AGÈNCIA D'ENERGIA
DE BARCELONA

The energy, climate change and air quality plan of Barcelona
(PECQ 2011-2020)

Ajuntament
de Barcelona

Barcelona
pel Medi
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Presentation

In 2002, Barcelona City Council approved the Barcelona Energy Improvement Plan (PMEB). This innovative document provided the frame of reference for the city's energy policy between 2002 and 2010. The 59 projects that were launched have not only made it possible to make improvements in energy efficiency, they have also saved money, promoted local energy sources and reduced greenhouse gas emissions. The city's social and economic partners, as well as the general public, have been actively involved in the projects. As a continuation of the PMEB, the Barcelona Energy Agency (AEB) has drawn up a new plan called the Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020 (PECQ). More extensive than the PMEB, the PECQ deals with the current circumstances not just in terms of energy but also in terms of the climatic situation and the air pollution that affects the city. Led by Barcelona City Council, the new plan needs to promote the positioning of the city in the national and international arenas and to confront the challenges of today. The plan also needs to ensure that the public administration is provided with strategic instruments that lead to improvements in the health of the general public by reducing polluting emissions, promoting the efficient use of energy resources, and reducing greenhouse gas emissions.

The PECQ updates the PMEB and includes actions that are more cross-cutting and more ambitious, that aim to outline Barcelona's energy commitment in the framework of the European Union's Covenant of Mayors: to reduce the emissions of greenhouse gases associated with municipal activity by 20% by 2020. The plan also analyses what has been done to date – the extent to which PMEB projects have been carried out, the obstacles that have hampered progress, the keys to the successes achieved – and puts forward objectives and strategies for the future. The PECQ can be seen as two complementary programmes - one city and one municipal – each of which goes into the data in more detail, separating city consumption from municipal activities. This is one of the main new features of the Plan.

A number of sectoral studies performed by experts in their respective fields provided the basis for preparing the PECQ. The City Programme (PC), along with some of the studies, was coordinated and written by Barcelona Regional, whilst the Municipal Programme (PM) was coordinated and written by the Barcelona Energy Agency – part of Barcelona City Council's Department of the Environment - which also coordinated the PECQ itself.

Executive summary

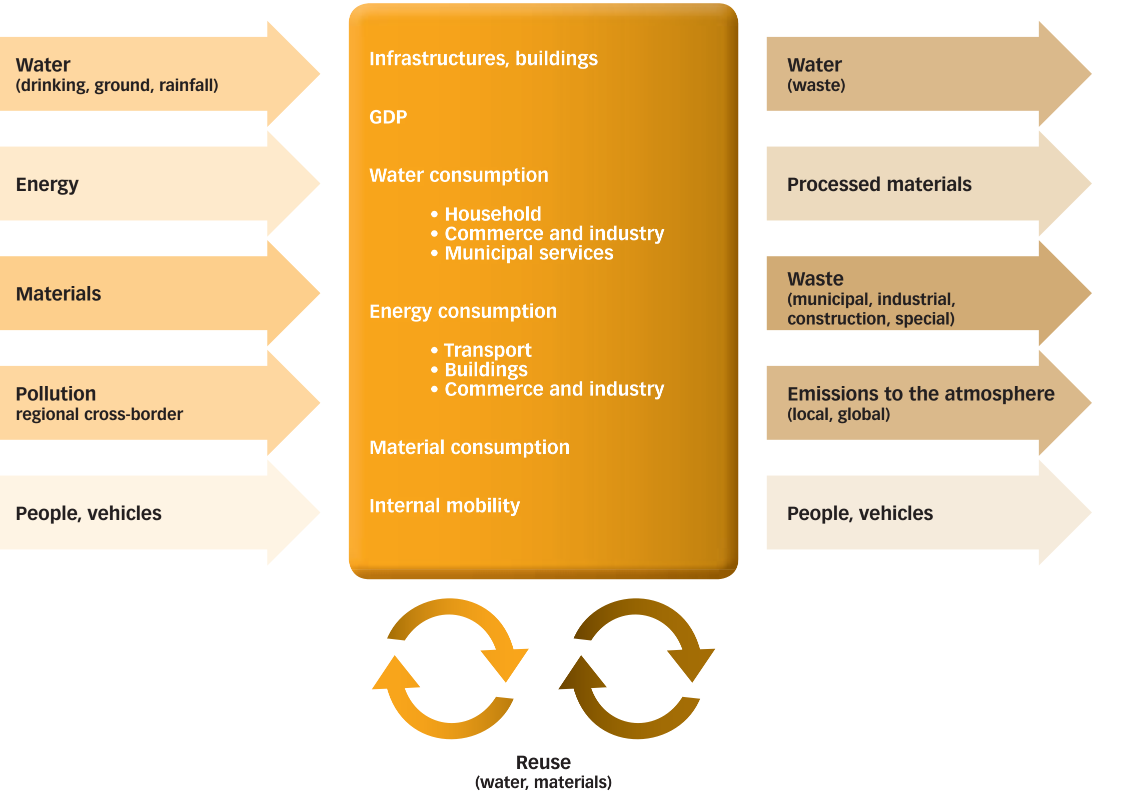
Barcelona's PECQ (Energy, Climate Change and Air Quality Plan of Barcelona) is a plan hosted by Barcelona's City Council aiming to provide Public Administration with strategic tools in order to improve citizens' health, as well as to improve Planet health by increasing energy efficiency and reducing greenhouse gas emissions together with other local effect pollutants.

Since the end of the 20th century, Barcelona is promoting initiatives to reduce the environmental impact derived from municipal activity; and it was in 2002, during a plenary sessions, that the City Council approved the PMEB (Barcelona Energy Improvement Plan for 2001-2010), a municipal action plan provided with a range of projects and measures aiming to increase energy efficiency improvement, to reduce greenhouse gases, and to increase energy generation with sustainable sources.

The results and conclusions derived from the implementation of PMEB projects lead us to talk about a final implementation of 71% of the initially proposed projects. The projects were divided into those which could be directly evaluated in terms of saving emissions of pollutant gas, those which work as a tool to develop other projects, and whose results are hard to be quantified directly. In this sense, the first ones have been carried out up to 65%, while the rest have been carried out up to 76%.

At the end of the projected period for the PMEB, Barcelona's City Council decides to strengthen and to continue its sustainability policy, by developing a new plan, the PECQ: a strategic plan which will set the municipal guidelines and steps to be developed in Barcelona during the period 2011 – 2020, whether in terms of energy efficiency, energy demand management or energy generation through alternative sources.

FIGURE 1 | DISTRIBUTION OF URBAN METABOLISM FLOWS



This new PECQ, therefore, sets the following objectives for the next decade:

- To reduce the increase of energy consumption in Barcelona.
- To reduce the increase of greenhouse gas emissions related to Barcelona.
- To improve air quality in Barcelona especially regarding NO_x and particulate-matter.

Moreover, a series of specific objectives have been settled with regard to the baseline year 2008, such as the accomplishment of international commitments acquired by the City Council, for instance the Covenant of Mayors.

Two parallel programmes

The Plan is structured in two parallel programmes. One of them, at a city level, called City Programme, and the other one at a City Council level, called Municipal Programme, which includes every aspect directly depending on the City Council. This fact will allow clarifying the municipal action scale, which could seem limited but it is outstanding.

Thus, we talk about a City Programme in which all generals aspects concerning the city are discussed, those who depend on the City Council management as well as those depending on the public as a whole.

On the other side, a Municipal Programme referring to those aspects depending exclusively and directly on the City Council (public buildings, public lightning, public fleets and urban services) is created.

The City Programme

The methodology used in the development of the PECQ's City Programme derives from the previously settled one in the PMEB. Technical help has also been offered by different sector work groups which have focused all efforts in specific studies on the city key sectors. Moreover, this PECQ improves certain methodological aspects such as: an in-depth analysis of the city air quality by modelling pollutants dispersion, an analysis of social behaviour concerning energy consumption, an economic analysis of the city as well as the economic effects that can result from the plan measures implementation, or an analysis of the industrial sector, among other methodological improvements already put into practice.

An extensive process of participation has been carried out with citizens and groups of interest in the drafting of the plan, which has gathered more than 250 participants whether experts and organizations or associations representatives, firms, professional associations, trade unions, guilds, political parties, universities and research centres, as well as administrations and public companies. At the end of this process, over nine hundred contributions have been collected.

As shown by the energy and environmental assessment of the city, many of the data and historical indicators compiled during the last years have reflected a constant increase in energy consumption up to year 2005. From this year on, the general tendency observed from the 90's inverts as energy consumption decreases until year 2008.

It is necessary to recall that winter 2005 was one of the coldest winters during the last 12 years, this fact redounded in a crest of energy consumption in heating and sanitary hot water compared to those in previous years. This fact took place not only in Barcelona city, but also in other parts of Catalonia and Spain.

It is also remarkable the fact that the development of the PECQ has met with the economical and financial crisis at a world level, which has affected our country, not only in economical terms, but also, as an after-effect of social behaviour towards saving, deriving in a decrease of energy consumption and, therefore, a decrease of greenhouse gas emissions since 2008.

When summarizing the main energy results of Barcelona, it appears that the final energy consumption in 2008 was of 17,001.78 GWh, which means 10.52 MWh/inhabitant, taking into account the 1,615,908 inhabitants censed in 2008; while in 1999 15,664.78 GWh were consumed, that is 10.42 MWh per inhabitant. This means a cumulative annual growth rate since 1999 of 0.91% in absolute terms of energy and of 0.11% in relative terms per inhabitant.

Energy consumption was distributed as follows: 29.9% in the tertiary sector, 27.9% in residential, 24.1% in transport, 17.2% in the secondary sector and 0.8% in other sectors such as the primary sector, energy, building and public works. Similarly, in terms of energy sources, electricity prevails with 44.5%, followed by natural gas with 31.8%, gas oil with 15.4%, and oil with 7.0%, and LPG (butane and propane) with 1.4%.

The analysis of the energy consumption evolution between 1999 and 2008 shows a rise of intensity in electricity consumption in the domestic sector (especially between 1999 and 2005) as well as in the tertiary sector (especially between 1999 and 2007), which seems to go along with the evolution and rise of the ICT in houses and offices, as well as a larger number and diversity of household appliances and electronic devices found in the market (even though electronic devices have improved in terms of energy efficiency). This increase of electric consumption is thwarted with a high decrease, after 2005, in intensity in natural gas consumption within different sectors which may be initially due to climate effects and, later on, it may be due to the effect of the economic crisis. In 2008, the energy consumption of the secondary sector reached approximately the same level as the previous one in 1999, even though during this period it has not been a constant value, because the consumption increased until 2001; it showed a constant consumption until 2005, and finally it showed a fall of consumption down to the levels of the 90's. Energy consumption in the transport sector, whose figures in 2008 were above those in 1999, shows a light but sustained decrease since 2001. This performance derives most probably from the Public Administration policy in making public transport more competitive than private transport, in addition to a better efficiency of new vehicles.

During this period, the city has had an important economic growth; it must be said the city GDP growth has been superior to energy consumption growth, which suggests that the wealth has been created with less energy demand. So, energy intensity since 2005 has been decreasing (which means a higher energy efficiency of the macro system), showing an annual tax since 1999 until 2008 of -1.11%, up to a figure of 269.44 Wh/€. It is a relatively positive tax in Spain and it is higher than the Spanish reduction values (-1.01% 1999-2008) as well as Europe's (-1.03% 1999-2005).

Considering energy in its origin, during 2008, Barcelona consumed 30,783.6 GWh of primary energy, with a contribution (considering the mix of electricity generation in Catalonia) of 44.8% of nuclear energy, 32.3% of natural gas, 12.3% of liquid fuels, and 3 % of hydro power and renewable energy among other sources of less importance.

According to the annual balance of 2008, 68% of the electricity consumed in Barcelona and Sant Adrià de Besòs was generated by electric generation facilities located in Barcelona and in the Besòs river mouth area. It is expected that, with the new combined cycle power plants (Besòs 5 and the CCPP in the Port of Barcelona), the needs of these two cities and the surrounding area will be fully covered. Therefore, in the short term, Barcelona and its surrounding area will have enough installed power as to export electricity.

It is remarkable that, in the last few years, the evolution of renewable energies in Barcelona, especially solar thermal energy associated to the Solar Ordinance, allowed, in 2008, to have 65,506 m^2 of solar collectors to heat water (in 1999 there were only 2,500 m^2). Moreover, 6,116,5 kWp of installed power in photovoltaic modules are registered (in 1999 there were only 2.5 kWp). In addition, in 2008, photovoltaic power generated by private property firstly exceeded the one generated by municipal property.

With regard to greenhouse gas emissions it is confirmed that, in 2008, 4,053,765.5 t GHG (considering the electric mix in Catalonia) were emitted, which means a ratio of 2.51 t GHG per inhabitant and year. The annual average rise tax since 1999 has been -1.72% (1999-2008); considering that in 1999, 4,737,299.9 tones were emitted, which means a ratio of 3.15 t GHG per inhabitant and year.

It is worth pointing out that not all decreases in GHG emissions between 1999 and 2008 are due to energy efficiency improvement. An important part of this decrease in emissions is due to changes produced in this period for a better treatment of urban solid waste, while another part is due to methodological upgrades of emission factors.

Among greenhouse gas emissions, the transport sector was the main emitter (26.2%), followed by residential (20.6%), commercial and service sectors (19.4%), the secondary sector (13.5%), as well as other sectors (0.5%) such as the primary, energy, building and public works. Some 8.1% of the GHG emissions was also caused by municipal solid waste treatment, and 11.8% was due to the Port of Barcelona activity as well as these related to Barcelona Airport which has a direct impact on the city.

The PECQ has analyzed, through modelling the dispersion of those pollutants with immission levels above the EU legislated values, nitrogen dioxide (NO_2), concentration and particulate matter fewer than 10 microns of diameter (PM_{10}) in the city air which affect, in high concentrations, people's health. This analysis has allowed to know the origin of emitting focus, as well as the possible future scenario which can guarantee the regulatory compliance of set up limits since 2010 by the EU, and, therefore, guarantee an ideal air quality for the public.

As a result of this modelling, and after doing the data calibration from measurement stations located in Barcelona and its surrounding area, it turns out that as an annual average, 65.6% of NO_2 located in the air of Barcelona derives from vehicle engines; 8.6% from the residential sector and the tertiary sector (natural gas and LPG); 4.8% from the secondary sector and energy generation; and 2.1% from the Port of Barcelona, while 0.1% comes from Barcelona Airport. It remains an 8.6% of background pollution (pollution coming from external focus) and 10.1% of local background pollution (internal emitting focus, in the city, with emission levels or emission profiles different to those modelled).

Regarding the origin of PM_{10} in the air, it mainly derives from vehicles (11%), even though an important part comes from out of the city (47.9% of background pollution) and 40.2% is considered local background pollution, so these are unidentified focus or focus with levels or hourly/monthly profiles different from those modelled. The remaining 0.9% are emissions coming from other sectors (residential, tertiary, secondary, etc.).

The scope of this City Programme is as transversal as possible, since energy problems affect almost every aspect concerning the city lifestyle. This analysis is mainly pointed at giving importance to behavioural aspects towards energy, through a social analysis related to the rational use of energy as well as citizens' perception towards climate change, since one of the most important factors to reduce energy consumption includes an efficient management of energy demand.

This Plan's main outcome has been to have identified six segments of population with a different behaviour towards energy and the environment: Aware (29% of population), Comfortable (27%), Dynamic (23%), Passive (17%), Anti-establishment (2%), and Convinced (2%). The Aware and Convinced segments are those more active in saving energy and recycling, while the Comfortable and Passive segments are the less receptive and sceptical in changing their behaviour in order to reduce energy consumption and pollutant emissions. This fact will imply that the PECQ plan of action will have a high factor of social awareness as well as an approach to the public, providing citizens with enough tools and information so they can make their own decisions and take action according to the PECQ's aims.

Another key sector that has been studied in the PECQ is the building energy renovation, a significant aspect in a city with few expansion chances such as Barcelona. In this sense, different proposals have been carried out concerning the direct relation between city planning and energy efficiency.

Mobility, as a main actor in air quality terms and as a consumer of 24% of city final energy, has a key role in this document, as well as other different key vectors in the running of a city such as waste, energy supply quality or local and renewable energy generation.

Any energy analysis is not complete enough if not linked to the city economic sector, from classical actors such as the secondary sector up to key infrastructures such as the Port and the Airport of Barcelona.

This analysis has stated a whole of 85 projects which deal with each and every detected problem. It is worth mentioning that apart from the projects included within the PECQ, measures or projects done and passed before the PECQ have also been added, having a special importance in Barcelona, whether related to energy or pollutant emissions.

The Municipal Programme

The cross-cutting issues referring to energy problems need the complicity of many city sectors in order to reach the goals of a local energy plan with full success warranty. One of the main agents involved has to be the City Council itself, which should take on the environmental challenge in its government lines. So, it is important to settle a Municipal Programme which allows the City Council to take on the leadership in the cause against climate change and the improvement of air quality by means of a municipal action.

The main objective is that the success of municipal action spurs on all citizens to take over the commitments made by the city relating the environment. The proper communications of the City Council's efforts in actions and aspects related to energy saving, efficiency, emissions reduction as well as usage of renewable energies can break the perpetuation of some myths and barriers linked to certain attitudes and technologies.

For this reason, the Municipal Programme works transversally together with other plans of Barcelona City Council (Urban Mobility Plan, Green Spaces Plan, Tourism Plan, etc.), as well as with other municipal actors (lighting, mobility, sports facilities, etc.).

Thus, all aspects considered in the Municipal Programme (such as public buildings, lighting, municipal fleets and urban services) consumed 473 GWh during 2008, and emitted 84,400 tonnes of greenhouse gas, which meant 2.8% of the city total energy consumption. The main consumers in this sector were municipal buildings (52%), followed by public lighting (20%) and waste collection fleet (16%), 9% municipal services and 3% by other municipal fleets. Regarding energy sources, almost 60% of consumption was electricity, 24.5% was natural gas and 11.5% was gasoil. It is remarkable to point out the share of a 1.5% of solar thermal energy, above other sources such as oil (0.5%) and very close to LPG (2%).

The main amount of energy consumption in municipal buildings has derived in the development of a specific subset plan, called PEMEEM (Saving and Improvement Efficiency Plan in Municipal Buildings), which, in the framework of the PECQ, will try to speed up all measures related to municipal buildings.

These municipal consumption rates are the base in order to reach a lowering of related emissions of a 20% facing 2020, with the implementation of the 23 projects which define the Municipal Programme.

All City Council's stakeholders had the opportunity to make proposals and express their opinion in a participation process carried out for the Municipal Programme.

City Programme Objectives

It is expected that all projects included in the PECQ will have an energy reduction potential of 1,678.85 GWh/year (an -10% of 2008 energy consumption), and a 709,000 t/year of GHG emissions (an -18% of 2008 value), as well as 2,742, t/year of NO_x emissions, 288.1 t/years of PM_{10} and 253.3, t/year of $PM_{2.5}$.

After applying the business as usual (BAU) scenario for 2020, and the above mentioned reduction potentials, the expected *"PECQ Scenario"* for 2020 will lead the city to a +10% energy consumption increase (compared to the +19% of the BAU scenario), and a +1% of GHG emissions (compared to the +17% of the BAU scenario).

The price of implementing all the measures was evaluated in 2,431.74 M€, of which about 1,960.22 M€ will be paid by the Barcelona City Council.

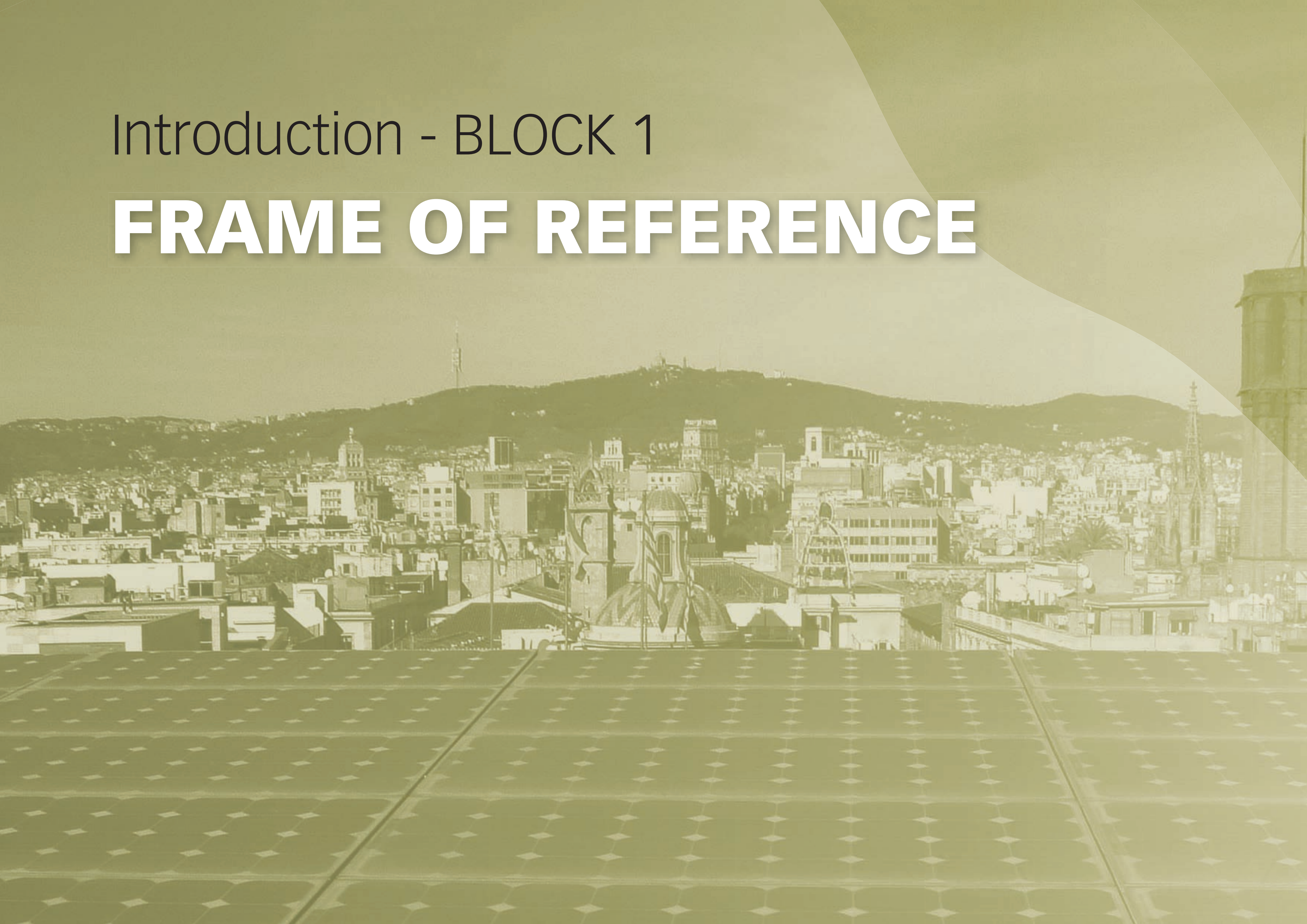
Municipal Programme Objectives

As an extraction of the City Programme, it is expected that the projects included in the Municipal Programme of the PECQ will have an energy reduction potential of 58.2 GWh/year (a -19.59 % of 2008 per capita energy consumption), and 14,827 t/year of GHG emissions (a -23.45 % of 2008 per capita emission value).

With this 23.45% GHG per capita emission reduction for 2020, Barcelona accomplishes the Covenant of Mayors Commitment.

Introduction - BLOCK 1

FRAME OF REFERENCE



1.1 - Scope of the PECQ

1.1.1 - SPHERE OF ACTION

The scope of the Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020 (PECQ) is the city of Barcelona. Nevertheless, the analysis of a number of issues has meant adjusting the limits of the Plan to the functional unit of the study or to the required action, as stated in the sections that follow.

The PECQ covers a ten-year period (2011-2020), coming into force at the end of the implementation period of the Barcelona Energy Improvement Plan (PMEB) on 31 December 2010. It comprises 7 programmes and 108 projects and is structured across 2 parallel programmes, which cover different territorial areas:

- **The City Programme** (85 projects) refers to all the general aspects of the city, except those that are the direct competence of the Municipal Authority. It includes the following sectors: domestic, commercial, industrial, road mobility (excluding municipal vehicles), public transport, energy generation, waste management, etc.

- **The Municipal Programme** (23 projects) is an action plan that encompasses only direct municipal competences. It includes municipal buildings, lighting, public services, green spaces, municipal vehicles and waste collection, etc.

As Barcelona forms part of a wider territory, not only from an administrative and functional point of view (metropolitan area) but also from the perspective of the ecosystem, issues relating to energy management systems, air quality and climate change must extend to, at least, the metropolitan area and cannot be limited to municipal boundaries.

FIGURE 2 | **SPHERES OF THE PECQ**

The PECQ investigates in more depth a number of issues that were covered in the PMEB but that have become more important over recent years

- managing demand, communication and awareness,
- transport networks and electrical supply,
- new fuels and energy sources,
- the impact of large infrastructures (the Port and Airport),
- the current situation of industry,
- energy performance of the City Council's energy facilities and services.

In addition, the PECQ incorporates a number of innovative perspectives with regard to the relationship between energy, air pollution and climate change, as well as consumption and emissions in the distribution of goods.

Furthermore, the PECQ is cross-cutting in nature in that it proposes actions in areas that are covered by other strategic municipal plans and that have an impact on energy related matters: the Urban Mobility Plan, the Infrastructure Master Plan, the project that is evaluating the quality of electricity supply services in Barcelona, and the Tourism Plan, among others.

FIGURE 3 | PERSPECTIVES OF THE PECQ

The relationship between energy and climate change

The relationship between energy and air quality

The perception and social use of energy

The economic impact of energy use

1.1.2 - THE OBJECTIVES

The Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020 (PECQ) is a local administration instrument aimed at the following during that time frame:

- improving energy efficiency and reducing energy consumption in the city,
- cutting the increase of greenhouse gas emissions (GHGs),
- improving urban air quality, in particular with regard to NO_x gases and PM_{10} particles,
- and, improving the quality of energy supply.

Similarly, the PECQ needs to be a means of meeting the city's commitment to reducing GHGs from its municipal activities by 20% by 2020.

To achieve these challenges, a series of specific, strategic objectives are proposed in the PECQ 2011-2020 that set out a diagnosis of, and proposals for, strategic action. These objectives are set out below:

STRATEGIC OBJECTIVES

- Position Barcelona in the current context of energy at the level of Catalonia, Spain and Europe, and redefine its energy strategy with new objectives and action plans.
- Establish a municipal strategy with regard to climate change and air quality, fully coordinated with the energy strategy.
- Raise awareness of the Council's commitment to the above, led by senior figures, and generate a climate of involvement amongst all agents that participate in conceiving and executing the new Plan.
- Position Barcelona in approximately 2020 as a highly competitive city. Energy efficiency, the generation of renewable energy, and air quality need to help bring this about.

SPECIFIC OBJECTIVES

- Involve the general public in the Plan, by means of ambitious projects in the areas of raising awareness, communication, and the positioning of Barcelona City Council vis-à-vis the public.
- Incorporate current and pending planning at local and regional level, as well as new, overarching directives and legislation.
- Define future scenarios that are both possible and desired, and establish quantifiable objectives with regard to such scenarios.
- Determine and define actions and projects to carry out in order to
- achieve the target scenario based on putting forward a range of strategic lines.

FIGURE 4 | OBJECTIVES OF THE PECQ

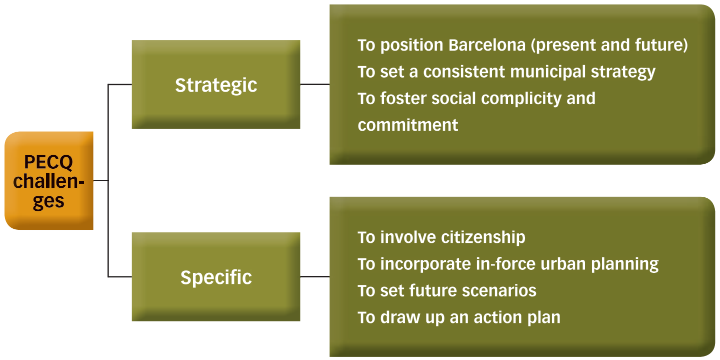
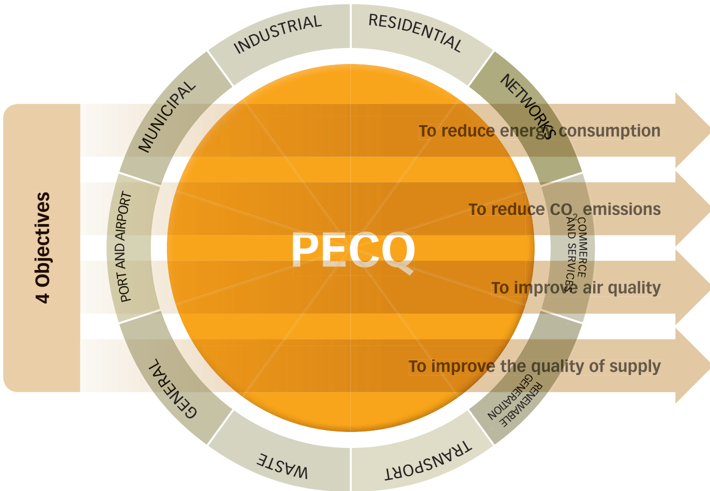


FIGURE 5 | STRUCTURE, CONTENTS AND OBJECTIVES IN THE FRAMEWORK OF THE PECQ



1.1.3 - BACKGROUND

The City's environmental and energy achievements

The city of Barcelona has traditionally been a driving force of initiatives to incorporate environmental issues into urban planning and management and to move forward in the application of the principles and values of a culture of sustainability to municipal policies. This strategy is also evident in terms of energy savings and in the efficient use of energy, and also in the promotion of sources of renewable energy.

After signing the Charter of European Cities & Towns Towards Sustainability (the Aalborg Charter) during the First European Conference on Sustainable Cities and Towns in 1994, Barcelona set up the Commission on Environmental and Sustainability Policy, in 1995, to provide impetus to the process of preparing an Agenda 21 for Barcelona. Three years later, in 1988, the Municipal Council for the Environment and Sustainability was set up and was put in charge of promoting Agenda 21 by means of a participatory forum with the sectors and public and private organisations involved.

Under the Council, in 1999, 13 working groups were set up to prepare reflections and proposals on a set of key issues in the area of the City's sustainability strategy: energy, water, waste, urban areas, education, participation, mobility, economic activity, solidarity and the global impact of Barcelona's urban system.

Subsequently, on 21 May 2002, the Municipal Council for the Environment and Sustainability approved the text of the City Commitment to Sustainability - Agenda 21 in Barcelona. This text was the result of more than three years' work by the Council - and the contributions of hundreds of organisations and people - to define and reach a consensus on ten objectives for the 2002-2012 period. Each of the objectives contained 10 lines of action (100 in total) that covered all aspects of urban life as well as their impact beyond the city limits. Objective number five incorporated lines of action regarding the situation concerning energy in Barcelona.

During the same period, the Municipal Action Plan 2000-2003 was presented. The Plan set down a set of initiatives and proposals aimed at improving environmental quality in the city and introducing a model based on a new energy culture: developing public transport infrastructures, creating green spaces, promoting more sustainable urban design and construction models, promoting clean energy and reducing the energy consumption of municipal buildings, etc.

In the specific area of energy actions, in July 1999 the Solar Thermal Ordinance was passed, coming into force a year later.

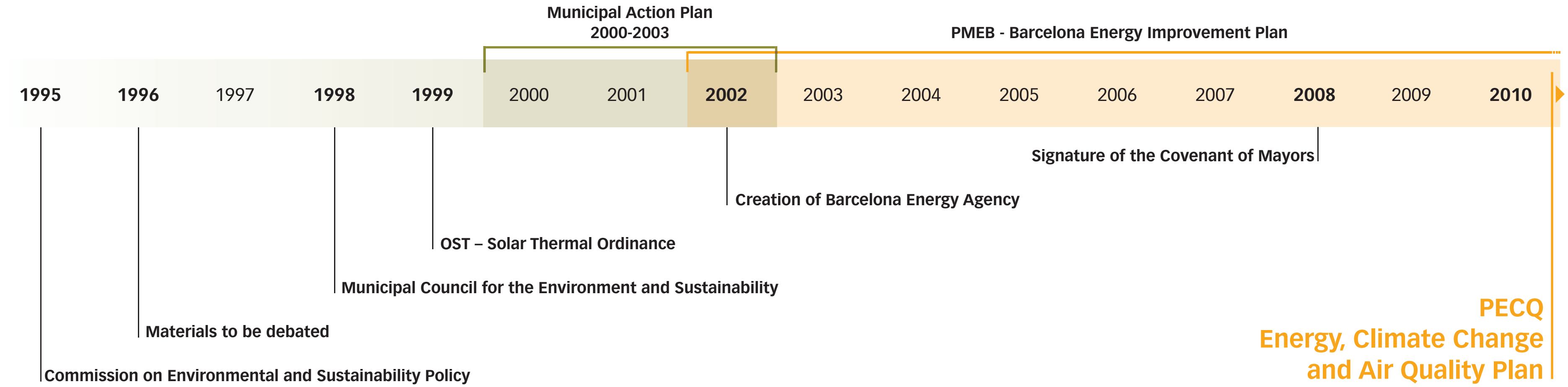
In 2002, the Plenary Council approved the Barcelona Energy Improvement Plan 2002-2010 (PMEB) - a strategic document at municipal level consisting of an analysis covering energy, and emissions of polluting gases and greenhouse gases. The PMEB also contained an action plan with proposals and measures (54 projects, or action units, and 5 complementary projects) to make progress in improving energy efficiency, reducing gas emissions and promoting sources of renewable energy.

In 1996, Barna GEL was set up. Under the umbrella of the European Commission's SAVE programme, it started to carry out the tasks of a local energy agency for the city. In 2002, the Barcelona Energy Agency (as it is known today) was set up as a municipal instrument to carry out measures contained in the PMEB by means of the execution of energy infrastructure projects or renewable energy facilities and also by defining policies covering information, dissemination and raising social awareness with regard to the rational use of energy. The Agency was also set up to monitor energy consumption and gas emissions in the city as a tool to control and monitor the development and impact of the projects carried out.

In 2008, Barcelona signed the European Union's Covenant of Mayors - an initiative promoted in 2007 to contribute to the reduction of greenhouse gas emissions. This was part of a package of Energy for a changing world measures taken by the European Commission aimed at unilaterally reducing CO_2 emissions by 20% by 2020, increasing energy efficiency by 20% and ensuring that 20% of energy comes from renewable sources.

The Covenant of Mayors aims to bring this challenge down to a local level with the active participation of the general public and proposes reducing emissions from signatory cities by 20% (against a base year) by 2020. The Covenant was the result of an informal consultation process between a large number of European cities and is open to all cities, irrespective of their size. This document is a response to that commitment.

FIGURE 6 | THE PECQ - BACKGROUND



Implementation of the PMEB, 2001-2010

According to a monitoring report on the PMEB in 2010, the overall project implementation status (calculated as the average implementation percentage) was 71%. There were 33 finished projects (56%) and 19 were underway (32%). It was not possible to start 7 (12%) of the projects. With regard to evaluable projects[1] (27), some 65% were implemented, whilst the figure for instrumental projects[2] (32), was 76%.

In terms of sectors, those that had the highest degree of implementation were, in descending order: Others, Distribution networks, and Transport. By contrast, those with the lowest degree of implementation were Residential, Offices, and Services and Commercial. At a medium level of implementation were Public buildings and equipment, and General. For programmes, in descending order: Education, Information and communication, Renewable Energy, and Management. By contrast, those with the lowest degree of implementation were Energy efficiency, and, considerably lower down, Consumption savings. In the middle was Regulatory review.

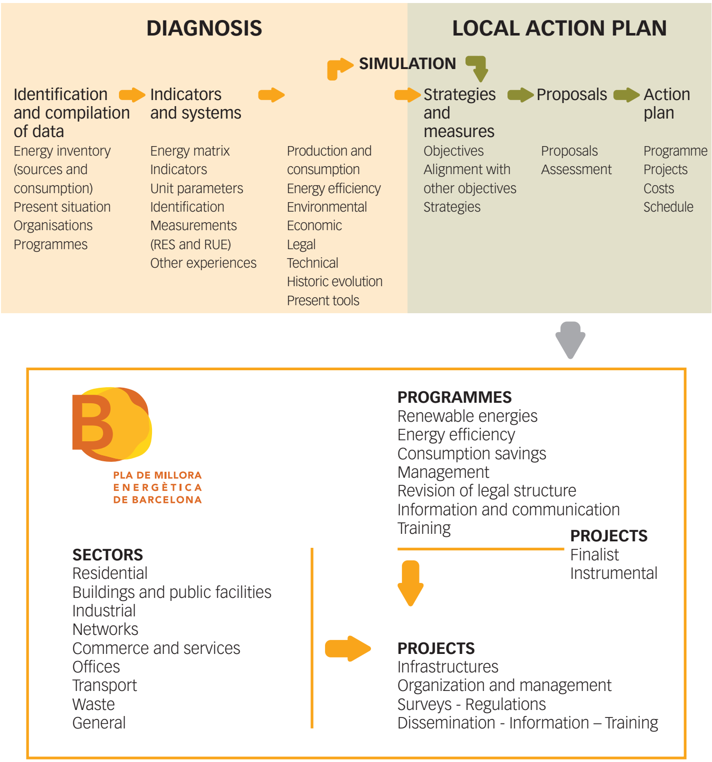
Overall, the following conclusions can be drawn:

- The degree of development of the projects was not uniform.
- The evaluation of progress in some projects cannot only be quantitative (based on the percentage of implementation) - it also needs to be qualitative.
- The collaboration with socioeconomic partners and with the city's energy sector has been positive, although this still needs to be developed further.
- Efforts need to be stepped up in the public infrastructure sector and also in instrumental projects by means of actions such as studies and regulations.
- The collection of statistical information needs to improve in order to have a more complete database that allows for indicators to be developed.
- A process of reflection is required to look at the difficulties of carrying out projects where co-generation is the main technology.
- In the future, projects need to be promoted related to savings, energy efficiency and legislation in the residential and services sector.

1. Evaluable projects are projects that can be evaluated directly in terms of energy savings or polluting gas emissions.

2. Instrumental projects: tools for the development of other projects. Instrumental projects are difficult to quantify directly.

FIGURE 7 | PHASES AND PROJECTS OF THE PMEB (2001-2010)



In terms of energy savings, carrying out the projects in the PMEB were estimated to involve the annual generation of 148,731 MWh of electricity with yearly energy savings of 779,876 MWh. To date, it is estimated that approximately 80,000 MWh have been generated and more than 428,000 MWh saved as a direct result of applying the projects.

In terms of conclusions for the future, the monitoring report proposes the following:

- The need to differentiate municipal actions (the responsibility of, and are carried out directly by, Barcelona City Council) from city actions (general aspects related to the Council's management and the conduct of, and actions taken by, the general public as a whole).
- The need to prioritise the management of demand in the overall approach to energy, as well strategic lines, actions and projects in the new energy plan. The Council, as the closest public administration to the general public, needs to be involved in raising awareness amongst the population, and to enable knowledge to be turned into action.
- The new Plan needs to be less analytical and much more executive.
- It is important to work with the largest possible number of actors involved - at municipal level, any other actions and plans being promoted in other areas or sectors of the Council need to be taken into account.
- The generation of renewable energies, savings and energy efficiency must continue to be the main foundations of both the Plan and the city's energy policy.

1.1.4 - METHODOLOGY

The PECQ continues the methodology applied in developing Barcelona's first energy improvement plan (PMEB) covering 2002-2010. The starting point has been the knowledge base and data that have been updated over recent years and that have been published in successive documents entitled El Comptador (The Counter) by the Barcelona Energy Agency via the Energy Observatory.

As was the case with the process of conceptualising the PMEB, the PECQ received technical support from different sectoral working groups (details are given later in this document), which have contributed a cross-cutting vision that has enriched the project. Various meetings were also held with interest groups that contributed with their opinions, reflections and suggestions. The PECQ, however, extends and improves the diagnostic work carried out during the preparation of the PMEB with new aspects and themes, and also updates specific emission and energy efficiency factors. Noteworthy amongst these changes and improvements are:

- The study of air quality in Barcelona, modelling the dispersion of pollutants and detecting their origin.
- The categorisation of vehicles that drive around the city and their pollutant emission levels.
- An analysis of social attitudes towards energy use.
- An economic analysis that may derive from executing the Plan from the perspective of new business opportunities, new jobs, etc.
- A study of the economic and environmental effects of the Port and Airport on the city.
- An updating of the emission factors of different pollutants in accordance with internationally applied methodologies.
- An analysis of industrial energy performance.
- A detailed study of the public buildings and facilities sector.
- A study of safety in the supply of energy.
- Preparation of an environmental report.

During the preparation of the PECQ, a series of instruments were applied that facilitated an in-depth study of energy performance of different sectors, as well as the integration of all the results of the sectoral analyses into a single tool. The key applications were as follows:

- **Geographic Information System (SIG):** a tool that makes it possible to link large databases with territorial coordinates to produce geo-referenced databases that can represent maps or conduct territorial analysis.
- **Pollutant dispersion model:** this makes it possible to analyse air quality based on an emissions inventory by means of pollutant dispersion modelling and chemical reactions that may be generated in the field of study.
- **Overall analysis model of the city:** this makes it possible carry out an overall analysis of the city and of the typologies that comprise it from the perspective of energy and greenhouse gases.
- **Classification tool for projects and grouping scenarios:** this tool classifies, orders and groups the Plan's projects according to different criteria so as to define scenarios, make decisions about prioritising, visualise the environmental effects (be they positive or counter-productive) of the measures, and to model the applications of the projects over time.
- **Thermal simulation model for buildings:** a dynamic analysis of thermal demand and consumption of buildings that makes it possible - by means of building typologies that were originally defined in the PMEB and that represent the construction typologies that exist in Barcelona - to model energy consumption when certain measures are applied to buildings.
- **Economic model:** this allows for simulations of economic forecasts for Barcelona.
- **A tool for detecting and analysing vehicles that drive around the city:** categorises vehicles, according to technical and environmental criteria, that drive around the city using a system that reads registration plates and detects emissions from the vehicle's exhaust.

1.1.5 - THE PARTICIPATION PROCESS

The approach taken in the sessions

From the conceptualisation of the PECQ, it was considered that the participation of the general public, partners and sectors related to energy matters was of paramount importance. Thus, in 2008, a number of working sessions were proposed to define what the new Plan needed to cover. These areas set the course that led to the development of the Plan.

FIGURE 8 | **PARTICIPATORY SESSIONS CARRIED OUT**

So that the final version of the PECQ would also incorporate the points of view, suggestions, sensitivities and proposals from different partners and sectors associated with environmental and energy realities in the city, a participatory process was conducted during 2010 consisting of a number of sessions to present the results of the Plan and to gather together the contributions of the partners involved.

The working sessions were organised in two phases: a city working session, held in June, and a municipal working session, in October. The city working session involved eight sectoral working groups organised over one or two sessions, depending on the subject matter covered:

- G1 – Managing energy demand and performance.
- G2 – Energetic rehabilitation of buildings.
- G3 - Managing the quality of the energy supply.
- G4 – Renewable-energy generation and special schemes.
- G5 - Transport and energy.
- G6 – Climate change and air quality.
- G7 – Economic and legal analysis.
- G8 - Industry.
- Final joint session.

During the participatory sessions, participants' comments, contributions and suggestions were collected into two documents (the Final Report of the sessions and the Communication Report), which were used to define the PECQ's project proposals. Participants were invited depending on which issues were being discussed, although they were given the option of attending all the groups. A total of 268 people attended the meetings held at the Agenda 21 secretary's office.

Six web forums were organised for the online sessions. At each web forum, the strategic lines and action projects were presented, along with the proposals submitted by the participants at the face-to-face sessions. The nature of the forum was such that any visitor could see, in real time, the comments and stance of the other participants.

Alongside the sessions for individuals and organisations involved in the city, a municipal-level session was also held that was restricted to council administration bodies. A total of 86 people were invited.

FIGURE 9 | NUMBER OF PARTICIPANTS IN THE CITY WORKING GROUPS

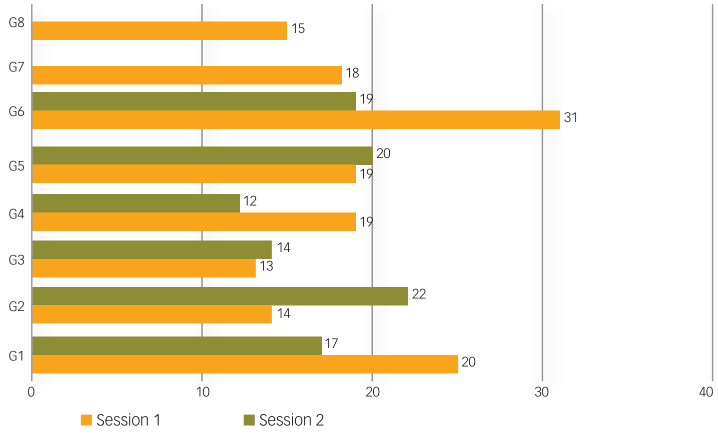
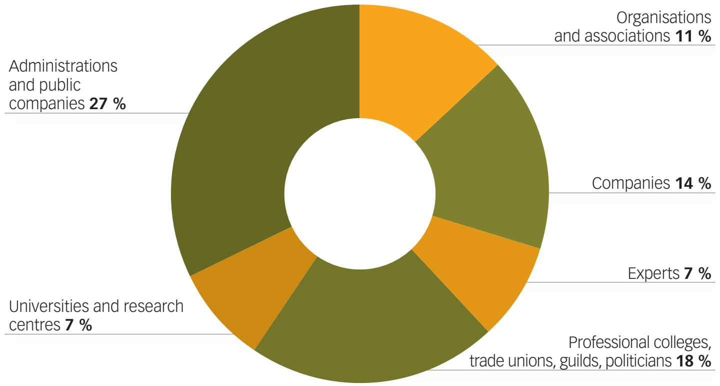


FIGURE 10 | SECTORS TO WHICH THEY BELONG



ORGANISATIONS INVITED TO THE MUNICIPAL SESSION

Districts

Public enterprises:

- Agència del Carmel
- BAGURSA
- Barcelona Regional
- BIMSA Barcelona Infraestructures Municipals
- BSM Barcelona Serveis Municipals
- Consorci Educació Barcelona CEB-IMEB
- Foment de Ciutat vella
- IBE - Institut Barcelona Esports
- ICUB- Institut de Cultura de Barcelona
- Institut Municipal de Mercats
- Pro-EIXAMPLE
- SPM Pro-Nou Barris sa PRONOVA

Departments and Municipal Sectors:

- Department of Social Action and Citizenship
- Department of Energy and Environmental Quality Services – Area of the Environment
- Department of Investment Services and Green Spaces – Area of the Environment
- Department of Water Cycle Services – Area of the Environment
- Department of Knowledge Management Services – Area of the Environment
- Department of Environmental Education Services – Area of the Environment
- Department of Waste Management and Cleaning Services – Area of the Environment
- Department of Prevention, Safety and Mobility
- Department of General Services and Territorial Coordination, Area of Human Resources and Organisation, Area of Education, Culture and Welfare
- Fire Prevention and Extinction and Safety Services
- Network of Energy Managers of the Energy Savings and Improvement Plan for Municipal Buildings

Conclusions of the process

The main conclusions of the final session of the process (at city level) were as follows:

1. **Ensure that local pollution is classified as a public health problem.**
   The direct relationship between air pollution and health is well known. Efforts are required to discover the local reality and to know how to adapt behaviour to that reality.
2. **Demonstrate the supra-environmental benefits of specific energy savings and renewable-energy installations.**
   In addition to the environmental benefits, renewable-energy installations have associated economic and social benefits in the form of savings and new jobs, as well as in terms of energy generation and a reduction in monopolistic tendencies, etc.
3. **Share reduction commitments with the general public (shared responsibility).**
   It will be impossible to meet sustainability objectives without the commitment of the public, i.e. with just political support. It is not a question of placing the responsibility on the general public but, rather, of emphasising the importance of their role whilst highlighting the responsibility taken on by other sectors that have, in the past, shown low levels of commitment.
4. **Publish periodic energy data and environmental indicators in order to raise awareness of the problem (right to information).**
   In general, there is a lack of information about energy consumption except for fuel economy data relating to vehicles. The standardisation of energy information will mean energy will be another variable when making decisions, as is the case with cars (miles per gallon) and refrigerators (simple information involving classification by letter). This energy education will become more important as the price of energy increases.
5. **Reinforce certain messages related to energy efficiency and renewable energies using the main communication tools.**
   Make use of the mainstream media to promote discussion about energy efficiency and renewable energy to reinforce the message.
6. **Place the emphasis on explaining the financial savings and that the maintenance of solar installations is an act of responsibility.**
   Lack of information leads to poor functioning of solar thermal installations. Experience has shown that simply providing information can lead to a user taking ownership of a system, discovering the benefits and deciding to carry out maintenance work.
7. **Provide examples of public installations and examples from the tertiary sector.**
   The third sector has a power to set an example to the public and must, therefore, be required to demonstrate the same awareness demanded of the public. The public administration, on the other hand, needs to be the first to stimulate this kind of behaviour.
8. **Set up a one-stop-shop for licences and permits.**
   For both construction projects and renewable-energy installations, simplifying administrative procedures via a single point of contact would reduce the associated costs of such procedures, which often have the effect of halting the project. In the case of renovations, simplifying procedures could avoid using unqualified personnel and be beneficial to well-qualified professionals, thus creating a communications space with the customer that produces the most efficient solutions.
9. **Positively incentivise good practices rather than apply penalties.**
   A policy of subsidies may encourage the public and property owners to opt for the best available solutions. Prioritise tax breaks as opposed to offering direct grants.

