: Sistema eléctrico	EER 1,70
	B4, C2, C3: Sistema eléctrico + toldo programable	EER **1,59**

Análisis del consumo y las emisiones



Nota: Conductividades de los aislantes empleados: en cubierta, con espesor 50mm 0,035 W/Km y con espesor 60mm 0,027 W/Km; en fachada, en sistema SATE 0,034 W/Km, en inyección en cámara 0,038 W/Km y en aislamiento por el interior 0,032 W/Km.

AHORROS

Zona climática	Original	Estándar	Avanzado	Estándar	Avanzado
	Energía final (kWh/m² año)			Ahorros (%)	
B3	84,10	33,10	16,50	61%	80%
B4	71,40	33,70	12,30	53%	83%
C1	114,70	36,20	22,20	68%	81%
C2	102,50	39,40	21,80	62%	79%
C3	120,50	39,00	20,10	68%	83%
D1	164,80	45,40	30,20	72%	82%
E1	188,30	57,90	41,40	69%	78%