FIGURE 11 | DEGREE OF APPRAISAL OF THE PARTICIPATIVE PROCESS

▲ If the colour green indicates a good evaluation and yellow a good evaluation but with reservations, a high evaluation of the 12 items that participants were able to evaluate during the sessions was observed. The least-well evaluated item (referring to the interest aroused by the session objectives) received a 70% acceptance (between green and yellow)

With regard to the municipal session, the key aspects to come out were as follows:

- All the sectors were aware of the problems associated with the energy issue, although they cited a lack of both technological and instructive information that prevents them from exploiting their willingness to act.
- In general, the lack of benchmark information when it comes to energy issues generates dispersed data and complicates the gathering and processing of data.
- When designing new buildings, it is essential to take into consideration its future use so as not to oversize or undersize the systems.
- Audits and energy consumption checks are also needed, in particular in the case of buildings.
- In the case of vehicle fleets, there is considerable confusion about the environmental benefits/drawbacks of the various engine types. This means that those in charge of acquiring new vehicles are not in possession of all the necessary information in order to add environmental criteria to the purchase.

In general, all those who took part stressed the importance that this should be a plan for the whole Council, indeed, for the whole city, rather than just for the Department of the Environment.

1.2 - The context

1.2.1 - ENERGY AND CLIMATE CHANGE

Cities and climate change[3]

Cities are part of the problem of climate change insofar as they account for a significant proportion of emissions and energy consumption throughout the world. For this reason, they are a key part of the solution. The impacts of climate change are also felt in the cities. Generally speaking, city infrastructures are at risk given rising sea levels, fluctuations in the supply of drinking water and sea storms, whilst the population is subject to the combined effect of increasing global temperatures, the heat island effect, the consequent reduction in air quality, and heat waves.

In this context, cities, like regions and countries, essentially need to act on two fronts: mitigation and adaptation. The actions taken by local authorities are very important to manage climate change at both a local level (in that they improve the lives of the population), and at a global level, given that more than 60% of the world's population live in urban environments. In the European Union, 74% of the population live in urban areas, which account for 75% of energy consumption.

The importance of the issue can be seen in the number of international initiatives – for example, with regard to energy, the Covenant of Mayors within the European Union (which involves commitments to monitor emissions), a 20% reduction in emissions, and the International Council for Local Environmental Initiatives (ICLEI), an organisation made up of a large number of cities and regions throughout the world with the aim of working at local level to tackle sustainability issues, and that has a particularly active role in energy management and climate change.

Cities and their metropolitan areas constitute a strong link between town planning, the use of energy and GHGs. Urban density and spatial organisation are key factors that influence energy consumption, in particular in the areas of transport and buildings. Over the second half of the 20th century, and, in particular, over the last 20 years, the Barcelona Metropolitan Area has experienced significant urban and economic transformation that has, on the one hand, led to a larger urban area with new districts, and, on the other, a process of urban dispersion.

These two phenomena affect, in different ways, the conduct of the city with regard to climate change. However, in the cities, and, in Barcelona in particular, on account of its size and influence, these factors must be taken into account when managing climate change.

3. Josep Enric Llebot. Professor of Condensed Matter Physics, Department of Physics at the Autonomous University of Barcelona, and coordinator of the reports on Climate Change in Catalonia.

GREENHOUSE GASES

Carbon dioxide (CO_2) is the main greenhouse gas on account of its high level of concentration and is responsible for 55% of climate change. It can be produced during the complete combustion of hydrocarbons, during the oxidation of CO, or during the incomplete combustion of volatile organic compounds (VOCs). Vegetation absorbs CO_2 as a result of photosynthesis.

The potential of **methane** (CH_4) to heat the atmosphere is 25 times greater than that of CO_2; however, it is easier to reduce CH_4 emissions, given its shorter atmospheric lifetime (12 years). It also has the advantage that it can be used as a source of alternative energy and can be obtained, in particular, from controlled landfill, where it is produced during the breakdown of organic waste. Emissions of methane from transportation are, however, insignificant.

Nitrous oxide (N_2O) is the third of the main greenhouse gases. Whilst its concentration in the atmosphere is low, its global warming potential is 298 times that of CO_2.

Fluorohydrocarbons (HCFCs), **perfluorocarbons** (PFCs) and sulphur hexafluoride (SF_6) can also contribute to the greenhouse effect, although to a much lesser degree.

Temperature changes and precipitation in Barcelona

The warming of the atmosphere caused by the concentration of greenhouse gases in the atmosphere is a fact that is beyond doubt. The concentration of greenhouse gases in the atmosphere, especially CO_2, is increasing everywhere. The use of isotopic analysis confirms that a large part of this increase is due to human activity, in particular the use of fossil fuels. At a local level, measuring the environmental effects of this increase can be done from a number of different perspectives, although the most basic approach involves measuring changes in temperature and precipitation. In the Mediterranean area - and, therefore, in the Barcelona Metropolitan Area - it is also important to monitor extreme phenomena. Therefore, we will also conduct an analysis of what follows.

The results of the data series from the Fabra Observatory show that annual mean temperature has increased significantly from 1950 to today. The same analysis, although now applied to the annual mean of maximum and minimum temperatures, indicates that, during recent years, the trend of increasing temperatures is more apparent with regard to the maximum temperature than with the minimum. Seasonal analysis indicates that summer has experienced the most pronounced increase, whilst autumn is the only time of year that does not show a statistically significant trend.

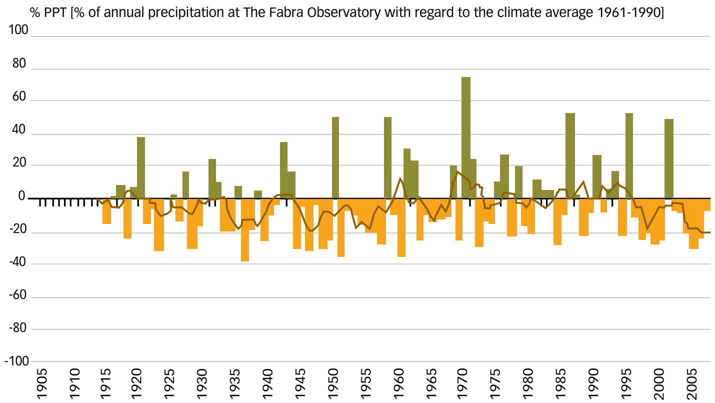
TABLE 1 | CHANGES IN TEMPERATURE AT THE FABRA OBSERVATORY IN BARCELONA EXPRESSED AS AN INCREASE PER DECADE

TEMPERATURE	MEAN	MAXIMUM	MINIMUM
Increase ºC	0,21	0,24	0,22

Source: Informació extreta de Martín-Vide 2010

The precipitation trend in Catalonia, in particular in Barcelona, does not show such a defined pattern as that relating to temperature, given the high seasonal variability. An analysis of annual and seasonal rainfall at the Fabra Observatory does not, for this reason, show a clear trend over the last century. Thus, any increases in rainfall, or low levels of rainfall, are not statistically significant and no conclusive trend can be observed. Nevertheless, measurements have been made that, in common with other observatories, would appear to indicate changes over the medium term: a slight increase in autumn and winter precipitation with lower precipitation in the summer.

FIGURE 12 | CHANGES IN ANNUAL PRECIPITATION ANOMALIES IN BARCELONA (1914-2008))



▲ The blue bars indicate positive percentages, i.e. years with abundant rainfall, whilst the orange bars represent dry years. The unbroken black curve shows the five-year moving average (taken from Martín Vide 2010 and the Meteorological Service of Catalonia. Annual Bulletin of Climate Indicators, 2008).

Climate projections for temperature changes and precipitation

- AT A CONTINENTAL LEVEL: THE MEDITERRANEAN REGION

The second report on climate change in Catalonia (Calbó et al. 2010) presents information about climate projections for the region classified as Europe and the Mediterranean. This area corresponds to the area defined as lying between the 30ºN and 75ºN parallels and the 10ºW and 40ºE meridians, sufficiently representative of what could take place in Catalonia.

As simulations depend on future emissions, a range of different scenarios have been designed at international level that aim to cover all future eventualities concerning demographic, economic and technological changes. The results that follow correspond to one of the intermediate scenarios with regard to changing emissions projections and the results relate to the end of the century (2080-2099).

- TEMPERATURE

According to the fourth Intergovernmental Panel on Climate Change (IPCC) report, for the area that includes Barcelona, the average temperature increase at the end of the century is expected to be 3.5ºC [3.0-4.0] - the first value is the mean, whilst the range in square brackets corresponds to the 25th and 75th percentiles.

The increase will be more pronounced in the summer (4.1ºC [3.7-5.0]) than in the winter (2.6ºC [2.5-3.3]). The analysis indicates that all the years at the end of the century – and most seasons—will be considered *"very warm"* compared with today's climate.

TABLE 2 | SUMMARY OF THE PROJECTIONS OF 21 MODELS FOR THE MEDITERRANEAN REGION, SCENARIO A1B TAKEN FROM THE FOURTH IPCC REPORT. DIFFERENCES IN TEMPERATURE (ºC) BETWEEN 2080-2099 AND 1980-1999

MONTHS	MIN	50TH PERCENTILE	MAX
December/January/February	1,7	2,6	4,6
March/April/May	2,0	3,2	4,5
June/July/August	2,7	4,1	6,5
September/October/November	2,3	3,3	5,2
Annual	2,2	3,5	5,1

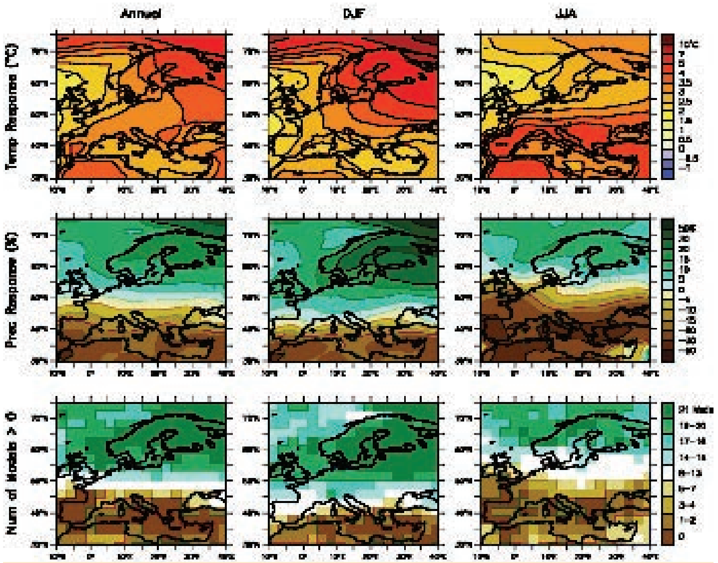
Source: Calbó et al. (2010)

To explain the spatial variability of these changes in temperature and precipitation, a number of maps of the Europe/Mediterranean region (see Figure 13) have been developed using the results of the global models used in the IPCC report. Maps are also given for the end of the century (2080-2099) compared with the end of the last century (1980-1999) and they are calculated as the mean of the variations given for all the models that were prepared. They are also given per annum and for the summer months (June, July and August) as well as for the winter months (December, January and February).

From an analysis of these maps, the following conclusions can be drawn:

- With regard to temperature, we can see that the average annual temperature for the Iberian Peninsula may increase by between 2.5ºC and a little over 3.5ºC. This is an estimate equivalent to that done for the whole of the globe and less than that for the rest of Europe.
- All of Catalonia lies within the line marking an increase of between 2.5ºC and 3ºC.
- On a seasonal basis, the situation is very differentiated. In winter, the pattern resembles that for the whole year, with increases in the Iberian Peninsula (and, in the Mediterranean in general) lower (2.5ºC) than those for north-eastern Europe. However, in summer, temperature increases for the Mediterranean area will clearly be higher than those in the rest of the continent, reaching values in excess of 4ºC in most of the Iberian Peninsula.

FIGURE 13 | CHANGES IN TEMPERATURE (TOP) AND PRECIPITATION (MIDDLE) IN EUROPE USING SIMULATIONS FROM 21 GLOBAL MODELS FOR THE A1B SCENARIO



▲ Differences between 2080-2099 and 1980-1999. From left to right, by annual mean, in winter and summer. Below, an evaluation of the uncertainty in projecting changes in precipitation, indicating the number of models that predict increases (Calbó et al., 2010).

- PRECIPITATION

The Mediterranean is one of the few regions in the world where estimates of overall lower precipitation (and also lower throughout all seasons of the year) are unanimous amongst the majority of global models. Using the projections drawn up to date, the following can be seen:

- Reductions in mean annual precipitation of 12% can be expected for the Mediterranean area.
- The decrease will be more pronounced in the summer (24%) than in winter (6%).
- Compared with today's climate, at the end of the century, almost half of the number of years would be considered as *"very dry"*.
- Situations that correspond to high rainfall in today's climate will be very rare.
- Around the year 2040, precipitation could fall by between 4% and 8%.
- The maps shown in Figure 12 reveal a marked latitudinal gradient in the area studied. In Catalonia, and, therefore, in Barcelona, precipitation is predicted to reduce by between 10% and 15% on an annual basis.
- In summer, the reduction in precipitation will be even more pronounced in the Iberian Peninsula (more than 30%, possibly as high as 50%).
- In winter, a large part of the Peninsula would come within an area of little change (0%-5%).
- There is a lack of homogeneity in the robustness of the precipitation projections. Most models agree that there will be lower precipitation in southern Europe, including the Iberian Peninsula. On the other hand, when it comes to winter, there are approximately the same number of models that predict lower rainfall as there are models that predict an increase: thus, with regard to winter, we can say that results are uncertain, or that the predicted changes are less significant.

TABLE 3 | CHANGES IN PRECIPITATION: SCENARIO A1B FOR THE MEDITERRANEAN AREA. PERCENTAGE DIFFERENCES IN PRECIPITATION BETWEEN 2080-2099 AND 1980-1999

MONTHS	MÍN	50TH PERCENTILE	MAX	WET SEASONS (%)	DRY SEASONS (%)
December/January/February	-16	-6	6	3	12
March/April/May	-24	-16	-2	1	31
June/July/August	-53	-24	-3	1	42
September/October/November	-29	-12	-2	1	21
Annual	**-27**	**-12**	**-4**	**0**	**46**

Summary of the projections from the 21 IPCC models (Calbó et al., 2010).

- OTHER BIOPHYSICAL SYSTEM VARIABLES OF INTEREST

Indicators of trends in climate extremes

The effects of climate change at a regional level cannot only be considered by an analysis of any trends observed in temperature or mean precipitation; they must also be considered in the light of verified changes in the frequency and intensity of different climatic extremes.

- The indicators show that, in Barcelona, there has been a reduction in the frequency and duration of cold periods and an increase in the frequency, intensity and duration of hot periods. With regard to precipitation, a slight increase in intensity has been observed.
- There is a significant positive trend in the number of days with precipitation measuring less than 10 mm between 1854 and 2005.
- No increase in the number of days with heavy rain has been detected.

TABLE 4 | CLIMATE INDICES APPLIED TO DAILY DATA TAKEN AT THE FABRA OBSERVATORY IN BARCELONA (1914-2008)

INDEX	FABRA OBSERVATORY
Frost day	Reduction
Summer's day	Increase
Tropical night	Increase
Length of growing season	Increase
Maximum annual maximum temperature	Increase
Maximum annual minimum temperature	Increase
Minimum annual maximum temperature	Increase
Minimum annual minimum temperature	Increase
Cold night	Reduction
Cold day	Reduction
Warm night	Increase
Warm day	Increase
Duration of hot spell	Increase
Duration of cold spell	Reduction
Annual temperature range	Increase
Simple index of precipitation intensity	Increase
Number of days with precipitation of >20 mm	---

▲ Only those indices that are statistically significant are shown. Meteorological Service of Catalonia. Annual Bulletin of Climate Indicators, 2008

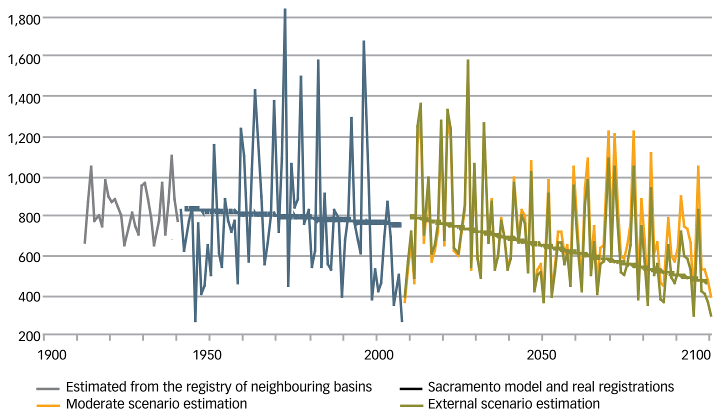
Droughts and water resources

In addition to the temperature and precipitation projections, an important element for the Metropolitan Area of Barcelona is the provision of water. Although this depends, to a large degree, on rainfall, it also depends on other factors related to the foreseeable increase in evapotranspiration and the increase in wooded areas at river headwaters.

A recent study on the supply of water showed the likely trend in annual contributions to the network of reservoirs connected to the Ter and Llobregat rivers (which supply the Barcelona Metropolitan Area) throughout the 21st century and compared with what was observed during the 20th century.

A downward trend appears likely, in particular during the second half of the 21st century. Naturally, this conclusion does not mean that the contribution of the rivers will be inferior every year, rather, that towards the middle of the 21st century, annual contributions will have a tendency to be lower than they were during the end of the 20th century, following a trend that cannot be ignored.

FIGURE 14 | HISTORIC CHANGES IN THE ANNUAL CONTRIBUTIONS TO RESERVOIRS SERVED BY THE TER AND LLOBREGAT RIVERS AND POSSIBLE CHANGES DURING THE 21ST CENTURY



Source: Manzano 2009

Heavy rain and flooding

Generally speaking, the risk of downpours and floods in Catalonia is along the coast, which means the Barcelona Metropolitan Area is also affected. From the climate indices calculated by the Meteorological Service of Catalonia in reference to the Fabra Observatory, the change in the maximum value for daily precipitation shows a positive, although statistically insignificant, trend. The maximum annual precipitation registered over 5 consecutive days was positive, although not significant, neither was the positive trend in the number of days in which rainfall exceeded 50 mm or days with very abundant precipitation, or the trend in total accumulated rainfall on days when daily rainfall exceeded the 95th percentile (very rainy days) and the 99th percentile (extremely rainy days).

Total annual precipitation divided by the number of days with more than 1 mm of rainfall, or the Simple Index of Daily Intensity, is the only index related to heavy rainfall that shows a positive trend that is statistically significant. Nevertheless, given that other indices relating to extreme precipitations have not shown, to date, any trend, it cannot be concluded that there is an increase in intense precipitations. Therefore, it cannot be stated that there is an increased risk of catastrophic flooding, given that such events are directly associated with climatic variations.

Strong winds

Traditionally, strong winds are meteorological events that result in more reports by the meteorological services on account of their repercussions in terms of damage and insurance claims. In Barcelona, they are also important because of how they are related to sea storms and how they affect the whole coast (beaches, etc.). Recently, more attention has also been paid to tornadoes, a phenomenon that has been well-known for many years in Catalonia, as can be seen in the number of names given to these spectacular meteorological events: bufaruts (strong wind), mànegues (whirlwinds), esclafits (cracks), tornados (tornadoes), fiblons (stings) and cap de fibló (water tornado). No predictions have been made about such atmospheric phenomena, although, from a purely speculative and qualitative point of view, it could be thought that an increase in air and sea temperature may lead to a greater frequency of tornadoes and wind storms.

With regard to sea storms, the more vigorous waves near Barcelona come from the east, corresponding to a wind run that creates the longest waves. Along the Catalan coast (and it would be logical to presume the same applies to the Barcelona coastline), there has been a trend towards a slight reduction in the number of severe storms, whilst there has been a slight increase in the number of moderate storms. The average duration of moderate storms, on the other hand, has remained constant, whilst severe storms are tending to last longer. Such trends are not statistically significant because they are linked to the fact that the sea level along the Barcelona coast has hardly changed over the last 16 years (Sánchez-Arcilla 2010).

Over the future medium term, no significant physical impacts are expected with regard to wind storms.

Heat waves and high temperatures

Heat waves and high temperatures are risks of an exclusively meteorological origin. They have acquired particular importance because they are linked to climate change. The definition of a heat wave is an event that lasts for at least three consecutive days and nights during which time maximum and minimum temperatures exceed the 90th-95th percentile for the values for the period from June to September. Although it may appear more likely that heat waves are more common inland, particularly taking into account that they are also associated with low humidity, in the Barcelona Metropolitan Area and in inhabited coastal areas in general, it is important not to underestimate the effect of such meteorological events, which can cause health problems - in particular for those at risk - when the humidity factor (and, thus, a stifling temperature) is added.

An analysis of maximum temperatures can be carried out using indices associated with and calculated using the data series from the Fabra Observatory in Barcelona (since 1913). Climate indices for the following indicate a statistically significant increase in heat waves: the number of summer days (maximum temperature 25ºC and above), the number of tropical nights (minimum temperature 20ºC and above), the maximum values for daily maximum temperatures and daily minimum temperatures, the percentage of days where the maximum and minimum are above the

90th percentile, the number of days in a year when there are at least 6 consecutive days where the maximum is above the 90th percentile, and the annual temperature range.

All the scenarios and models predict a future of high temperatures and heat waves. Furthermore, if we take into consideration that the heat island effect has an influence on this risk, we can see that this is one of the future risks relating to the impact of climate change that has an impact on the health of the population.

Quality of life and climate change

Cities consume most of the energy in the world and are, globally, the major source of greenhouse gas emissions. Actions at local level that could be carried out to tackle climate change can be classified in four categories:

- The city, as a consumer of energy in public buildings and in the facilities it manages, can set objectives and make commitments with regard to efficiency.
- The city, as a provider of services, has an influence on the development of infrastructures and needs to provide efficient services, whilst also taking into account climate change (transport, water, etc.).
- Given that the city regulates and prices its activities, this must have a bearing on reducing the impact of its activities, on cutting greenhouse gas emissions and on adapting to change.
- The city is the coordinating body in economic environments where it is one of a number of actors and, therefore, can help establish collaboration mechanisms with other sectors.

The contributions to climate change on the part of Barcelona can be classified in three areas, each of which has specific initiatives attached to it.

- Direct emissions of greenhouse gases: these include carbon dioxide, methane, nitrous oxide and halocarbons. The factors that contribute to emissions of these gases are transport, energy generation and conversion, waste and sewage treatment, and refrigeration systems, amongst others.
- Indirect emissions of greenhouse gases: these are caused by the activities of the city and of those who live there. Examples include emissions resulting from generating energy far from the point of consumption (cement, steel and glass production, etc.) that are used in civil infrastructures in the city.
- Changes in local atmospheric chemistry and in the city's surface albedo: an example of such processes is the generation of ozone associated with lighting causing light pollution and nitrous oxide in the city arising from transport and that also have a direct effect on health. The roofs of buildings and urban elements can affect the reflectivity of the city's surfaces (albedo), which has an influence on the heat island effect. The design of urban infrastructure also has an influence on the heat island effect.

Although the impact of cities on the global climate can be described as diverse and complex, greenhouse gas emissions from the continuous increase in energy consumption are the main one. In Barcelona, as in many other cities, emissions increase not so much as a result of industrial activity but as a result of energy consumption associated with lighting, heating/cooling public and private buildings and, above all, transport. Logically, cities are a very important and essential element when it comes to energy policies and, consequently, in reducing emissions.

International agreements

The first worldwide initiative to analyse the influence of human activity on the climate was held in Stockholm in 1972 during the United Nations Conference on the Human Environment. However, the Kyoto Protocol – an international agreement to make advances in reducing greenhouse gases - was not signed until 1997. The Kyoto Protocol was part of the United Nations Framework Convention on Climate Change (UNFCCC), signed at the Earth Summit in Rio de Janeiro in 1992.

The commitment of the Protocol is to reduce emissions by 5% (8% for the EU) compared with 1990 by, at the latest, 2008-2012, when the Protocol expires. Given, however, that the circumstances of each country are different, the specific commitment of Spain during that period is not to increase emissions by more than 15% compared with 1990.

In 2005, the Emissions Trading System came into being in the European Union (via Directive 2003/87/EC). The system establishes a means of trading greenhouse gas emission allowances in the EU with the aim of complying with the obligations derived from the Framework Convention on Climate Change and also from the Kyoto Protocol at European level. The market makes it possible to differentiate, within the emission inventories, emissions from sectors covered by the Directive from those arising from other sectors, known as *"diffuse sectors"* (transport and domestic).

Thus, the Directive makes the following distinction:

- Industrial sectors covered by the Directive: combustion, electricity generation, steel, ceramics, lime, cement, paper, oil refining and glass.
- Other emission sources, organised in the following groups (diffuse sectors): combustion plants of less than 20 MW, extraction and distribution of fuels, use of solvents, transport, waste, agriculture and other sources.

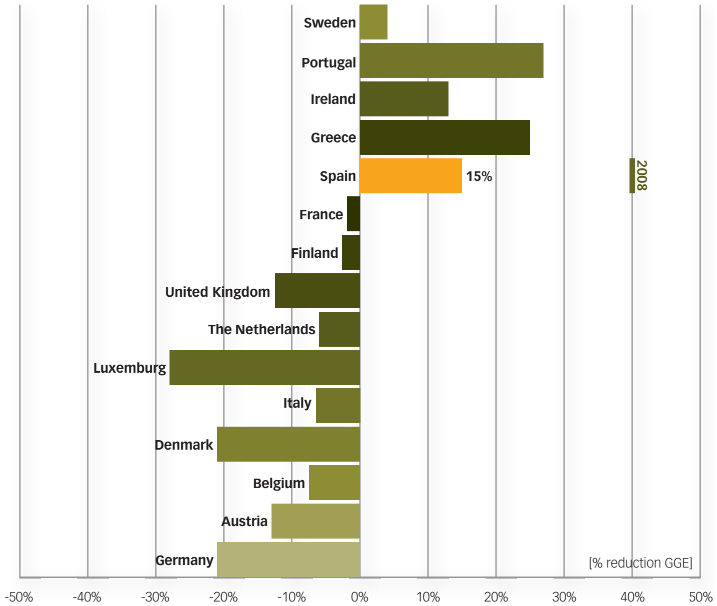
The same year, the members of the UNFCCC met in Montreal (Canada) to establish a working/monitoring group aimed at defining agreements beyond 2012.

In December 2007, in the framework of the 13th Earth Summit in Bali (Indonesia), participating countries re-orientated climate strategy in order to tackle climate change by means of a new, long-term agreement. During the working meetings held in Pozna in December 2008 and Barcelona in November 2009 (BCN Climate Change Talks), a work plan was approved that was supposed to be used to reach a key consensus agreement with new challenges to move towards mitigating climate change.

The process was due to have been completed at the Copenhagen Summit (the 15th Climate Change Conference - COP15). However, despite all the efforts made, no consensus agreement was reached, although it was established that there is a need to create transparent mechanisms with regard to the measurement and inventory of emissions, and reductions pledged by different countries.

The signature of a global agreement that sets new objectives for the post-Kyoto period (2012-2020) remains outstanding. Spain is currently one of the countries that is furthest away from complying with the Protocol, with emissions in 2008 exceeding 40% of their 1990 level.

FIGURE 15 | **REDUCTION COMMITMENTS BY THE DIFFERENT COUNTRIES IN THE EUROPEAN UNION**



National action strategies

With the aim of reducing the impact of the energy system on the climate, work has been carried out over recent years in Europe to improve energy efficiency and diversify energy sources towards systems that are less polluting or renewable. This has been accompanied by raising social awareness of the issues.

Public institutions, be they national, regional or local, play a fundamental role in consolidating a new energy culture (savings, efficiency, renewable energies and diversification). To adopt an efficient environmental and energy policy, the first step is to define the future scenario to be achieved and also to define the mechanisms that will be required to promote the strategy.

In the case of Spain and Catalonia, the following documents have been prepared over recent years to make progress in this line of action:

- **Revised version of the Energy Plan for Catalonia 2006-2015,** which establishes energy policies for Catalonia, the plan for renewable energies and energy supply.
- **The Spanish Climate Change and Clean Energy Strategy 2007-2012-2020,** which sets out the actions required to cut GHGs, establish flexible mechanisms for sustainable development, and boost the rational use of energy and energy efficiency along the lines of the **2008-2012 Action Plan of the Strategy for Energy Saving and Efficiency in Spain.**
- **The National Allocation Plan and the Spanish Strategy for Climate Change and Clean Energy** (Ministry of the Environment, 2007), aimed at reducing emissions in the diffuse sectors (i.e. those outside the scope of the Emissions Trading System Directive).
- **Spanish Strategy for Sustainable Mobility (Ministry of Development, 2008)** - a diagnosis of the transport system in Spain and proposed measures and initiatives to reduce consumption and emissions associated with the sector.
- **Catalan Plan to Mitigate Climate Change, 2008-2012,** which establishes the objective of reducing GHGs in Catalonia by 5.33 m tonnes during that period by means of a set of proposals arising from an intensive participative process.

PRINCIPAL IDEAS ABOUT CITIES AND CLIMATE CHANGE

- **Climate change represents a threat to urban infrastructures and to the quality of life of the population of Barcelona.**
  The impact of environmental changes associated with atmospheric warming - such as rising sea levels, heat waves and the heat island effect, sea storms and wind storms, and, directly, the increase in temperatures – raises the question of quality of life of the population and, in particular, leads to an increased risk of health problems for those population groups most at risk.
- **The way in which the city grows and functions is important with regard to climate change.**
  The use of energy and the energy production mix have an impact on greenhouse gas emissions. Urban density and city planning are key factors that affect energy consumption, in particular with regard to transport and construction. Therefore, projects such as @22 are flagship projects on account of their demonstrative character; but they are also important because of their impact as an absolute value.
- **How the public live in the city is very important with regard to emissions.**
  Emissions depend on lifestyles - i.e. it is not the city or urbanisation that are the sole determinants of greenhouse gas emissions.
- **Where the city's energy comes from is important.**
  The impact of energy consumption on greenhouse gas emissions depends not just on the amount of energy consumed but also on the source of the energy and how it has been generated. Barcelona has important electricity generation structures close to the city - a factor that increases efficiency. The activities of the city's Government related to the generation of renewable energy (especially solar) - something that makes the city an international benchmark – are moving forward in this regard.
- **Local actions must be coordinated with the CO_2 reduction objectives of other administrations.**
  The city's objectives must be coordinated. Therefore, actions must be carried out that are consistent with the emission reduction objectives, which are included in the Catalan Plan to Mitigate Climate Change 2008-2012, set by the Generalitat de Catalunya.
- **It is in the city where compromise between economic growth and environmental priorities needs to find an optimum balance.**
  Besides affecting the health of the population, pollution also affects competitiveness and the appeal of the city. However, more business activity involves higher energy consumption, more transport, and, therefore, more pollution. Barcelona's key infrastructures, such as the Port and Airport, contribute, although by increasing air and transport pollution.
- **Full policy evaluations need to be carried out.**
  Although it is difficult and complicated, an integrated evaluation of the effects of certain policies against climate change needs to be done.
- **Strategic plans for the city need to incorporate contributions and vulnerabilities to climate change.**
  Strategic planning cannot neglect to take into consideration the phenomenon of climate change, that it is, and will be, a factor during the years to come, both in terms of its impact and the repercussions of mitigating actions.
- **Use can be made of the flexibility mechanisms in the Kyoto Protocol.**
  In order to obtain emission reduction credits or sources of financing, it is possible to make use of clean-development mechanisms or joint implementation mechanisms. Barcelona is home to one of the most active companies in the field of emission allowance trading: Sendeco.
- **Barcelona is in a position to collaborate in creating efficient markets, products and services.**
  Municipal purchasing policies for goods and services that incorporate criteria related to managing climate change, integrating environmental objectives into the exploitation and planning of municipal services (for example, transport), and promoting initiatives or setting up *"green"* sector companies, in particular in the field of energy, which could lead to innovation and new jobs.

1.2.2 - ENERGY AND AIR QUALITY

Whilst gases such as CO_2, methane and nitrous oxide have a global environmental impact because they contribute to the greenhouse effect, other compounds have a local effect that mainly affect the health of the population by worsening the quality of the air, particularly in urban areas. These pollutants include nitrogen oxide (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), airborne particles and volatile organic compounds (VOCs). The burning of hydrocarbons such as petrol, particulate matter gas, liquefied petroleum gas, or natural gas, besides producing these compounds, facilitates their reaction between oxygen and nitrogen in the air and the emission of greenhouse gases.

Air quality in Barcelona and the metropolitan area

Air quality in Barcelona has been, since the end of the 1970s, one of the city's main environmental problems, as is the case with the majority of large conurbations throughout the world. Poor-quality air has a direct effect on human health.

The first control points to measure air quality in Barcelona were introduced in the 1980s (Parc de la Ciutadella in 1984 and Jardins Josep Trueta in 1988), mainly to measure the concentration of pollutants derived from the use of fuels such as coal and fuel oil (SO_2). The gasification of the city, combined with improvements in industrial processes and the renovation of electricity power stations has contributed, over recent years, to these fuels being replaced, leading to a decrease of SO_2 in the air.

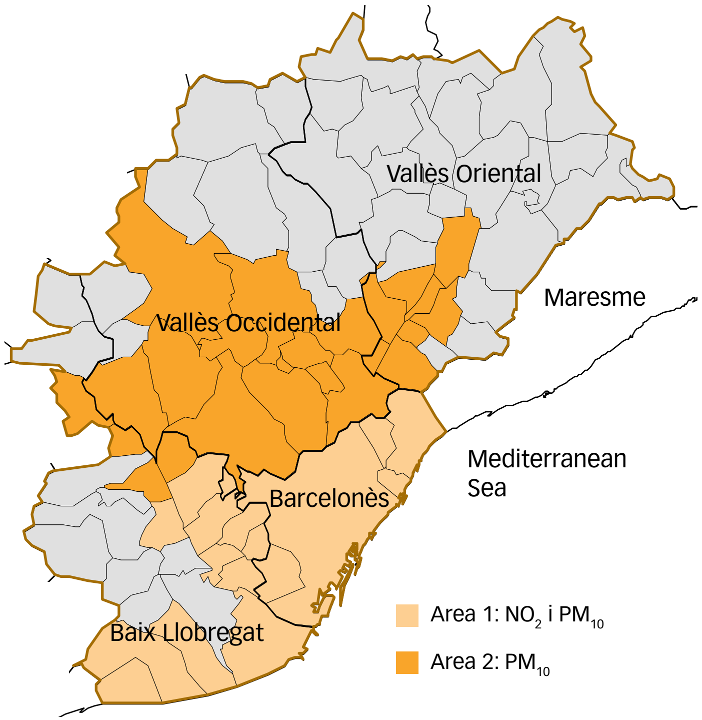
However, one of the main changes experienced by the city over the last 30 years, and that has influenced air quality, has been the increase in the number of private vehicles (aggravated by a larger proportion of diesel vehicles), which has led to increases, in particular, in concentrations of nitrous oxide and solid particles. Sulphur dioxide (SO_2) has continued to be a residual pollutant.

Barcelona, and other European cities (such as Paris, London, Berlin and Rotterdam), currently exceeds the limits for average annual concentrations of NO_x and PM_{10} (particles less than 10 µ) established by the EU to protect health (since 2010, the European limit for the highest annual average concentration is 40 µg/m³ for NO_2 and PM_{10}.). This fact requires new strategies for action at all levels – from vehicle manufacturers to legislators – to improve air quality in the metropolitan areas.

Existing legislation (Law 22/1983, of 21 November, on the protection of the atmospheric environment) proposes guidelines to improve air quality. In this context, in 2006, Decree 226/2006 was passed declaring a number of towns in Barcelonès, Vallès Oriental, Vallès Occidental and Baix Llobregat as Special Protection Areas of the Atmospheric Environment. Later, in July 2007, the Department of the Environment and Housing approved an action plan to improve air quality in the areas declared as Special Protection Areas of the Atmospheric Environment. This new regulation established two areas: a NO_2 and PM_{10} protection area known as Area 1 to which Barcelona belongs and a PM_{10} protection known as Area 2.

Although the main aim of the Generatlitat of Catalonia's action plan is to reduce immissions (concentration of pollutants received by the population) of NO_2 and PM_{10} in order to bring them into line with the limits established under European legislation for 2010, the measures put forward will also contribute to reducing the emissions of greenhouse gases and, therefore, will help ensure that Catalonia complies with the Kyoto Protocol.

FIGURE 16 | SPECIAL PROTECTION AREAS OF THE ATMOSPHERIC ENVIRONMENT



One of the tools for evaluating air quality is the information supplied by the measurement stations that comprise the Air Pollution Surveillance and Control Network (XVPCA), set up under Law 22/1983, of 21 November on protecting the atmospheric environment. The network comprises a set of fixed and mobile stations to monitor, forecast and measure atmospheric pollution.

The evaluation of air quality via the XVPCA stations is carried out by comparing immission levels measured in Catalonia with the air quality objectives established by the EU. The XVPCA presents two kinds of immissions results in accordance with legal requirements: one provides information about immissions of contaminants as an annual average for NO_2, PM_{10} and $PM_{2.5}$, whilst the other measures hourly averages (for NO_2) or daily averages (for particulates), depending on the pollutant being measured, as the law establishes that, in a calendar year, a set number of hourly or daily limit values must not be exceeded.

The Public Health Agency has 11 active stations (automatic and manual) in Barcelona within the XVPCA measuring atmospheric pollutants. Amongst the fixed (automatic and manual) measuring stations and mobile units (that measure immisions at locations that are not covered by the fixed stations), there are a total of six that measure NO_X, ten that measure PM_{10} and three that measure $PM_{2.5}$.

GASES AND CONTAMINANTS WITH LOCAL EFFECTS

Nitrous oxide (NO_x) results from the reaction of oxygen and nitrogen in the air at high temperatures. Motor vehicles account for 65% of nitrous oxide emissions and it is calculated that, in urban areas, transport may represent between 60% and 70% of total emissions.

Airborne particles include unburned particles arising from the combustion of hydrocarbons or produced by the friction of vehicle tyres on asphalt, by the abrasion of the asphalt itself, by vehicle braking, by road works, or by the resuspension of dust on roadways. They can be classified as Total Suspended Particles (TSPs, which measure ≥ a 100 μm) or as Particulate Matter (PM), which include different categories, depending on their size. For example, PM_{10} applies to particles measuring less than 10μm in diameter, whilst $PM_{2.5}$ is used for particles with a diameter of less than 2.5μm. Particles smaller than PM_{10} affect human health on account of the fact that they can enter the respiratory system.

Carbon monoxide (CO) is produced by the incomplete combustion of fuel caused by a lack of oxygen. It is a pollutant that is characteristic of urban areas and is an indicator of traffic volume. Motor vehicles are responsible for 85% of carbon monoxide emissions in Catalonia.

Volatile organic compounds (VOCs), as with CO, are caused by the incomplete combustion of fuel. Transport represents approximately 50% of VOC emissions.

Sulphur dioxide (SO_2) is formed by the oxidation of sulphur in fuel; its emission is constant for each type of fuel. Fuels such as natural gas or liquefied petroleum gas (LPG) do not emit SO_2 because they do not contain sulphur. Emissions caused by transport, however, only represent 10% of total SO_2 emissions in Catalonia.

Tolerance thresholds

During 2008, Directive 2008/50/EC of the European Parliament and of the Council was approved regarding air quality and cleaner air for Europe. This Directive superseded previous legislation (Directive 96/62/EC, Directive 1999/30/EC, Directive 2000/69/EC, Directive 2002/3/EC and Decision 97/101/EC), with the exception of Directive 2004/107/EC relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons. The law also introduced the measurement of airborne particles measuring less than 2.5 μ ($PM_{2.5}$) in diameter and their related air quality objectives.

The legal limits established by the European Union are in line with studies carried out by the World Health Organisation (WHO).

- NO_2: epidemiological studies have shown that bronchitis symptoms in children with asthma increase with prolonged exposure to NO_2. In the same way, the reduced development of lung function is also associated with the concentrations of NO_2 that can currently be observed in cities in Europe and North America. Levels recommended by the WHO are the same as those set by the EU (annual average of 40 μg/m³ and an hourly average of 200 μg/m³).
- PM_{10} i $PM_{2.5}$: particulates affect more people than any other pollutant. They are mainly composed of sulphates, nitrates, ammonia, sodium chloride, carbon, mineral dust and water. They are formed by a complex mixture of liquid and solid particles of organic and inorganic substances in suspension. Chronic exposure to particulates increases the risk of cardiovascular and respiratory diseases and of lung cancer. The levels recommended by the WHO to obtain 95% confidence do not completely coincide with the levels set by the EU: the WHO establishes an annual average threshold of 20 μg/m³ for PM_{10} and 10 μg/m³ for $PM_{2.5}$, and a 24-hour average of 50 μg/m³ for PM_{10} and 25 μg/m³ for $PM_{2.5}$.

Action points in Barcelona

For many years now, Barcelona City Council, along with other public administrations, has been taking action to improve air quality by means of a number of different measures. The impact has, for the most part, been at an industrial level: modernisation of the waste-to-energy recovery facility, the conventional power stations at Besòs have been replaced with combined heat and power plants (lower emissions of pollutants). Furthermore, renewable energy has been given a boost by means of the Solar Thermal Ordinance, for example, and energy savings and energy efficiency have been promoted via projects included in the Barcelona Energy Improvement Plan.

However, it should be remembered that the main source of pollutants today is transport. In accordance with the Action Plan of the Generalitat de Catalunya associated with the Special Protection Areas of the Atmospheric Environment, land transport contributed to 40% of NO_x emissions and 52% of airborne particles and is the main source of both contaminants.

Attention must, however, be drawn to the efforts made to reduce emissions of pollutants: public transport has been enhanced with a fare integration system and the bus and metro networks have been improved, support has been given to promoting alternative means of transport with a more extensive network of cycle lanes and an improved Bicing (community bicycle) service. These measures have been accompanied by the introduction of parking regulations throughout many parts of the city.

However, more needs to be done – especially in the area of private transport – because Barcelona does not meet the air quality standards set by Europe.

TABLE 5 | IMMISSION LIMITS SET BY THE EU FROM 2010

POLLUTANT	SPECIFIC LIMIT VALUES	ANNUAL AVERAGE LIMIT VALUE
NO_2 (RD 1073/2002)	Hourly: 200 µg/m³ [Limit not to be exceeded: 18 times a year]	40 µg/m³ [42 µg/m³ el 2009]
PM_{10} (RD 1073/2002)	Daily (24 hour): 50 µg/m³ [Limit not to be exceeded: 35 times a year]	40 µg/m³
$PM_{2.5}$ (RD 2008/50/CE)	--	2010 objective: 25 µg/m³ 2015 limit: 25 µg/m³ 2020 limit: 20 µg/m³

FIGURE 17 | TRENDS IN POLLUTANT CONCENTRATIONS (NO_2)

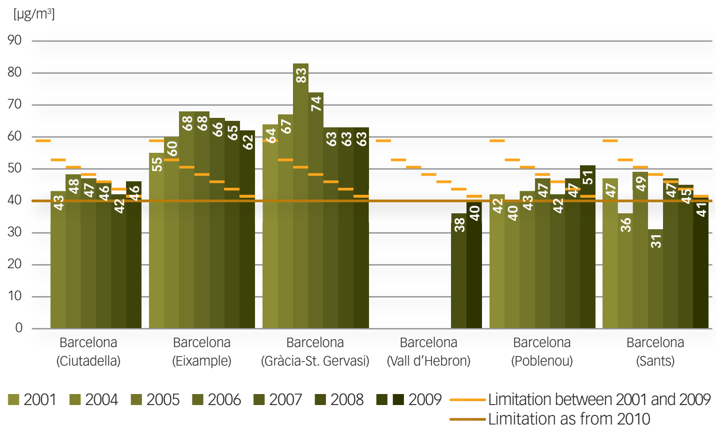
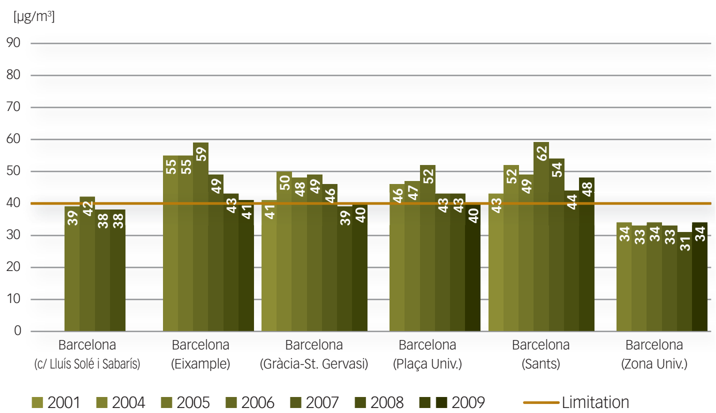


FIGURE 18 | TRENDS IN POLLUTANT CONCENTRATIONS (PM_{10})



Source: Direcció de Serveis de Vigilància Ambiental, Agència de Salut Pública i Departament de Medi Ambient. Ajuntament de Barcelona

▲ The horizontal line in the graphs represents the limit of 40 µg/m3 that must be met from 2010 onwards, according to the EU.

1.2.3 - THE REGULATORY FRAMEWORK FOR ENERGY

The PECQ was drawn up in the context of a complex regulatory framework relating to energy savings and efficiency, the use of renewable energies, the reduction of greenhouse gases and improvements in air quality. The laws and bylaws – at local, regional, state or European level – that are more relevant in these areas are listed below:

Building regulations

- **European Directive 2002/91CE**: Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings aims to promote energy efficiency in buildings via energy calculations and minimum efficiency requirements, energy certification, and periodic inspections of boilers and air conditioning systems.
- **Technical Building Code (CTE)**: approved by Royal Decree 314/2006, of 17 March, and partially modified by Royal Decree 1371/2007, of 19 October, this is the regulatory framework for setting basic quality requirements that buildings need to meet, including their installations, so as to satisfy basic requirements in terms of safety and habitability. A number of the basic requirements it covers are associated with fire safety, noise protection and energy savings.
- **Ecoefficiency Decree**: in addition to the CTE, in Catalonia, Decree 21/2006, of 14 February, regulates the adoption of environmental and ecoefficiency criteria in buildings with regard to water, waste, materials and construction systems.
- **Habitability Decree**: approved in 2009, this decree (55/2009) on the habitability of housing sets criteria related to sustainability and energy savings.
- **Barcelona Environmental Bylaw (OMA)**: since 2011, the OMA has included a section on energy that incorporates the Solar Thermal Ordinance in order to promote and regulate, by means of the local regulation, low-temperature solar energy facilities to produce hot water for

use in buildings (the regulation was modified in 2006), and the new photovoltaic bylaw, which regulates the incorporation of photovoltaic systems in new builds and refurbishments, depending on their use.

- **Royal Decree 1826/2009**: this law establishes minimum requirements in terms of energy efficiency for heat generators. Since 2010, it has been illegal to install boilers that do not meet the performance requirements specified in the decree. The decree also limits the interior temperature of occupied buildings that have air conditioning and that are used for administrative, commercial purposes or that are frequented by people.
- **Royal Decree 47/2007**: this decree is a fundamental law for the energy certification of new builds. Each building is assigned an energy efficiency class that ranges from A for the most efficient, to G for the least efficient.

Vehicles

- **Regulations governing vehicle emissions**: Directive 98/69/EC, governing passenger and light-use vehicles, and Directive 99/96/CE, affecting heavy-duty goods vehicles. A number of European directives, known as Euro directives, have come into force since 1992 to control vehicle emissions and to move progressively towards less-polluting vehicles that satisfy the requirements established in the directives about emission controls. The limit values for emissions and other considerations of a technical nature established by the regulation apply to all new vehicles that are mass produced and in use in a member State. It excludes vehicles that are already on the road or that are for export.
  Meeting the emissions levels established by Euro I (1992) and Euro II (1996) was achieved by making adjustments to traditional engines. The adaptation by manufacturers to new emissions standards took place over a gradual, two-stage process (Euro III and Euro IV), which required engines to be re-designed so as to offer greater environmental efficiency. Euro III brought about a significant reduction in emissions compared with previous periods and made it possible on a general level, as of 2001, to prepare the way for a definitive reduction in emissions, which took place in a second phase (Euro IV) from 2006 onwards. In some cases, the regulation makes it possible for emissions levels established by Euro IV to be met in two stages. It is planned that the second of these (called Euro V) will begin to be applied during the course of this Plan.
  To reduce CO_2 emissions, the European Union reached an agreement in 1998 with the European Automobile Manufacturers' Association (ACEA), which undertook to obtain average emissions of 140 gCO_2/km for vehicles sold in Europe by 2008. That was equivalent to a 25% reduction in CO_2 emissions from newly registered vehicles during 1995-2008. Furthermore, the ACEA committed itself to producing vehicles with average emissions of 120 g/km from 2000 and to review the agreement with the European Union in 2003.
- **Directive 2003/30/EC**: this Directive set a target of 5.75% biofuels use, calculated on the basis of energy content of all petrol and diesel sold for transport by 31 December 2010.
- **2009/28/EC, of 23 April 2009. Article 3:** this article stated that every Member State needs to ensure that the share of energy from renewable sources in the transport sector must amount to at least 10% of final energy consumption by 2020.
- **2009/28/CE, 23 April 2009. Article 17**: this article proposed a reduction in greenhouse gases produced from the use of biofuels and bioliquids by at least 50% from 1 January 2017. From 1 January 2018, this reduction will be increased to 60% for biofuels and bioliquids obtained in installations in which production started from 2017 onwards.
- **2009/28/CE, 23 April 2009. Article 5**: the amount of energy consumed by aviation should not exceed 6.18%, as a proportion of gross final energy consumption of that Member State.
- The Action Plan for Energy Saving and Efficiency, 2008-2011: this plan was approved by ministers at their Cabinet meeting on 1 August 2008. One of its targets was to reach a total of 1 million electric vehicles by 2014 throughout the state territory.

Energy efficiency measures

- **Commission Regulation (EC) No. 859/2009, of 18 September 2009, and Commission Regulation (EC) No. 244/2009, of 18 March 2009:** these regulations establish eco-design requirements for the sale of non-directional lamps for household and non-household use and when they are integrated into other products. Incandescent light bulbs will be progressively withdrawn (depending on wattage) up until 2012, when the regulation will be applied to all wattages.
- **Royal Decree 1890/2008, of 14 November:** this decree approved the Regulation on energy efficiency in external lighting systems and their technical instructions EA-01 to EA-07. The Regulation applies to the following installations of more than 1kW: exterior lighting (referred to in the ITC-BT 09), fountains (ITC-BT 09), and lighting for festivals and at Christmas (ITC-BT 34).
- **UNE 16001, energy management systems, requirements and guidance for use:** official European standard for energy management systems that has superseded all previous standards, including the old UNE 216301 standard.

Public buildings

- **The Action Plan for Energy Saving and Efficiency, 2008-2011, approved by ministers at their Cabinet meeting on 1 August 2008:** the Plan establishes compulsory targets set by the General Government Administration to reduce electricity consumption by 10% during the first half of 2009 compared with the same period in 2008. This level of saving is to be maintained during the current three-year period.

Waste

- The **main laws that govern waste management** are the Waste Framework Directive (Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008), Directive 1999/31/EC of the Council of 26 April 1999 (on the landfill of waste); Law 62/2003, of 30 December (on fiscal, administrative and social measures, and which amended aspects of Law 10/1998); the Integrated National Waste Plan 2008-2015 (PNIR) approved by the Cabinet on 26 December 2008; Catalan Law 6/1993, of 15 July (regulating waste), amended by Law 15/2003, of 13 July and by Law 9/2008, of 10 July; Implementing Decree 1/2009, of 21 July; and Law 8/2008, of 10 July (on financing waste management infrastructures and taxes on the disposal of waste).

Air pollution

- **Decree 152/2007,** of 10 July, approving the Action Plan to improve air quality in areas declared as Special Protection Areas of the Atmospheric Environment by means of Decree 226/2006, of 23 May. Together with Decree 203/2009, of 22 December, extending the action plan to improve air quality in the areas declared as Special Protection Areas of the Atmospheric Environment, approved by Decree 152/2007, of 10 July.
- **Decree 226/2006,** of 23 May, declaring a number of towns in Barcelonès, Vallès Oriental, Vallès Occidental and Baix Llobregat as Special Protection Areas of the Atmospheric Environment on account of particle levels and pollution in the form of nitrogen dioxide.
- **Royal Decree 1073/2002,** of 18 October, on assessing and managing environmental air quality with regard to sulphur dioxide, nitrogen dioxide, nitrous oxide, particles, lead, benzene and carbon monoxide, transposing directives 96/62/CE, 99/30/CE and 00/69/CE.
- **Decree 397/2006,** of 17 October, on the application of the system of trading of greenhouse gas emission allowances and for the regulation of the accreditation system for verifiers of greenhouse gas emission reports.

1.2.4 - INTERNATIONAL BENCHMARKS

When preparing its energy strategy, rather than acting in isolation from the rest of the world, Barcelona took into account policies carried out by other cities. As part of the preparation process for the PECQ, an international benchmarking study was carried out to look at the climate change and energy efficiency policies of other cities.

The following criteria were used to select the cities: those that have publicly expressed their concern for environmental and sustainability issues (e.g. cities that belong to ICLEI or that have a local Agenda 21), and cities that have, in the last five years, drawn up a plan or programme about energy, climate change or atmospheric quality.

The cities used for purposes of comparison were: London, Paris, Vienna, Stockholm, Fribourg, Amsterdam, New York and Sydney. In terms of the number of inhabitants and the surface area of the metropolitan areas, none of the cities were comparable with Barcelona. Vienna has a similar number of inhabitants, although it is much larger.

A wide diversity was found in the names of the plans. Nevertheless, two groups were identified: those that use a more traditional name and those that came up with a name, or even a slogan, that had more appeal from a communications point of view.

Most plans consider a long-term time frame as well as a short- or medium-term perspective. Stockholm has a very short-term plan (covering the years after the Plan was approved). The long term runs until 2050 (4 plans), followed by 2030 (2 plans). All intermediate time frames cover between 2010 and 2020, except for Stockholm (2005/2030).

From a conceptual point of view, all the plans shared the same objective (except Vienna), focusing on reducing CO_2 compared with a benchmark year. From a quantitative point of view, however, the plans are very different. Those that have set the highest reduction targets are Paris (75%), Sydney (70%), Stockholm (60-80%) and London (60%).

En general all the plans cover issues related to energy and climate change. Air quality is implicitly included in most of the plans (which incorporate measures to reduce air pollution), although only Fribourg and New York included it explicitly, dedicating a specific section to it. Most of the plans cover a wider scope. Other issues that are also covered are waste management, water management and tourism.

With regard to energy sources, most plans address petroleum and coal (except Fribourg), natural gas (except Stockholm) and biomass (except Stockholm and Sydney). Those energy sources given the most attention are solar thermal (7 plans), photovoltaic solar energy, wind energy and biofuels (6 plans). Hydroelectric energy (4 plans), tidal energy and geothermal energy (2 plans) are given less attention. Most of the plans (6) consider hydrogen as a valid alternative to current technology over the long term, based mainly on petroleum used in vehicle engines. With regard to electricity generation, all the cities are strongly committed to cogeneration, although only two consider self-generation.

Half the current plans include measures for capturing and storing CO_2 (by means of planting forests), although with, in all cases, complementary measures. Only the plans of Paris, New York and Sydney include measures to adapt to climate change.

All the action plans are mainly based on energy efficiency in buildings and measures related to transport and mobility. Most incorporate measures affecting buildings, in both the private sector (housing) and public sector (offices, equipment, housing and other municipal buildings) and also in the commercial sector (business premises).

TABLE 6 | PECQ – INTERNATIONAL BENCHMARKS

CITY (population)	AREAS COVERED		
	Energy	Climate	Air
LONDON (7,684,000) ▶ The London Plan - 2004	Yes	Yes	Yes
PARIS (2,167,000) ▶ Paris Climate Plan - 2007	Yes	Yes	No
VIENNA (1.670.300) ▶ Urban Energy Efficiency Programme - 2006	Yes	No	No
STOCKHOLM (798.700) ▶ Stockholm's Action Programme against Greenhouse Gas Emissions - 2003	Yes	No	No
AMSTERDAM (751.700) ▶ Amsterdam Climate Programme - 2007 ▶ Air Quality Plan - 2006	Yes	Yes	Yes
FRIBOURG (217.500) ▶ Freiburg Green City. Approaches to Sustainability - 2007 ▶ The Clean-Air Plan - 2006	Yes	Yes	Yes
NEW YORK (8.214.400) ▶ Plan NYC. A greener, greater New York - 2006	Yes	Yes	Yes
SYDNEY (164.500) ▶ Environmental Management Plan - 2007	Yes	Yes	No

DIAGNOSIS - Block 2 -

The City Programme

2.1 - Scope of analysis

2.1.1 - THE CONTEXT: THE CITY

Cities therefore have a great opportunity to become more efficient by making a more rational use of the resources available to them, with the advantages this brings as regards energy saving and reduction of their environmental impact, especially with regard to local emissions (pollution) and global emissions (climate change)

Over recent years, cities and major conurbations have emerged as the greatest energy consumers worldwide. According to expert estimates, 75% of world energy is dedicated to maintaining the complex organisation of cities, which are now home to over 60% of its inhabitants.

When analysing the metabolism of cities, it should be remembered that they function systematically, similar to any natural ecosystem with regard to the demand for resources, water, energy and information and the generation of solid, liquid and gaseous waste. They are, however, much more complex as the human ability to concentrate activities and uses into a given area generally exceeds its capacity, i.e. the potential for meeting the needs and disposing of the waste products using their own resources. These flows therefore determine the city's relationship with the exterior.

Unfortunately, modern cities have a linear metabolism, and this is one of the chief causes of their heavy demand for resources, as the resources injected into the system are not used or re-utilised efficiently and neither are autochthonous, renewable resources rationally leveraged, especially energy resources.

Cities therefore have a great opportunity to become more efficient by making a more rational use of the resources available to them, with the advantages this brings as regards energy saving and reduction of their environmental impact, especially with regard to local emissions (pollution) and global emissions (climate change). To make progress in this area, action can be taken in different aspects such as reducing the demand for private vehicle transport, diversification of power production centres, the recovery of waste for energy purposes, the utilisation of renewable sources, improved efficiency of public buildings and facilities or the promotion of green urban areas, amongst others.

This new scenario also requires active involvement on the part of local government which should not act as simply another consumer in the energy market. Its role as a manager and legislator is necessary, naturally, but it must also play a major role in innovation, planning, education and promotion.

2.1.2 - BARCELONA IN THE TERRITORY

Barcelona is located on the plain of the same name, which stretches from north to south, between the river basins of the Llobregat and the Besòs, and from east to west, between Serralada de Collserola and the sea. It covers a surface area of 101 km^2, and the maximum dimensions of the city are some 8 km between Collserola and the Port, and 9 km between Montjuïc and the river Besòs.

Barcelona's area of influence reaches beyond the administrative limits of the city. Over the past forty years, a characteristic phenomenon of large cities around the world has spread, metropolitinisation, such that Barcelona has become the centre of a large urban system in which the nearby towns, and even the outlying districts, have become a new geographic reality.

This has involved a process of extending the urban limits entailing major environmental implications for the territory. The current territorial references of Barcelona therefore depend on the area under consideration: The municipality itself, the Barcelonès district, Metropolitan area or the districts forming the Metropolitan Region. Thus, any planning or territorial decision taken or any socio-economic change to this territory as a whole clearly affects the functioning and dynamics of Barcelona.

This reality becomes especially clear in the planning and management of natural resources or services which have an obvious environmental element such as the collection and processing of waste, the drinking water supply and processing of waste water, the network of natural spaces or mobility and collective public transport. Energy, as occurs with natural systems, is the driver of this set of fundamental activities for the daily maintenance and operation of the urban system, signifying that the planning, arrangement and urbanisation of this set of elements which form the territory have a special effect on end consumption and the resulting generation of emissions.

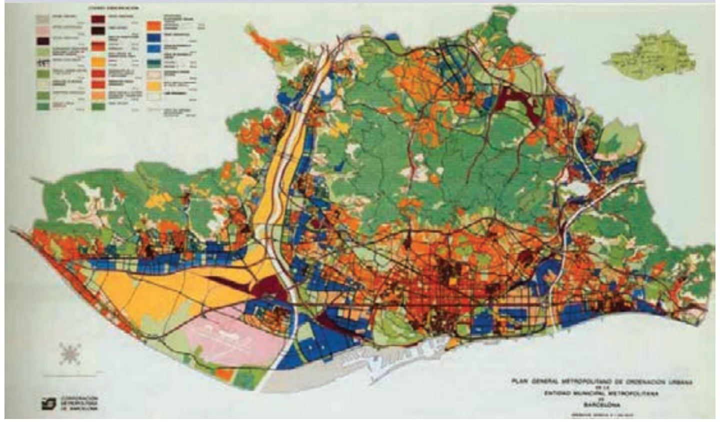
Although intervening in an existing city is a complex issue, new urban transformations and new districts must be designed and managed in keeping with sustainability criteria, so as to reduce the consumption of natural resources and energy and their socio-environmental impact. As regards energy, for example, over recent years Barcelona has adopted new criteria as regards the promotion of urban projects – in the development of districts such as Vallbona, for example-, and has introduced technological and regulatory innovations which have had a significant impact on the sector, such as district heating and cooling networks or the thermal solar Bylaw, amongst others.

Given this situation, it becomes necessary to move beyond these parameters and reflect on how urban evolution and territorial planning must address the issues of energy, climate change and air quality.

THE GENERAL METROPOLITAN PLAN

The town planning of Barcelona and twenty-six other municipalities in the Metropolitan area of Barcelona is governed by the general urban plan (PGM), a planning mechanism approved by the Provincial Urban Planning Committee of Barcelona on 14 July 1976.

The PGM is still in effect, despite having undergone numerous amendments over the years, to adapt it to the evolution of a complex territory in which urban centres and the economic activity coexist with natural spaces of great eco-systemic value.



2.1.3 - THE POPULATION

The population of Barcelona grew from just over half a million inhabitants at the beginning of the 20th century to over 1.9 million at the end of the Seventies, due to the strong migratory influx.

As from 1980 and over two decades, the city saw a demographic reversal. This phenomenon had not occurred at any time during the 20th century and was caused by two different factors which converged during this period: the slowdown in migratory processes of the city, due to the crisis; and the urban decentralisation process, of both production and residential activities, a feature which has progressively consolidated a metropolitan structure characterised by a considerable immobility.

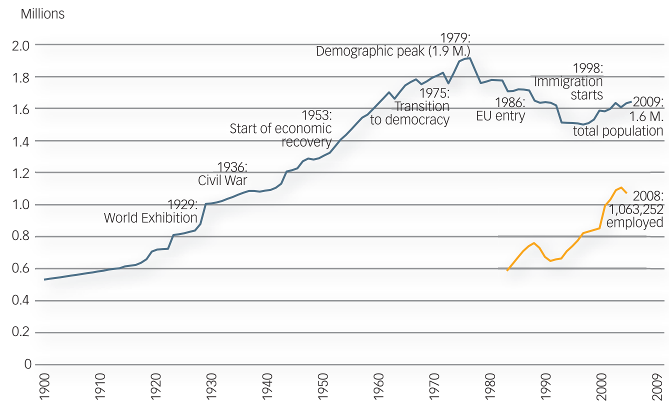
At the start of 2000 the situation changed again: this time in the form of foreign immigration, spurred on by the strong increase in the availability of employment, which coincided with a slight recovery in the birth rate. The number of jobs existing in the city reached its historical maximum in 2007 and the first semester of 2008, totalling 1.1 million, a figure which has progressively fallen with the economic crisis.

Barcelona currently has approximately 1.6 million inhabitants, well below the maximum figure of 1.9 million it achieved in 1979, but with a far higher residential stock due to the reduction in the average number of members per household. Thus, the population growth rate between 1992 and 1999 was negative (-1.15% a year), while between 1999 and 2009 it was slightly positive (0.8% a year), but falling short of the figures for 1992.

Throughout Catalonia and Spain, the long fall in the birth rate has transformed the traditional age pyramid for cities into an urn shaped figure, with the average age in Barcelona at 43.1, very high when compared to the Catalan average of 40.3, or the rest of the Metropolitan area of Barcelona which is approximately 39.

By age groups, 11.8% of the population in 2009 was between 0 and 14, 4.0% between 15 and 24, 63.9% between 25 and 64, and 20.3%, 65 or over. Nou Barris, Horta-Guinardó and Eixample are the districts with the highest percentage of elderly persons (65 or over), although this population sector accounts for over 19% in all districts, except Ciutat Vella. Sarrià-Sant Gervasi is the district with the most children (0 to 14) and Eixample that with the most young people (15 to 24).

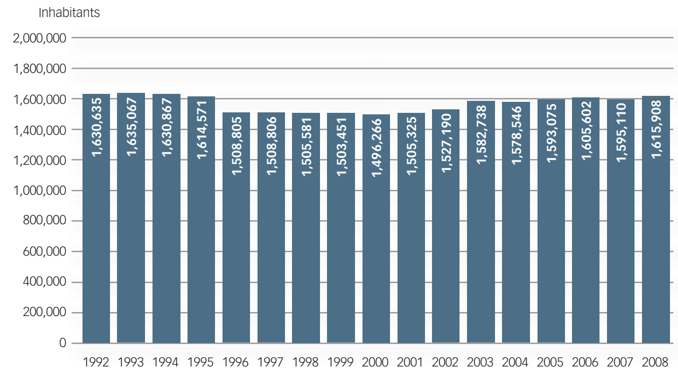
FIGURE 19 | EVOLUTION OF THE POPULATION OF BARCELONA (1900-2009)



Source: Department of Statistics Barcelona City Council

Immigration has increased and now accounts for 17% of the total population of the city, although the current economic situation is curbing this migratory process, especially from developing countries. All these factors make Barcelona a city of great social and multicultural complexity, with highly diversified patterns of insertion in the employment and housing markets. This is significant when evaluating the evolution of energy consumption in the city, as social attitudes towards energy is strongly linked to the intensity of society's energy consumption and each culture often interprets energy use in a different manner.

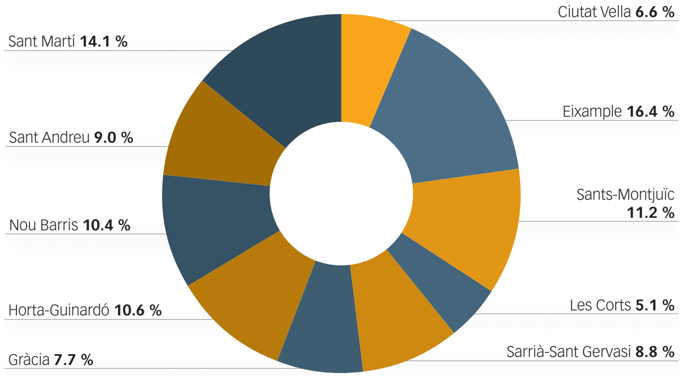
FIGURE 20 | EVOLUTION OF THE POPULATION OF BARCELONA (1992-2009)



Source: Department of Statistics Barcelona City Council

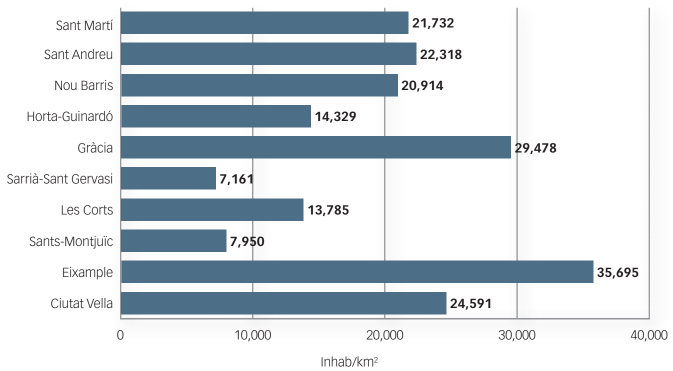
The highest population density is to be found in the districts of Eixample and Gràcia (35,695 and 29,478 inhab/km² respectively), while Sarrià-Sant Gervasi and Sants-Montjuïc are those with the least density (7,161 and 7,950 inhab/km² respectively).

FIGURE 21 | DISTRIBUTION OF THE POPULATION OF BARCELONA BY DISTRICT (2009)



Source: Department of Statistics Barcelona City Council

FIGURE 22 | DENSITY OF THE POPULATION BY DISTRICT (2009)



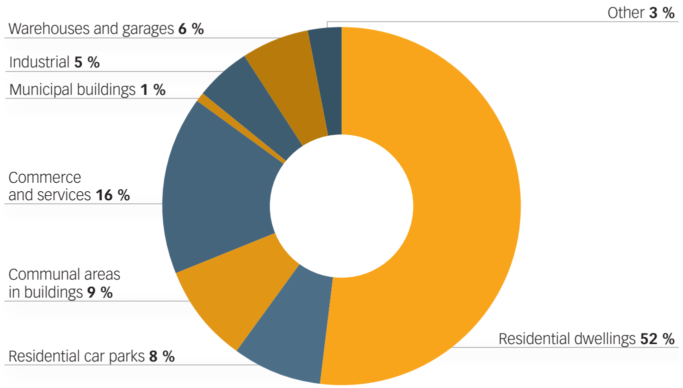
Source: Department of Statistics Barcelona City Council

2.1.4 - THE BUILDING STOCK

Throughout its history, the built-up land space area in Barcelona has seen sustained growth, with periods of heavy construction during transition periods, migratory waves or large urban growth.

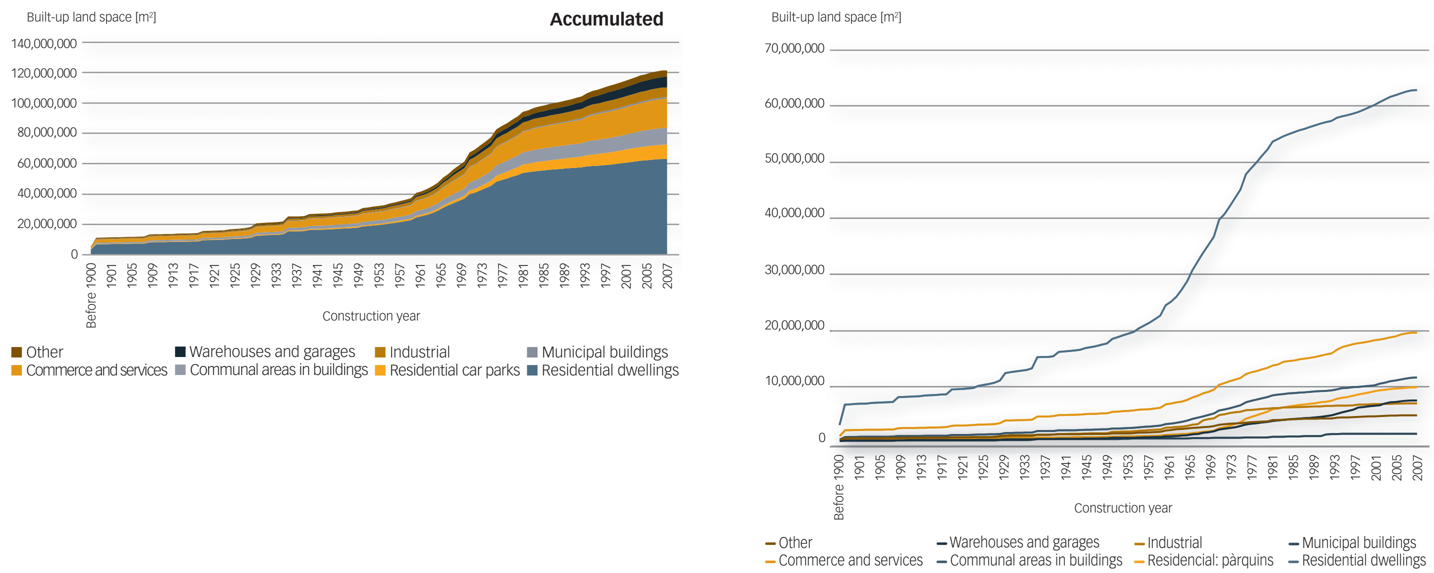
Over recent years, the rate of construction has been more moderate, with annual growth levels of under 1%. Despite this, between 1999 and 2007 approximately 3.2 million m² of new land space was built in Barcelona, totalling 121.35 million m². According to the land register database, over half is residential stock (62.7 million m²), followed by industrial facilities, garages and shops (22.9 million m²). There is also a notably large surface area dedicated to the business and office sector (8.2 and 6 million m² respectively).

FIGURE 23 | LAND SPACE IN BARCELONA (2007)



Source: Barcelona Land Register

FIGURE 24 | EVOLUTION OF THE DISTRIBUTION OF BUILT UP LAND SPACE IN BARCELONA BY AGE (1900-2007)



▲ A comparison of the land space data by use in 1999 reveals that over recent years, Barcelona has seen a significant reduction in industrial land space (-0.8% a year) – accompanied by a move towards the services sector, with an increase in the office, commercial and sports stock. Chief amongst these is the business sector, with an annual growth of 4.5%, which rose from 5.7 million square metres in 1999 to 8.2 million in 2007. The residential sector also saw an increase of approximately 1.4 million square metres.

2.1.5 - ECONOMIC FACTORS

Barcelona is undergoing a long process of demographic and social change, which has also transformed its economic model. The city maintains a diversified economic structure, unlike other large urban centres, which have a critical dependence upon one or two subsectors. Barcelona is spearheading the deindustrialisation process of the Catalan economy.

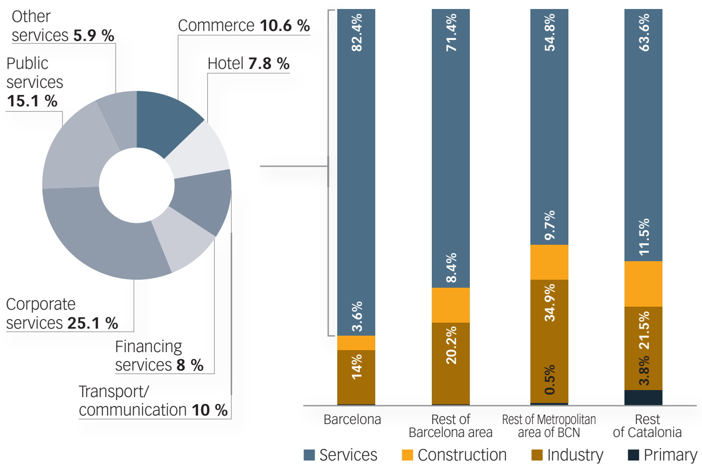
Economic sectors and labour market

Overall, corporate services account for 25% of the services sector and over 20% of the city's total economy. Hotel and commercial services also play a significant role in this service sector process. In quantitative terms, the growth of GDP in Barcelona averaged 2.5% between 2001 and 2008, totalling 63,100 m € in 2008. That year, GDP per capita was 38% higher than the average for Catalonia, an indication of how highly business is concentrated in the city.

Despite this growth in GDP, between 1991 and 2006 Barcelona saw its share of the Catalan economy fall, from 36.5% of GDP to 29.2%. This is a result of greater decentralisation of the production activity throughout Catalonia. It should be noted, however, that in 2008, when the change in the economic cycle was becoming apparent, the Barcelonès district was the most economically dynamic in Catalonia, with a growth of 1.7%, while the overall growth in Catalonia stood at 0.2%.

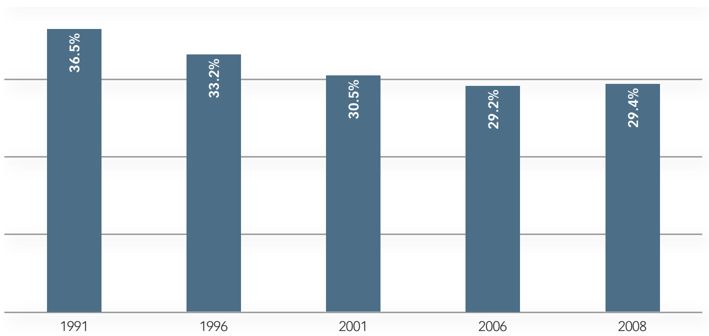
If we analyse the technological level of these industries and services, Barcelona is at the forefront in technology and knowledge, with an industrial fabric in which 10% of jobs have a high technological component and 41% a medium-high component. In the services sector there is also a trend towards specialisation, with 5% of services based on high technology and 43% on knowledge.

FIGURE 25 | DISTRIBUTION OF GDP OF BARCELONA IN CATALONIA (2008)



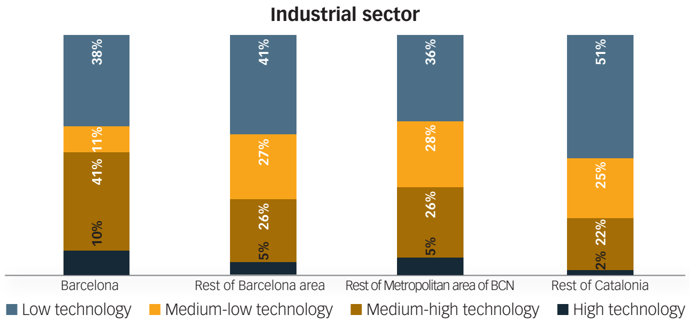
Source: Idescat and Caixa Catalunya

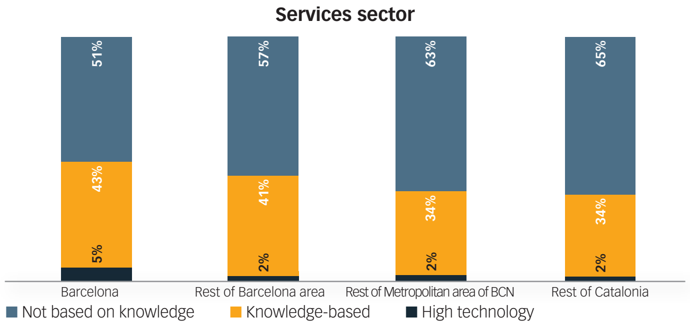
FIGURE 26 | EVOLUTION OF THE IMPORTANCE OF BARCELONA IN THE CATALAN ECONOMY (1991-2008)



Source: Caixa Catalunya

FIGURE 27 | DISTRIBUTION OF CORPORATE ACTIVITIES BY TECHNOLOGICAL INTENSITY (2009)



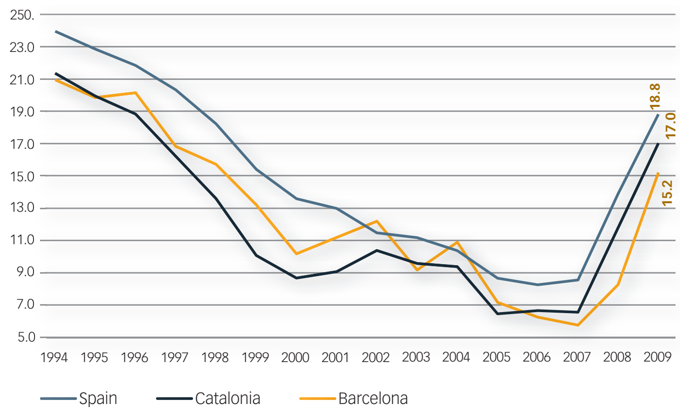


Source: Social Security

As regards the evolution of employment, the number of jobs in Barcelona grew by 15% between 2000 and 2007. Indeed, during the first quarter of 2008 it reached almost 1.1 million, although the current economic situation has led to a reduction of this figure, which at the end of 2009 stood at approximately 997,000.

The unemployment rate totals 15% of the active population. This is lower than the Catalan average and falls far short of the figure for Spain as a whole. The long period of economic growth had led to a continued drop in the rate of unemployment, which stood at 5.8% in 2007, a level bordering on full employment.

FIGURE 28 | EVOLUTION OF THE UNEMPLOYMENT RATE OF BARCELONA (1994-2009)

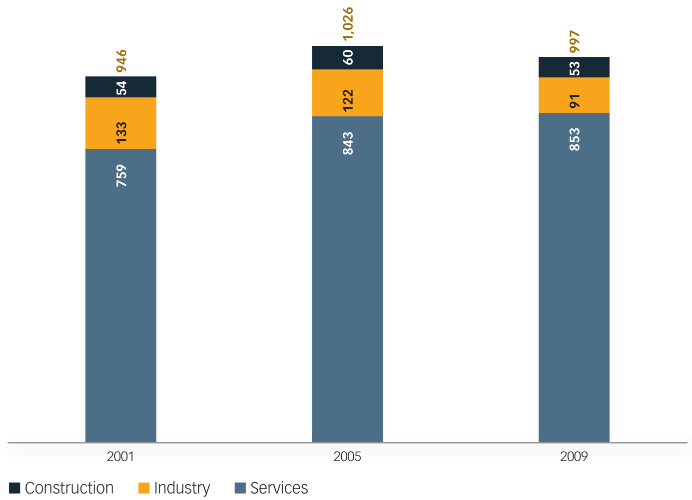


Source: Labour Force Survey (EPA)

The crisis, however, has triggered an increase in unemployment, similar to that of Catalonia and Spain. The transport sector, those sectors engaged in social, health and educational services and, overall, those associated with public services have seen the highest growth in unemployment. Another which has also seen a significant increase in unemployment is the hospitality sector, an indication of the growing importance of tourist activity in the city.

On the other hand, services for companies, which are the most important in the city's production structure and which had seen major growth until 2007, have been affected by the situation of the property sector. Commerce and personal services have been heavily affected by the fall in demand, while the financial system shows signs of difficulties and the need for re-structuring

FIGURE 29 | EVOLUTION OF JOBS BY SECTORS IN BARCELONA (2001-2009)



Source: Social Security

FIGURE 30 | EVOLUTION OF INDUSTRIAL JOBS BY PRODUCTION SECTOR (2002/2009)

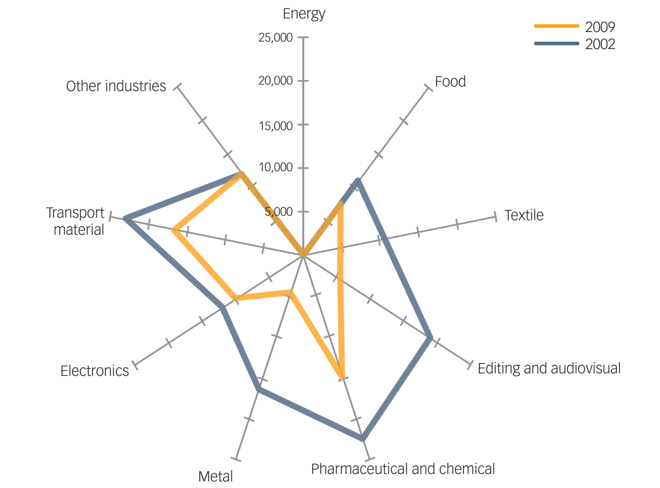
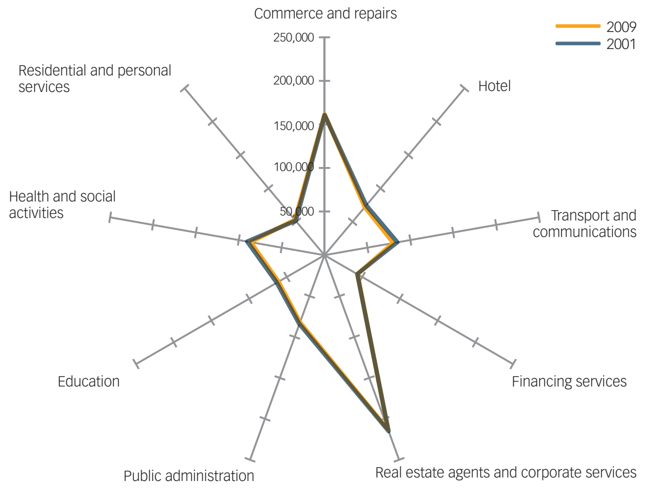


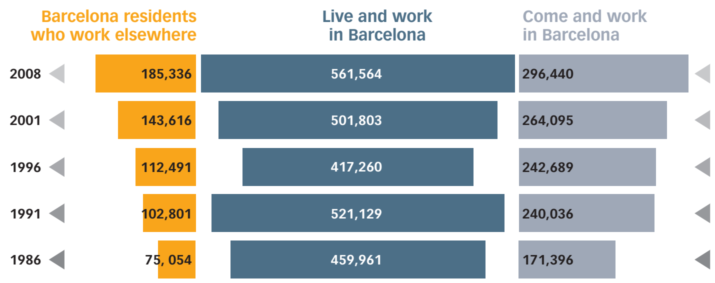
FIGURE 31 | EVOLUTION OF SERVICE INDUSTRY JOBS BY SECTOR (2002/2009)



Source: IDESCAT and Social Security

This evolution of the labour market has also entailed an increase in labour mobility. Barcelona attracts residents from other locations, but there are also a significant number of Barcelona residents who work outside the city. Commuter figures show a progressive growth in the number of journeys, with the resulting effect on energy consumption and transport-related emissions.

FIGURE 32 | EVOLUTION OF LABOUR MOBILITY IN BARCELONA (1986-2008)



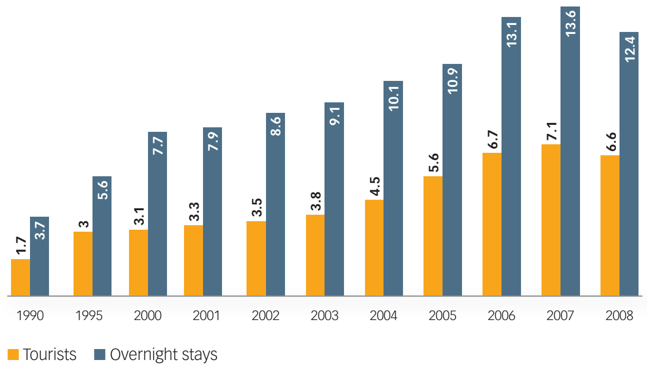
Source: IDESCAT

Tourist sector activity

The economic and socio-cultural context of recent years has fostered the international projection of the city. Furthermore, the development of transport infrastructures such as the Airport, the Port and the high-speed train have benefited tourist demand in Barcelona. The boom in low cost transport throughout Europe, the increase in the number of travellers worldwide and the popularisation of short stays in urban centres have also contributed to its success as a tourist destination.

An analysis of the evolution of the number of travellers and overnight stays in the city reveals that they have increased fourfold over the past twenty years, fomenting other forms of accommodation, such as apartments. Foreigners account for around 68% of overnight stays by tourists in Barcelona, 29% are visitors from the rest of Spain and the remaining 3% are from Catalonia.

FIGURE 33 | EVOLUTION OF THE NUMBER OF TRAVELLERS AND OVERNIGHT STAYS IN BARCELONA (1990-2008)

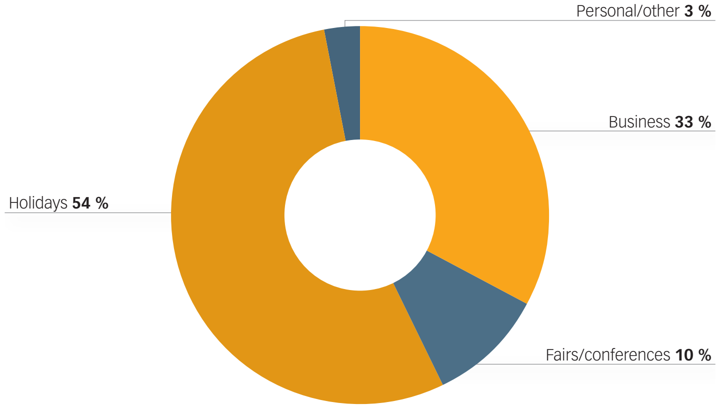


Source: Barcelona Tourist Dept

There is a notable balance between overnight stays for leisure purposes and for business and congresses. The former are strongly linked to an interest in architecture and cruises, while a large proportion of business tourism is linked to trade fairs. Barcelona ranks third in the world in the organisation of congresses, according to the ICCA (International Congress and Convention Association) and second by number of participants. Approximately 54% of tourists who stay at hotels in Barcelona are on holiday and 33% on business, without counting the travellers to trade fairs and congresses, who account for a further 10%.

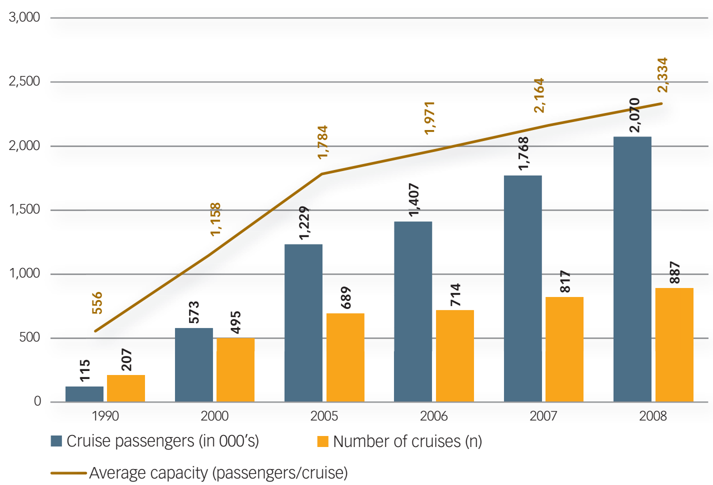
The emergence of new segments, such as cruises, has also led to an increase in the number of visitors, to such an extent that the Port of Barcelona currently ranks 5th in the world by number of cruises. This type of tourism does not involve accommodation in the city, but it brings a large expenditure in shops as this type of visitor has a medium/high level of income.

FIGURE 34 | REASON FOR TRAVELLING OF TOURISTS STAYING AT HOTELS IN BARCELONA (2008)



Source: Barcelona Tourist Dept.

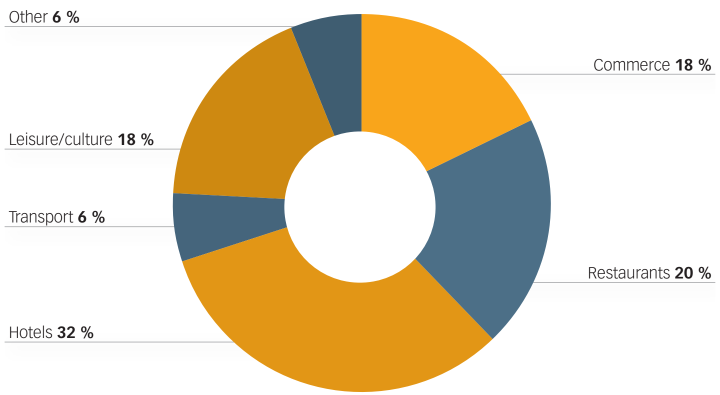
FIGURE 35 | EVOLUTION OF THE NUMBER OF CRUISES AND PASSENGERS AT THE PORT OF BARCELONA (1990-2008)



Source: Barcelona Tourist Dept.

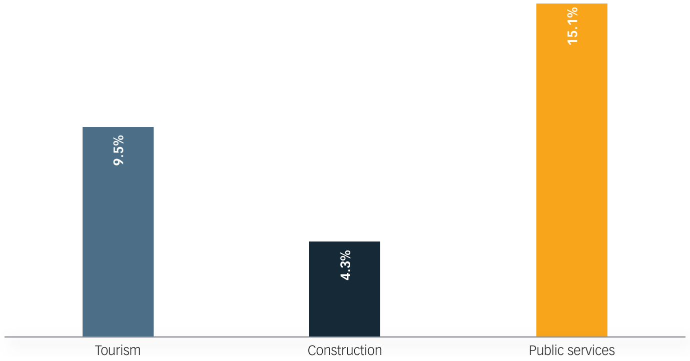
Tourism is a transversal activity which affects other production segments, with a strong impact on commerce and leisure and cultural activities, in addition to those related to the hospitality sector. Insofar as commerce offers services produced by other industrial sectors, the positive impact of tourism also encompasses other sectors. Overall, estimates indicate that tourist spending accounts for 9.5% of Barcelona's GDP[4], a sign of its importance for the city's economy.

FIGURE 36 | DISTRIBUTION OF TOURISM IN THE CITY'S PRODUCTION SECTORS (2008)



Source: IDESCAT

FIGURE 37 | THE IMPORTANCE OF TOURISM IN THE ECONOMY OF BARCELONA (2008)



4. In order to analyse the economic impact of tourism on Barcelona, various sectoral surveys have been used, such as those with visitors arriving in Catalonia and conducted by the Department of Innovation, University and Companies, nationwide data based on the Egatur survey, and those taken from the Tourist Activity Index prepared by the UAB.

2.1.6 - SOCIAL BEHAVIOUR

Research and defined variables

Individual attitudes and habits, and by extension social behaviour, have a great influence on the rational consumption of energy resources. For this reason, when drafting the Plan, a qualitative survey[5] was conducted to gain a detailed overview of the perception of energy based on a proposal for segmentation made during prior quantitative[6] surveys.

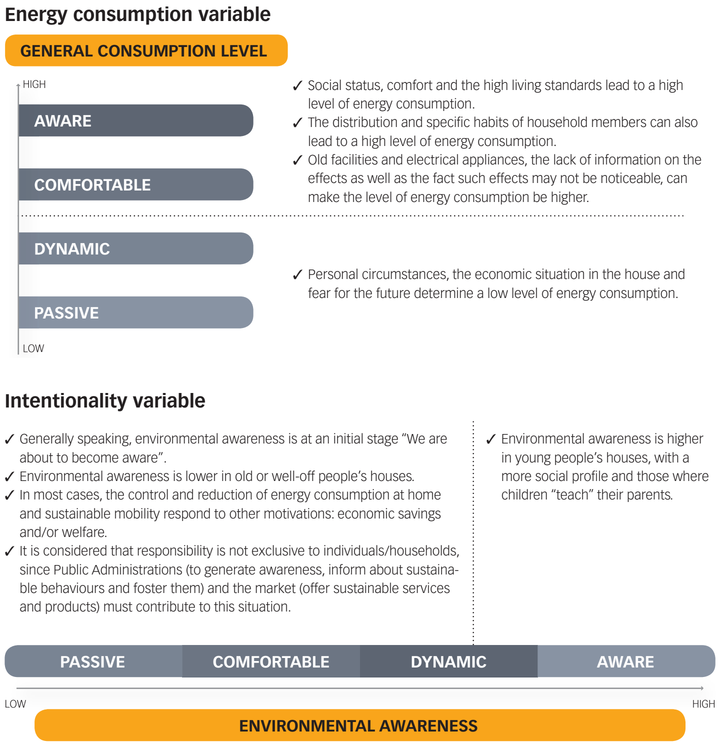
The survey identifies and characterises the energy-related needs, perceptions, motivations and attitudes of a varied public to energy use, their consumption habits and environmental awareness. Subsequently, a series of actions or projects are proposed which are designed to enhance energy consumption management from the viewpoint of social behaviour.

This initial statistical basis indicates that, in Spain, 86% of the public state they are concerned about climate change but this opinion is not reflected in their subsequent behaviour. A similar situation can be observed when analysing the European map of the population's attitudes with regard to environmental issues, for although Spain appears to be one of the countries with the highest environmental awareness, it is one of the least active.

Based on these statistical analyses, six different population segments are proposed, based on their behaviour towards rational energy use: aware, comfortable, dynamic, passive, anti-establishment and convinced. Of this proposed segmentation, it is estimated that the first four account for the majority (they represent 96% of the population), while the other two are less representative in the city as a whole. The study has focussed on the four segments considered the largest as they represent the majority of the population.

Two variables of social behaviour are used to classify the public in relation to their behaviour regarding energy use: Energy consumption variable and intentionality variable. The first variable segments the population according to their degree of energy consumption – and related articles and services -, identifying their spending capacity and predisposition to spend or consume. The second identifies those population segments according to their knowledge of environmental issues and their attitudes towards them.

FIGURE 38 | SOCIAL BEHAVIOUR VARIABLES STUDIED



5. Creafutur: Estudi de comportament social envers l'energia and Pla estratègic d'informació, educació i comunicació per a l'ús racional de l'energia. Barcelona, 2009. Commissioned by the Barcelona Energy Agency

6. Creafutur: Sostenibilitat i oportunitats de negoci i El futur del consumidor d'energia a la llar. Barcelona, 2008.

Ethnographic research

In order to define the measures and policies which can drive a change of perception towards energy use, the study centres on the citizens of Barcelona who have different economic and social circumstances. Based on a survey conducted in different dwellings, eight were chosen which are comparable to the characterisation proposed above:

- Single person's home in the Gothic Quarter
- Young family home in Diagonal Mar
- Home of an elderly couple without children in Les Corts
- Widow/er's home to the right of the Eixample
- Home of young couple in Nou Barris
- Single parent home in Sants-Montjuïc
- Home of retired persons to the left of the Eixample
- Home of North African immigrants in Ciutat Vella

The ethnographic study was conducted in two phases:

- **Diary of energy routines:** The families have recorded the energy consumption in their home (taking two working days and the weekend as a reference), and have prepared a photographic inventory of the appliances in their home.
- **Interview:** With the completed diary and data analysis, a team of experts has conducted a series of in-depth interviews to ascertain people's attitudes and behaviour in connection with energy consumption and saving in their home.

Thanks to the results of this research, certain priority actions have been established.

Population segments

Based on the segmentation produced by the aforementioned statistical studies and the ethnographic study, a characterisation has been formed of each segment:[7]:

- AWARE (29%)
  - Medium purchasing power, with a medium/high cultural level and aged between 25 and 35 (baby boom generation).
  - As a general rule, they are young families with small children, though there are also students sharing a flat or other young professionals.
  - The fundamental values and aspects are: Family, friendship, the future and improving the local environment (before the global environment).
  - High environmental awareness. They show interest in the environment and the impacts it receives and would like to learn more. They would readily change their lifestyle to be more *"sustainable"* if they knew how to and what the impact would be. They would also be prepared to pay more for clean energy.
  - Medium/high energy consumption. Those with medium consumption levels would like to consume less if they were taught how to.

- COMFORTABLE (27%)
  - Segment format per famílies amb un nivell adquisitiu mitjà/alt, i amb un nivell cultural molt variable.
  - Majoritàriament, són famílies amb pares de 40 a 60 anys, amb fills grans que tant poden viure a casa com estar emancipats.
  - S'estima que l'any 2020 aquest segment representarà només el 17% dels ciutadans[8].

- DYNAMIC (23%)
  - They have medium/high purchasing power with a medium/high cultural level.

7. It is significant that some of the definitions proposed by the authors were made in the scenario prior to the economic crisis and this may have altered certain associated behaviour, such as the inclusion of certain types of population in the segments.

8. Creafutur: *Sostenibilitat i oportunitats de negoci i El futur del consumidor d'energia a la llar.* Barcelona, 2008

- This segment includes persons aged between 35 and 55. They may be families of executives or middle management positions, young professionals (with academic studies and/or international work experience), who live alone, in a couple and with or without children.
- This segment is expected to grow to 27% over the next 10 years[9].
- They are aware of energy spending but do not find it high. The aspects they most appreciate are flexibility, communication, simplicity, originality and status, changing the world and enhancing the global sphere.
- Medium/high environmental awareness. They are aware of the impact of their lifestyle but will not sacrifice their standards of comfort.
- High energy consumption level. They are highly mobile and make intensive use of entertainment and communications devices.

• PASSIVE (17%)
- This segment is expected to shrink to 12% by the year 2020[10]. However, as it also includes retired persons and pensioners, it may tend to increase due to the ageing of the population.
- Segment comprising families with low purchasing power and variable cultural level. There are retired persons with low pensions, unemployed persons or families with an unemployed member, single parent families, young persons with few resources and certain collectives of immigrants.
- The persons in this segment are highly aware of what they pay, they consider that energy prices are high and would like to spend less. They therefore comprise the segment which consumes the least energy. The fundamental values and aspects are the family and the community, work, sacrifice and saving.
- Low environmental awareness. They would find it very difficult to change their current lifestyle if they do not obtain an economic benefit, in certain cases due more to reasons of economic precariousness rather than lack of willingness.

9. Creafutur: Sostenibilitat i oportunitats de negoci and El futur del consumidor d'energia a la llar. Barcelona, 2008.

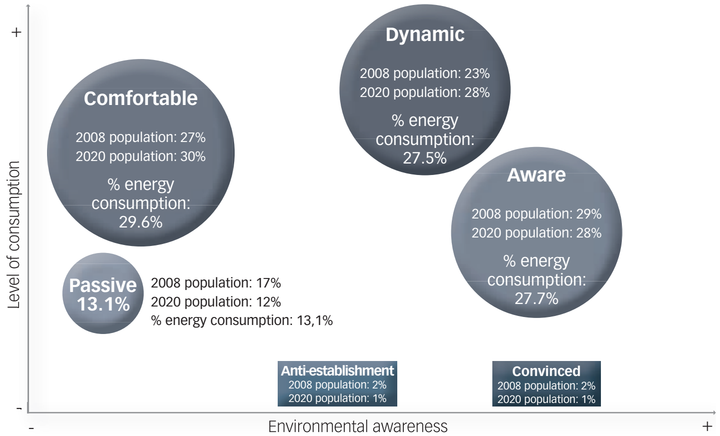
10. Creafutur: Sostenibilitat i oportunitats de negoci and El futur del consumidor d'energia a la llar. Barcelona, 2008.

- Low level of energy consumption, due basically to their low purchasing power (and to the fact they control their spending) and/or a relaxed lifestyle.

• ANTI-ESTABLISHMENT (2%) and CONVINCED (2%)

These have not been included in the subsequent ethnographic study as they account for a very small percentage of the total. Therefore, any measure centring on these two segments would have a low impact on the population as a whole.

FIGURE 39 | TABLE OF THE POSITIONING TOWARDS AWARENESS AND LEVEL OF ENERGY CONSUMPTION OF EACH SEGMENT



Priority actions

The behavioural study detects the need to act globally on the population as a whole, but it is the Comfortable and Dynamic segments which show the greatest potential for reducing their energy consumption.

The basic courses of action identified for these segments, which entail a series of measures and projects to be carried out over the coming years, are as follows:

- Provide information on the environmental impact of energy consumption in the housing sector. There is a percentage of the population that does not consider or is not aware that the housing sector and individual mobility have an environmental impact.
- Raise awareness of the economic saving to be gained from rational energy use, both by the individual (not wasting energy), and via technological efficiency. In schools, encourage the role of children to transmit environmental awareness and rational energy use to their parents.
- Provide greater support or personalised advisory services on energy/economic saving in the home. Equipment can be developed to monitor and display consumption in the home and incentivise the involvement of installation companies, home maintenance insurance companies, refurbishment professionals or energy suppliers to create the figure of the energy saving advisor.
- To raise environmental awareness a general demand for *"results feedback"* has been identified, to highlight poor practices and the effects that individual actions have on the environment. Therefore, educational work and feedback are necessary, with examples, experience, evidence and facts to increase people's awareness. It is also necessary to create user benchmarks (standard home consumption figures, etc.) for comparative purposes. There also exists a demand on the part of certain segments for economic incentives to drive good practices and saving.

The PECQ is clearly different to previous studies when characterising the vehicle population of Barcelona, as it is not based on the premise that the actual population is the same as that registered

2.1.7 - THE VEHICLE POPULATION

The analysis methodology

Road traffic energy consumption and its emissions must be determined indirectly. This is a differential feature compared to other sectors, the data for which can be established directly via the readings of power supply service connections.

To make this estimate as accurate as possible, it is necessary to obtain detailed information on the characteristics of the vehicles (horsepower, fuel, type, age), the average traffic speeds and kilometres covered by the vehicle population as a whole. The analysis of these data employs standard methodologies recognised by the European Union, such as the CORINAIR/COPERT[11] (CORe INventory AIR emissions).

The objectives of this methodology are to:
- Ascertain the exact composition of the vehicle population, via a representative sample.
- Improve energy consumption calculations and the resulting emissions of GHG associated with the vehicle population.
- Improve the calculation of local polluting emissions associated with the vehicle population.

The PECQ is clearly different to previous studies when characterising the vehicle population of Barcelona, as it is not based on the premise that the actual population is the same as that registered. A detailed study of the population vehicles in circulation has shown that it is clearly different to that registered; in particular, the former is more modern than that registered, an important factor when defining effective policies. The procedure used has made it possible to empirically measure the emissions from the exhaust pipes of the vehicles registered and compare these data with the CORINAIR emission factors.

11. Methodology created by the European Council of Ministers in 1985 within the framework of the EU programme to help member states to carry out emissions inventories. CORINAIR provides a full range of pollution emission factors by different types of vehicles, ages and horsepower. The latest version is from 2009.

The Plan identifies the road transport segments with the greatest emissions which provides a suitable viewpoint when deciding the strategy to be introduced as regards air quality and, above all, for fostering more effective measures by the relevant authorities.

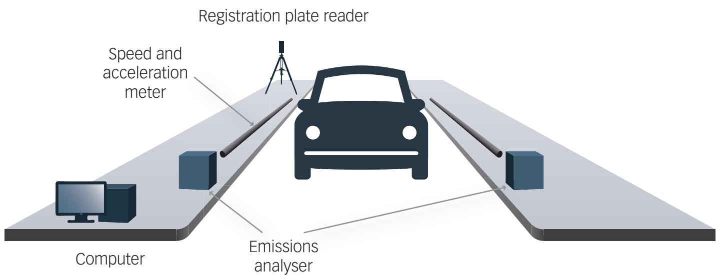
The inventory of the real vehicle emissions in Barcelona was carried out via a study made at 16 points throughout the city over thirty-two days in May and June 2009. Based on a reading of the registration plates of some 42,000 vehicles, the real vehicle population was determined with great accuracy together with their polluting emissions, as the registration data reveal the type of vehicle, its technical characteristics and the municipality of residence of its user.

The study also used a detection system for exhaust pipe emissions called RSD (Remote Sensing Device), which, unlike other onboard emissions detection systems is not intrusive, as it records the data without modifying the speed or acceleration of the vehicles. The RSD system subjects the vehicle to infrared and ultraviolet light to detect the vehicle's emissions instantly, and therefore thousands of recordings can be taken in just a few hours. The RSD was created in the USA and has been widely used since the nineties in countries such as Austria, Japan, the United Kingdom and Singapore, amongst others. The system has been verified and certified by the Automotive Research Bureau, California.

To improve the collection of information, speed and acceleration sensors were installed at various road points, making it possible to associate the emissions with the conditions under which each vehicle was circulating, as its dynamics are important when comparing data between vehicles. It should be noted that polluting emissions and particles (PM, CO, HC, NO_x) are measured in relative terms compared to CO_2 emissions. The recordings of the registration numbers were processed by the Traffic Authorities in order to obtain the specifications of each vehicle (type, horsepower, age, fuel and municipality of origin).

Of the sixteen points installed, fourteen recorded road traffic, while the other two were used to measure fleets of vehicles such as taxis and lorries entering the Port of Barcelona. In addition, the recordings of vehicles using the public municipal car parks and the entry toll to Mercabarna were analysed. The aim was to determine whether the type of vehicles using the car parks and the type of vans are representative of those in the city.

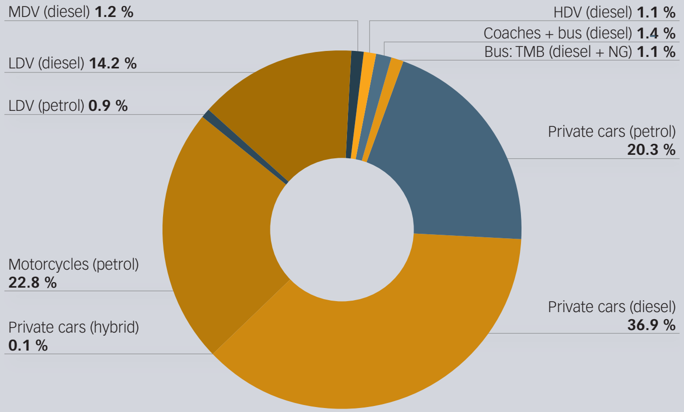
FIGURE 40 | RSD SYSTEM OPERATING SYSTEM



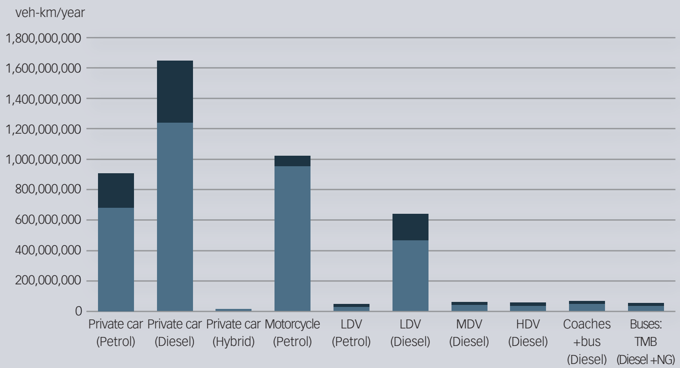
THE PROFILE OF THE VEHICLES

- The most common type of vehicle is diesel cars (including taxis), which account for 36.9% of the traffic in the city and the ring roads.
- Petrol cars account for 20.3% of the 4.439 million veh-km covered in 2008.
- The percentage of motorcycles and mopeds was 22.8%.
- 14.2% of the traffic were diesel vans (Light Duty Vehicles or LDV: with a maximum authorised weight of under 3.5 t.)
- These four segments accounted for 94.2% of total road traffic.

FIGURE 41 | DISTRIBUTION OF ROAD TRAFFIC IN BARCELONA AND RING ROADS, BY TYPE OF VEHICLE (2008)



Type	City veh-km/year (2008)	Ring Roads veh-km/year (2008)	City + Ring Roads veh-km/year (2008)
Private car (Petrol)	679.249.493	219.942.316	899.191.809
Private car (Diesel)	1.236.854.185	400.495.809	1.637.349.994
Private car (Hybrid)	3.962.371	1.283.024	5.245.395
Motorcycle (Petrol)	949.525.520	62.235.838	1.011.761.364
LDV (Petrol)	29.923.962	10.711.511	40.635.473
LDV (Diesel)	464.690.181	166.339.397	631.029.578
MDV (Diesel)	40.787.069	14.600.043	55.387.112
HDV (Diesel)	36.374.250	13.020.441	49.394.691
Coaches +bus (Diesel)	49.622.009	11.760.981	61.382.990
Buses: TMB (Diesel + NG)	38.622.700	9.154.020	47.776.720
Total	**3.529.611.742**	**909.543.378**	**4.439.155.126**



- AVERAGE VEHICLE AGE

The characterisation of the vehicle population performed within the framework of the PECQ revealed that the average age of the vehicles circulating in the city was 5.7 years. If we compare the population registered in Barcelona and that in circulation, the following results are obtained:

- 52% of the vehicles in circulation in the city are from outside Barcelona.
- The average age of the population of passenger vehicles (5.53 years) is lower than that of the registered population (9.13 years), indicating that probably the oldest vehicles circulate less than the newer vehicles (drivers who circulate more usually renew their car earlier).
- This difference is greater in the case of pre-EURO vehicles – both diesel and petrol-, as the registered population has over 20% of pre-EURO cars, while the pre-EURO vehicles account for just 1.8% of cars.
- The average age of taxis is 3.4 years, and that of lorries entering the Port of Barcelona, 6.5 years.

An age classification of the vehicles by type of fuel shows that petrol driven vehicles are older than diesel versions, with an average of 7.58 years. This is probably due to private users or companies who prefer to acquire diesel vehicles with the intention of using them more frequently, and also the lower cost of the technology, making them more affordable. i.e., these are vehicles which generally cover more kilometres than petrol cars, meaning that they reach the end of their useful life or depreciation earlier.

FIGURE 42 | AVERAGE AGE OF VEHICLES IN CIRCULATION IN BARCELONA (2008)

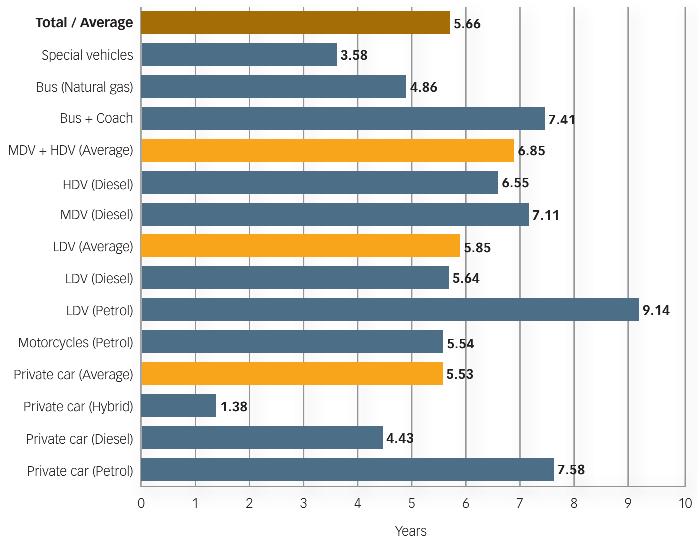


FIGURE 43 | AVERAGE AGE OF TAXIS IN CIRCULATION IN BARCELONA (2008)

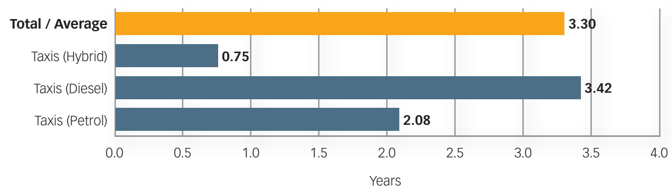
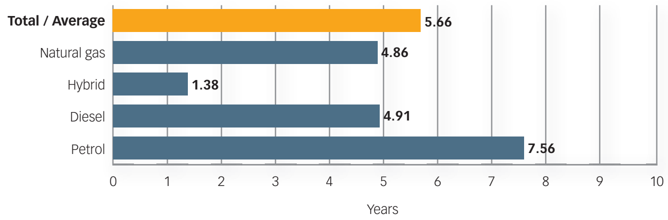


FIGURE 44 | AVERAGE AGE OF THE VEHICLES IN CIRCULATION IN BARCELONA, BY TYPE OF FUEL 2008 (2008)



According to the EURO[12] classification, 67.2% of traffic comprises EURO IV and EURO III vehicles. Generally speaking, they are vehicles manufactured in 2000 or later (except in the case of motorcycles, which have been subject to the EURO III standard since 2006). 39.2% are EURO IV vehicles which came into circulation in 2005 or later (except motorcycles which currently have no EURO IV classification, as the latest applicable standard is the EURO III). 28% are EURO III, vehicles manufactured between 2000 and 2004 (except in the case of motorcycles, to which EURO III has been applicable since 2006). EURO II vehicles account for 13.6% of traffic, the EURO I, 6.3% and the pre-EURO, 12.5%. The EURO V was still testimonial in 2009, with just 0.4%, as that year it was only applicable to buses and lorries, and not to passenger cars, vans or motorcycles.

12. European standard on local pollutants (NO_x, HC, CO and particles) which regulates the acceptable limits for new vehicle exhaust gas emissions sold in the member states of the European Union. The EURO I standard is the oldest –and therefore the least restrictive; previously there were the pre-EURO- standards, while the EURO V and future EURO VI are the most restrictive, as they require lesser polluting emissions per kilometre. Measurements are made according to a standard driving cycle defined by Europe.

FIGURE 45 | DISTRIBUTION OF VEHICLES IN CIRCULATION IN BARCELONA AND THE RING ROADS BY EURO CLASSIFICATION (2008)

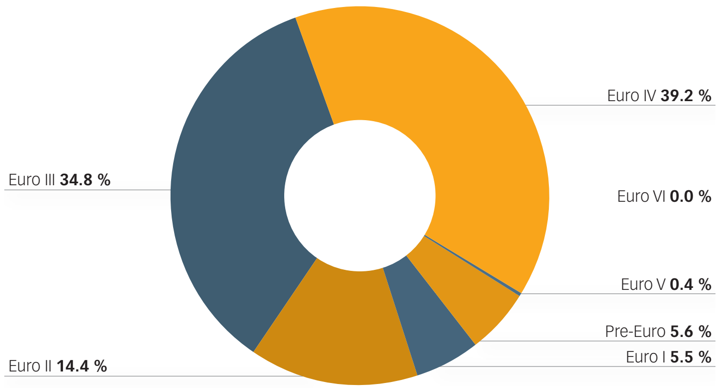
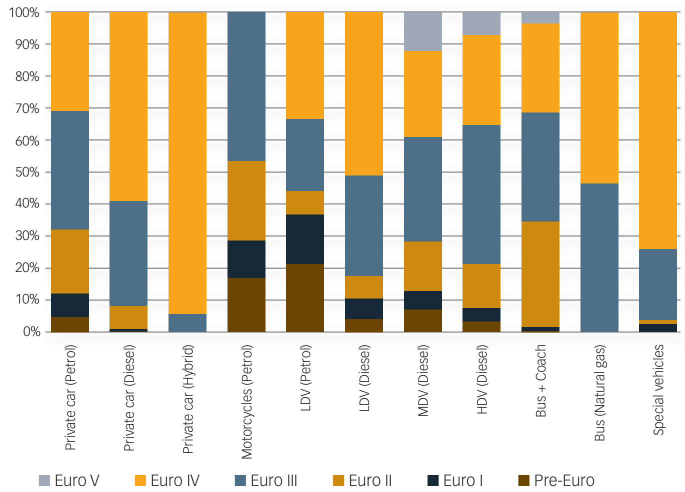


FIGURE 46 | CLASSIFICATION OF VEHICLES IN CIRCULATION IN BARCELONA AND THE RING ROADS AS PER THE EURO STANDARD BY TYPE OF VEHICLE (2008)

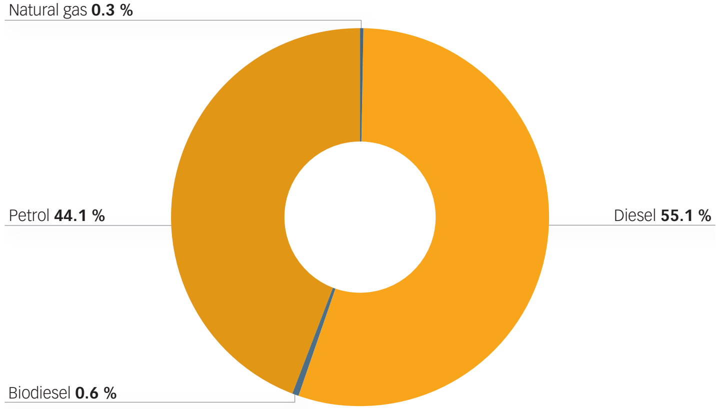


▲ The vehicles which account for the highest percentage of EURO II or previous standards are petrol LDVs, with 44.2%. Buses and coaches account for 34.7%, and petrol passenger cars, 32.1%.

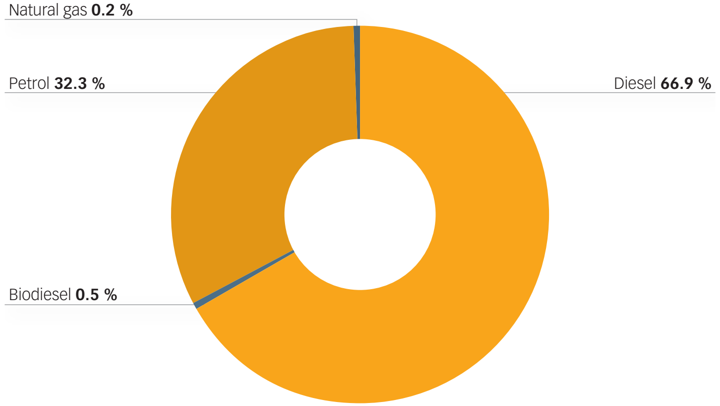
- TYPE OF FUEL USED

In accordance with the characterisation of the vehicle population, the most widely used fuel in 2008 was diesel, with 55.1% of the kilometres covered, while petrol accounts for 44.1%, natural gas 0.3% and biodiesel 0.6%. This distribution is totally different in the ring roads, as the lighter motorcycle traffic and prohibition of mopeds signifies an increase in the proportion of diesel vehicles up to 66.9%.

FIGURE 47 | DISTRIBUTION OF VEHICLES IN CIRCULATION IN BARCELONA CITY AND THE RING ROADS (UPPER) AND ONLY THE LOWER RING ROADS (2008)



▲ Road Traffic: 14.439.16 Mveh-km/year



▲ Road Traffic: 909.54 Mveh-km/year

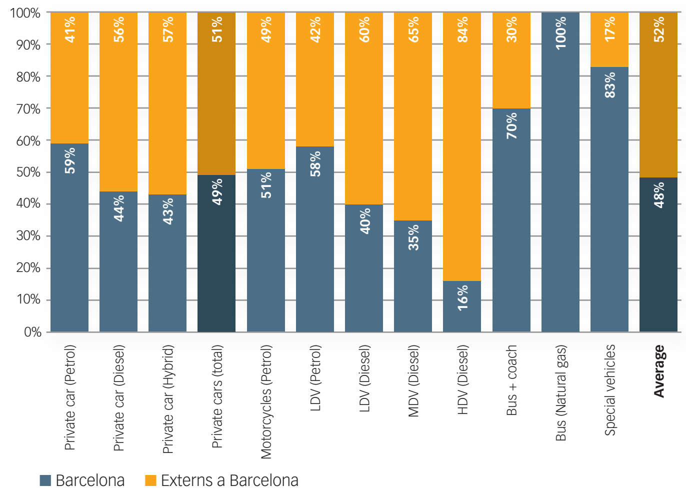
- THE ORIGIN OF THE VEHICLES

The municipality of residence is determined by where the vehicle is registered. It should be noted that the real origin of the vehicle does not have to coincide in all the registries with the municipality where the vehicle resides, although the consistency of the data – and the errors implicit in any sample or database-, lead us to believe that the results are fairly consistent and accurate.

In this respect, the conclusions which can be drawn from the study are as follows:

- 52% of the vehicles in circulation in Barcelona come from other municipalities.
- 49% of the passenger cars in circulation on working days are registered in Barcelona.
- Petrol vehicles have the largest number of owners, with 59%, while diesel vehicles account for 44%. This is understandable if we take into account that the user of diesel vehicles generally drives more kilometres per year, and is therefore driven by users from outside Barcelona.
- As regards LDVs, the proportion is similar to that of passenger cars: 58%, petrol vehicles and 40%, diesel.
- On the other hand, all the medium size or large delivery lorries (over 12 t) are diesel and only 35% and 16% respectively are from Barcelona. This is to be expected in view of the fact that many logistics companies' storage facilities are located in industrial areas outside the city.
- 70% of the diesel buses and coaches (one of the oldest fleets in the city) are registered in Barcelona, while 100% of the natural gas buses are registered there as they form part of the TMB fleet.

FIGURE 48 | CLASSIFICATION OF VEHICLES ACCORDING TO ORIGIN, BY TYPE (2008)



2.2 - Energy consumption

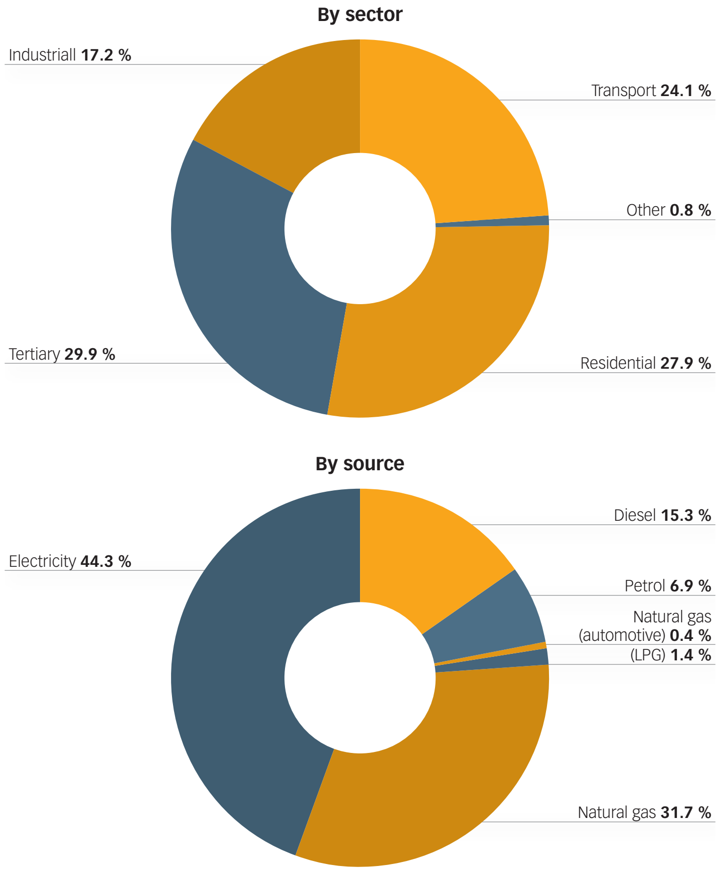
2.2.1 - FINAL ENERGY CONSUMPTION

In 2008, Barcelona consumed 17,001.78 GWh of final energy[13]. This figure can be divided almost equally between the services sector, with 29.9%, the residential sector, with 27.9% and the transport sector with 24.1%. 17.2% of the remainder was consumed by the industrial sector and 0.8%, other sectors (primary, energy, construction and public works).

By energy source, 44.5% of consumption was electricity, 31.8% natural gas, and the remainder diesel (15.4%), petrol (7.0%) and liquefied petroleum gases or LPG (1.4%). Thermal energy generated directly via solar systems was also consumed, although in a very small percentage (almost 0.3%, despite its importance in global energy consumption for hot water) its contribution is not shown in the relevant graph.

This energy consumption represents 1.38% of all the energy consumption of Spain in 2008.

FIGURE 49 | ENERGY CONSUMPTION IN BARCELONA (2008)



Source: ICAEN and Repsol

13. This figure includes consumption by the treatment facility of the Estació Depuradora d'Aigües Residuals Metrofang, but not the energy generated using solar thermal systems. If we consider only the treatment proportional to the use made by Barcelona of this water treatment plant, the final energy consumption of Barcelona in 2008 would be 16,896.6 GWh, plus the 52,405 GWh generated that year directly using solar thermal energy.

The consumption ratio per inhabitant was 10.52 MWh/inhab, less than half the energy consumption by inhabitant of Spain (25.47 MWh/inhab in 2008). When comparing these data, it should be borne in mind, however, that the bio-geographic and urban characteristics of Barcelona (a compact, Mediterranean city) signify that the consumption per inhabitant is often lower than in other cities.

Putting energy consumption in Barcelona into perspective, there has been a clear upward trend over recent years, with an average annual growth rate of 0.91% (1999-2008)

TABLE 7 | FINAL ENERGY CONSUMPTION IN BARCELONA (1999/2008)

Final energy consumption in Barcelona (1999/2008)		
	1999 [GWh]	2008 [GWh]
Total	**15.664.78**	**17.001.78**
Total per inhabitant	**10.42 MWh/inhab.**	**10.52 MWh/inhab.**

Putting energy consumption in Barcelona into perspective, there has been a clear upward trend over recent years, with an average annual growth rate of 0.91% (1999-2008) which rose from 15,664.78 GWh of final energy in 1999 to 17,001.78 GWh[14] in 2008 (including consumption of electricity, natural gas, LGP and automotive petrol).

THE SOURCE OF FINAL ENERGY

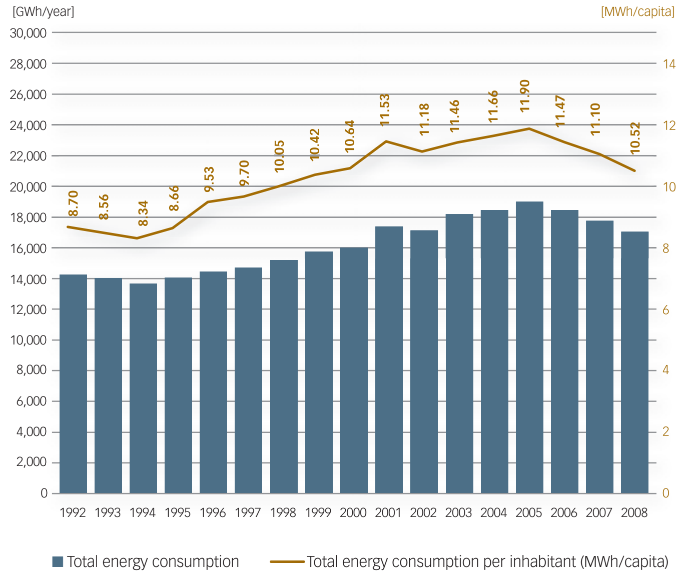
Electricity is a form of final energy as it is produced from other energy sources. When we consider the electric mix of Catalonia in 2008, the electricity consumed in Barcelona originated chiefly from nuclear plants (54.1%) and combined cycle power plants (22.8%). In the case of Spain, the main source was coal, nuclear energy and combined cycles.

The source of the final energy consumed in Barcelona varied significantly during the period 1999-2008. In the case of fuels, while petrol consumption fell 8 points compared to 1999, diesel consumption increased by almost 7 points due to the increase in the population of diesel powered vehicles. Overall, consumption of automotive petrol fell by 23.8% of final energy (1999) to 22.2% (2008), a percentage to which 0.4% of automotive natural gas should be added.

As regards other energy sources, we should highlight the significant increase in the importance of electricity in total consumption (from 37.2% to 44.3%) and the drop in natural gas (from 36.4% to 31.7%) and LGP (from 2.6% to 1.4%).

This increase has not been sustained over time, as until the end of 2005 there were annual growth rates of over 3% and as of that year, consumption has dropped significantly, with rates of -4.03% a year. Consumption per inhabitant increased over the period 1999-2008 at an average annual rate of 0.119% (under 2.24% for the period 1999-2005), up to 10.52 MWh/inhab in 2008.

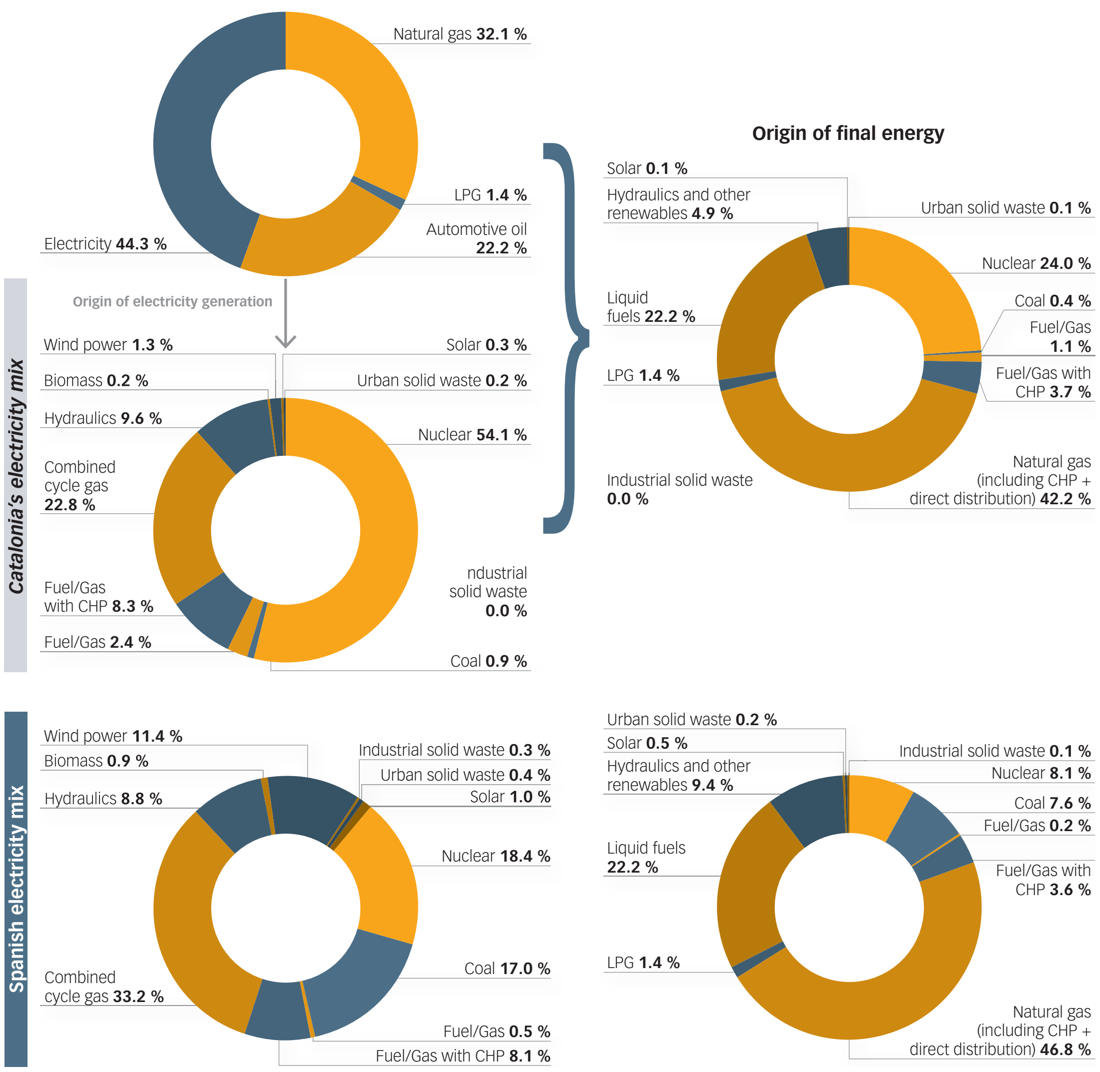
FIGURE 50 | EVOLUTION OF ENERGY CONSUMPTION IN BARCELONA (1992-2008)



Source: ICAEN

14. The recorded value of energy consumption for 1999 was 15,902.9 GWh. However, with the introduction of changes in calculation methodology in 2008, this figure was recalculated to keep it consistent. This modification responds to the difference seen between the registered vehicle fleet and the actual fleet in the streets of Barcelona and this is why the originally-calculated consumption levels of automotive petrol were adapted proportionally to such difference.

FIGURE 51 | SOURCE OF FINAL ENERGY IN SPAIN AND CATALONIA (2008)



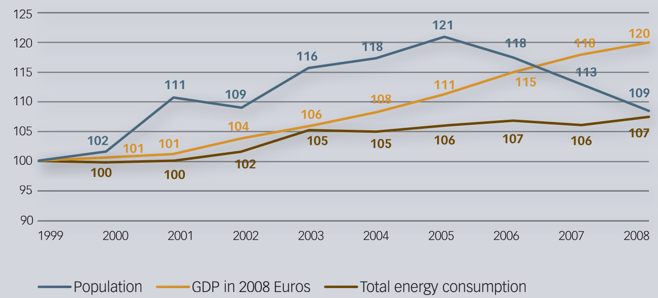
Source: ICAEN

ENERGY AND GROSS DOMESTIC PRODUCT

It has been seen that the increase in energy consumption evolved in a similar manner to the increase in Gross Domestic Product (GDP) until 2005, the year when energy consumption saw a change in trend. The increase in the population, however, does not seem to affect the upward trend in energy consumption. The reasons for this shift in trend in the evolution of energy consumption are to be found in the lower automotive fuel consumption and especially natural gas.

Energy intensity (i.e., the amount of energy per unit of production or service) during the period 1999-2008, therefore fell at an annual rate of -1.11%, to the current level of 269.44 Wh/€. This reduction was chiefly connected with the fact that GDP rose significantly during these years. This a highly positive rate and above the reduction in Spain (-1.01% between 1999-2008, according to the Energy in Spain report by the MITC 2009) and Europe as a whole (-1.03% 1999-2005).

FIGURE 52 | EVOLUTION OF ENERGY AND GDP IN BARCELONA (1999-2008)



2.2.2 - CONSUMPTION BY SECTOR

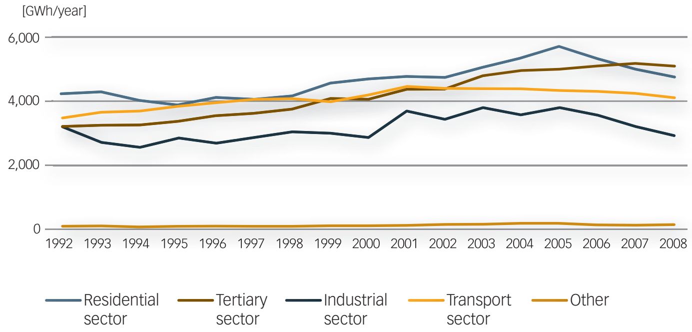
Sectoral trends

The increase in energy consumption in Barcelona between 1999 and 2008 has different causes, by sector. This evolution offers an overview of the change in economic structure undergone by the city over recent years

The increase in energy consumption in Barcelona between 1999 and 2008 has different causes, by sector. This evolution offers an overview of the change in economic structure undergone by the city over recent years,

- The **DOMESTIC SECTOR** saw an energy consumption of 4,749 GWh in 2008, slightly higher than in 1999, which totalled 4,556 GWh. If we analyse the behaviour of the sector during the period 1999-2008, a notable feature is the increase in consumption until 2005 – especially as from 2002, with a growth rate of 3.77%-, and the marked drop during the period 2005-2008 – with a negative rate of 5.85%-, such that during the period 1999-2008 the resulting annual rate was 0.46%. Therefore, between the years 1999 and 2008, consumption in this sector saw virtually no rise.
  To understand this, it must be borne in mind that there was an overall drop in the consumption of natural gas, which the domestic sector is highly sensitive to. The slight increase in the population of Barcelona – which directly affects consumption in this sector -, was accompanied by a change in the density of the residential sector which slightly offset consumption. There was an increase in the intensity of electricity consumption per inhabitant – caused by the growing penetration of technology in homes – and the above drop in the intensity of natural gas consumption per inhabitant.
  The reason for this lower natural gas consumption is, amongst others, the reduction in consumption for heating purposes: in 2006 because it was warmer than 2005, and in 2008 possibly because the onset of the economic crisis gave rise to greater energy saving. Another factor to be taken into account is the reduction in consumption as a result of improved energy efficiency in new dwellings and their equipment.
- In the **SERVICE SECTOR**, energy consumption in 2008 was 5,083 GWh, vs. 4,049 GWh in 1999. The annual growth rate during this period was 2.56%, with a more regular behaviour in the domestic sector, despite the reduction in consumption seen also in 2008.
  This continued increase in service sector consumption during the period 1999-2008 was related to a net growth in the economic activity and greater presence of electrically powered technology. On the other hand, natural gas consumption underwent a slight reduction.
- In the **INDUSTRIAL SECTOR**, consumption in 2008 totalled 2,929 GWh, less than in 1999, 2,993 GWh. The annual growth rate was therefore negative (-0.24%). A year-on-year analysis shows the varied behaviour, with a drop in consumption as from 2005 as occurred in other sectors.
- In the **TRANSPORT SECTOR**, there was a slight rise in consumption during the period 1999-2008, as it rose from 3,965 MWh to 4,100 MWh. However, consumption can be considered virtually stable with an annual growth rate of 0.37%, which over recent years proved negative (-1.69% between 2005 and 2008).
  As a result of governmental policies, there was an increase in the number of users of electric means of public transport (metro, train and tram) and an increase in the natural gas powered fleet of buses. Despite the resulting growth in electricity and natural gas consumption, energy consumption per passenger improved.
  On the other hand, private transport saw a reduction in the number of cars in circulation and an increase in efficiency per km covered, a factor which led to a slight reduction in the consumption of automotive fuel. At the same time, however, the greater traffic of goods lorries, buses and two-wheeled vehicles signified that total petrol consumption in 2008 (diesel and petrol) was practically the same as in 1999.
- The **OTHER SECTORS (OTHERS)** is a group comprising the primary, energy, construction sector and public works. Over all, between the years 1999 and 2008 their energy consumption grew by 3.68%, with a sharp increase until 2005 and a reduction in subsequent years. We should also take into account their limited importance compared to the total energy consumption of the city (0.8%).

FIGURE 53 | EVOLUTION OF ENERGY CONSUMPTION BY SECTOR (1992-2008)



Source: ICAEN and Repsol

TABLE 9 | AVERAGE ANNUAL GROWTH RATES OF ENERGY CONSUMPTION BY SECTOR (1999/2008)

Average annual growth rates of energy consumption by sector (1999/2008)			
	1999 – 2008	1999 - 2005	2005 - 2008
Residential	0.46%	3.77%	-5.85%
Tertiary	2.56%	3.51%	0.68%
Industrial	-0.24%	4.02%	-8.24%
Transport	0.37%	1.42%	-1.69%
Other	3.68%	10.46%	-8.67%
Total	**0.91%**	**3.23%**	**-3.57%**
Total per inhabitant	**0.11%**	**2.24%**	**-4.03%**

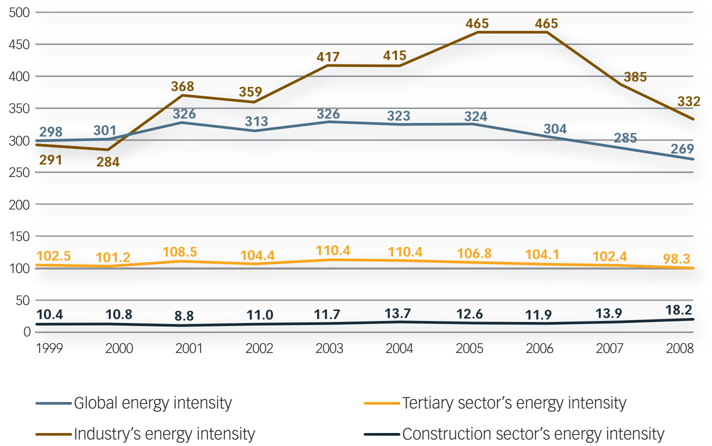
Source: ICAEN and Repsol

TABLE 8 | ENERGY CONSUMPTION BY SECTOR (1999/2008)

Energy consumption by sector (1999/2008)			
	1999	2008	1999 - 2008
Residential	4,556.04	4,749.34	0.46%
Tertiary	4,049.60	5,083.79	2.56%
Industrial	2,993.50	2,929.76	-0.24%
Transport	3,965.88	4,100.83	0.37%
Other	99.76	138.07	3.68%
Total	**15,664.78**	**17,001.78**	**0.91%**
Total per inhabitant	**10.4 MWh/inhab.**	**10,5 MWh/inhab.**	**0.11%**

Source: ICAEN and Repsol

FIGURE 54 | EVOLUTION OF ENERGY INTENSITY BY SECTOR (1999-2008)



▲ The global energy intensity of Barcelona – i.e. the amount of energy used per unit of production or service – has fallen over recent years, from 298 Wh/€ in 1999 to 269 Wh/€ in 2008. This drop was mainly due to the improved efficiency of the industrial sector and, to a lesser extent, the services sector. In the construction sector, however, it has increased.

Traffic study

In order to determine the energy consumption in transport, it is first necessary to estimate the consumption of automotive fuel based on the data and traffic network of the city. This, in turn, enables us to obtain annual vehicles in vehicle-km to calculate the consumption and associated emissions.

In Barcelona, energy consumption for transport (both private vehicles and buses) recorded a significant rise as from 1992, mainly due to the construction of roads offering greater traffic capacity, the Ring-roads. As from 2002, following this period of growth, the city again became saturated and as a result, private cars encountered greater difficulties, a trend resulting in a slight downward curve both in traffic and fuel consumption.

This reduction in traffic was the result not only of the saturation of the road network at peak times, but also of the local government's adoption of measures to make mobility in private vehicles less competitive: The improvement of the bus network, the creation of *"blue zones"* (metered parking), the introduction of the *"green zones"* (residents' parking), the enlargement of spaces for pedestrians...

The renovation of the vehicle population and introduction of better technologies in combustion engines, with the resulting energy efficiency have contributed to the reduction in energy consumption. Thus, if 57% of the vehicles registered in Barcelona in 1999 were older than in 1992 (prior to Euro I), in 2008 this percentage dropped to 18.7%. 32.8% of vehicles were Euro I and II, 22.5% Euro III and 21.8% Euro IV.

We should note that, based on the data obtained in the characterisation study of the vehicle population of Barcelona (see section 2.1.7), the population of passenger cars in circulation is more modern than that of the vehicles registered, a feature which has a major impact on energy consumption and polluting emissions calculations.

FIGURE 55 | EVOLUTION OF THE VEHICLE POPULATION, REGISTERED AND IN CIRCULATION IN BARCELONA (1999-2009)

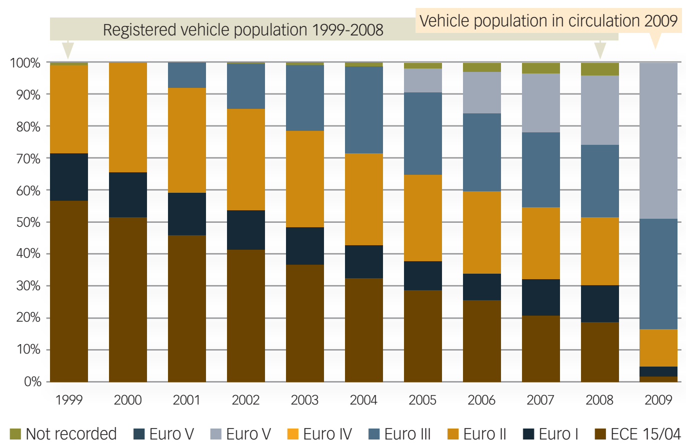
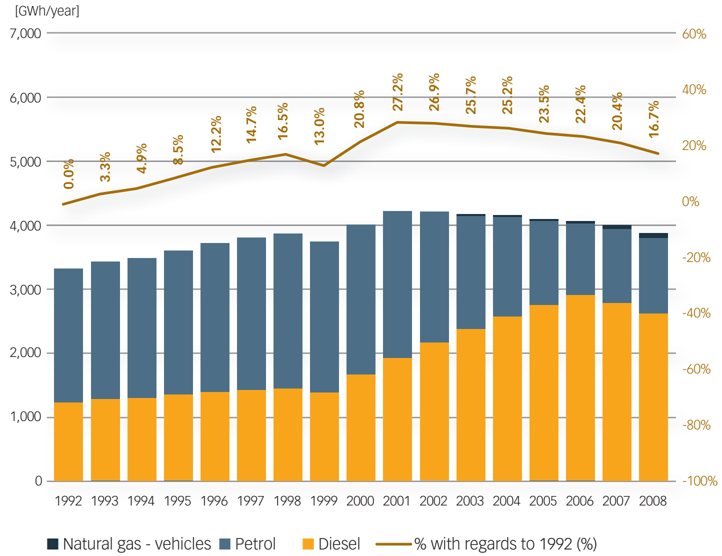
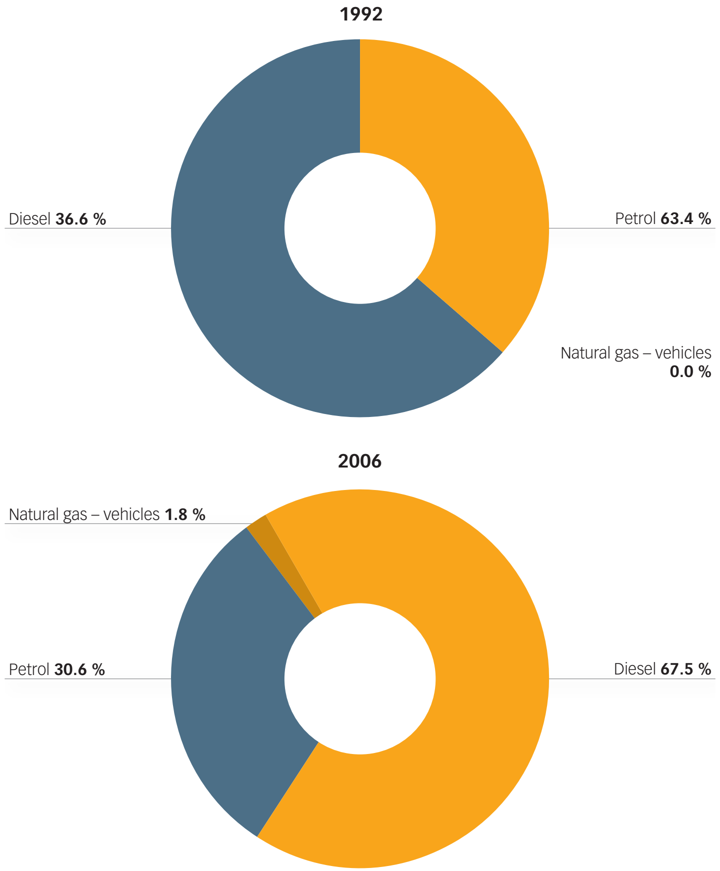


FIGURE 56 | EVOLUTION OF ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1992-2008)



▲ Based on the difference observed between the registered population and that in circulation, and taking into account that this difference is probably smaller in historic series, the evolution of automotive fuels has been recalculated to standardize the series.

FIGURE 57 | ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1992-2006)



The annual growth rate of energy consumption by the automotive sector between 1999 and 2008 was 0.37%, although it reached 6.11% during the period 1999-2001. As from that year, until 2008, the rate fell to -1.22%. If we add road traffic consumption with rail consumption (248.47 GWh) and LPG (2.19 GWh), the total consumption by transport in Barcelona stood at 4,100.83 GWh in 2008.

TABLE 10 | ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1999/2001/2008)

Energy consumption by vehicles in Barcelona			
	1999 [GWh]	2001 [GWh]	2008 [GWh]
Automotive oil (Petrol)	2,361.71	2,290.94	1,178.91
Automotive oil (Diesel)	1,364.22	1,904.05	2,600.07
Automotive natural gas	0.00	0.11	71.19
Electric vehicle (electricity)	0	0	0
Total	**3,725.93**	**4,195.10**	**3,850.17**
Total per inhabitant	**2.48 MWh/ inhab.**	**2.79 MWh/ inhab.**	**2.38 MWh/ inhab.**

TABLE 11 | AVERAGE ANNUAL GROWTH RATES OF ENERGY CONSUMPTION BY VEHICLES IN BARCELONA (1999/2008)

Average annual growth rates of energy consumption by vehicles in Barcelona			
	1999 - 2008	1999 - 2001	2001 – 2008
Automotive	0.37%	6.11%	-1.22%
Energy per inhabitant	-0.44%	6.04%	-2.21%
Population	0.80%	0.06%	1.01%

TABLE 12 | TRANSPORT CONSUMPTION IN BARCELONA (1999/2008)

Transport consumption in Barcelona			
	1999 [GWh]	2001 [GWh]	2008 [GWh]
Total	**3,965.88**	**4,425.90**	**4,100.83**
Total per inhabitant	**2.64 MWh/inhab.**	**2.94 MWh/inhab.**	**2.54 MWh/inhab.**

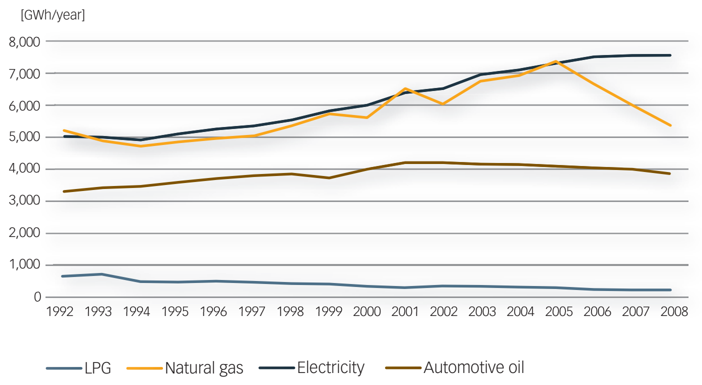
2.2.3 - CONSUMPTION BY ENERGY SOURCE

If we observe the evolution of energy consumption by energy source, the largest energy increase during the period 1999-2008 was led by electricity consumption with an average annual rate of 2.91%, but also the drop in consumption of natural gas and LPG, especially pronounced as from 2005 in the case of natural gas, at figures similar to those of 1992 and below those for 1999.

The reasons for the drop in natural gas consumption is believed to be related to milder weather as from 2006 (2005 was a harsh year, especially in winter, as shown by the generalised peak in energy consumption in Catalonia and in Spain).

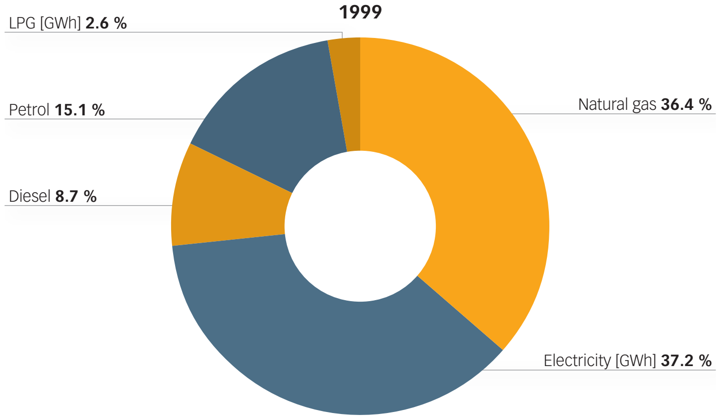
We also observe a reduction in the increase in consumption of automotive fuels, petrol and diesel which is attributed to two factors: less private transport road traffic in the city and enhanced energy efficiency of the vehicle population in circulation, as explained above.

FIGURE 58 | EVOLUTION OF ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE (1992-2008)

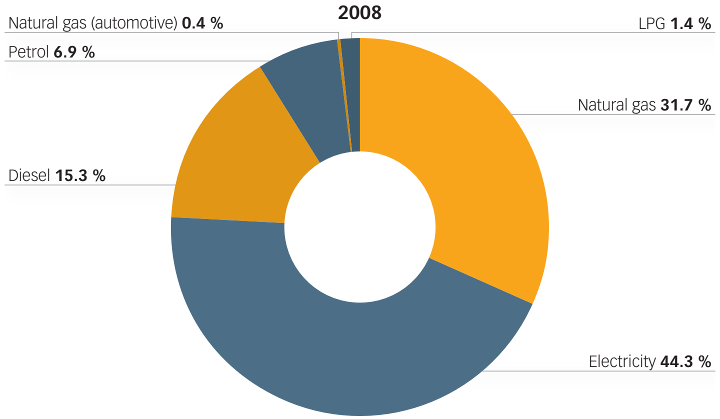


Source: ICAEN (electricity, natural gas and LPG) and Barcelona Regional (automotive fuel)

FIGURE 59 | ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE (1999/2008)



▲ Consumption in 2008: 15,664.78 GWh



▲ Consumption in 2008: 17,001.78 GWh

Source: ICAEN

TABLE 13 | AVERAGE ANNUAL GROWTH RATES OF ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE (1999/2008)

Average annual growth rates of energy consumption in Barcelona by energy source		
	1999 - 2005	1999 - 2008
Electricity	3.80%	2.91%
Natural gas	4.22%	-0.64%
LPG	-5.32%	-6.21%
Automotive oil	1.49%	0.37%
Total	**3.23%**	**0.91%**
Total per inhabitant	**2.24%**	**0.11%**

TABLE 14 | FINAL ENERGY CONSUMPTION IN BARCELONA, BY ENERGY SOURCE (1999/2008)

Final energy consumption in Barcelona, by energy source		
	1999 [GWh]	2008 [GWh]
Electricity	5,824.20	7,536.66
Natural gas	5,699.67	5,381.83
LPG	414.98	233.12
Automotive oil	3,725.93	3,850.17
Total	**15,664.78**	**17,001.8**
Total per inhabitant	**10.42 MWh/inhab.**	**10.52 MWh/inhab.**

Source: ICAEN (electricity, natural gas), REPSOL-YPF (LPG) and Barcelona Regional (automotive fuel)

Evolution of electricity consumption

Barcelona consumed 7,536.66 GWh of electricity in 2008, 29% up over 1999. By sectors, consumption was distributed as follows: 55.1% in the services sector, 30.4% in the residential sector, 9.4% in industry and 5.1% other minority sectors. When comparing the distribution of electricity consumption in 2008 with that of 1999, we observe that, over this period, the services sector increased by 4.2%, while the industrial sector fell by 5.1%.

TABLE 15 | ELECTRICITY CONSUMPTION IN BARCELONA, BY SECTOR (1999/2008)

Electricity consumption in Barcelona, by sector		
	1999 [GWh]	2008 [GWh]
Residential (electric)	1,711.36	2,289.58
Tertiary (electric)	2,961.77	4,148.98
Industrial (electric)	845.49	711.57
Traction (electric)	205.83	248.47
Other (electric)	99.75	138.06
Total	**5,824.20**	**7,536.66**
Total per inhabitant	**3.87 MWh/inhab.**	**4.66 MWh/inhab.**

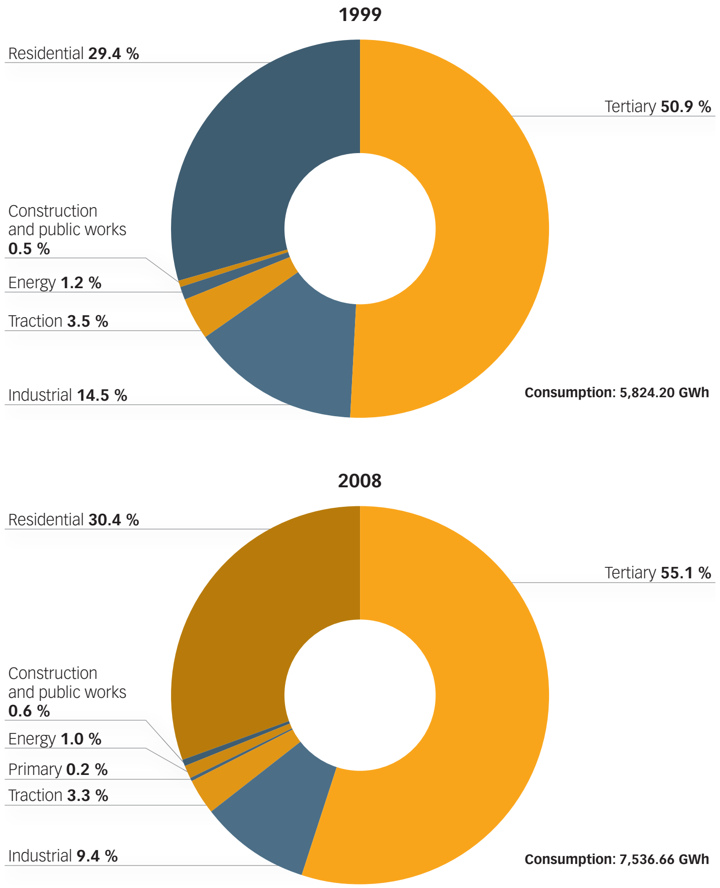
Source: ICAEN

TABLE 16 | AVERAGE ANNUAL GROWTH RATES OF ELECTRICITY CONSUMPTION (1999-2008)

Average annual growth rates of electricity consumption	
	1999 - 2008
Electricity	2.91%
Electricity per inhabitant	2.08%
Population	0.80%

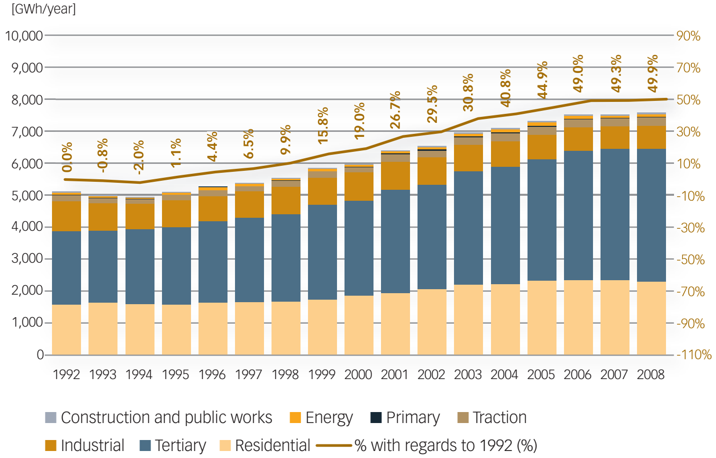
Source: ICAEN

FIGURE 60 | ELECTRICITY CONSUMPTION IN BARCELONA, BY SECTOR (1999/2008)



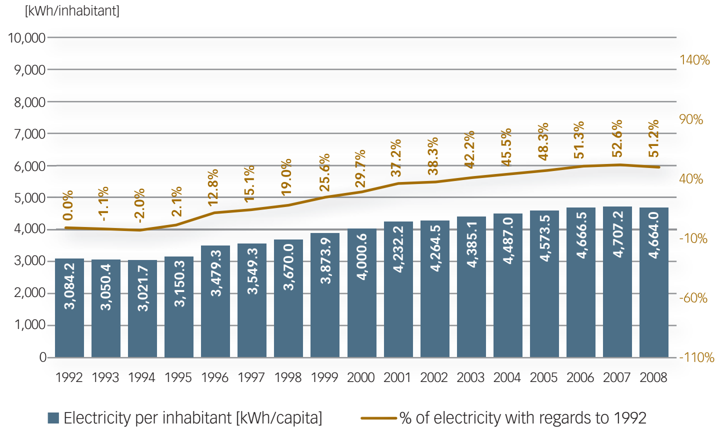
Source: ICAEN

FIGURE 61 | EVOLUTION OF ELECTRICITY CONSUMPTION (1992-2008)



Source: ICAEN

FIGURE 62 | EVOLUTION OF ELECTRICITY CONSUMPTION PER INHABITANT (1992-2008)



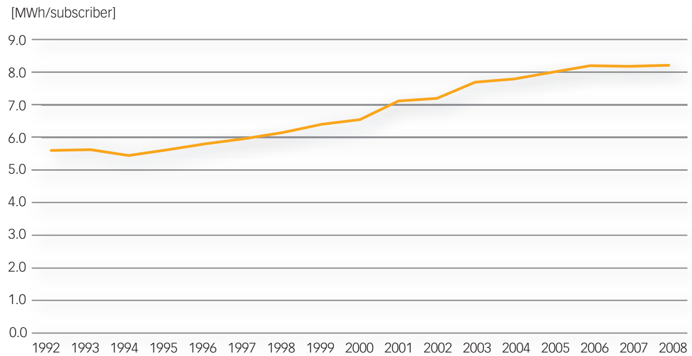
The evolution of electricity consumption has always shown an upward trend (except in 93 and 94), and in particular in 1996 and 2003. As from 2006 the increase in consumption slowed down compared to previous years.

The ratio of electricity consumption per inhabitant underwent a similar process, as the increase as from 2006 was well below that of earlier years, totalling 4.65 MWh/inhab in 2008. However, if we consider only the residential sector, consumption per inhabitant reached 1.42 MWh/inhab in 2008, while in 1999 this figure was 1.14 MWh/inhab.

The historic evolution of the electricity consumption ratio by service connection also rose at a rate of 1.94% a year during the period 1992-1999 and 2.81% a year during the period 1999-2008. The largest growth took place between 1999-2003, with an annual rate of 4.70%.

In general, the entire 1999-2008 period was heavily influenced by the technological evolution of society, both in the use of new appliances and the increase in the number of infrastructures necessary to meet the needs of the population.

FIGURE 63 | EVOLUTION OF ELECTRICITY CONSUMPTION BY SUBSCRIBER (1992-2008)



Source: ICAEN

n this respect, the residential sector is that which has seen most growth in technological equipment, especially with the generalised installation of air-conditioning systems and the Internet boom, which explains why consumption by this sector is greater than the increase in the rest, both in absolute terms and as a ratio per inhabitant.

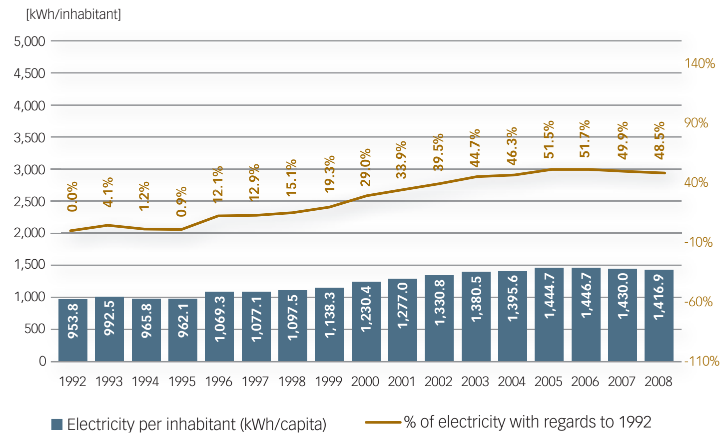
Despite this increase, during the latter years of the period 1999-2008, electricity consumption in the residential sector levelled out and even fell slightly during the last two years. The commencement of the economic crisis and purchase of more efficiency equipment would seem to be the causes which have led to this energy saving, according to a technical study carried out by Repsol[15], in which it estimated that the specific consumption of equipment had fallen by over 20%.

TABLE 17 | AVERAGE ANNUAL GROWTH RATES OF ELECTRICITY CONSUMPTION IN THE RESIDENTIAL SECTOR IN BARCELONA (1999-2008)

Average annual growth rates of electricity consumption in the residential sector in Barcelona	
	1999 - 2008
Residential electricity	3.29%
Residential electricity per inhabitant	2.46%
Population	0.80%

Source: ICAEN

FIGURE 64 | EVOLUTION OF ELECTRICITY CONSUMPTION OF THE RESIDENTIAL SECTOR PER INHABITANT (1992-2008)

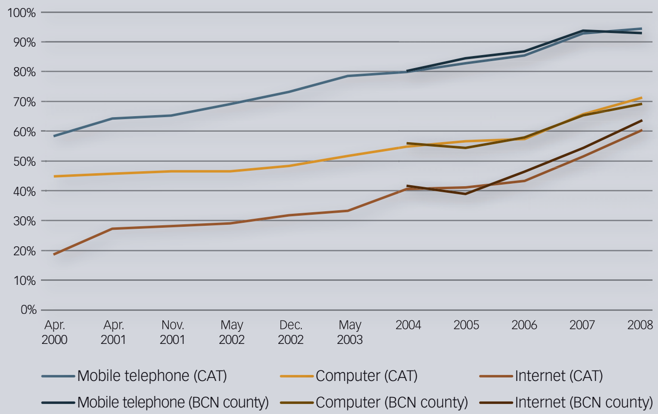


15. Repsol Technical Study Consumo de energía en España 2008.

HOME EQUIPMENT AND ENERGY CONSUMPTION

Over recent years there have been significant changes in the appliances in Spanish homes, as some have been renewed (refrigerators, freezers, washing machines and dishwashers, especially) and new ones have been added, in particular those related to communication technologies. Two examples of this are the increase in the number of computers (+11% between 2004 and 2007) and microwave ovens (+24% during the period 2000-2005).
The improved efficiency of these appliances is evident from the reduction in specific consumption, approximately -23% to -37% during the period 1990 to 2006, according to different studies.

FIGURE 65 | EVOLUTION OF ICT EQUIPMENT IN HOMES IN CATALONIA (2000-2008)



Source: Observatory for the Information Society [OBSI] and IDESCAT

Evolution of natural gas consumption

The consumption of natural gas in Barcelona in 2008 was 5,381.83 GWh. By sector, 41.9% was consumed in the residential sector, 40.7% in the industrial sector and 17.4% in the services sector. These percentages are very similar to those of 1999.

Natural gas consumption underwent a sharp increase during the period 1999-2005, although as from that year, consumption dropped markedly until 2008, with figures similar to those of 1992 and lower than in 1999.

An analysis by sector shows that while the average annual increase in the residential and services sector in the period 1999-2005 was 3.87% and 1.49% respectively, during the period 2005-2008 there were annual reductions of 10.11% and 7.70% respectively. The industrial sector also saw similar fluctuations, because while consumption increased at a rate of 5.85% in the period 1999-2005, subsequently this trend reversed during the period 2005-2008 at a rate of 10.04%. The industrial sector is the only one which has a virtually identical consumption between the years 1999 and 2008.

As regards the consumption of natural gas per inhabitant, this figure stood at 3.79 MWh in 1999, then increasing by 3.22% a year to a total of 4.58 MWh/inhabitant in 2005. One of the reasons behind this peak in consumption would be the low winter temperatures recorded that year which, compared with those of other years, showed differences in the minimum temperatures of over one degree.

TABLE 18 | CONSUMPTION OF NATURAL GAS IN BARCELONA, BY SECTOR (1999/2005/2008)

Consumption of natural gas in Barcelona, by sector			
	1999 [GWh]	2005 [GWh]	2008 [GWh]
Residential (natural gas)	2,472.22	3,105.53	2,255.90
Tertiary (natural gas)	1,087.83	1,188.66	934.81
Industrial (natural gas)	2,139.62	3,009.77	2,191.12
Total	**5,699.67**	**7,303.96**	**5,381.83**
Total per inhabitant	**3.79 MWh/ inhab.**	**4.58 MWh/ inhab.**	**3.33 MWh/ inhab.**

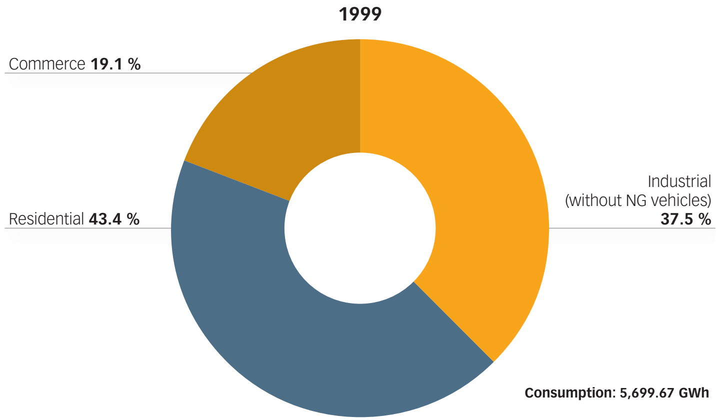
Source: ICAEN

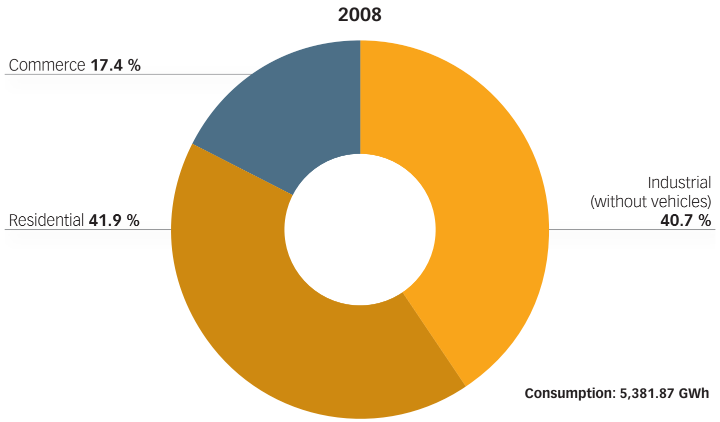
TABLE 19 | AVERAGE ANNUAL GROWTH RATES OF NATURAL GAS CONSUMPTION (1999-2008)

Average annual growth rates of natural gas consumption		
	1999 - 2005	1999 - 2008
Natural gas	3.84%	-0.64%
Natural gas per inhabitant	3.22%	-6.96%
Population	0.97%	0.80%

Source: ICAEN

FIGURE 66 | CONSUMPTION OF NATURAL GAS IN BARCELONA, BY SECTOR (1999/2008)



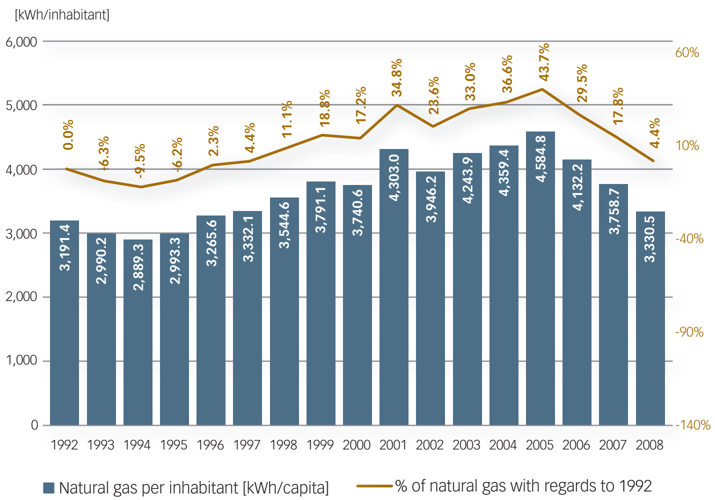


Source: ICAEN

As from 2005 there was a clear change in the trend and the ratio fell at an annual rate of 10.11% to 3.33 MWh/inhabitant in 2008. Such a low per capita consumption had not been seen since the year 1997.

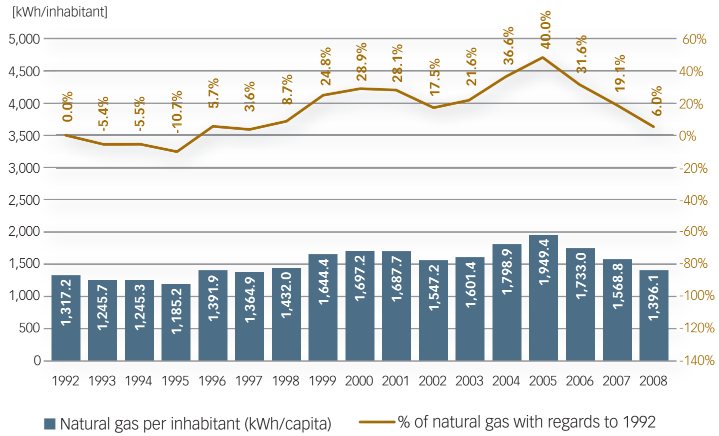
Despite this, the energy efficiency improvement policies in housing and heating systems may also be a factor – though to a lesser degree - together with possible changes in the facilities in refurbished homes (installation of electrical systems in housing intended for rent, with a lower investment). This contrasts with the evolution of electricity consumption in the residential sector, opposed to that of natural gas. If we analyse solely the residential sector, we can see how the reduction in natural gas consumption is greater than that of consumption throughout the city for the period 2005-2008.

FIGURE 67 | EVOLUTION OF NATURAL GAS CONSUMPTION PER INHABITANT (1992-2008)



Source: ICAEN

FIGURE 68 | EVOLUTION OF NATURAL GAS CONSUMPTION IN THE RESIDENTIAL SECTOR PER INHABITANT (1992-2008)



Source: ICAEN

TABLE 20 | AVERAGE ANNUAL GROWTH RATES OF NATURAL GAS CONSUMPTION IN THE RESIDENTIAL SECTOR (1999-2008)

Average annual growth rates of natural gas consumption in the residential sector		
	1999 - 2005	2005 - 2008
Residential natural gas	3.87%	-1.01%
Residential natural gas per inhabitant	2.88%	-1.8%
Population	0.97%	0.80%

Source: ICAEN and Barcelona City Council

Evolution of the consumption of liquefied petroleum gases (LPG)

The consumption of liquefied petroleum gases or LPG (butane, propane and mixes) in Barcelona was 233.12 GWh in 2008, well below the 414.98 GWh of 1999. Therefore, the downward trend is inversely proportional to the upward trend in consumption of natural gas and electricity.

TABLE 21 | CONSUMPTION OF LIQUEFIED PETROLEUM GASES IN BARCELONA BY SECTOR (1999/2008)

Consumption of liquefied petroleum gases in Barcelona by sector		
	1999 [GWh]	2008 [GWh]
Residential (butane)	372.46	203.86
Commerce/industrial (propane)	8.39	27.07
Traction (mix)	34.13	2.19
Total	**414.98**	**233.12**
Total per inhabitant	**0.28 MWh/inhab.**	**0.14 MWh/inhab.**

Source: ICAEN

TABLE 22 | AVERAGE ANNUAL GROWTH RATES OF LIQUEFIED PETROLEUM GAS CONSUMPTION (1999-2008)

Average annual growth rates of liquefied petroleum gas consumption	
	1999 - 2008
LPG	-6.21%
LPG per inhabitant	-6.96%
Population	0.80%

Source: Repsol-YPF

Since 2005 (the year in which practically 95% of the LPG sold in Barcelona was butane, closely related to the residential sector) there was an increase in the proportion of propane for the services sector to a total of 11.6% in 2008. Global consumption of LPG and especially butane in the residential sector continued to fall as from 1999, except for a recovery in 2002. Butane mix (used in certain machinery used in logistics) has almost disappeared. Thus, current sales of LPG in Barcelona are mostly of butane and there is a small proportion of propane which is used in the commercial/industrial sector.

As regards the consumption of LPG per inhabitant, in 2008 this was 0.14 MWh with a rate of reduction of 6.96% during the period 1999-2008.

FIGURE 69 | EVOLUTION OF THE CONSUMPTION OF LIQUEFIED PETROLEUM GASES (1992-2008)

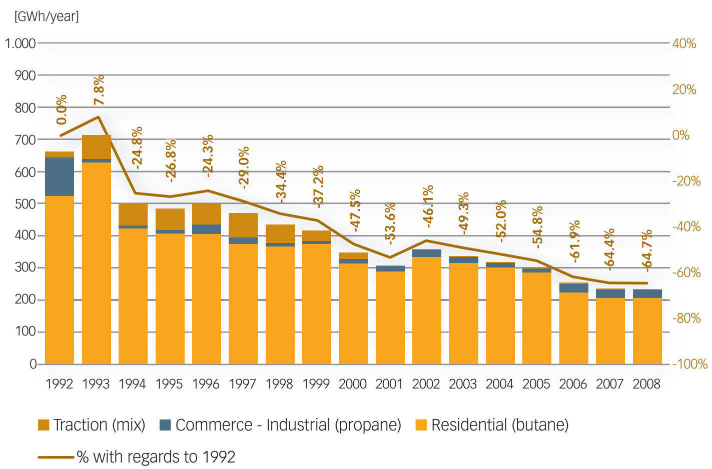
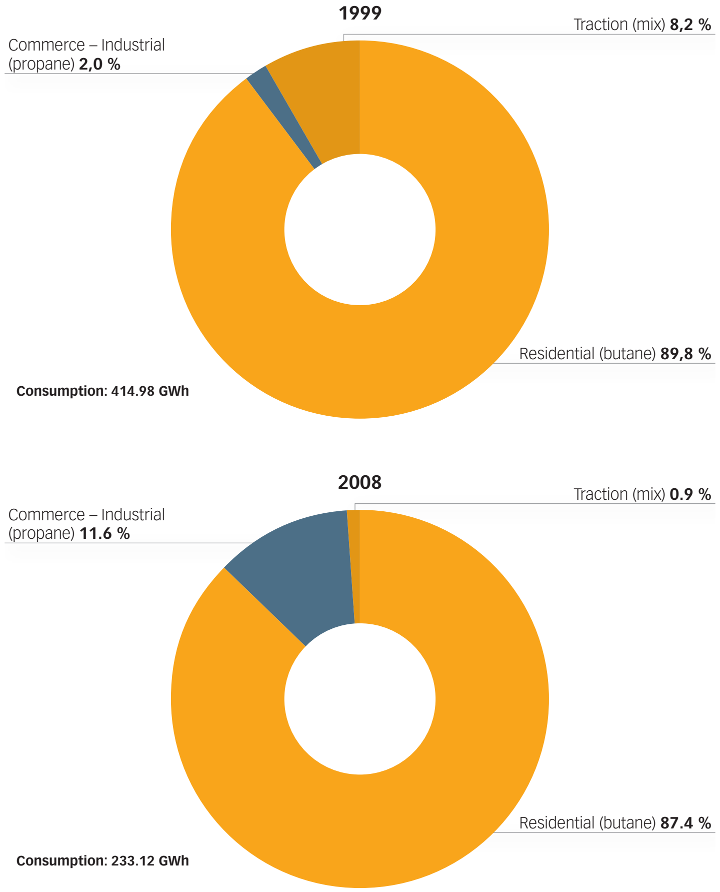


FIGURE 70 | CONSUMPTION OF LIQUEFIED PETROLEUM GASES IN BARCELONA BY SECTOR (1999/2008)



Source: Repsol-YPF

FIGURE 71 | EVOLUTION OF THE CONSUMPTION OF LIQUEFIED PETROLEUM GASES PER INHABITANT (1992-2008)

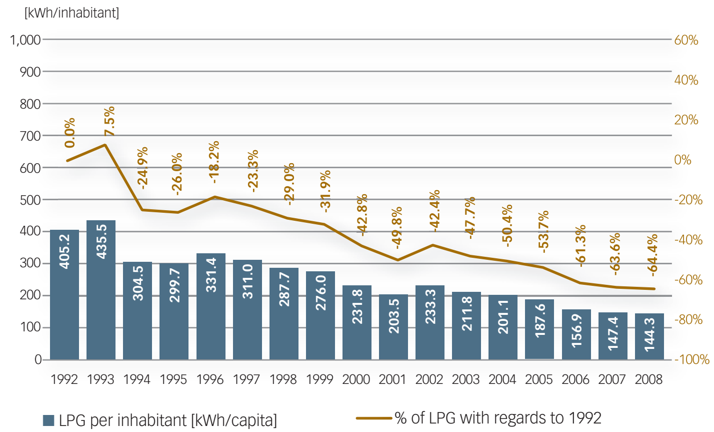
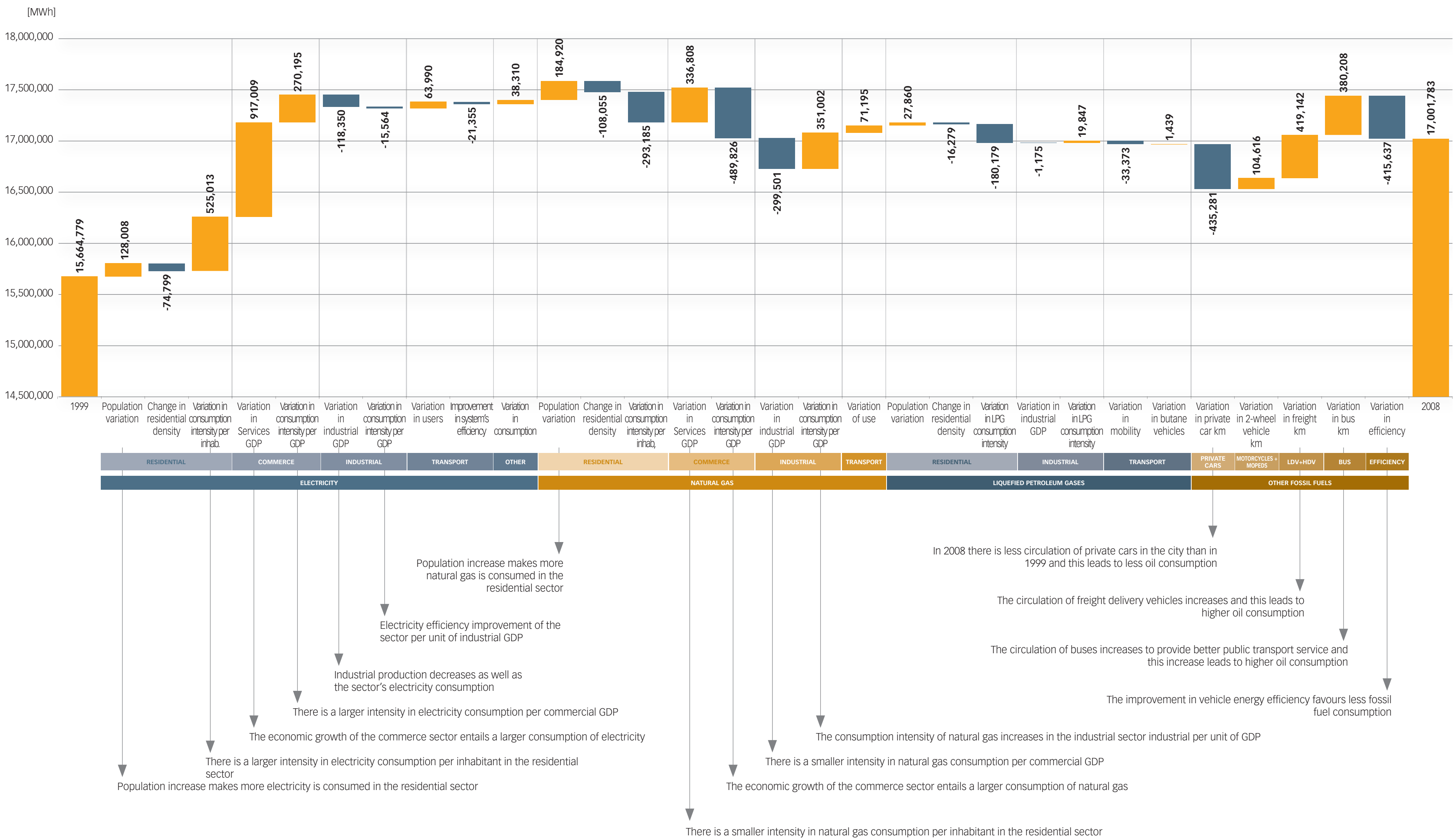


FIGURE 72 | VARIATION IN THE CONSUMPTION OF FINAL ENERGY IN BARCELONA (1999-2008)

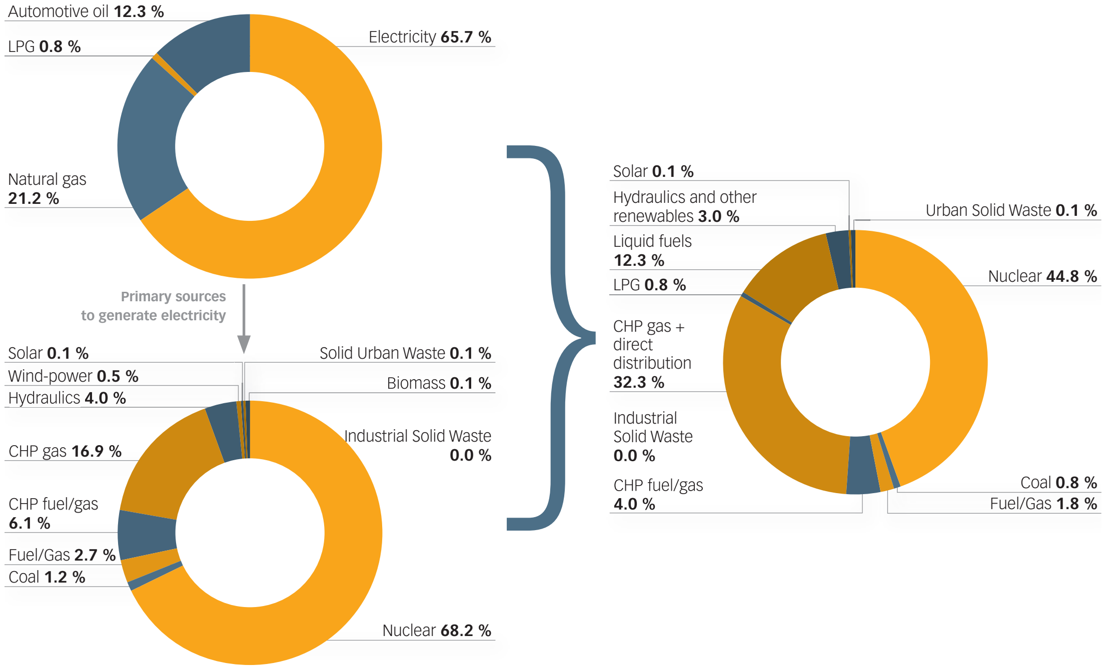


2.2.4 - PRIMARY ENERGY CONSUMPTION

In order to meet the final energy demand of Barcelona in 2008 (17,001.78 GWh of final energy), 30,783.60 GWh of primary energy were necessary, 9.3% more than in 1999. This figure includes the transformation losses of primary energy into final energy in the electricity production system of Catalonia, and the consumption of the energy sector itself and an estimate of the losses in energy transmission.

Notwithstanding this, the efficiency of the energy system is practically the same as in 1999, despite an improvement in the electricity system, probably due to the greater importance of combined cycles in thermal plants (which are more efficient than conventional systems), and renewable energy sources.

FIGURE 73 | PRIMARY ENERGY SOURCES IN BARCELONA (2008



Of the total primary energy, 65.7% was used to generate and transmit electricity, while the rest is distributed between natural gas (21.2%), liquid fuels for transport (12.3%) and LPG (0.8%).

Of the primary energy necessary to produce electricity, 68.2% was generated by nuclear energy (in 1999 this percentage was 77.9%), while 16.9% was generated by natural gas used in the new combined cycles (in 1999 it was 0% as combined cycle technology did not exist).

The arrival of combined cycles for electricity generation in Catalonia has reduced the percentage generated by nuclear energy by 9.7 points; generation by conventional thermal plants using fuel/gas by 4.4 points, while coal powered plants account for practically the same proportion as in 1999.

TABLE 23 | PRIMARY AND FINAL ENERGY CONSUMPTION IN BARCELONA (1999/2008)

Primary and final energy consumption in Barcelona		
	1999	2008
Final energy consumption	15,664.78 GWh	17,001.78 GWh
Primary energy consumption	28,158.87 GWh	30,783.60 GWh
System's efficiency	55.63%	55.23%
System's electricity efficiency	33.6%	37.3%

Source: ICAEN

2.3 - Energy generation

2.3.1 - GLOBAL GENERATION

In 2008, the energy infrastructures located in the municipality of Barcelona and Besòs (boundary with Barcelona), produced 5,243.2 GWh of electrical energy (5,684 GWh in 2006) and 52.4 GWh of solar thermal energy.

Of this energy, 93% was generated at the major production plants (Besòs 3 + 4, and Sant Adrià 1 + 3), which form part of the ordinary regime (OR). The remaining 7% was produced at small energy plants using cogeneration, at renewable energy facilities and waste energy recovery plants. All these facilities form part of the Special Regime (SR).

FIGURE 74 | **ENERGY PRODUCTION FACILITIES IN BARCELONA**

Ordinary regime facilities

- Thermal power plant (Sant Adrià)
- CHP plant (Besòs)

Special regime facilities

- Cogeneration engines
- Renewable sources
- Waste valorisation

FIGURE 75 | **ENERGY PRODUCTION FACILITIES IN BARCELONA**

PRODUCTION UNDER THE ORDINARY REGIME AND SPECIAL REGIME

Under the Spanish law on the electricity sector (54/1997), electricity production can take two forms, depending on the technology and the primary energy resource used:

- Ordinary regime: This is produced using conventional technologies utilised in coal, fuel-oil, natural gas, combined-cycle, nuclear plants, etc.
- Special regime: This refers to production in plants with an output no greater than 50 MW which use renewable sources as their primary energy (biomass, hydraulic, solar and wind) or waste, together with others such as cogeneration, which offer a high level of energy efficiency and saving..

2.3.2 - THE ORDINARY AND SPECIAL REGIMES

Production under the ordinary regime

In the Besòs area, adjacent to Barcelona, there are several electricity production facilities which meet a large part of the energy demand of Barcelona and its surrounding area: the Sant Adrià Plant, with three conventional thermal units (one of them closed down in January 2008) and the combined-cycle plants of Besòs 3 and Besòs 4. Prior to this, the Besòs 1 and 2 and Badalona II were closed down.

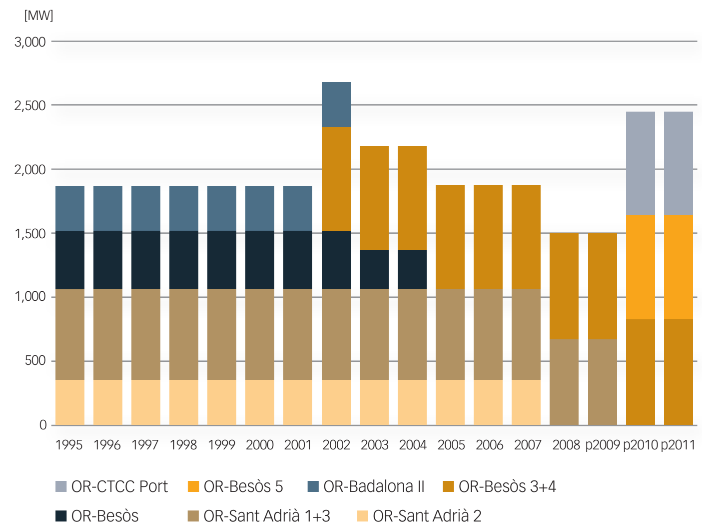
In 2008, in the Besòs area, and considering solely the ordinary regime (OR), there were 1,478 MW of installed capacity distributed as follows: 55.4% combined-cycles (Besòs 3 and 4) 44.6% thermal fuel/gas plants (Sant Adrià 1 and 3). The fuel plant (Sant Adrià 2) was closed down by the Generalitat de Catalunya in January 2008 due to its emissions, as this fossil fuel produces much more pollution than the natural gas which powers the Sant Adrià 1 and 3 facilities. This output produced 4,907 GWh in 2008, 96.3% by means of combined-cycles (Besòs 3 and 4) and the remaining percentage by means of conventional thermal plants (Sant Adrià 1 and 3).

The evolution of the percentage of energy produced in Besòs compared to that generated by Catalonia (only ordinary regime) as a whole, shows how this territory has gained in importance over recent years, as the new combined-cycle plants in Besòs have produced much more energy than the former plants

The evolution of the percentage of energy produced in Besòs compared to that generated by Catalonia (only ordinary regime) as a whole, shows how this territory has gained in importance over recent years, as the new combined-cycle plants in Besòs have produced much more energy than the former plants. Thus, in 2008, 13% of the total energy was produced in Besòs (Sant Adrià 1+3 and Besòs 3+4), while in 2001, the year before the Besòs 3+4 combined-cycle plants were commissioned, this figure was just 4.7%.

The installed capacity in 2008 under the ordinary regime in Besòs, compared to the total installed capacity in Catalonia was lower than in 2001 (16.1%, vs. 23.4%)

FIGURE 76 | EVOLUTION OF THE INSTALLED ELECTRICITY CAPACITY AND FORECAST FOR THE FUTURE (ORDINARY REGIME)



Source: Red Eléctrica de España

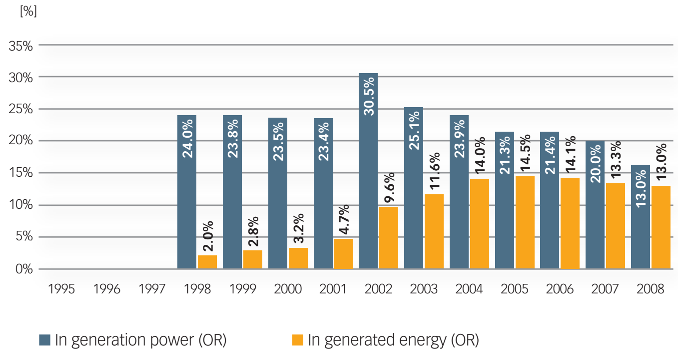
▲ In 2002 there was a peak of installed capacity due to the temporary overlapping of outputs during the substitution of the classic thermal plants by combined-cycles.

TABLE 24 | EVOLUTION OF THE INSTALLED ELECTRICITY CAPACITY IN FACILITIES AND TOTAL PRODUCTION 1995-2008 (ORDINARY REGIME)

Ordinary regime [MW]	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
OR-Sant Adrià 2 [Fuel]	350	350	350	350	350	350	350	350	350	350	350	350	350	0
OR-Sant Adrià 1+3 [Fuel/Gas]	700	700	700	700	700	700	700	700	700	700	700	700	700	659
OR-Besòs [Fuel/Gas]	450	450	450	450	450	450	450	450	300	300	0	----	----	----
OR-Besòs 3 and 4 [CHP]	0	0	0	0	0	0	0	800	800	800	800	812	812	819
OR-Badalona II [Fuel]	344	344	344	344	344	344	344	344	0	----	----	----	----	----
OR-Besòs 5 [CHP]	----	----	----	----	----	----	----	----	----	----	----	----	----	----
OR-CTCC Port of Barcelona	----	----	----	----	----	----	----	----	----	----	----	----	----	----
Ordinary regime power [BESÒS ENVIRONMENT]	**1,844**	**1,844**	**1,844**	**1,844**	**1,844**	**1,844**	**1,844**	**2,644**	**2,150**	**2,150**	**1,850**	**1,862**	**1,862**	**1,478**

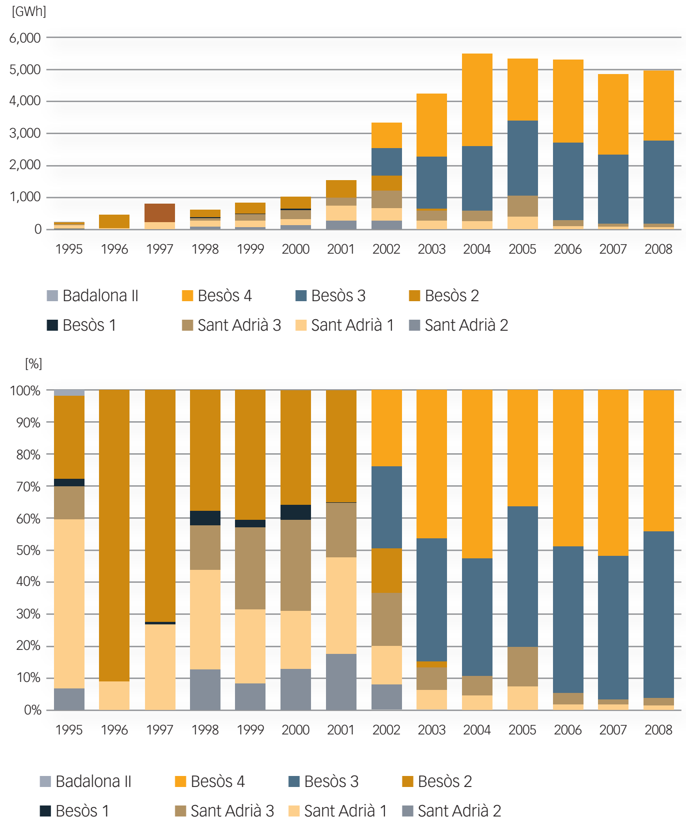
Ordinary regime [GWh]	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
OR-Sant Adrià 2 [Fuel]	15	0	0	75	68	128	264	264	0	-----	-----	-----	-----	-----
OR-Sant Adrià 1+3 [Fuel/Gas]	141	39	211	268	401	463	719	939	562	579	1,040	279	161	179
OR-Besòs [Fuel/Gas]	63	405	578	250	351	403	536	465	77	0	-----	-----	-----	-----
OR-Besòs 3 and 4 [CHP]	0	0	0	0	0	0	0	1,627	3,568	4,872	4,254	4,970	4,655	4,728
OR-Badalona II [Fuel]	4	0	0	0	0	0	0	0	0	-----	-----	-----	-----	-----
Ordinary regime total production [BESÒS ENVIRONMENT]	**223**	**444**	**789**	**593**	**820**	**994**	**1,519**	**3,295**	**4,207**	**5,451**	**5,294**	**5,249**	**4,816**	**4,907**

FIGURE 77 | EVOLUTION OF THE IMPORTANCE OF ELECTRICITY PRODUCTION IN BARCELONA AND BESÒS WITH REGARD TO CATALONIA (ORDINARY REGIME)



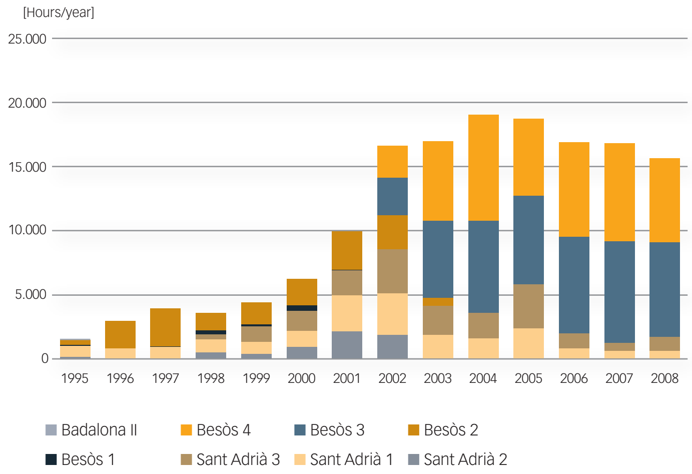
The energy production plants built over recent years (combined-cycles), despite having a lower output compared to the total installed output in Catalonia, produce a larger amount of electricity as they operate more hours.

FIGURE 78 | INSTALLED CAPACITY AND ENERGY PRODUCTION BY GENERATOR UNITS (ORDINARY REGIME)



Source: Red Eléctrica de España

FIGURE 79 | REAL OPERATING HOURS OF THE DIFFERENT GENERATOR UNITS (ORDINARY REGIME)

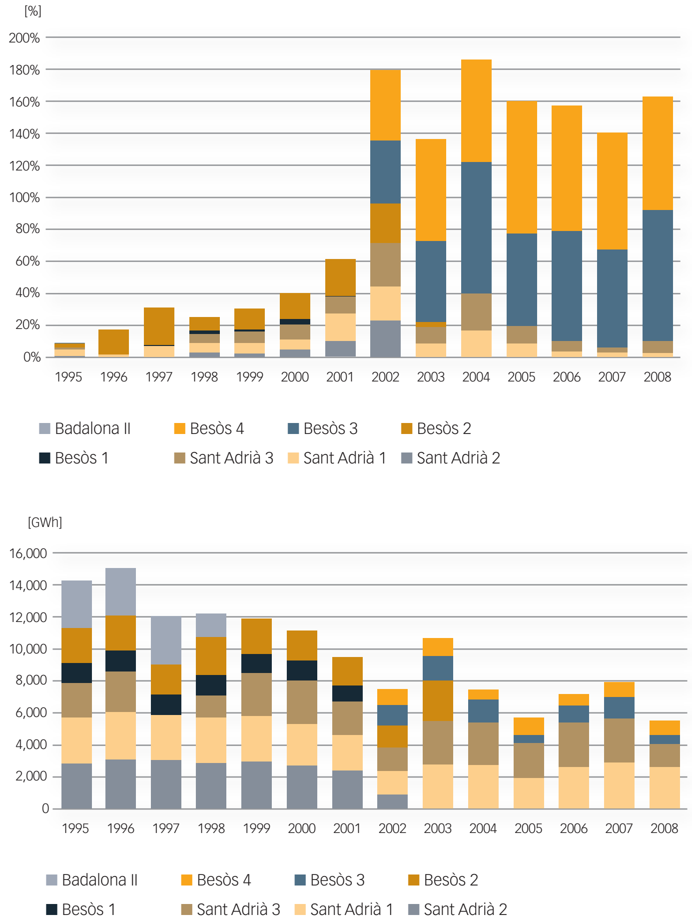


Source: Red Eléctrica de España

The real operating hours of the various energy units increased significantly between 2002 and 2008, as the new combined-cycle units were in operation for more hours to meet the higher electricity demand. In 2008, the Besòs 3 and 4 units operated for 7,469 hours and 6,635 hours respectively.

As regards the usage according to the available production (i.e. the quotient between the real production and the available production or maximum production achieved by the plant operating at nominal output during the hours it is functioning), the two combined-cycles at Besòs 3 and 4 totalled 82.1% and 70.8% respectively in 2008. This indicates that their *"surplus generation capacity"* is being reduced (available production minus real production).

FIGURE 80 | PERCENTAGE OF USE IN ACCORDANCE WITH AVAILABLE PRODUCTION (ORDINARY REGIME)



Source: Red Eléctrica de España

Production under the special regime

In addition to the ordinary regime facilities, Barcelona also has small electricity production plants which operate under the special regime of electricity generation (SR), which includes renewable energy sources and electricity and heat cogeneration processes. [16]Although several of these facilities are not located within the municipal boundary of Barcelona (such as the waste recovery plants) they must be taken into account when taking stock of the city's energy1. [17]This is the case of the power plant in Vall d'en Joan (the controlled landfill in Garraf, now closed) and of the three eco parks located within the metropolitan area (Eco park-1 in Barcelona, Eco park-2 in Montcada i Reixac and Eco park-3 in Sant Adrià), where electricity is obtained using the biogas generated during the decomposition of organic matter from municipal waste and the energy recovery plant in Sant Adrià, attached to the Eco park-3.

Most of the energy is produced in natural gas cogeneration plants (45.4%) and the solid waste recovery plant in Sant Adrià de Besòs (34.9%). Electricity was also produced using the biogas generated in the controlled landfill in Vall d'en Joan del Garraf (weighted energy of waste which was historically disposed of by the city of Barcelona compared to the total production in 2008), and the Eco park-2 (9.5%) and the sludge drying plant (Metrofang) (7.8%). The photovoltaic solar energy facilities (2.1%) and the mini-hydraulic plant in Trinitat (0.4%) account for lower, yet still significant percentages.

Over recent years, electricity production under the special regime totalled approximately 400 GWh a year, although this fell to 370 GWh in 2008 due to the reduction in production of the Metrofang cogeneration plant, coinciding with the change in the sludge drying technology.

16. These plants treat waste from the entire metropolitan area, so to ascertain the energy and GHG balance the same fraction of energy and emissions are assumed for Barcelona as the tonnes of city waste treated at the plant.

17. Eco Park 3 injected 167,504 MWh into the electricity grid in 2008 (obtained from incineration and energy recover from the waste) and 59,912 tonnes of steam to the district heating and cooling of the Fòrum (Districlima).

In the specific case of energy production at the controlled landfill in Vall d'en Joan del Garraf, it must be taken into account that no waste has been disposed of there since 2007. However, the generation of biogas continues, due to the methanisation of waste disposed of during previous years. Barcelona should be assigned part of this production together with the mean fraction of waste over the past four years' operation of the facility.

FIGURE 81 | DISTRIBUTION OF THE ELECTRICAL ENERGY PRODUCED IN BARCELONA AND THE BESÒS AREA, BY FACILITY, 2008 (SPECIAL REGIME)

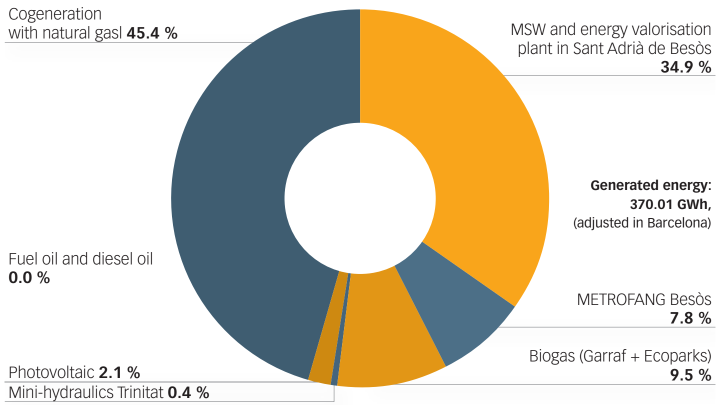


FIGURE 82 | EVOLUTION OF THE ELECTRICAL ENERGY PRODUCED IN BARCELONA AND THE BESÒS AREA 1999-2008 (SPECIAL REGIME)

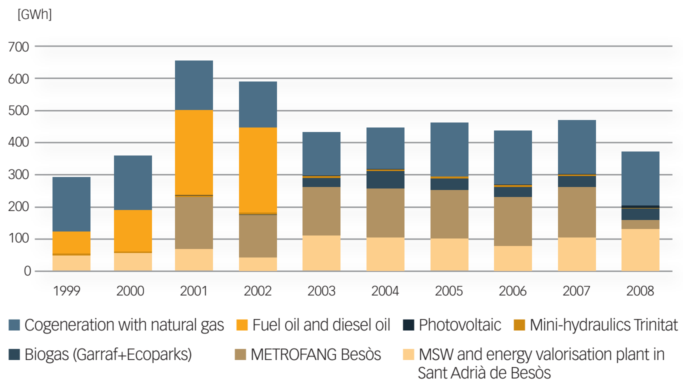


TABLE 25 | EVOLUTION OF ELECTRICITY PRODUCTION IN SPECIAL REGIME FACILITIES, 1999-2008

Special regime [GWh]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
MSW valorisation in Sant Adrià de Besòs	47.51	54.18	66.57	40.45	108.65	103.04	99.30	76.45	102.86	129.23
METROFANG Besòs	0.00	0.00	163.23	132.00	151.97	151.97(*)	151.97(*)	151.97(*)	156.65	28.81
Biogas (Garraf+Ecopark)	0.00	0.00	0.00	2.66	28.40	54.95	36.08	32.58	35.57	35.04
Mini-hydraulics Trinitat	6.22	5.71	5.16	6.30	6.13	5.11	5.11(*)	5.11(*)	3.34	1.47
Photovoltaic	0.003	0.024	0.046	0.130	0.158	0.758	1.01	1.23	1.45	7.62
Cogeneration with fuel oil and diesel oil	68.00	128.00	264.00	264.00	0.00	0.00	0.00	0.00	0.00	0.00
Cogeneration with natural gas	169.33(*)	169.33	153.71	141.76	135.21	128.62	167.85	167.85(*)	167.85(*)	167.85(*)
Special regime total production [BCN + BESÒS ENVIRONMENT]	**291.06**	**357.25**	**652.72**	**587.29**	**430.53**	**444.44**	**461.31**	**435.18**	**467.72**	**370.01**

* Estimates

Own consumption of locally produced electricity

If we consider both production under the ordinary regime (OR) and under the special regime (SR) in Barcelona and the Besòs area, the electricity produced in 2008 totalled 5,277,01.2 GWh (93% in OR and 7% in SR).

Own production of electricity in the territory increased without interruption until 2004, the year when production in the Besòs area started to fall due to the two new combined-cycles in Tarragona coming into full production. When these combined-cycles were commissioned, own consumption had reached a maximum of 81%, but this subsequently fell by 13 points in 2008.

Barcelona and the Besòs area therefore produce 68% of the electricity the municipalities of Barcelona and Sant Adrià de Besòs consume on an annual basis, i.e. it is necessary to import 32% of the electricity per year.

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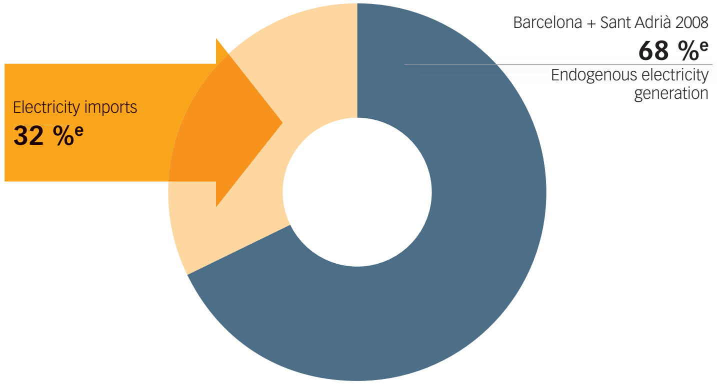
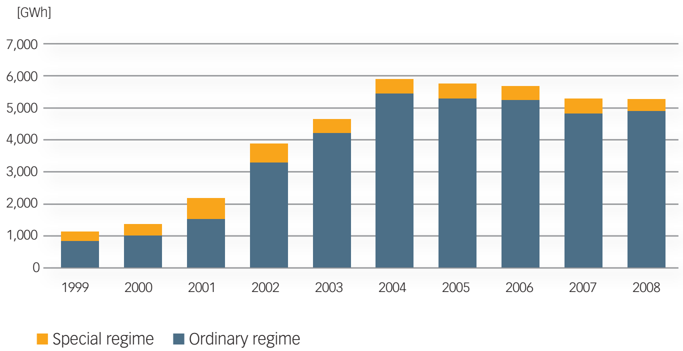


FIGURE 83 | EVOLUTION OF TOTAL ELECTRICITY PRODUCED IN BARCELONA AND THE BESÒS AREA 1999-2008 (SPECIAL AND ORDINARY REGIMES)



Source: Red Eléctrica de España and Barcelona Energy Agency

FIGURE 84 | EVOLUTION OF ELECTRICITY CONSUMPTION IN BARCELONA AND THE BESÒS AREA COMPARED TO PRODUCTION, 1995-2008 (SPECIAL REGIME AND ORDINARY REGIME)

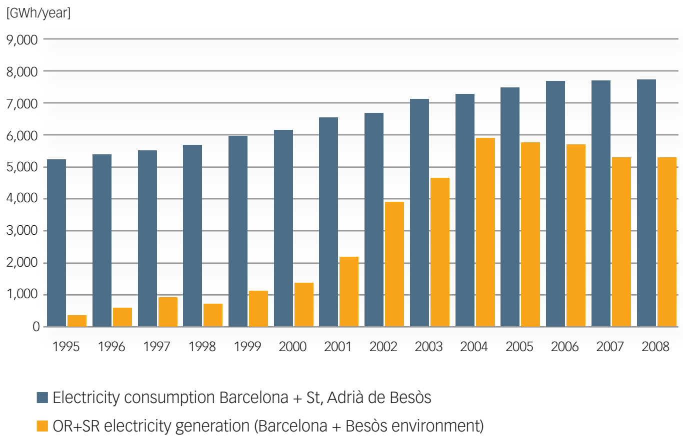
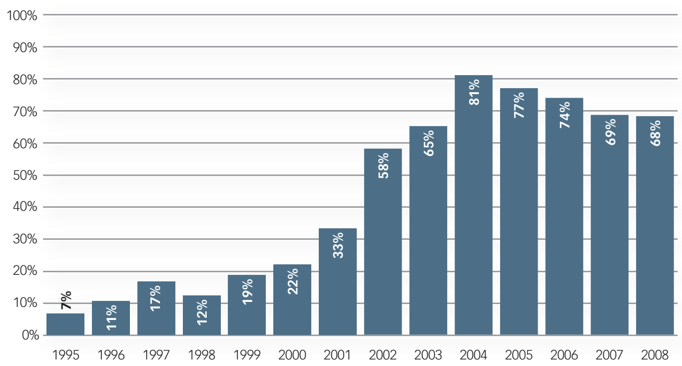


FIGURE 85 | EVOLUTION OF OWN ELECTRICITY CONSUMPTION IN BARCELONA AND THE BESÒS AREA COMPARED TO PRODUCTION, 1995-2008 (SPECIAL REGIME AND ORDINARY REGIME)



2.3.3 - EFFICIENT PRODUCTION SYSTEMS

The special regime not only includes renewable technologies for electricity production but also, as mentioned above, efficient production systems such as cogeneration and micro-generation or waste-to-energy recovery.

Cogeneration

Cogeneration refers to efficient, simultaneous production of heat and electricity. This technology is the most efficient of all fuel based production systems based on fuels, using gases (natural gas, biogas), liquid fuels (fuel-oil, gas-oil, LPG) or solid (coal, biomass, municipal waste). The generation occurs in alternate motors, gas turbines, steam turbines or fuel cells. Cogeneration can be implemented in all industrial or service sector industries which consume thermal energy.

In Barcelona there are various cogeneration plants in operation (both in hospitals and in different industries) which chiefly use natural gas as a fuel. These plants, together with the energy-to-waste recovery facility in Besòs, produced over 325 GWh of electricity in 2008.

In industry, cogeneration has been implemented in most sectors which require large amounts of heat (paper, chemicals, ceramics, etc.) and therefore those in which energy is an important production cost factor. Technically, the services sector is also highly suited for this technology although certain matters should be taken into account:

- It is advisable to take maximum advantage of the residual energy, by preventing it dissipating into the atmosphere.
- For cogeneration projects to be economically viable, the number of hours operation of the facility should be as high as possible.
- It should be remembered that in certain types of building, it may come into conflict with the solar thermal Ordinance.

The high efficiency of cogeneration systems is achieved by taking advantage of the heat generated by electricity production. The installation is sized in accordance with the heat flux used in the climate control of the building or buildings, while the electrical flux is circumstantial.

This heat can be used by passing it to a single consumer who requires it to meet the demand for heat and/cooling - saving on primary energy from other energy resources – or it can be distributed to a climate control network, District Heating and Cooling, making the system even more efficient.

District heating and cooling of the Fòrum and 22@

Barcelona has, for several years, opted to foster centralised climate control, as greater centralisation of heating and cooling improves performance and increases the efficiency.

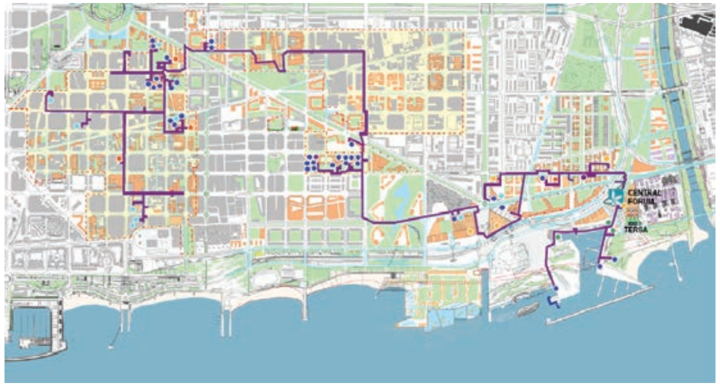
There is currently a centralised climate control network in the Fòrum and district 22@, under the management of Districlima, which operates by using the residual heat from the waste energy recovery plant in the Besòs (TERSA). There is another under construction in Zona Franca and La Marina del Prat Vermell - by the company Ecoenergies-, using biomass and residual cold from the regasification plant in the Port of Barcelona.

Barcelona has, for several years, opted to foster centralised climate control, as greater centralisation of heating and cooling improves performance and increases the efficiency.

The heating and cooling network of the Fòrum was the first to come into operation in Barcelona during the urban development stage of this area in 2004, and it continues to expand. Most users connected to the system pertain to the services sector, although public residential buildings are also adopting this energy. For energy support, the plant has high-efficiency heating and cooling equipment to ensure a continuous supply for system users.

The energy balance of the centralised climate control system of the Fòrum-22@, as a whole, represented a consumption of TERSA's residential heat of 34,895 MWh in 2009, gas consumption with auxiliary energy of 940 MWh and electricity consumption of 9,92777 MWh. Thus, 95% of the heat and 19% of the cold supplied originated from the residual heat of the TERSA plant, achieving a primary energy saving of 39,403 MWh/year and a reduction in CO_2 emissions of 7,076 t/year (51% and 58% respectively, compared to conventional systems). This network is still not complete, as it is in the process of expanding and growing within the area of the Fòrum and district 22@.

FIGURE 86 | DISTRICT HEATING AND COOLING OF THE FÒRUM AND DISTRICT 22@



Cooling power: 63.8 MW | Heating power: 41.3 MW | Number of buildings: 57 | Km: 12.0

Clients in operation:

Hotels / Residences · Offices · Dwellings · Commerce · School centres · Other

Source: Districlima

TABLE 26 | CHARACTERISTICS OF THE DHC NETWORK OF THE FÒRUM AND 22@

Characteristics of the DHC network of the Fòrum and 22@ (2009)		
	FÒRUM	22@
Network extent (km)	4.3	7.7
Number of clients	22	28
Subscribed heating power (kW)	22,415	14,793
Subscribed cooling power (kW)	31,842	25,925
Installed heating power (MW)	40*	
Subscribed cooling power (MW)	39*	
Demanded heating power (MWh/year)	14,482	6,685
Demanded cooling power (MWh/year)	20,499	20,364

Source: Districlima

(*) This output is currently installed at the Fòrum plant and construction has commenced on a plant in Carrer Tànger (22@)).

DISTRICT HEATING AND COOLING)

District Heating and Cooling is an energy distribution system in the form of hot and cold water for climate control, hot water and industrial processes which require heating or cooling. It is distributed via underground pipework in the city, industrial or service sector estates and groups of buildings such as airports or hospitals.

The DHC networks comprise the following:

- Energy production plant: where the centralised production of hot and cold water is generated using efficient conventional technologies or renewable energies.
- Distribution network: this comprises the pipework which must be perfectly insulated to ensure a good supply. It is the hub between the production plant and points of consumption.
- Points of consumption: heat exchangers are installed in the thermal substation to transmit the energy from the primary to the secondary circuit. This is used to supply heating, cooling and hot water.

This technology offers a reliable, efficient and economically viable means for the climate control of buildings. The facility will produce more or less global pollution depending on how the hot and cold water is generated at the production plant. The most recommendable means is via the use of renewable energies (chiefly biomass) or cogeneration. DHC systems help to cut down emissions and save energy..

2.4 - Renewable energies

2.4.1 - GLOBAL GENERATION

Renewable energy production in Barcelona saw a significant increase between 2003 and 2008 up to a maximum of 96.53 GWh, 0.57% of all the energy consumed (electricity, natural gas, automotive fuel and LPG). The energy sources used for this production were photovoltaic energy, solar thermal, small-scale hydraulics (Trinitat plant) and biogas (the proportional part of the gas produced at the controlled landfill in Vall d'en Joan del Garraf which corresponds to Barcelona and the treatment of waste from the eco parks).

If we consider solely the electricity produced using renewable sources produced in Barcelona (with biogas, photovoltaic solar and small hydro plants), with regard to overall electricity consumption in the city, the percentage in 2008 was 0.59%..

TABLE 27 | EVOLUTION OF ENERGY PRODUCTION USING RENEWABLE SOURCES IN BARCELONA, 1999-2008

Renewable energies [GWh]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Electricity with biogas (Garraf + Ecopark)	0.00	0.00	0.00	2.66	28.40	54.95	36.08	32.58	35.57	35.04
Mini-hydraulics Trinitat	6.22	5.71	5.16	6.30	6.13	5.11	5.11 (*)	5.11 (*)	3.34	1.47
Photovoltaic	0.003	0.024	0.046	0.130	0.158	0.758	1.009	1.227	1.453	7.620
Solar Thermal	0.464	0.664	6.410	12.633	16.560	20.846	26.842	34.155	43.299	52.405
Total renewables production	**6.68**	**6.40**	**11.62**	**21.72**	**51.25**	**81.66**	**69.03**	**73.07**	**83.66**	**96.53**
Renewable energies [m^2]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solar Thermal	580	830	8,013	15,791	20,700	26,058	33,552	42,694	54,123	65,506

FIGURE 87 | EVOLUTION OF ENERGY PRODUCED USING RENEWABLE ENERGIES, BY ENERGY SOURCE IN GWH AND PERCENTAGE (1999-2008)

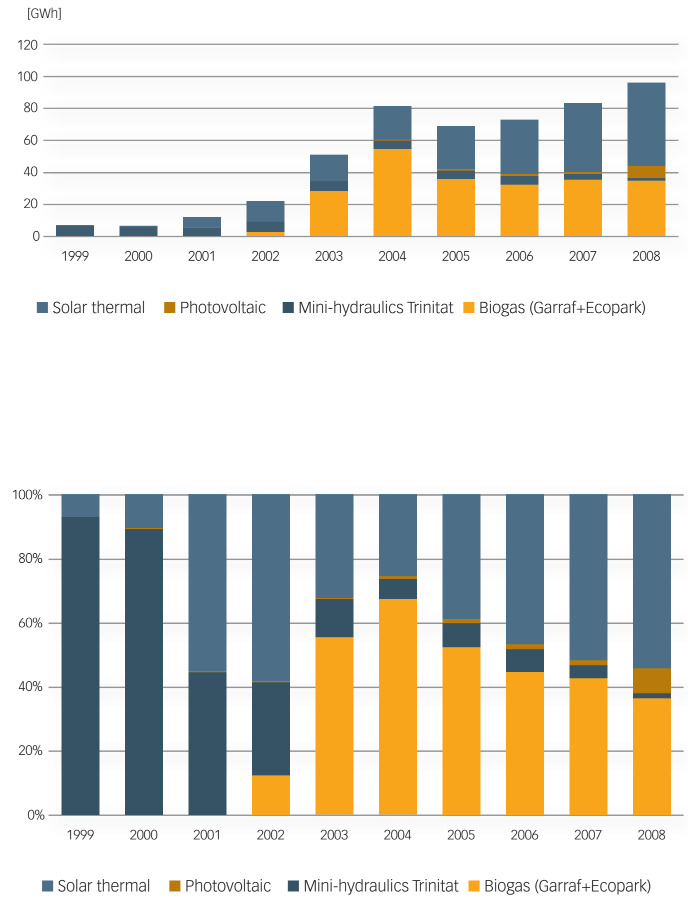


FIGURE 88 | EVOLUTION OF GLOBAL ELECTRICITY PRODUCED USING RENEWABLE ENERGIES, IN GWH AND PERCENTAGE (1999-2008)

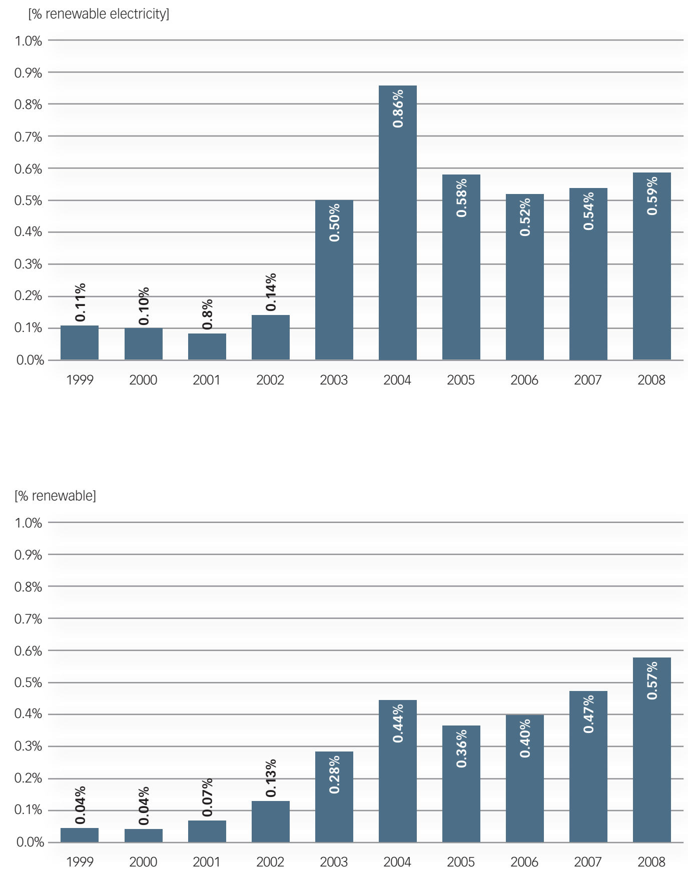


FIGURE 89 | % OF ELECTRICITY PRODUCTION USING RENEWABLE SOURCES IN WITH REGARD TO THE CITY'S ELECTRICITY CONSUMPTION

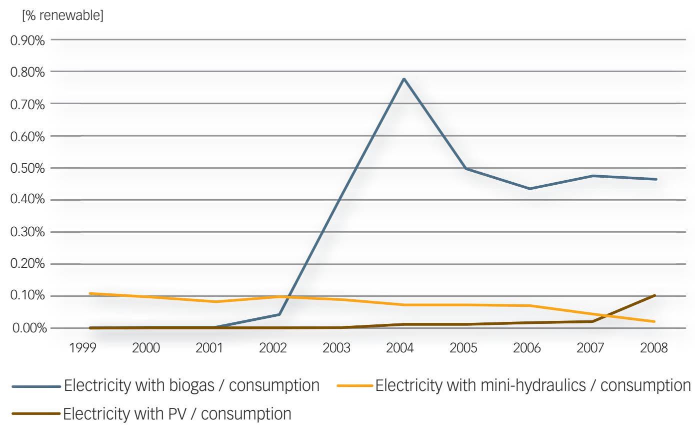
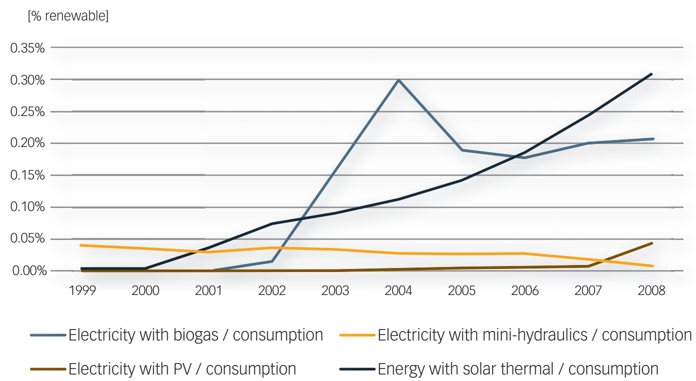


FIGURE 90 | % OF ENERGY PRODUCTION USING RENEWABLE SOURCES IN WITH REGARD TO THE CITY'S ENERGY CONSUMPTION



2.4.2 – SOLAR THERMAL ENERGY

The evolution of surface area for solar thermal energy

Solar energy is the chief renewable resource of the city, and solar thermal energy emerges as the most widely used renewable energy in the city, accounting for 52% of the total renewable production.

This is chiefly due to the boost it received from Barcelona City Council which, in 1999, in a plenary session, approved the solar thermal capture appendix to the general environmental Ordinance, known as the Barcelona Solar Thermal Ordinance (OST). For the first time, a regulation was approved which made it compulsory for new buildings and those under refurbishment to incorporate solar energy systems to meet the demand for hot water.

In 2002, Barcelona City Council also approved the Energy Improvement Plan of Barcelona (PMEB) which undertook to increase energy production using renewable sources of primary energy, especially solar thermal energy. It also established the objective of reaching 96,300 m² of solar thermal panels by the year 2010.

The Ordinance was approved and has been implemented during these years within a context of a growing economy, a greater built-up surface area and energy consumption.

During these years, Barcelona has grown in reach and built-up surface area, forming an increasingly complex city. [18][19]During these ten years, over 2,500,000 m² of land space has been built1, especially in housing, garages and car parks and the services sector (shops, offices and hotels) with an accumulated growth rate of 0.33% per year1. The new urban fabric is

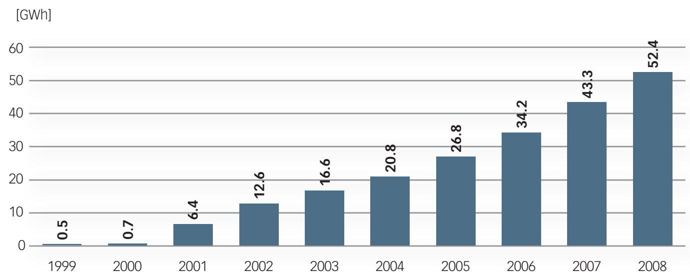
18. According to the Land Register and IMI data, in 1999 in Barcelona there were 107,349,390 m² of land space, while in 2006 there were 109,843,343 m².

19. These figures do not include those buildings which were built to replace older land space. An analysis of buildings built after 1999 shows almost 5 million m².

currently being developed via land reutilisation, as there is practically no available land, signifying that major urban projects are carried out by reassigning land use.

In both cases, the new built-up surface area has meant that solar thermal energy has spread throughout the urban fabric, to a figure of 65,506 m^2 of solar surface authorised in 2008, 2,687 m^2 of voluntary installation as a result of the implementation of the OST.

FIGURE 91 | EVOLUTION OF SOLAR THERMAL SURFACE AREA IN BARCELONA (1999-2008)



Source: Barcelona Energy Agency

Balance of the Solar Thermal Ordinance[20]

The first appendix to the General environmental Ordinance on Solar Thermal Capture, also known as the *"Solar Ordinance"*, was approved and published in July 1999 (BOP no. 181 / page 25-27, dated 30/7/99) and came into force in August 2000, one year after publication due to a moratorium agreed between the Council and other players involved in its implementation.

Before the Solar Thermal Ordinance came into effect, Barcelona had seen several attempts to encourage the installation of thermal systems for solar energy, such as the campaign launched by Barnamil, the financial assistance under the *"Barcelona posa't guapa"* campaign, etc. These did not, however, have any significant impact, except the initiative of the Municipal Housing Board, with the social housing projects in Vores de les Rondes, where a total of 750 m^2 of solar thermal panels were installed. This initiative was carried out in parallel to the approval of the Solar Ordinance during the year's moratorium and acted as a pilot test of the application of the Ordinance.

Thus, at the time the Solar Ordinance came into effect, the solar thermal surface installed in the city covered 1,650 m^2, mostly promoted by the local government.

20. Balance of the Solar Thermal Ordinance1Agència d'Energia de Barcelona. Barcelona Energy Agency

Following the approval of the Barcelona Energy Improvement Plan in 2002 (PMEB), the implementation of the Solar Ordinance was monitored to ascertain the extent to which the ordinance was accepted, to record the number of installations and square metres installed, and to monitor the condition of the installations and their operation.

The experience of the local government during the initial years of the Solar Ordinance and the resulting identification of its strong and weak points led to the text of the Ordinance being reviewed. This revision was carried out between 2004 and 2005, and in addition to the municipal experience, it took into account that of other towns and cities which had implemented this regulation within their municipalities.

[21]In 2005 a debating table was formed, called the Solar Table20, for the purpose of debating the implementation, needs for improvement and the amendments to be made to the text of the Ordinance and which approved the definitive text.

The new drafting of the Ordinance introduced amendments as regards appropriation, making exemptions more restrictive, the quality of the facilities, setting out the conditions for certification and the technical criteria for maintenance and use of same and their harmonisation with other regulations on a national or autonomic scale.

The introduction of the Ordinance

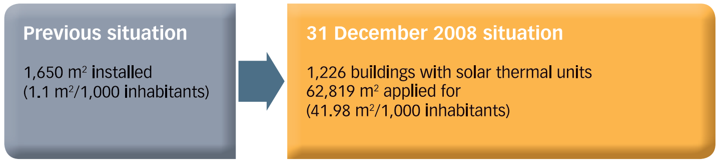
As a result of the solar Ordinance, until 31 December 2008, 1,226 buildings have been forced to install solar thermal capture systems for hot water production, with a total solar thermal surface of 62,819 m^2.

[22]The solar energy installations which are compulsory under the Ordinance are estimated to produce an energy saving of 50,255 MWh/year21,

The housing and residential sector is that with the highest percentage of solar surface processed, with 69% of the total surface used for solar thermal capture in the city, followed by hotels, with 16% of the total.

The result of the application of the Solar Thermal Ordinance as regards the number of buildings affected since it came into effect in 2000, has been one of sustained growth during the years since. There was, however, a turning point in 2006 caused by the larger number of buildings involved, a direct result of the high number of buildings constructed during the years 2006, 2007 and 2008.

FIGURE 92 | EVOLUTION OF SOLAR THERMAL ENERGY IN BARCELONA



21. The agents who took part in the Solar Table were:the Association of Building Engineers and Technical Architects, the School of Industrial Engineers of Catalonia, APERCA, the Spanish Association of Solar Energy and Alternative Energy Companies, ASENSA, the School of Property Administrators of Barcelona, the Association of Developers and Builders of Barcelona, the Consumer and User Organization of Catalonia, the Association for the promotion of renewable energies and energy saving, BARNAMIL, the Municipal Institute of the Urban Landscape and Quality of Living, the Municipal Housing Board, the School of Architects of Catalonia, Barcelona City Council, The Catalan Energy Institute, the Fitters Guilds of Barcelona, FERCA and the Barcelona Energy Agency.

22. A final energy production of 800 kWh/m^2 has been assumed for the solar thermal capture area. Source:Pla de millora energètica de Barcelona. Barcelona Energy Improvement Plan.2002.

FIGURE 93 | DISTRIBUTION OF THE SOLAR THERMAL SURFACE AREA BY USE (2008)

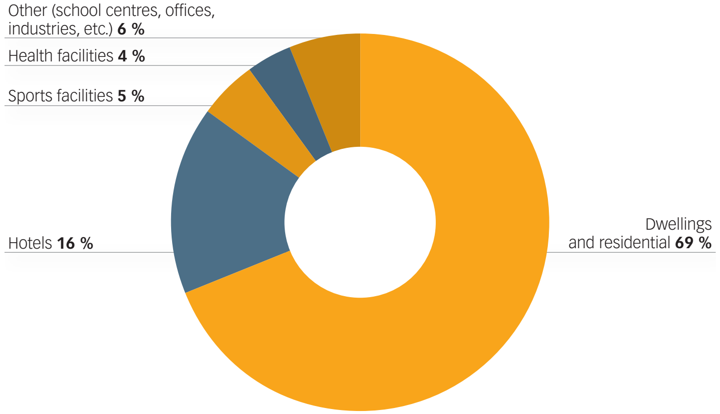
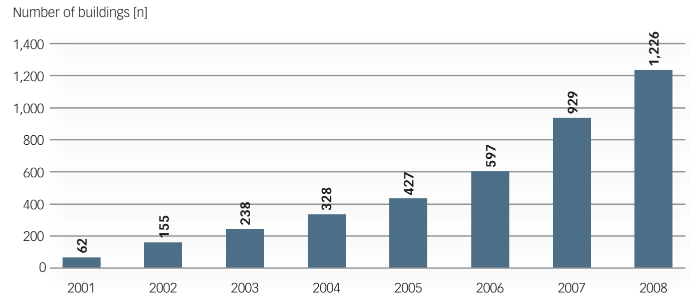


TABLE 28 | DISTRIBUTION OF THE NUMBER OF BUILDINGS AND SOLAR THERMAL SURFACE AREA BY USE (2008)

Type of use	Number of buildings with ST	Solar collectors' area [m²]
Dwellings and residential	959	43,231
Hotels	115	10,198
Sports facilities	20	3,125
Health facilities	25	2,223
Other (school centres, offices, industries, etc,)	107	4,4041
Total	**1,226**	**62,819**

FIGURE 94 | EVOLUTION OF THE NUMBER OF BUILDINGS AFFECTED BY THE OST (2001-2008)

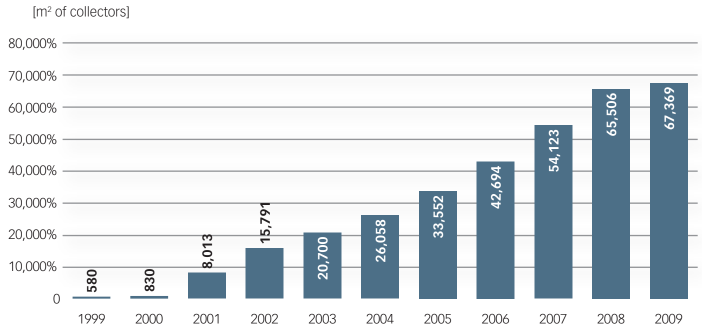


Between 2006 and 2007 there was a change of trend as regards the number of buildings affected by the new regulations, which almost doubled. The evolution of the solar surface, on the other hand, did not continue the same trend and the increase was not as marked as expected.

This is mainly due to the fact that most of the new buildings which are obliged to incorporate solar thermal systems are small, and therefore the solar surface does not have a significant effect on the total surface for the remaining types of buildings which the previous regulations already took into account.

The considerable increase in the solar thermal capture surface as a result of the solar Ordinance, in addition to the surface area installed prior to the solar Ordinance and the facilities built but unrelated to it, chiefly at the initiative of Barcelona Council, signify that the solar thermal surface installed or planned exceeds 65.506 m². This is forty times the surface area prior to the solar Ordinance.

FIGURE 95 | EVOLUTION OF TOTAL SOLAR THERMAL SURFACE AREA (1999-2009)



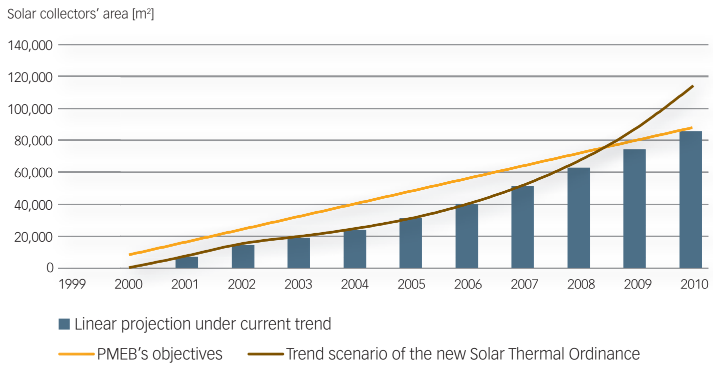
The solar capture surface in proportion to the current population of Barcelona is 41,98 m²/1,000 inhabitants, a significant figure given the ratio prior to the OST (1.1 m²/1,000 inhabitants) and which is in line with the rest of Europe and far in excess of the national average.

It should be remembered that the Barcelona Energy Improvement Plan (PMEB) established a target of 96,300 m² of solar thermal panels installed in the city by 2010, with a planned thermal production of 77,810 MWh/year (280,000 GJ/year). Of this surface area, it was estimated that 88,015 m² of solar capture would be installed as a result of the solar thermal Ordinance.

With the amendment and implementation of the Ordinance in mid-2006, which eliminated the limits on its application, the number of buildings obliged to install solar thermal energy systems was expected to increase to well over the surface targeted in the PMEB. In view of the results achieved during 2007 and 2008, we can see that this is not the case, as the number of homes currently affected in respect of the surface area are very few.

Despite this, according to the figures for 2010, the aims set forth in the PMEB to install 88,015 m² of solar thermal panels has almost been achieved by the solar thermal Ordinance, as at 31 December 87,600 m² had been implemented.

FIGURE 96 | COMPARISON BETWEEN THE REAL TREND OF EVOLUTION OF THE OST AND THE TREND FORESEEN IN THE NEW OST



The implementation systems and challenges overcome

As mentioned earlier, the chief driver of the introduction of solar thermal energy in the city was Barcelona Council which, with clearly political motivations, approved a pioneering regulation which initially met with some rejection and mistrust among the various players involved in its implementation, all of which led to a one-year moratorium being put in place prior to its implementation.

Initially, the pioneering nature of the solar Ordinance also presented certain dysfunctional ties as regards its implementation due, on the one hand, to the Council's virtual lack of experience in drafting and applying a regulation of these characteristics (especially when specifying the exemptions) and on the other, to the lack of legal references for the formulation of the text and protocols.

The application of a regulation which makes it compulsory to introduce a new element in buildings, with the particular characteristics of solar energy installations, obliged the Council to put in place appropriate management systems to monitor compliance with the Ordinance and follow up its evolution within the city.

Thus, the Council, via the Barcelona Energy Agency sought the necessary instruments to define and put in place case review procedures and protocols, defining the administrative circuit to be followed so as to ensure the success of the solar thermal installations at every stage, from the planning phase to implementation and throughout their useful life.

These management instruments have culminated with the launch of an online processing management site for planned solar thermal installations which, placed at the disposal of the chief players, developers, designers and supervisors of solar thermal installations, seeks to furnish them with the necessary knowledge regarding the processing and standardisation of design criteria and formulation of projects to comply with the OST, optimising the administrative procedures and speeding up the formalities.

The initial moments of the pioneering solar Ordinance were difficult, giving rise to controversy and strong rejection from a part of the sector. The one year moratorium approved is a clear indication of this situation. The mistrust was not without grounds, as recent experience in Spain was minimal and the sector still recalled the failed experiments in the sector in the seventies.

It is also true (and this has been acknowledged by all the players involved - from the Administration, developers and technicians responsible for drafting the projects to the fitters) that the sector was not prepared to confront the challenge with any guarantee of success, and much uncertainty still surrounded the approval of this new ordinance, which required solar installations be fitted to all new buildings in the city of Barcelona.

Today, in hindsight, and after analysing the results achieved, it is evident that the inexperience led to errors in the installations, resulting in the correction and updating of certain loopholes in the Ordinance, such as the monitoring and maintenance of the installations in the amendment of 2006.

Moreover, the chief barriers to the development and application of the Ordinance are also its chief support. The implementation of the Ordinance is clear evidence that it is not possible to wait until sufficient experience has been acquired for such an important and significant undertaking as this, as sufficient progress would never have been achieved. Difficulties have been overcome or solutions are in progress and there exists a consensus that the operability and effectiveness achieved with the effort of all involved have made it possible to standardise solar thermal energy facilities.

The Solar Thermal Ordinance of Barcelona should be viewed as an essential step towards the standardisation of solar thermal energy in Spain, yet a simple, local measure cannot be expected to offer more than this. However, its impact has been clearly greater than that imagined when it was approved.

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The new challenges: revitalising solar thermal energy

Although solar thermal energy is now a reality in Barcelona, its day-to-day management and the use and maintenance of the current facilities still present challenges.

The objective, for the future, is to ascertain the condition of the installations executed under the OST. Aside from the surface area installed, it is necessary to ascertain how many installations operate correctly, to what extent they contribute to energy saving and what issues or difficulties users encounter during the life of the facilities. This knowledge should be used to define strategies and courses of action with a view to ensuring proper operation of the facilities and optimisation of solar power.

Another major challenge is to incorporate solar systems into pre-existing buildings, to which the Ordinance is not applicable. Therefore, new promotional measures must be put in place which are more effective than those taken to date.

Last but not least, the other matter pending in Barcelona regarding solar energy is to extend solar thermal systems for other uses (not only hot water), such as solar climate control, electricity production or injecting heat into district networks, using solar concentration technologies for these purposes.

Given its magnitude and potential for energy saving, these are the challenges for the coming years in the field of solar thermal energy in Barcelona. Together with the approval of the photovoltaic solar Ordinance, they will extend solar energy even further, increasing the production of renewable energy in the city.

2.4.3 – SOLAR PHOTOVOLTAIC ENERGY

The installed photovoltaic capacity in 2008 in Barcelona totalled 6,116.5 kWp; 27% in municipal areas and the remainder (73%) in private areas.

This figure is a major step forward compared to previous years, when the output was 296 and 832 kWp respectively. This increase is caused firstly by the municipal policies and actions to promote renewable energies, such as the launch of the initial phase of the photovoltaic structure in the Fòrum (which signified multiplying the total installed capacity in 2003 almost threefold), the installation of facilities in schools and, more recently, the introduction of 270 kWp more in municipal facilities and the completion of the second phase of the 650 kWp photovoltaic plant of the Fòrum.

Secondly, the increase was the result of the economic incentives for remuneration of photovoltaic installations on rooftops, which spurred the private sector to occupy numerous industrial roofs with photovoltaic panels. One example of this is the Barcelona Trade Fair which installed 1.2 MWp in 2008.

The energy produced by these installations in the aggregate in 2008 was 7.62 GWh, a figure which represents an annual increase of 226% since 2004.

FIGURE 97 | EVOLUTION OF THE TOTAL PHOTOVOLTAIC CAPACITY INSTALLED IN BARCELONA, BY OWNERSHIP (1999-2008)

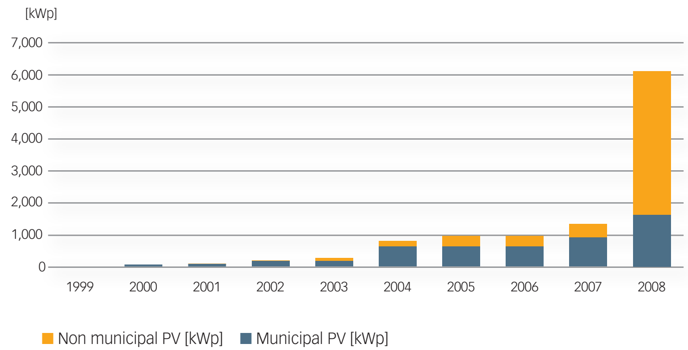


FIGURE 98 | EVOLUTION OF ENERGY PRODUCTION BY PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (1999-2008)

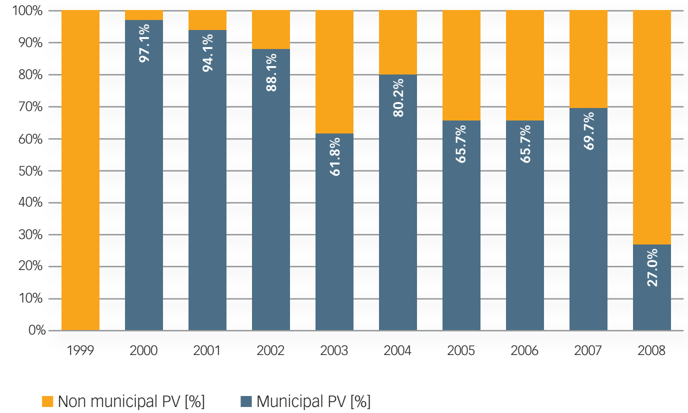


FIGURE 99 | EVOLUTION OF OWNERSHIP OF PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (1999 – 2008)

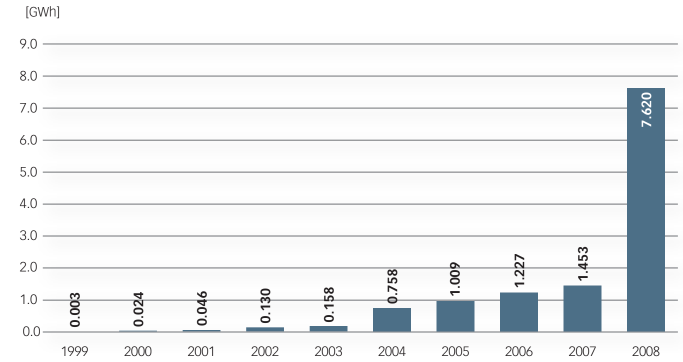


TABLE 29 | EVOLUTION OF ENERGY PRODUCED BY PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (1999 – 2008)

FV [kWp]	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Municipal PV [kWp]	0.0	85.2	120.4	183.1	183.1	667.1	667.1	667.1	947.7	1,649.0
Non municipal PV [kWp]	2.5	2.5	7.6	24.8	113.0	165.2	348.6	348.6	412.9	4.467.6
Total PV [kWp]	**2.5**	**87.7**	**128.0**	**207.9**	**296.1**	**832.3**	**1,015.7**	**1,015.7**	**1,360.6**	**6,116.5**

2.4.4 - BIOGAS

The network of eco parks where municipal waste is treated in Barcelona and its metropolitan area (Eco park-1 in Barcelona, Eco park-2 in Montcada i Reixac and Eco park-3 in Sant Adrià) generate biogas for energy use.

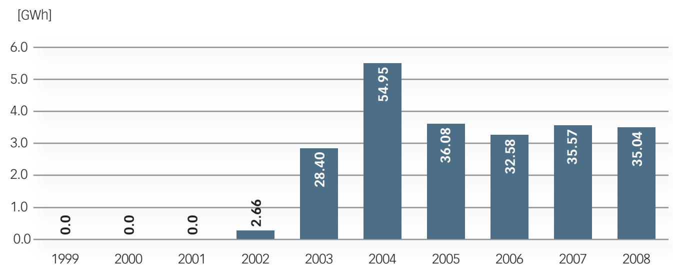
In 2008, 9,153 m^3 was generated by Eco park-2 in Montcada i Reixac and 1,125,394 m^3 by Eco park- 3 in Sant Adrià. 20,18 MWh of electricity was produced directly by Eco park-2 biogas while Eco park-1 in Barcelona produced none. Eco park-3 had indirect electricity production via the energy-to-waste recovery Plan in the Besòs as both facilities are attached.

It should be borne in mind that in the energy balance of Barcelona, electricity production is calculated proportional to the amount of organic waste transferred by the city to Eco park-2, and which in 2008 accounted for 11% of the total waste received. This represents 2.22 GWh of electricity.

As regards the controlled landfill in Vall d'en Joan (closed down in 2007, but which continues to produce electricity using the biogas produced during the decomposition of organic material disposed of years earlier), a proportional part of the total electricity production (55.21 GWh in 2008) is attributable to Barcelona. Therefore, the production of this facility is weighted at 59.44%, a percentage which corresponds to the amount of waste the city produced over recent years compared to the total waste disposed of at the site. In the energy balance, this represents an attributable electricity production of 32.82 GWh in 2008.

Thus, in 2008 a total of 35.04 GWh was generated.

FIGURE 100 | EVOLUTION OF ENERGY PRODUCED USING BIOGAS IN BARCELONA, (1999-2008)

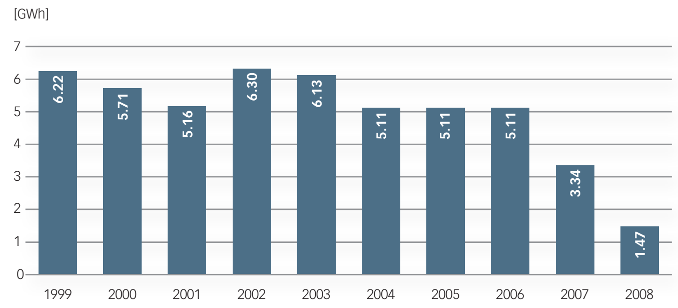


2.4.5 - SMALL SCALE HYDRAULIC FACILITIES

The energy produced by small hydro plants was 1.47 GWh (estimating the data from 2005 and 2006 using the production in 2004). The two years with the highest production were clearly 2002 and 2003.

In view of the rainfall of the Catalan basins which feed the small hydro-plant of Trinitat, it is not expected to exceed 6 GWh, although it will be necessary to see the data for 2009, which benefited from abundant rainfall.

FIGURE 101 | EVOLUTION OF ENERGY PRODUCED IN SMALL HYDRO PLANTS IN BARCELONA (1999-2008)



2.5 - The energy supply

2.5.1 - THE ELECTRICITY SUPPLY

The characteristics of the network

Barcelona is powered by the 400 kV network from the substations located in Sentmenat, Rubí, Pierola and Begues. 220 and 110 kV power lines from these four substations enter Barcelona mainly via the substations in L'Hospitalet, Santa Coloma, Sant Andreu and Besòs. The lines (aerial) and cables (underground) which currently form the electricity network of Barcelona are classified in line with their voltage:

- The high voltage (HV), with a total of 188 km, is formed by 220 kV (64%) and 110 kV (36%) cabling. Its chief purpose is distribution, even though given its voltage level it forms part of the transmission network.
- The medium voltage network (MV) is formed by 25 and 11 kV lines. The mesh and coexistence of these networks is the result of the three distribution companies which operated in Barcelona with different operating and maintenance criteria. The new lines are designed for 25 kV, but old 11 kV equipment continues to be replaced by new equipment with the same voltage.
- The low voltage network (LV), with total of 3,084 km, links the transformation centres with the end user. Different voltage levels also coexist: 220/127 V and 380/220 V, although the 220/127 V circuits are to be gradually replaced by 380/220 V to standardise them.

The non-standardized composition of the distribution network makes it complex to operate, especially the low voltage network, which has most impact on quality as perceived by the customer. The voltage transformation in Barcelona for users is carried out via twenty-two HV/MV substations with different distribution centres (DC) and the MV/LV distribution centres. The total transformation output currently installed in the area of Barcelona is 6,617 MVA.

In order to meet the new demand in the city, the planning of the transmission network provides for the creation of three new 400 kV substations in the Barcelona area (Viladecans, Santa Coloma de Gramenet and Sant Just Desvern), connection to the transmission network and the mesh between them and the current substations, all of which will supply the 400 kV network to the city. Eight new 220 kV substations are also planned to meet the new expected energy demand, to bring the supply points closer to the end user and to enhance the reliability and quality of the supply. The implementation of the new substations also includes the installation of new 220 kV lines (underground) to power them and create the mesh.

On the other hand, the approval of Law 18/2008 on the reliability and quality of the electricity supply in Catalonia sets out criteria for the creation of power lines which involve a modification and improvement of Barcelona's current electricity network. This law also states that 90% of the power supply of Barcelona must be channelled via two different substations.

The parameters for quality evaluation

In order to evaluate the quality of the electricity network, different indicators are used to measure the time and number of interruptions occurring and which affect the proper functioning of the power supply.

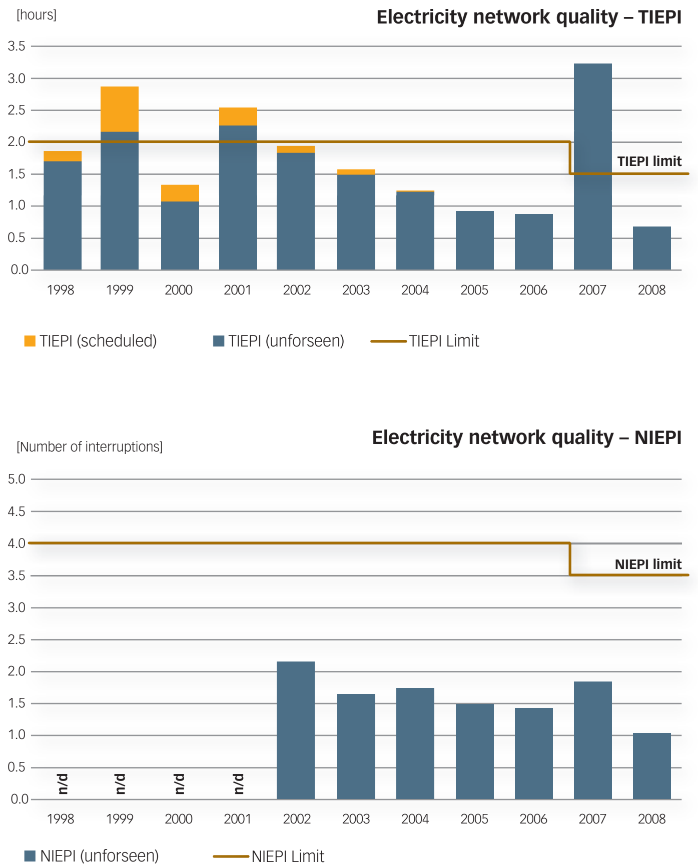
One of these indicators is the Interruption Time Equivalent to Installed Capacity which expresses the equivalent time during which all the installed capacity in a given area has been interrupted. This indicator can be programmed when the interruptions have been planned to carry out network maintenance work or other tasks, or can be random when unplanned interruptions occur due to system failures with regard to the installed capacity.

The evolution of this indicator in Barcelona has seen a downward trend over the past six years. Thus, in 2006 it had a level of 0.86 hours, below the service quality limit set forth in Royal Decree 1634/2006 which sets a limit of 1.5 hours for an urban area such as Barcelona (before, the limit was 2 hours, under Royal Decree 1955/2000). In 2007, this indicator underwent a sharp increase due to the blackout in July which left 330,000 subscribers without electricity during several days.

Another network quality indicator is the number of interruptions equivalent to the installed capacity. Its evolution in Barcelona has remained steady over recent years and at no time has it exceeded the service quality limit of four interruptions provided in Royal Decree 1955/2000 for the years prior to 2007, and three equivalent interruptions in Royal Decree 1634/2006 for 2007 and subsequent years.

When evaluating these data, it should be borne in mind that according to Order ECO/797/2002, only interruptions of over 3 minutes are recorded, for both indicators.

FIGURE 102 | EVOLUTION OF THE TWO EQUIVALENT INTERRUPTION INDICATORS IN BARCELONA (1999-2008)



Source: Department of Labour and Industry. Directorate General of Energy, Mines and Industrial Safety - Energy Supply Quality Service

Although Barcelona City Council is not responsible for electricity distribution and transport[23], it does participate in the Mixed Committee in monitoring the realisation of the investments contained in the five-year and annual investment plans in distribution and transmission facilities located in Barcelona (since the publication of the power supply reliability and quality law -LGQSE- in 2008).

Barcelona City Council, mindful of the importance of a high-quality service and power supply for the public and the economy, has various agreements with the distribution company which specify different actions to upgrade and improve the power network over the coming years.

When sizing the investment and improvement efforts of the power network, Barcelona Council considers it necessary to evaluate the quality of the power supply using different parameters, in addition to the Equivalent Interruption indicators:

- RELIABILITY OF THE SUPPLY
  The Interruption indicators reflect the quality of the service in relation with the number and duration of the interruptions, but the shortcomings of these indicators (for example, the level of aggregation) mean that they do not suffice to perform a suitable evaluation.
  These two indicators, as provided in current law, are grouped by municipalities, and therefore more accurate information must be available to obtain data on areas of customers who require more guarantees.

- RELIABILITY OF THE NETWORK
  This is the parameter which represents the probability of the system functioning correctly at any given moment. It is expressed as a percentage or the estimated unavailability time and is a key factor when making decisions on power network planning.
  Different indices can be used to evaluate the monitoring of this parameter, both for the current network and that planned for the future:
  - Failure rate (λ): number of annual failures occurring in an element.
  - Expected time to failure (ETTF): moment when the first failure of an element will occur.
  - Reliability (R): probability that an element functions correctly during a given time.
  - Probability of failure (Q): probability that an element does not function correctly during a given time.

- PRODUCT QUALITY OR QUALITY OF A VOLTAGE WAVE
  This parameter shows the probability of the voltage supplied remaining within acceptable perturbation limits. Long supply interruptions are not taken into account, however.
  Given that the quality of the voltage wave is not perceived or assessed uniformly by all users, it is necessary to evaluate its appropriateness in accordance with the impact on each customer so as to assess the need for, and justification of, a network investment vs. the cost of other systems to mitigate the effects of a wave alteration.
  The indices used to evaluate and monitor this parameter are as follows:
  - The average time outside the parameters of variations of the effective voltage value ($-7\% < UN < +7\%$).
  - The average number of brief interruptions (under 3 minutes).
  - The average duration of brief interruptions.

23. The National Government is the competent Authority in electric energy transport matters.The Planning of the Electricity and Gas Sectors 2008–2016, of the Ministry of Industry, Tourism and Trade provides for the implementation of transport networks throughout the country, including strategic actions planned in Barcelona.This document is scheduled to be revised to adapt it the pace of investments to the drop in demand. The Generalitat de Catalunya has the competencies in electrical energy distribution within the territory of Catalonia.

- CUSTOMER SERVICE QUALITY AND RELATIONSHIP WITH THE COMPANY
  The attention the customer receives and their relation with the company providing the services or future services has a significant influence on the overall perception of service quality. Electricity supply is no exception.
  For electricity, therefore, it is necessary to define the commercial quality as the user's perception of the degree of compliance or satisfaction with the electricity supply services, irrespective of the provider.
  Customer care services which condition the commercial quality can be evaluated in operations prior to contracting the supply and in operations during the supply contract. What is proposed is to create indices which reflect the commercial quality in an objective manner and which can be used to monitor the electricity companies.

- SUSTAINABILITY OF THE NETWORK
  These parameters seek to minimise the environmental impact when planning either improvements or enlargements of the electricity infrastructure network together with the electrical generation and consumption model.
  Defining network sustainability indices is necessary to answer questions such as:
  - Are the proposals and improvement or enlargement of the infrastructure appropriate from an environmental viewpoint? What action is being taken to minimise the impact?
  - What role do local generation and electricity distribution play in enhancing energy efficiency? What measures are being taken to avoid oversizing of the transmission network and help to contain the increase in electricity demand?

  How has the current electricity supply affected the general public's wellbeing? What inequalities are to be found in social and economic spheres due to the current supply conditions? How do customers assess the energy cost increase/supply quality increase ratio?
  In order to answer these questions, we propose initially evaluating seven sustainability indicators grouped into three types: environmental, efficiency and socioeconomic. With the data available to the Council, the following indices have been evaluated:
  - Environmental indicators: Appropriation of facilities and impact on land/subsurface.
  - Efficiency indicators: Local production and production using renewable energies.

FIGURE 103 | HIGH VOLTAGE ELECTRICITY NETWORK OF BARCELONA

2.5.2 - NATURAL GAS SUPPLY

The characteristics of the network

The total extension of the natural gas network in Barcelona is 1,553 km., of which 14 pertain to the small part of the transport network surrounding Barcelona and the remaining 1,539 km to the distribution network. 80% are low pressure and just 6%, high pressure.

Natural gas is distributed and transported via pressurised gas pipelines operating at different pressure ranges. The pressurisations are carried out at the regulation and measurement stations (RMS) and the regulation chambers (RC), equipment located in streets (aerial or underground) and designed so that the consumer receives the supply within a suitable pressure range (22 mbar for domestic consumption and different ranges for industrial consumption, depending on the process).

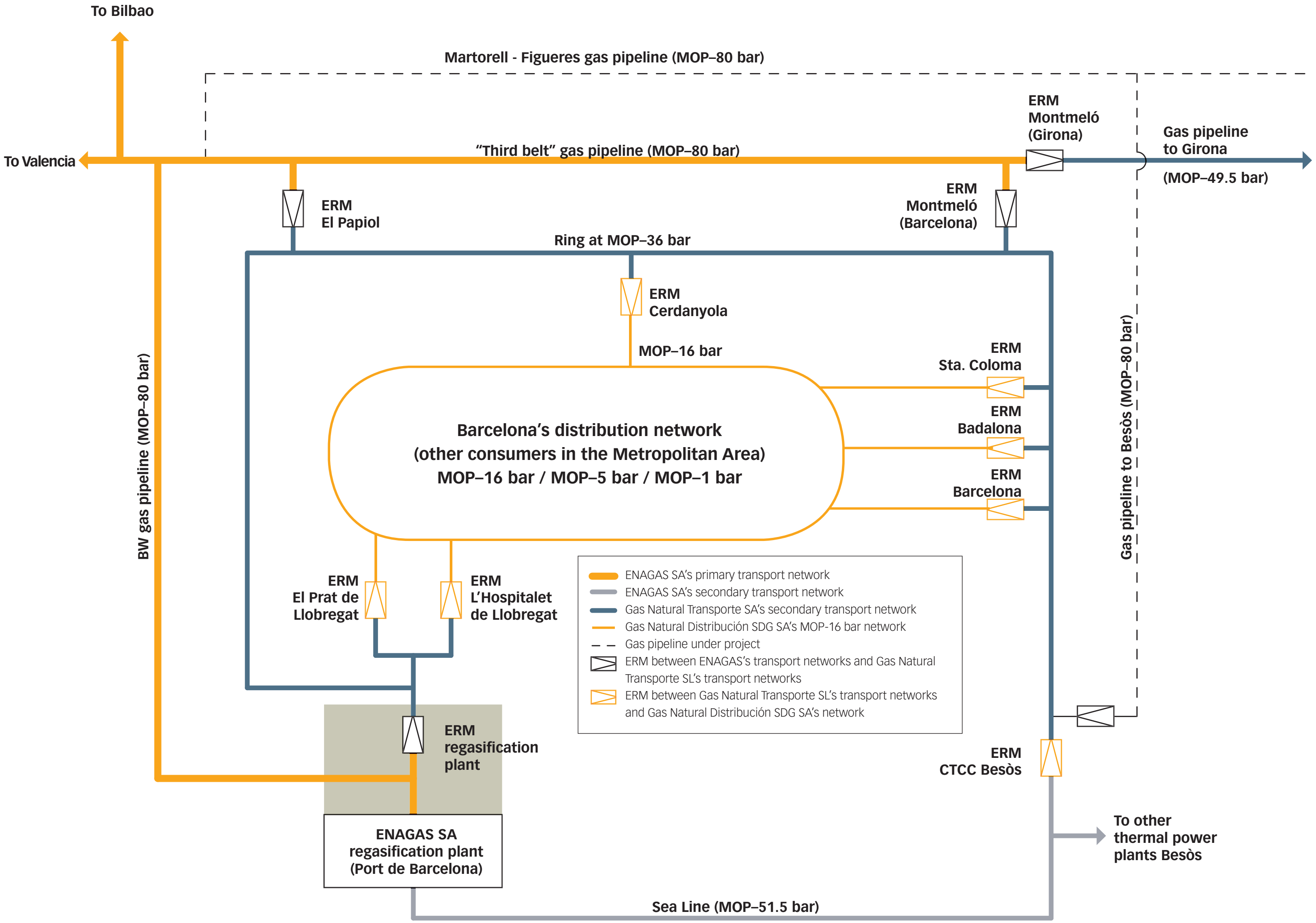
The distribution network in Barcelona is supplied by the transport network via 6 RMS located in 3 strategic areas (Zona Besòs: 3 MRS for connection from the east; Zona Llobregat: 2 MRS for connection from the southwest; Interior Area: 1 MRS for connection from the north-northeast). Future transport gas pipelines are planned for Martorell-Figueres and Besòs). In addition to the MRS and distribution and transport pipelines, the gas system in Barcelona has an Enagas regasification plant in the Port of Barcelona which receives liquefied natural gas from methane tankers, stores it and releases it into the transport network.

The current has network supplies in virtually all the inhabited areas except the new urban areas, where a higher degree of development is expected and in the new rollout areas where the extension of the network is at higher pressures.

In addition to these developments, where growth in domestic demand is expected, there are the new major consumers in the industrial sector (energy) concentrated mainly in:

- Combined-cycle thermal plants: Besòs 5, two 400 MW (commissioned in 2010).
- Combined-cycle thermal plants: Port of Barcelona, 1 and 2, 400 MW each one (commissioned in 2010).
- District heating & cooling in 22@ (planned to come into operation by the year 2011).
- Zona Franca-Gran Via Hospitalet energy plant, with a possible enlargement as a district heating & cooling plant (scheduled to come into operation by the year 2011).

FIGURE 104 | CONNECTION SCHEME BETWEEN THE TRANSPORT NETWORK AND DISTRIBUTION NETWORK IN BARCELONA



Source: Report on quality of gas supply services in Barcelona (QSSGB)

Planned infrastructures

Construction of two gas pipelines is planned for the area surrounding Barcelona - the future Martorell-Figueres pipeline, and the future pipeline in the Besòs, which will connect the former with the combined-cycle thermal plant in Besòs. Although this infrastructure does not directly affect natural gas supplies in Barcelona (as no connection is planned with the distribution network), a possible connection may be built in future.

The Planning of the electricity and gas sectors in 2008-2016. Development of the transport networks, approved by the Council of Ministers, does not provide for any new specific transport infrastructure to the gas pipelines which supply Barcelona and the metropolitan area. In view of this, taking into account the two planned pipelines, the transport network is sized to meet the foreseeable demand in 2008-2016.

This planning, however, does include enlarging the gas storage capacity in the Port of Barcelona, which is currently 540.000 m^3. Two more are planned for 2010-2011 (the 7th and 8th of the Barcelona plant), with a unit capacity of 150,000 m^3 together with the withdrawal from service of the three oldest and smallest tanks (two of 40,000 m^3 and one 80,000 m^3).

We should also underline how the investments made over recent years, the expanded capacity of the infrastructures up to a total of 250,000 m^3 (maximum moorage capacity of methane tankers), and the increase in the emission capacity of the regasification plant to 1,650,000 Nm^3/h in 2006, increased over the past three years to 1,950,000 Nm^3/h.

The measures to improve the capacity of the regasification plant in the Port of Barcelona were coming to an end in 2010 and the needs for 2008-2016 have been covered. For this reason no great modification is expected in the planning of the natural gas network for 2012-2020 which Enagas is starting to define

ENERGY SERVICE QUALITY

In order to monitor the quality parameters of the natural gas network, a series of changes is to be carried out over the coming years because, although Barcelona Council receives data on the quality of the electricity and natural gas supply, these are specific and fragmented.

It would therefore be necessary to ensure proper planning and management of the infrastructures, together with the commercial quality and information for users. In this respect, Barcelona City Council is working on a new agreement with the energy companies as a result of the meetings of the Urban Services Infrastructure Group (with the participation of the Council, the energy companies and several experts) to adopt agreements for the future development and improvement of the city’s energy infrastructure.

When monitoring the quality of the energy service it would also be necessary to factor in the parameters described above and monitor these indices in a centralised manner. It would be convenient to apply new information systems and mechanisms in addition to updating the communication protocols. It is only in this way that an overview of the service quality in the city can be obtained so as to react swiftly when incidents occur or for preventive reaction situations.

Thus, the PECQ incorporates the following proposals (described in greater detail in the projects chapter of this Plan):

- Information system on the network and quality of the energy services.
- Support mechanism for decision-making on electricity infrastructure planning.
- Updating of the incident reporting protocol for the electricity and gas supplies

2.6 - Greenhouse gas emissions

2.6.1 - THE VOLUME AND SOURCES OF THE EMISSIONS

[24]Greenhouse gas emissions (GHG)23 in Barcelona in 2008 totalled 4,053,765.5 t - considering the electricity mix of Catalonia, a value which produces a ratio of 2.51 t/inhab/year. [25]The average annual increase rate between 1999 and 2008 was 1.72%, as in 1999 4,737,299.9 t were emitted, with a ratio of 3.15 t/inhab/year24.

It should be borne in mind that not all the reduction of emissions during these years was the result of efficiency improvements or a reduction in energy consumption (as occurred with natural gas consumption) but also of the changes introduced in the methodology applied in the Barcelona Energy Improvement Plan.

Thus, when drawing up the PECQ, the methodology used to calculate the GHG of Barcelona Port and Airport has been improved compared to that used in the PMEB; the emissions caused by the vehicle population of the city have been updated (as the previous inventories of emissions were based on the registered population, significantly older and therefore the source of more pollutants than that in circulation); and the emission factors of waste treatment have been updated, adapting them to European methodologies, which has meant that the GHG emissions are lower than with the previous procedure.

80.1% of GHG emissions (3,247,101.3 t/year) were the result of energy consumption in the city, while the remaining 19.9% were related to the treatment of municipal waste (8.1%) and port and airport activity (11.8%). Energy consumption is therefore the main cause of GHG emissions in the city, and shared almost equally between natural gas consumption (26.8% of the total), electricity consumption (26.7%) and automotive fuel (25.3%), while the remaining 1.3% is attributable to the consumption of liquefied petroleum gases (LPG).

By energy-consuming sectors, transport - including electricity and natural gas – is the chief emitter of GHG (26.2%), followed by the residential/housing sector (20.6%) and the commercial and services sector (19.4%). Industry is responsible for 13.5% of the remaining emissions, together with 0.5% attributable to other sectors (primary, energy, construction and public works).

As regards GHG emissions associated with the treatment of municipal waste, 0.6% (23,450 t) were produced in the energy-to-waste recovery plant in Sant Adrià, 5.2% (212,420 t) to the controlled waste landfill and 2.3% (91,710 t) to the combined treatment of municipal waste (Eco park plus incineration, Eco park plus tip, etc.).

24. Greenhouse gases [GHG] chiefly include carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O].There are also other fluorinated gases produced by industry, but they are not directly related to energy consumption. CO_{2eq} or GWP (Global Warming Potential) is a measurement which uses the capacity of each substance to contribute to global warming in a single equivalent figure referenced for this purpose as regards CO_2 [$CO_{2eq} = GHG = CO_2 + 25CH_4 + 298N_2O$].

25. Due to variations in the calculation and updating method of the emission factors (applied both to calculations and historic data), the data published in the PMEB differ slightly from those mentioned here.

CALCULATION METHODOLOGY

While the emissions of the commercial and services sector, residential and industrial sectors are obtained from the billing details, the transport sectors, solid urban waste treatment, Port and Airport require an indirect or specific methodology.

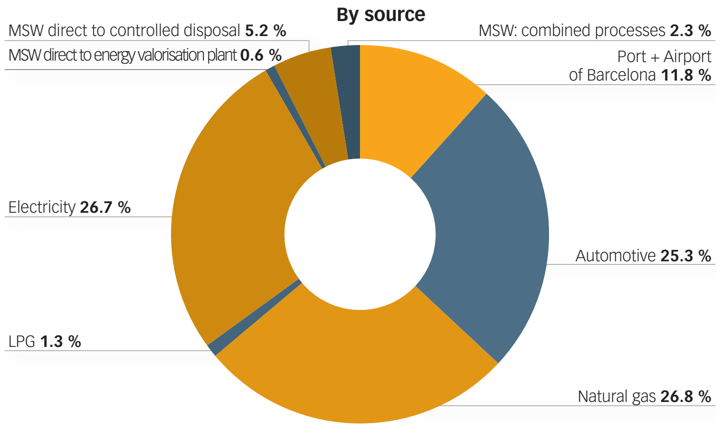
The **Port**: given that its activity takes place within the territory of the city, Barcelona assumes the total emissions calculated even though it serves other areas. The chief source of these emissions are goods and passenger transport vessels, tugs and ancillary systems and the circulation of vehicles - lorries and cars – within the Port area (this traffic is not included in the city road traffic figures). These emissions include vessels temporarily anchored outside the port awaiting entry, approach and stay with the engines running.

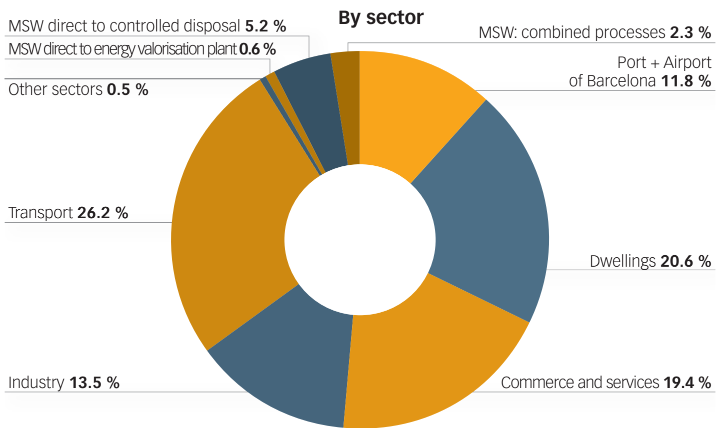
The **Airport**: Territorially located in the municipality of Prat de Llobregat, Barcelona Airport is of vital importance for the city's activity. According to a study commissioned as part of the PECQ, 48.1% of the economic activity generated by the Airport affects Barcelona, and accounts for 10.7% of the city's GDP. Thus, it was decided that Barcelona should bear 48% of the emissions associated with the Airport, which include handling and the Landing & Take-off cycle (LTO) of the planes.

Transport: public transport related emissions are readily ascertainable via the energy consumption monitored by the utility companies. On the other hand, road traffic emissions require a specific approach which is explained in Block 2 of this document.

Municipal Solid Waste treatment (MSW): waste treatment plants handle refuse from different municipalities. In order to assume emissions, those associated with the different plants in operation are weighted in accordance with the amount of material originating from the city of Barcelona. The emission factors have been updated with the latest figures published by the European Commission (proposed in the Waste Management Options and Climate Change report of the European Union).

FIGURE 105 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA (2008)





2.6.2 - EVOLUTION OF EMISSIONS

Evolution by sector and by energy source

GHG emissions in Barcelona between 1994 and 2005 saw sustained moderate growth (except for the years 2003 and 2004), up to a maximum of 4,917,700 t. From 2005 to 2008 there was a sharp drop down to 4,053,800 t (a figure below the levels of 1994).

Thus, the average annual rate of increase between 1999 and 2008 was -1.72%, a reduction caused by a drop in natural gas consumption, greater systems efficiency and improved waste treatment management. Despite this, a large part of this reduction in emissions must be attributed to changes in the methodology used, chief amongst which are the improved calculations of emissions from the Port and Airport of Barcelona, the more detailed study of the vehicle population and the updated emission factors for waste treatment.

The emissions which recorded the largest increase were those associated with electricity consumption - with an average annual rate of increase of 6.57%-, while those with the largest reduction were in municipal waste treatment, with a negative rate of 15.21% which includes the change in methodology mentioned in the preceding paragraph).

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FIGURE 106 | EVOLUTION OF GHG EMISSIONS IN BARCELONA (1999-2008)

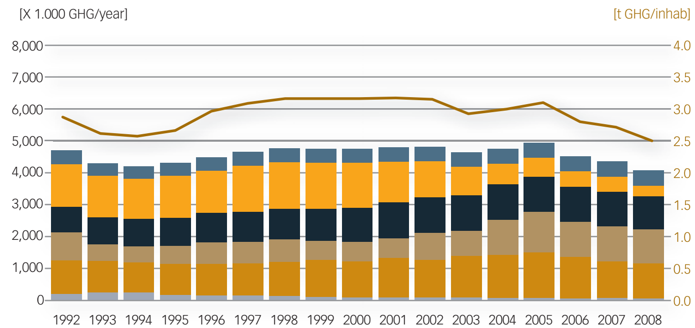


TABLE 30 | GHG EMISSIONS IN BARCELONA, BY SOURCE AND UNDER THE CATALAN ELECTRICITY MIX, IN TONNES (1999/2008)

GHG emissions in Barcelona, by source and under the Catalan electricity mix			
[t GHG x 1.000]	1999	2008	Average yearly increase rate 1999-2008
Liquefied petroleum gas (LPG)	97.15	53.15	-6.48%
Natural gas (not including vehicle NG)	1,152.14	1,086.78	-0.65%
Electricity	610.16	1,081.44	6.57%
Automotive (includes vehicle NG)	995.07	1,025.72	0.34%
MSW processing	1,446.40	327.58	-15.21%
Port and Airport	436.39	479.08	1.04%
Total [x1.000 Mt]	**4,737.30**	**4,053.77**	**-1.72%**
Total per inhabitant [Mt/inhab.]	**3.15**	**2.51**	**-2.50%**

By sectors, GHG emissions caused by the residential sector fell after 2006, following a sustained increase since 2001; the average annual rate of increase between 1999 and 2008 was 0.94%. The industrial and transport sectors (including electricity transport) underwent a similar evolution, with average increase rates of 0.49% and 0.40% respectively, between the years 1999 and 2008. On the other hand, the emissions produced by the commercial sector increased significantly, at a rate of 4.46%, although, like other sectors, it dropped over recent years, 2008 in particular.

This drop over recent years was basically in response to the reduction in energy consumption due to milder weather conditions. There was also a stabilisation of consumption in the transport sector due to road congestion in the city, the policies for the promotion of public transport over private transport and improved technology and efficiency of the vehicles.

[26]Total GHG emissions per inhabitant, considering the Catalan electricity mix, fell from 3.15 t/inhab in 199925 to 2.51 t/inhab in 2008, with a negative annual rate of increase of -2.50%. This figure is very low when compared with national European ratios or those of other cities.

As regards the GHG emissions factor per unit of energy consumed in the city - and using the Catalan electricity mix – it fell continuously between the years 1992 and 2008. The use of more efficient technologies in electricity production and final consumption appliances together with better waste treatment management were the chief causes.

FIGURE 107 | EVOLUTION OF GHG EMISSIONS IN BARCELONA BY SECTOR (1992-2008)

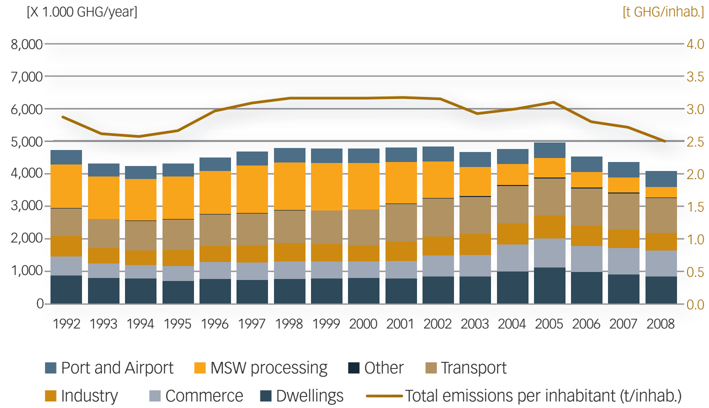
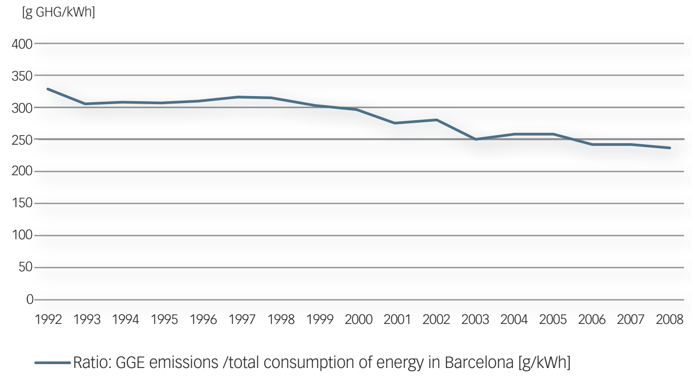


TABLE 31 | GHG EMISSIONS IN BARCELONA, BY SECTOR AND UNDER THE CATALAN ELECTRICITY MIX IN TONNES (1999/2008)

GHG emissions in Barcelona, by sector and under the Catalan electricity mix in tonnes			
[t GHG x 1.000]	1999	2008	Average yearly increase rate 1999-2008
Dwellings	766.22	833.43	0.94%
Commerce and services	530.18	785.47	4.46%
Industry	523.05	546.50	0.49%
Transport	1,024.62	1,061.89	0.40%
Other	10.45	19.82	7.37%
MSW processing	1,446.40	327.58	-15.21%
Port and Airport	436.39	479.08	1.04%
Total [x1.000 Mt]	**4,737.30**	**4,053.77**	**-1.72%**
Total per inhabitant [Mt/inhab.]	**3.15**	**2.51**	**-2.50%**

26. Due to variations in the calculation and updating method of the emission factors (applied both to calculations and historic data), the data published in the PMEB differ slightly from those mentioned here

FIGURE 108 | EVOLUTION OF THE ENERGY GHG EMISSION FACTOR IN BARCELONA (1992-2008)



Emissions in accordance with the electricity mix used

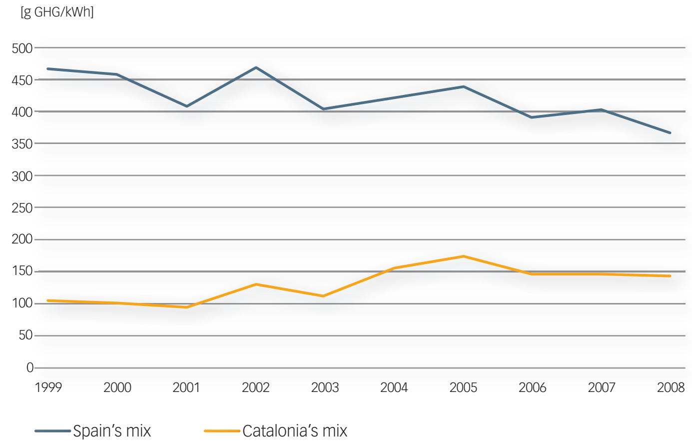
Electricity-related greenhouse gas emissions depend directly on the sources from which this energy has been produced, otherwise known as the electricity mix. This mix varies, however, depending on the territory under consideration -Catalonia or Spain- and therefore so does the calculation of the emissions (GHG emission factor per unit of electricity).

This emission factor, when calculated as the Catalan electricity mix, increased between 1999 and 2008, peaking in 2005 due to the greater use of combined-cycle power plants as water reserves for electricity production were insufficient due to the drought.

If, on the other hand, we consider the electricity mix of Spain, we find a reduction in the GHG emission factor per unit of electricity due to the change in the structure of Spanish power production over recent years: Greater utilisation of renewable energies and combined-cycle power plants, which reduced conventional thermo-electric production with coal and oil products, which are less efficient and more polluting.

The evaluation of total GHG emissions in Barcelona, depending on the use of either the Catalan or Spanish mix, shows a different distribution of each sector or source of the emissions. Thus, using the Spanish mix, the emissions resulting from electricity consumption increased in proportion, from 48.2% of the total (56% of emissions solely from energy consumption) exceeding those associated with natural gas consumption.

FIGURE 109 | EVOLUTION OF THE ENERGY GHG EMISSION FACTOR IN BARCELONA, ACCORDING TO THE CATALAN AND SPANISH MIXES (1999-2008)



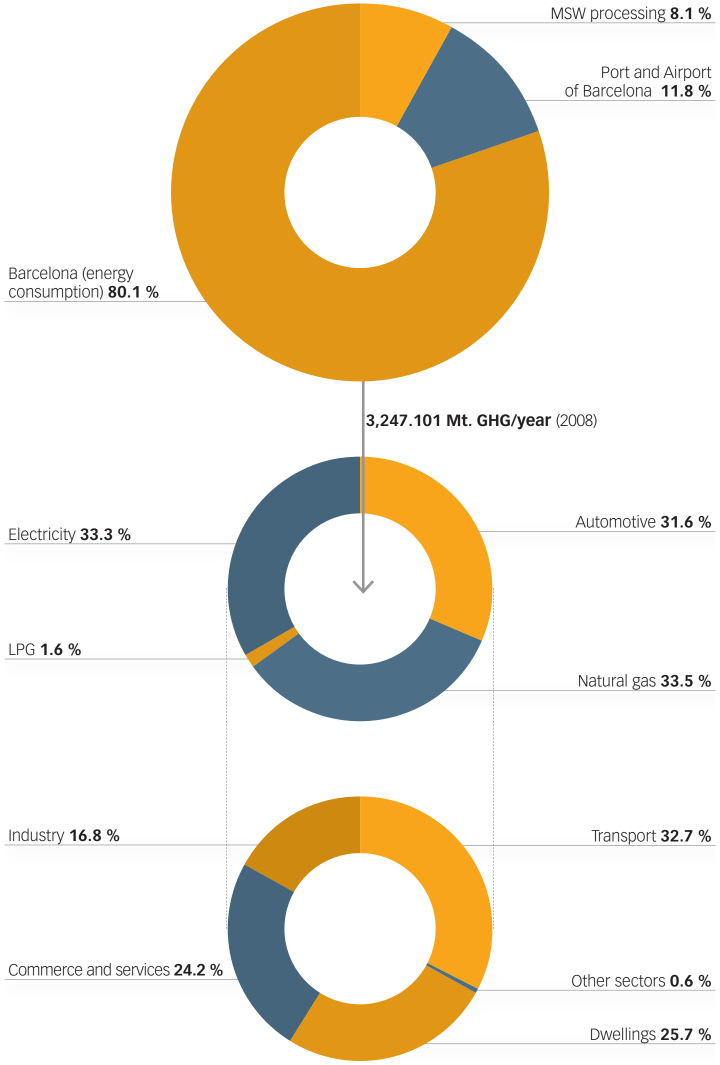
An analysis by sector shows that the distribution also varies when using the Spanish mix, as the commercial and services sector (29.8% of the total, 34.7% of energy consumption) and the residential sector (23.4% of the total, 27.3% of energy consumption) became the largest GHG emitter, exceeding even the transport sector (19.5% of the total, 22.7% of energy consumption).

The evolution of GHG emissions also shows differences between the electricity mixes. When we apply the Spanish mix, emissions due to electricity consumption rose at an average annual rate of 0.16%, while the Catalan mix shows a rate of increase of up to 6.57%. The evolution of emissions due to the commercial and services sector also increases, at an average annual rate of 0.72% when using the Spanish mix and 4.46%, the Catalan mix.

TABLE 32 | GHG EMISSIONS IN BARCELONA, BY SECTOR UNDER THE CATALAN AND SPANISH ELECTRICITY MIXES, IN TONNES OF GHG (2008 AND AVERAGE ANNUAL RATES 1999/2008)

GHG emissions in Barcelona, by sector under the Catalan and Spanish electricity mixes, in tonnes of GHG				
	2008		Average yearly increase rate 1999-2008	
[t GHG x 1000]	CAT's elec. mix	SPAIN's elec. mix	CAT's elec. mix	SPAIN's elec. mix
Dwellings	833.43	1,343.80	0.94%	-0.35%
Commerce and services	785.47	1,710.33	4.46%	0.72%
Industry	546.50	704.49	0.49%	-1.80%
Transport	1,061.89	1,117.27	0.40%	0.18%
Other	19.82	50.60	7.37%	0.92%
MSW processing	327.58	327.58	-15.21%	-15.21%
Port and Airport	479.08	479.08	1.04%	1.04%
Total [x1.000 Mt]	**4,053.77**	**5,733.2**	**-1.72%**	**-1.96%**
Total per inhabitant [Mt/inhab.]	**2.51**	**3.55**	**-2.50%**	**-2.74%**

FIGURE 110 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA FROM WASTE TREATMENT PLANTS UNDER THE CATALAN ELECTRICITY MIX (2008)



Total emissions: 4,053.766 Mt GHG

FIGURE 111 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA FROM WASTE TREATMENT PLANTS UNDER THE SPANISH ELECTRICITY MIX (2008)

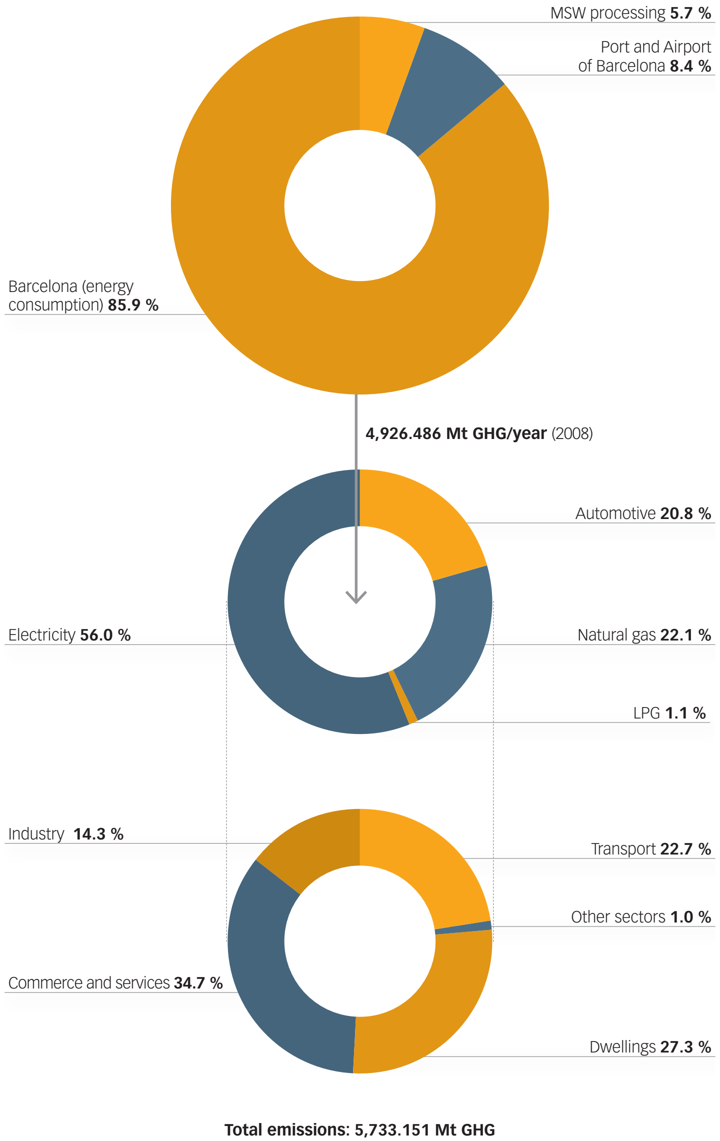
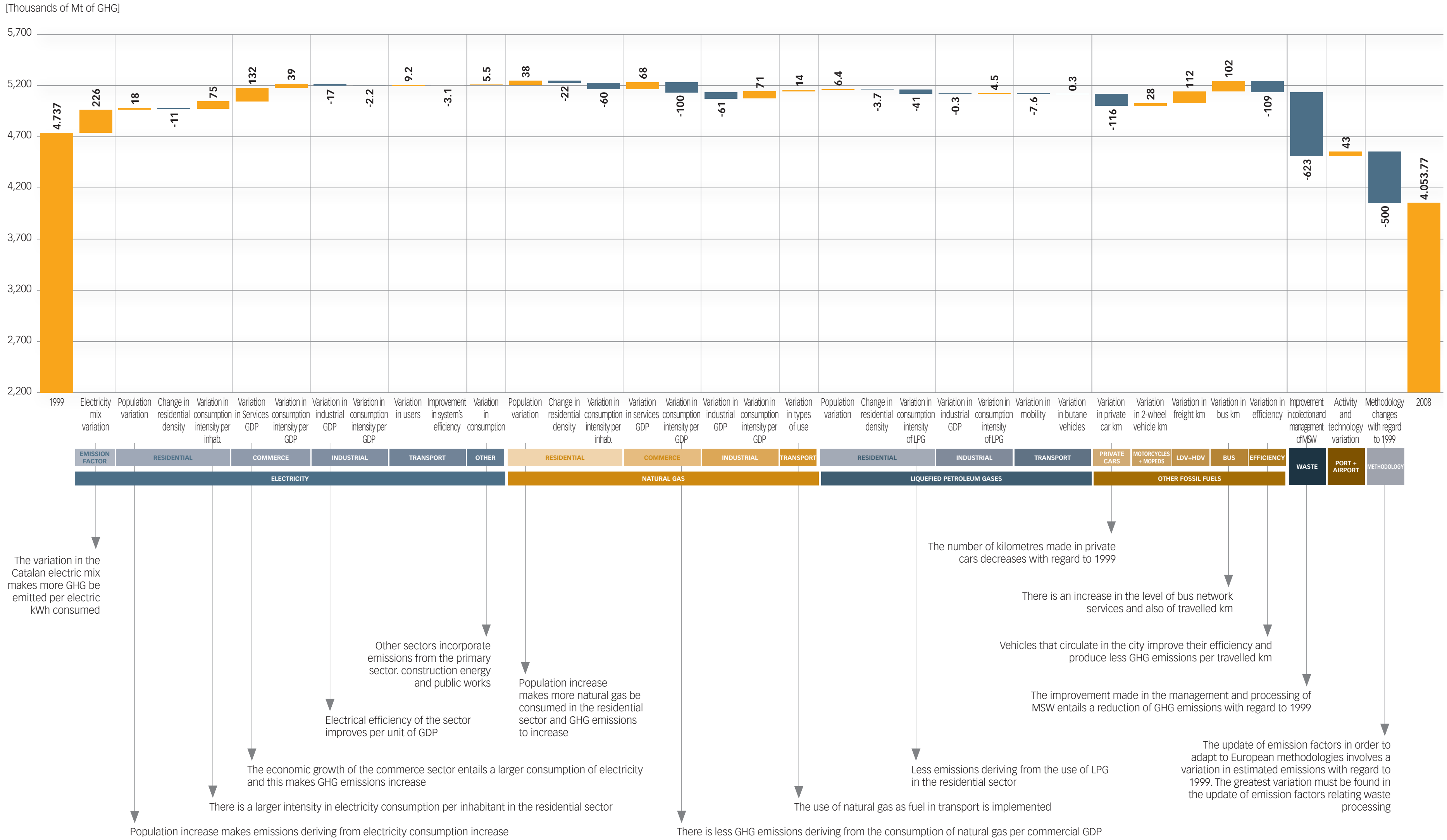


FIGURE 112 | VARIATION OF GHG EMISSIONS IN BARCELONA (1999-2008)



2.7 - Air quality

2.7.1 - EMISSIONS INVENTORY

One of the challenges for this PECQ was to determine which human and/or natural activities cause the highest concentration levels of pollutants in the air, so as to focus its efforts on addressing and adopting the most suitable measures to reduce these levels.

To achieve this objective, an instrument has been used to model the dispersion of pollutants and diagnose the air quality in a given territory, taking into account variables such as energy efficiency, global reach emissions (GHG) and also more local emissions which directly affect the population's health.

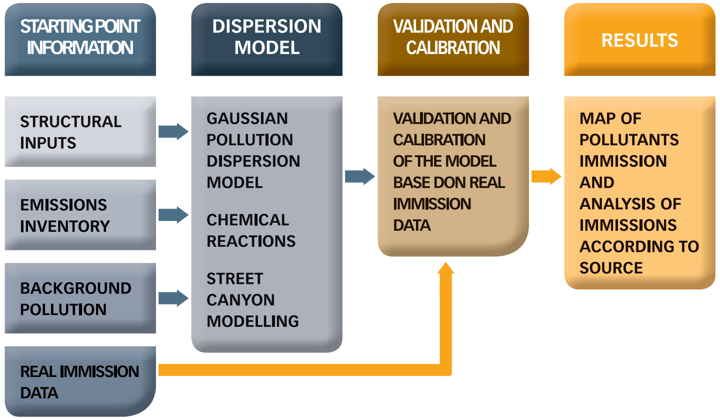
The methodology employed

The methodology employed to calculate the emissions is based on a pollutant dispersion model[27], used to model the chemical reactions between the various compounds and particles present in the atmosphere, together with the effects of solar radiation on them. This model also uses algorithms to evaluate wind speed at different altitudes, turbulence created by different land configurations and even air currents created at street level.

Hourly, weekly and monthly emission profiles can also be entered from the different sources of pollutants, so as to follow up the ongoing evolution of the emissions and their impact on the profiles. The model is also directly related with a Geographic Information System (GIS) and an emissions database for simpler quantification and geographic localisation of the sources of pollutants to a very accurate degree.

27. The Programme applied was the ADMS-Urban, a commercial programme used to evaluate the air quality in different cities worldwide, such as London, Manchester, Vienna and Beijing

FIGURE 113 | METHODOLOGICAL SCHEME USED TO MODEL AIR QUALITY IN THE PECQ



In the case of Barcelona, in order to model the levels of air quality it was necessary to perform a detailed inventory of the sources emitting pollutants over a larger area than the city itself (1,476 km^2), as atmospheric dynamics can carry compounds a great distance from the points of emission. Based on this inventory, and by using the integration of different bio-geographical and urban variables (wind conditions, rainfall, height of the terrain, building configuration, concentration of sources, etc.) the levels of nitrogen oxide and solid particles were calculated (NO_2 and PM_{10}), as these are the pollutants which in Barcelona exceed the EU limits.

In order to achieve the greatest degree of detail - at street level – a mesh of 150,000 virtual points was created, distributed uniformly within the territory under consideration, in addition to 50,000 points using intelligent gridding, a method for refining the influence of traffic emissions on the surrounding area. In order to perform this modelling, the work of twelve processors operating uninterruptedly for 30 days was necessary. The year chosen to perform this modelling was 2008.

In order to calibrate and validate the model, the data were compared with the measurement stations of the Air Pollution Surveillance and Control Network (XVPCA), with virtual measurement points entered into the model at the same geo-referenced position. This analysis was able to adjust the modelling parameters to obtain emission results the closest possible to the real situation.

It should be remembered that reality is not a mathematical model and there are variables unrelated to parameterizable behaviour which distort the standard emissions profile; specific or uncontrolled situations such as traffic jams, fires, demolition of buildings, etc.

CHARACTERISTICS OF THE ANALYSIS MODEL

It is specifically designed to analyse the immission of pollutants in urban and metropolitan environment with street-level resolution.

It is based on a Gaussian pollution dispersion model.

It incorporates a meteorological pre-processing model.

It uses an hour-by-hour processing module of the flows and turbulence across the entire terrain. The module used is FLOWSTAR, a high resolution model designed for complex terrains.

It uses the OSPM model, specifically aimed at evaluating the street canyon effect which appears in the junctions between buildings, arising from the recirculation of the air and the turbulence created by vehicles and the buildings themselves.

It takes into consideration the chemical reactions between the various emissions in the atmosphere and those emitted by different sources. It also takes into account the photochemical reactions caused by solar radiation.

It has an intelligent system of virtual receivers, plus a regular mesh of points throughout the territory, so as to automatically assign measuring points around the sources of streets and roadways to increase the level of detail..

FIGURE 114 | PROFILE OF STANDARD EMISSIONS ON A WORKING DAY IN MARCH IN BARCELONA

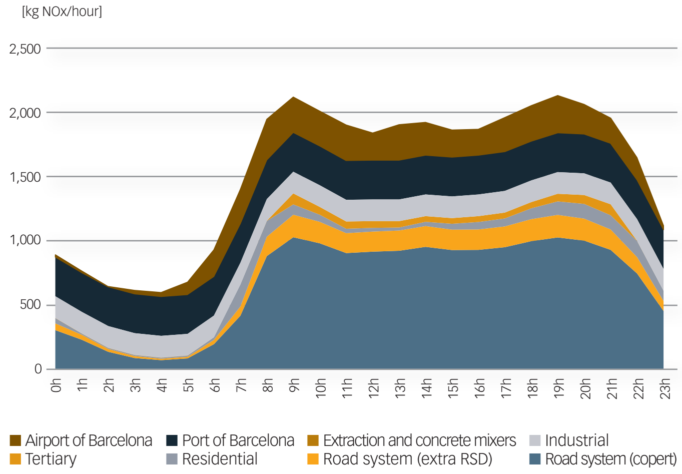
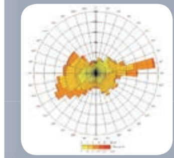


FIGURE 115 | STRUCTURAL INPUTS OF THE AIR QUALITY MODEL

Meteorological data

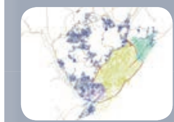


- In order to depict the scope under analysis, one of the key factors in order to analyse pollutants dispersion correctly is to obtain a series of meteorological data which are typical of the scope.
- The Meteorological Service of Catalonia has one of its centres in Barcelona's Raval neighbourhood, right in the city centre, which is highly representative of Barcelona's climate features. The hour-by-hour climate data used are those from 2008.

Cartography

- Orography and rough land. An hour-by-hour analysis is carried out on the air flows and turbulences originated in this area, deriving from the land's morphological characteristics.
- Contour lines have been extracted from the Catalan Institute of Cartography's topographic database. In addition, spot heights have been used to make up the group of points that are more representative from an orographic point of view, thus allowing the most uniform space coverage.
- The Soil Coverage Map of Catalonia has been used to determine the land's relief factor.

Road system infrastructures



- Ring-road system. The analysis is based on the traffic web prepared by Barcelona City Council Mobility Services, which incorporates the city road netting and other roads inside the area delimited by the ring-roads, in addition to those in the Besòs municipalities. There is a high level of detail, including crossroads and traffic intensity in every road stretch.
- Main and secondary out-of-city road system. The Department of the Environment and Housing provided data on the main road system close to Barcelona.
- Urban system in other towns. In order to round off the road system in municipalities neighbouring Barcelona information has been extracted from basic planimetry cartography prepared by the Catalan Institute of Cartography.
- TMB bus lines. Transports Metropolitans de Barcelona provided the routes of bus lines circulating in Barcelona and neighbouring towns.

Tri-dimensional building model

- A very important effect with regard to the dispersion of pollutants in urban areas is the organization of city streets due to turbulences created within. In order to calibrate such effect the OSPM (Operational Street Pollution Model) Danish model is used, which takes into account the actual turbulences created by traffic and those arising from neighbouring buildings' geometries.
- The Barcelona tri-dimensional model has been used to determine the heights of buildings from block to block.

NO_x and PM_{10} emission data

In 2008, 10,413 t of NO_x and 744 t of PM_{10} were emitted in the territory under study. The largest emitter was road transport, of both NO_x and PM_{10}.

The internal inventory of Barcelona for nitrogen oxides showed that traffic emissions were 4,849 t (4,157+692)[28] which account for almost half the total emissions within the city. The second source of emissions was the Port of Barcelona, with 3,078 t (1,566+1,512), part of which are caused by vessels (anchoring, approach and departure and tugs) and the rest from land operations (this includes vessels which are moored, the vehicles entering and leaving the port area and ancillary machinery). The third source of emissions were industrial activities, with 1,394 t of NO_x, which includes energy production activities, the chief industrial sources and other industries in the territory. The remaining volume of emissions originated from the residential and services sector with a total of 926 t.

As regards the emissions of particles in suspension, road transport within the city emitted 458 t from the following sources (according to the CORINAIR methodology): 91 t were direct emissions from exhaust pipes; 170 t were originated during combustion and the wear on brakes, tyres and asphalt; the remaining 197 t were obtained from the emissions measured in the streets of Barcelona, and revealed that vehicles in circulation had higher emissions than those stated in the European methodology (COPERT- CORINAIR).

The second source of particles were port activities, with 137 t (39 + 99), accounting for 18.5% of the total. The industrial and energy production sector as a whole emitted 133 t, and the residential and services sectors account for a total of 7 t. Emissions from extraction activities and major works were also considered and found to represent 8 t. It should be borne in mind that minor works also impact the total volume of emissions of particles in suspension, but their widely varying nature made it unfeasible to calculate in this inventory.

28. Road emissions are separated into two types: emissions according to COPERT (those calculated using the European methodology CORINAIR), and EXTRA RSD emissions (additional emissions which are detected in vehicle measurements in the city using the RSD system or Remote Sensing Device).

This volume of emissions refers to the inventory of those occurring within the municipal boundary of the city, yet for more refined and actual modelling of air quality, the territorial scope of the study must be extended as the different polluting compounds can travel great distances as a result of air currents. Thus, after analysing the results obtained, road circulation continues to be the chief emitter of both NO_x and PM_{10}.

If we compare the distribution of emissions by sectors in the city inventory with that of the broader territorial scope, there is a notable increase in the role of the industrial and energy generation sectors, the principal activities in the municipalities surrounding Barcelona. In the specific case of particles in suspension, emissions caused by extraction activities and major works represent 198 t of PM_{10}. Emissions at Prat Airport totalled at 1,608 t of NO_x and 21 t of PM_{10}, in 2008.

Lastly, we should add that part of the air pollution is caused by sources present in this territory and it either forms part of the usual concentration of these elements in the area or is due to the emissions of sources located at a great distance. This effect is called *"background pollution"*.

FIGURE 116 | SOURCES AND INVENTORY OF EMISSIONS IN BARCELONA

Road traffic emissions

- Traffic emissions per each street stretch in Barcelona (from one crossroads to the next) and neighbouring town roads.
- Monthly, daily and hourly profile based on traffic capacities.
- Description of vehicles circulating in the city as a whole. General picture of vehicles circulating in the city, focusing both on their characteristics and real emissions when they circulate. Please, see specific section for further information.
- Traffic emissions in the main roads outside Barcelona and urban roads in surrounding towns.
- TMB bus emissions with frequencies for each route and broken down per type of fuel.

Residential and tertiary sectors

- This is based on energy consumption data within the residential and tertiary sectors provided by ICAEN. These are distributed by energy uses and by territory according to building types as defined in the PMEB.
- NOx i PM_{10} direct emissions deriving from natural gas and LPG consumption are estimated according to consumption uses. The emission factors used are those set by the CORINAIR methodology.
- Monthly, daily and hourly profiles are being used.
- The same methodology is used for neighbouring towns estimating the land's distribution on the basis of land use according to the Map of Soil Coverage.

Energy generation and industrial sector

- The database used is owned by the Department of the Environment and Housing (DMAiH) and includes the mass emissions of the main NOx and PM_{10} emission focuses. This database incorporates the energy generation plants.
- In order to estimate the remaining emissions deriving from the industrial sector the consumptions of natural gas and LPG used are those provided by ICAEN and are distributed according to the geographical location of industries.
- In the case of neighbouring towns the same methodology is being used and emissions are distributed according to the use of soil.

Emissions deriving from the port's activity

- Emissions deriving from the Port's activity are taken into account on the basis of data provided by the Barcelona Port Authority.
- This includes emissions from vessels when approaching the port, while berthed and while anchored.
- It also includes emissions from auxiliary machinery and tugs.
- Monthly activity profiles are being used according to freight or passenger transportation.
- It includes emissions deriving from land transport within the port's area based on the number of vehicles and the survey on characterisation of vehicles in situ within the Port.

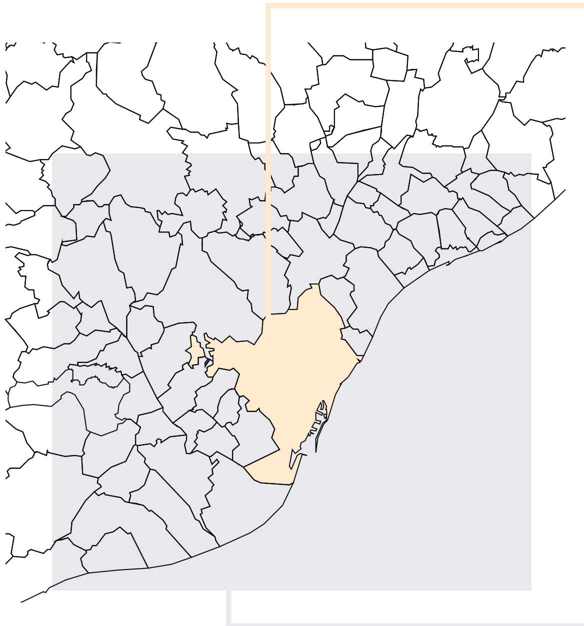
Airport emissions

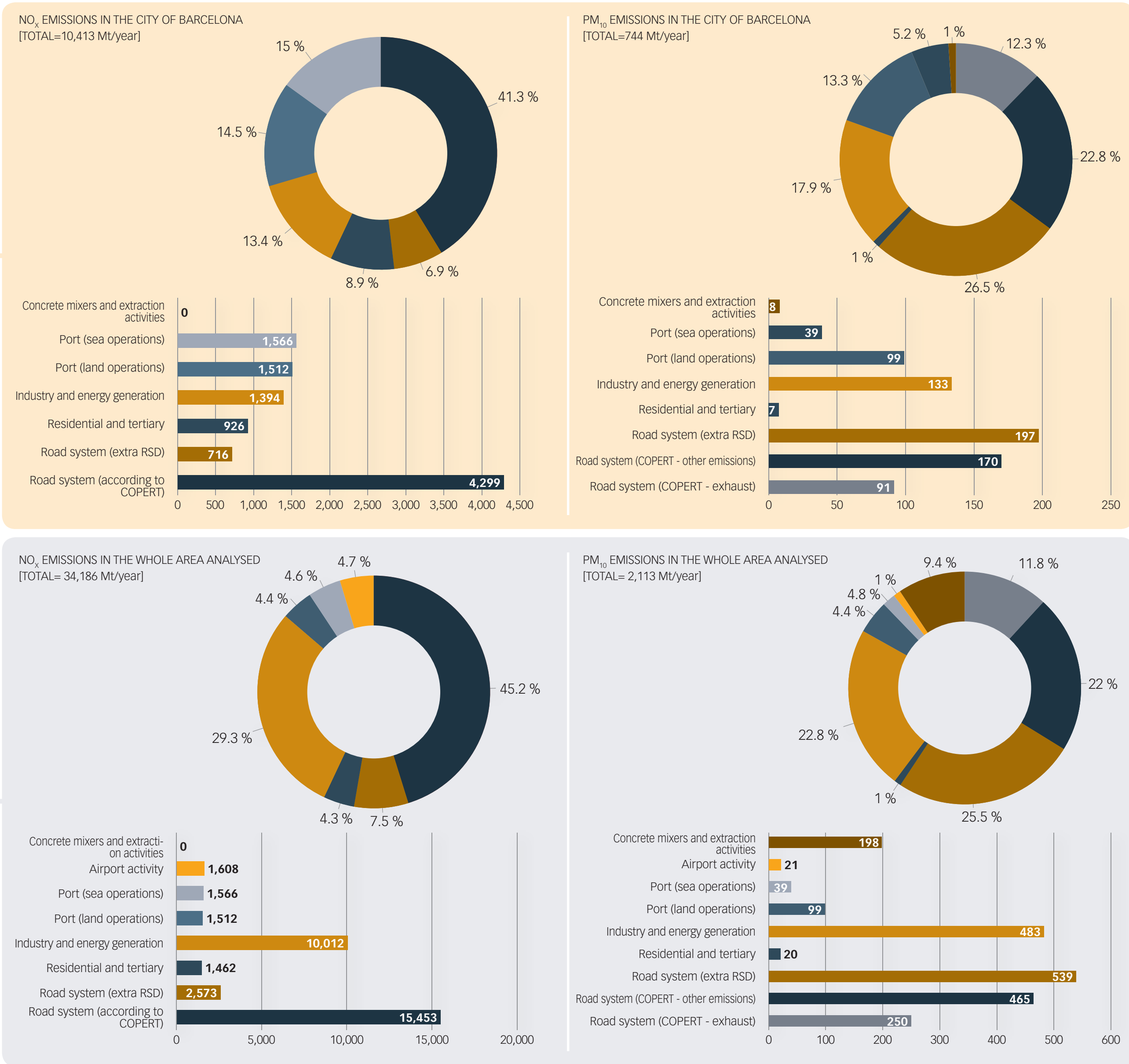
- NOx and PM_{10} emission data provided by AENA are being used.
- Direct emissions from aircrafts: these include the LTO cycle – landing, land movements and take off up to 3,000 feet.
- Auxiliary machinery and handling emissions.
- The trajectory of emissions according to flight operations in every runway is being considered bearing in mind monthly and hourly profiles of landings and take-offs.

Extraction activities and large concrete mixers

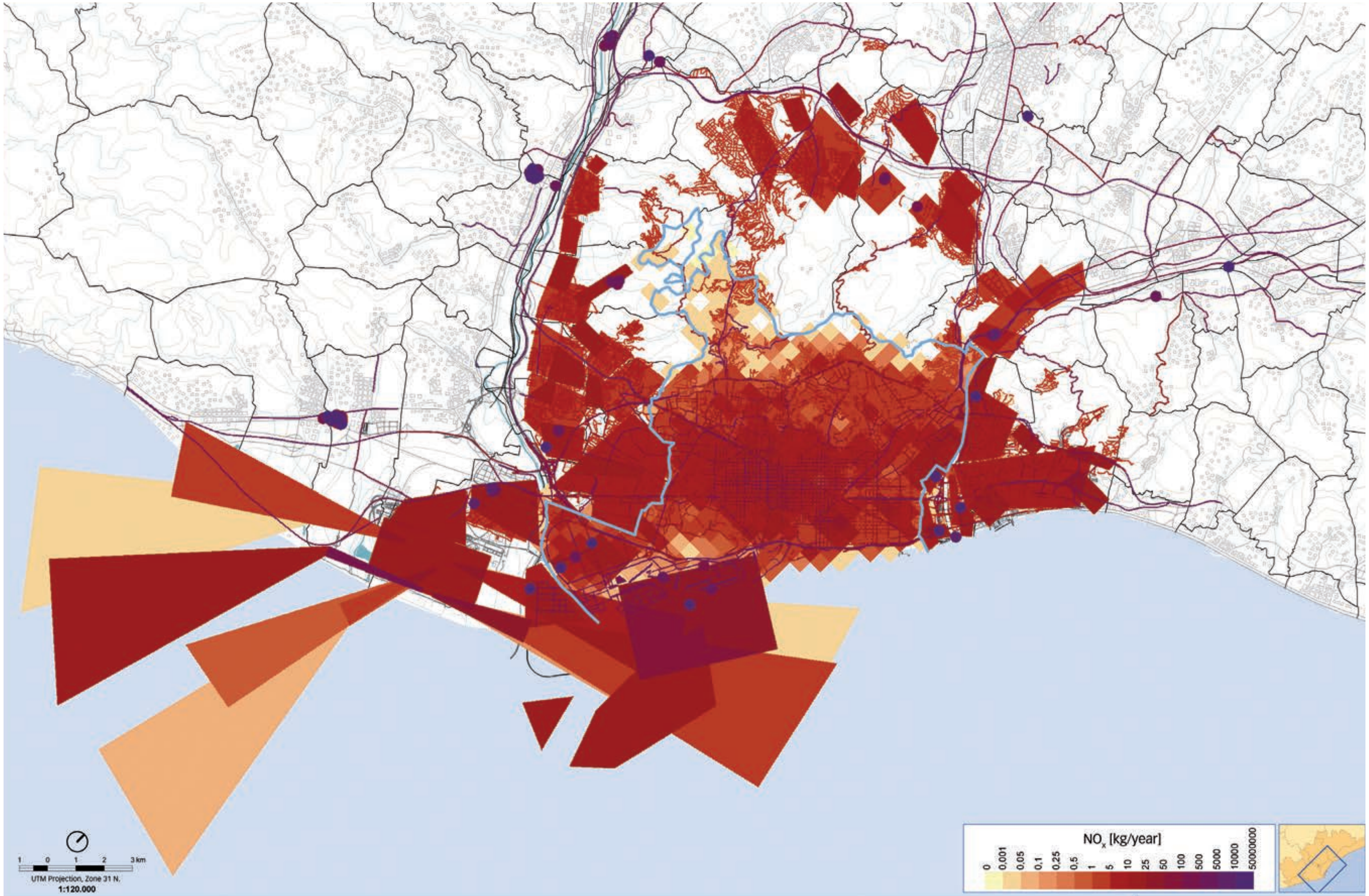
- The inventory of PM_{10} emissions deriving from extraction activities and from works with large mixers in the whole area under analysis, provided by the Department of the Environment and Housing.

FIGURE 117 | INVENTORY OF EMISSIONS IN BARCELONA CITY AND ACROSS THE ENTIRE SPHERE UNDER STUDY





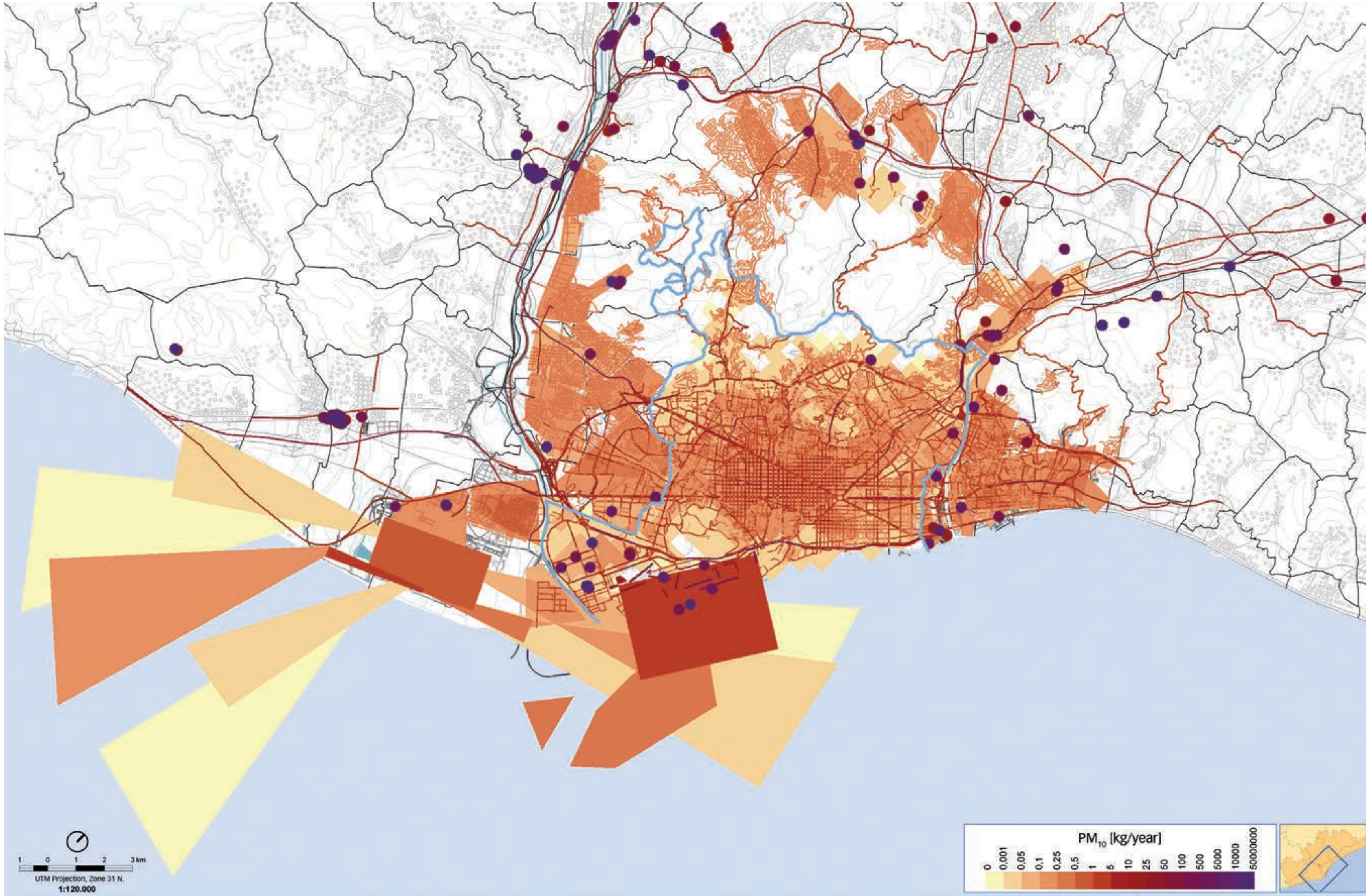
Note:
"COPERT - EXHAUST" are exhaust emissions from the engine.
"COPERT - OTHER EMISSIONS" are non-exhaust emissions including emissions from vehicle brakes' wear. tyre wear by bearing and asphalt wear.
"EXTRA RSD" are emissions not included in the COPERT methodology detected in the measurements of vehicle emissions by means of the RSD (Remote Sensing Device) system.



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Total annual NOx emissions in the analysed area in 2008

Agència d'Energia de Barcelona
Barcelona Regional



Ajuntament de Barcelona

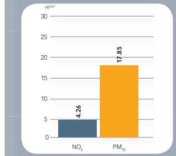
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Total annual PM$_{10}$ emissions in the analysed area in 2008

AGÈNCIA D'ENERGIA DE BARCELONA

BARCELONA REGIONAL

FIGURE 118 | SOURCES AND INVENTORY OF EMISSIONS IN BARCELONA

Data on levels of background pollution



- The data used was provided by AEMET's background pollution station in Cap de Creus in order to consider the levels of pollutants not directly linked to activities in the area.
- Hourly data on NO_2, NO, SO_2 and O_3, and daily data on PM_{10} are available.
- The annual average value of main pollutants are:
  NO_2 : 4,26 μg/m³ NO : 0,30 μg/m³ PM_{10} : 17,85 μg/m³
  SO_2 : 0,33 μg/m³ O_3 : 74,4 μg/m³

2.7.2 - IMMISSION DATA

The values detected

The pollutant dispersion modelling is carried out using the geo/referenced inventory of emissions and all the structural and boundary variables. In order to calibrate the model, the modelling parameters are adjusted to the real values recorded by the automatic and manual measuring points of the Air Pollution Surveillance and Prevention Network in Barcelona.

Calibrating the model entails adding the local background pollution: emission sources not calculated or underestimated, real background pollution, re-suspension of particles, specific episodes and/or system behaviour which differ from the daily, weekly or monthly profiles entered in the model. This local background pollution represents an average annual increase of 5 μg/m³ of NO_2 and 15 μg/m³ of PM_{10} in Barcelona.

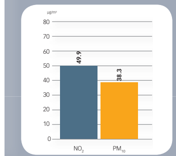
After performing the calibration, when the values obtained using the model are compared to the real levels of annual concentration, in the case of NO_2 the real average value of the city of Barcelona in 2008 was 49.9 μg/m³, while the model recorded a concentration of 449.5μg/m³. i.e., a 99.1% match with the real situation, with minor variations at certain measuring stations.

As regards PM_{10}, in 2008 the real average value was 38.3 μg/m³, while the model gave a concentration of 337.3μg/m³, slightly underestimating the total particles in suspension but achieving a strong similarity with the real figure of 97.4%.

We can therefore say that the pollutant dispersion model adapted to the conurbation of Barcelona offers a value strongly aligned with reality, making it possible to analyse in detail the factors and sources which most affect the concentration of NO_x and PM_{10}, and propose more effective policies and measures to improve air quality.

FIGURE 119 | DETAILS ON IMMISSION LEVELS IN BARCELONA AND ITS SURROUNDING AREA

Data on levels of immission in barcelona and its surrounding area

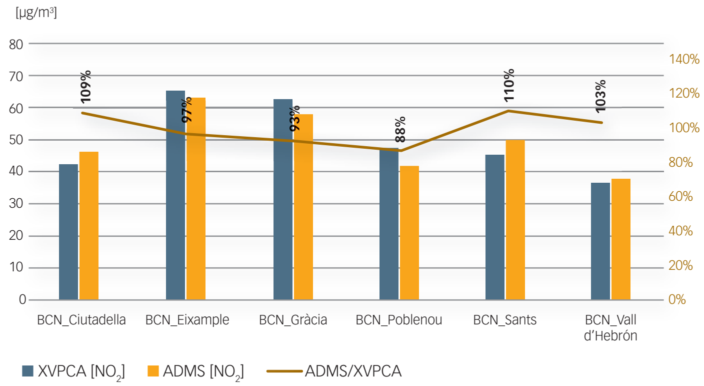


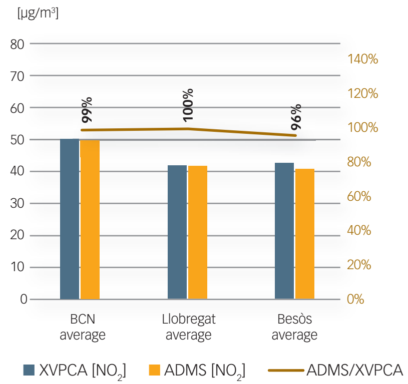
- Hourly and daily data on NO_2 immissions and particles in suspension in the city of Barcelona and its surrounding area.
- Manually and automatically-obtained data from the Air Pollution Surveillance and Control Network (XVPCA), to validate and calibrate the dispersion model.

DEFINITION: EMISSIONS / IMMISSIONS

Emissions are the amount of pollution which a specific source emits into the atmosphere over a given period of time. Immissions, on the other hand, are the concentration of a pollutant in a given place. Immission levels or air quality are those which determine the effect of a given pollutant on health. Therefore, in order to reduce air pollution, it is necessary to control atmospheric emissions and monitor the presence of pollutants in the air at different reception points (immission levels).

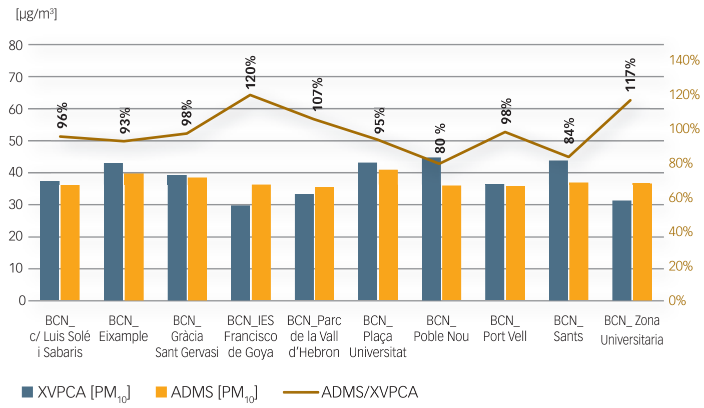
FIGURE 120 | COMPARISON OF REAL IMMISSION VALUES OF NO_2 WITH THOSE MODELLED IN BARCELONA (2008

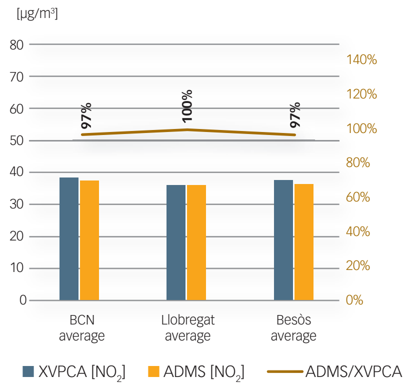




Source: XVPCA

FIGURE 121 | COMPARISON OF REAL IMMISSION VALUES OF PM_{10} WITH THOSE MODELLED IN BARCELONA (2008)





Source: XVPCA

CARTOGRAPHIC EXPRESSIONS OF RESULTS

After calibrating and validating the model with the data measured at the XVPCA immission stations, the map of air conditions in Barcelona is prepared. The pollutants regulated by Royal Decree 1073/2002 are NO_2 and PM10, which must not exceed a level of 40 µg/m³ on an annual average as from the year 2010. 55% of the territory (56 km2) exceeded 40 µg/m³ immissions of NO_2 in 2008. In the Eixample and neighbouring areas, the values totalled between 50 and 60 µg/m³. In areas near heavy traffic very high levels were also reached.

As regards the concentration of PM10, 17% of Barcelona exceeds the annual limit of 40 µg/m³, although a large part of the city was close to these levels. Specifically, and in accordance with the model, approximately two thirds of the territory was in the range of 35-40 µg/m³ and therefore very close to exceeding the annual limits. According to the dispersion maps, the annual average of 40 µg/m³ was exceeded in the Eixample and the surrounding areas of heavy traffic streets.

In order to detect the differences in air quality at different points in the city, an analysis of the immissions was carried out at three longitudinal sections of the map of the annual average concentration of NO_2. This analysis revealed the major impact of traffic on the concentration of pollutants, especially in the roads with the heaviest traffic and junctions. Immission peaks coincided with the junctions, but just a few metres from the traffic they fell off sharply. This phenomenon causes pollutant concentrations in buildings and parks to reach the levels of the city as a whole.

We should also underline the increased concentration in the city centre and especially the Eixample network, where the average immission was higher. On the other hand, in areas with large green spaces such as the Ciutadella Park or Montjuïc mountain, there was a clear reduction in the concentration given the non-existence of major sources of emissions.

FIGURE 122 | DISTRIBUTION OF THE SURFACE AREA OF BARCELONA IN ACCORDANCE WITH NO_2 IMMISSIONS(2008)

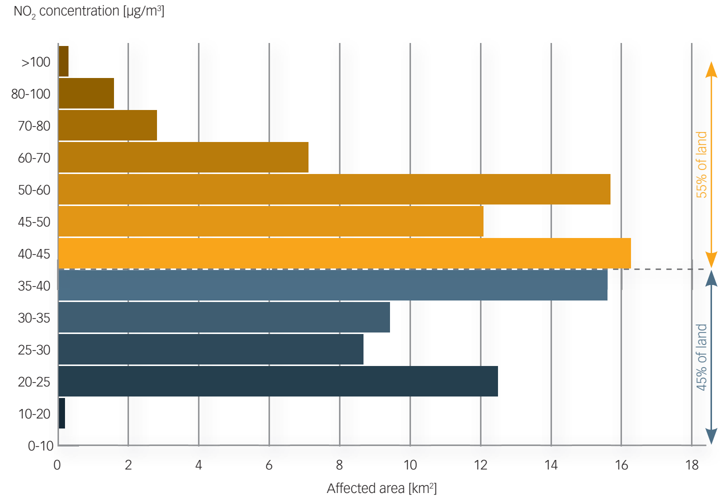
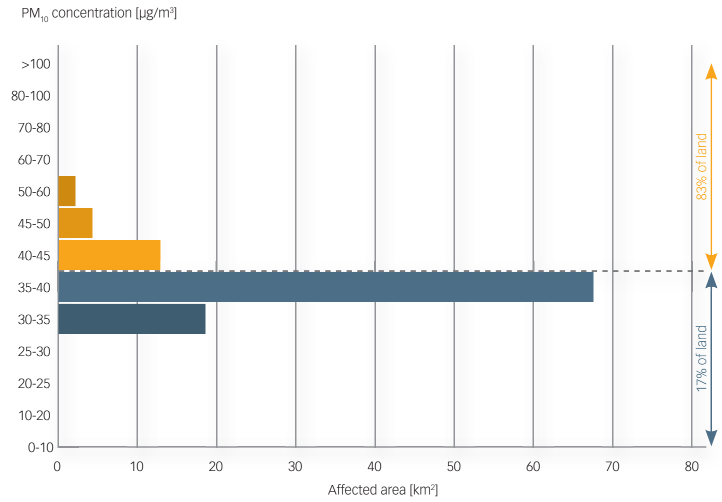
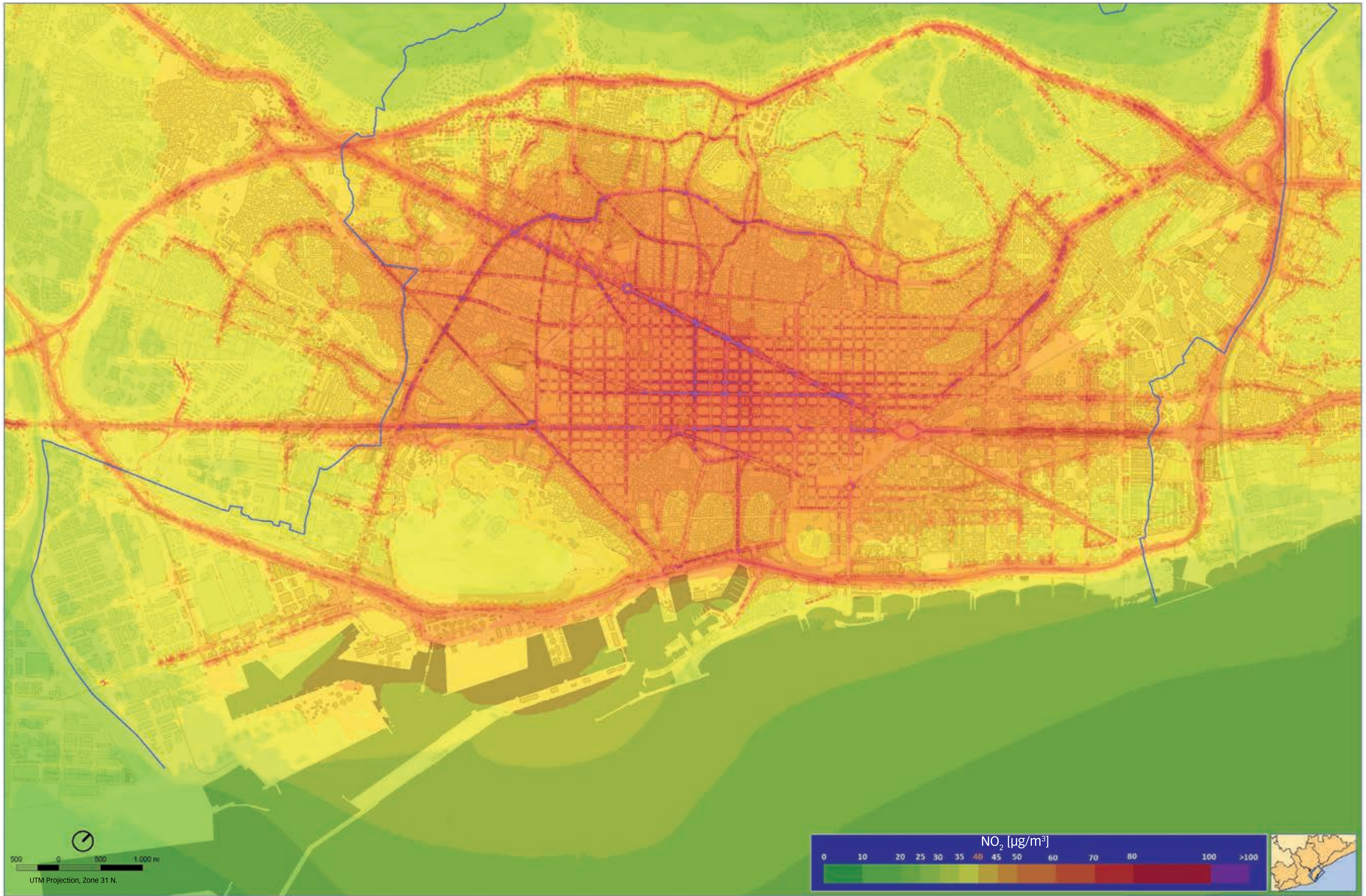


FIGURE 123 | DISTRIBUTION OF THE SURFACE AREA OF BARCELONA IN ACCORDANCE WITH PM_{10} IMMISSIONS (2008)

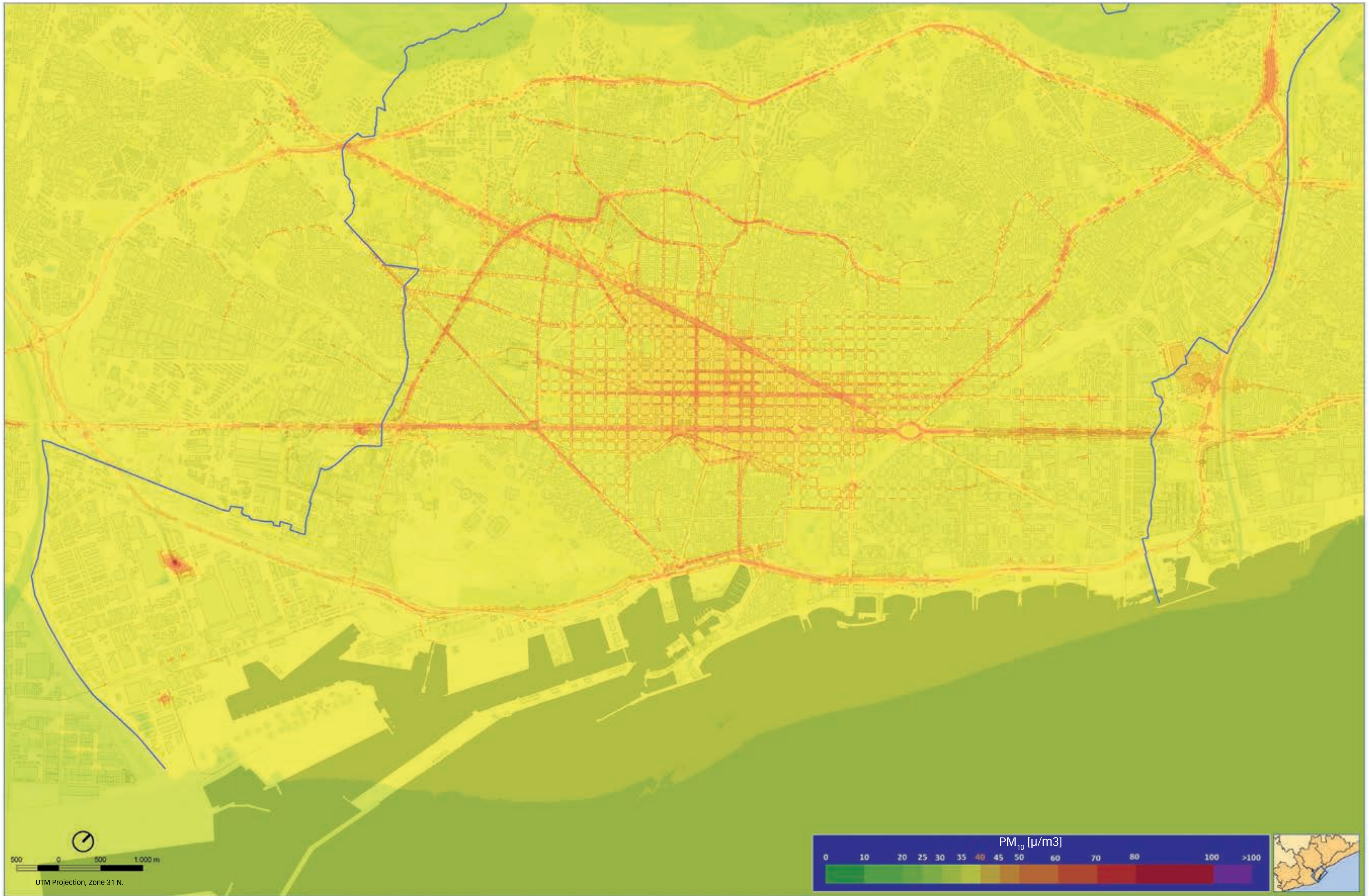




Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Annual average immission of NO_2 in Barcelona in 2008

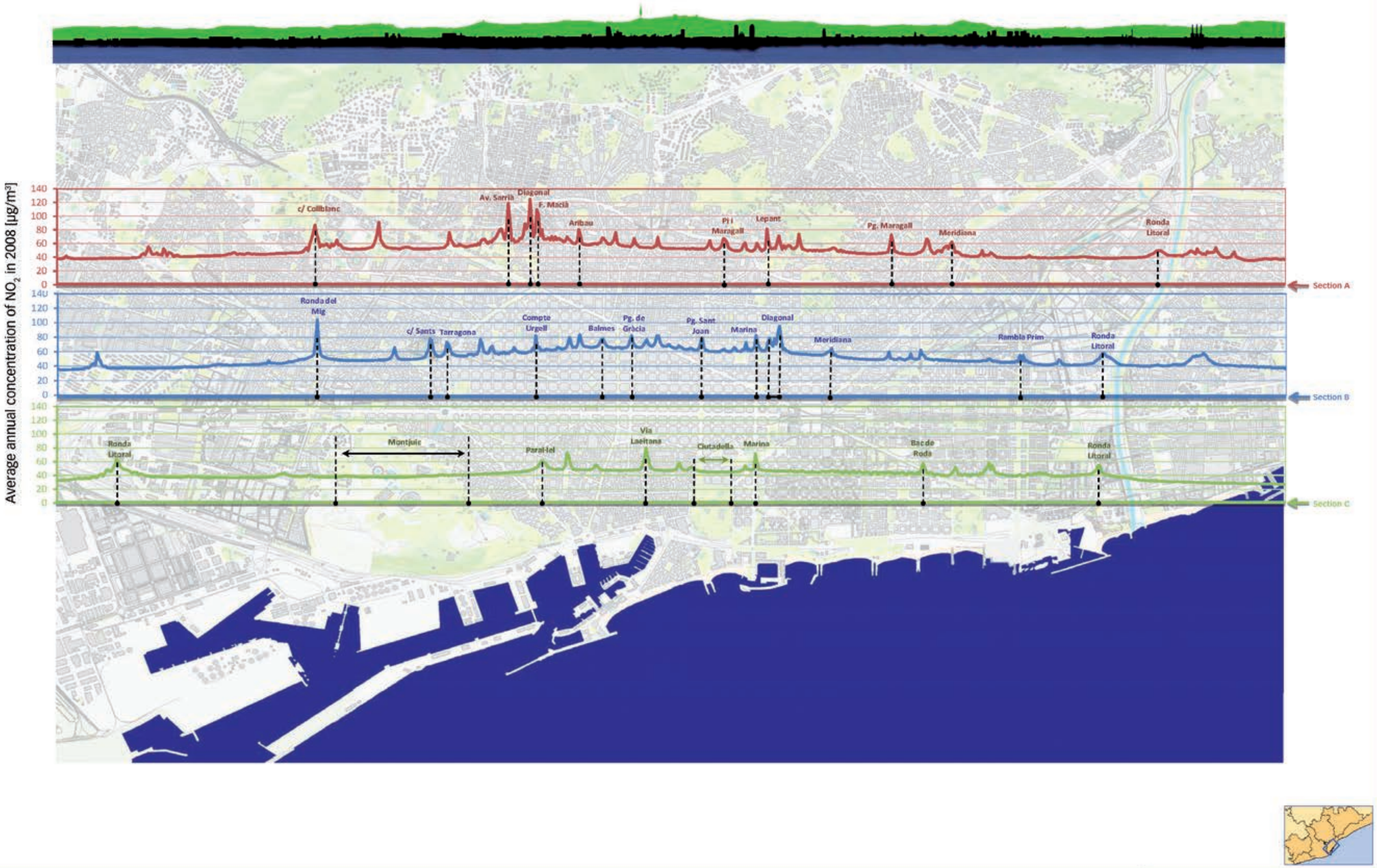
BARCELONA REGIONAL



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Annual average immission of PM_{10} in Barcelona in 2008

Agència d'Energia de Barcelona
Barcelona Regional



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Longitudinal sections of annual average immission of NO_2 in Barcelona in 2008

Immissions by source of emission

As not all the pollutant sources affect air quality to the same extent, it is necessary to ascertain in detail the origin of the pollution.

In Barcelona in 2008, approximately 65.6% of the concentration of NO_2 in the air (56%+9.6%) was caused by road transport, 8.68% by the residential and commercial sectors and 4.8% by the industrial and energy production sectors, 2.1% by port activity and 0.1% by the Airport. There was also a major affect by the regional background pollution, 10.1%, and local background pollution, 8.6%.

In the case of PM_{10}, the strong influence of regional background pollution was detected, which accounted for almost half the concentration (47.9%; 17 µg/m^3 according to the background station at Cap de Creus). Local background pollution accounted for 40.2% of total immissions. Of the pollution which is directly attributable to the city's activity, 11.0% was caused by traffic (6.3%+4.7%)[29], 0.3% by industrial and energy production activities, 0.3% from port activities and 0.2% by major works and extraction activities. The influence of the Airport was almost indiscernible.

The main conclusions of this analysis of emissions sources for the year 2008 are that:

- Road traffic is the human activity with the greatest influence on air quality in Barcelona, both for NO_2 and PM_{10}.
- NO_2 immissions are also strongly influenced by emissions from the residential, commercial and industrial sectors.
- In the case of PM_{10}, immissions, despite being strongly influenced by sources not directly attributable to the city, the industrial sector, port activity or works and extraction activities throughout the territory are a major cause of pollution.
- There is a noteworthy impact of background pollution, which in 2008 accounted for a large part of these immissions (8.6% in the case of NO_2 and 47.9% for PM_{10}), and which was caused by factors lying outside the territory.
- Local background pollution (especially in the case of particles in suspension) represents the immission due to emission sources, levels or profiles which are the most difficult to identify and parameterize (1.1% in the case of NO_2 and 40 2.% in the case of PM_{10}).

29. Road transport immissions are separated into two types: immissions from emissions according to COPERT (calculated according to the European methodology CORINAIR); and immissions from EXTRA RSD emissions (additional emissions detected in vehicle measurements using the RSD system or Remote Sensing Device).

FIGURE 124 | DISTRIBUTION OF THE ANNUAL AVERAGE OF NO_2, BY SECTOR (2008)

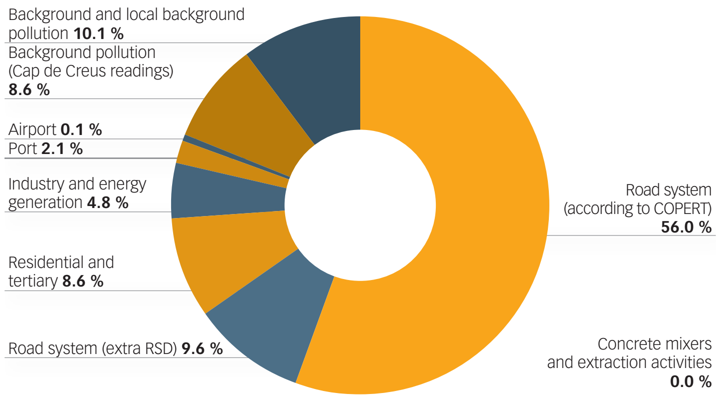
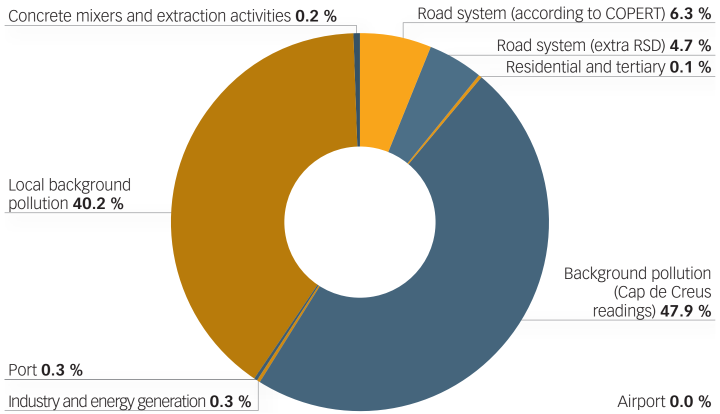
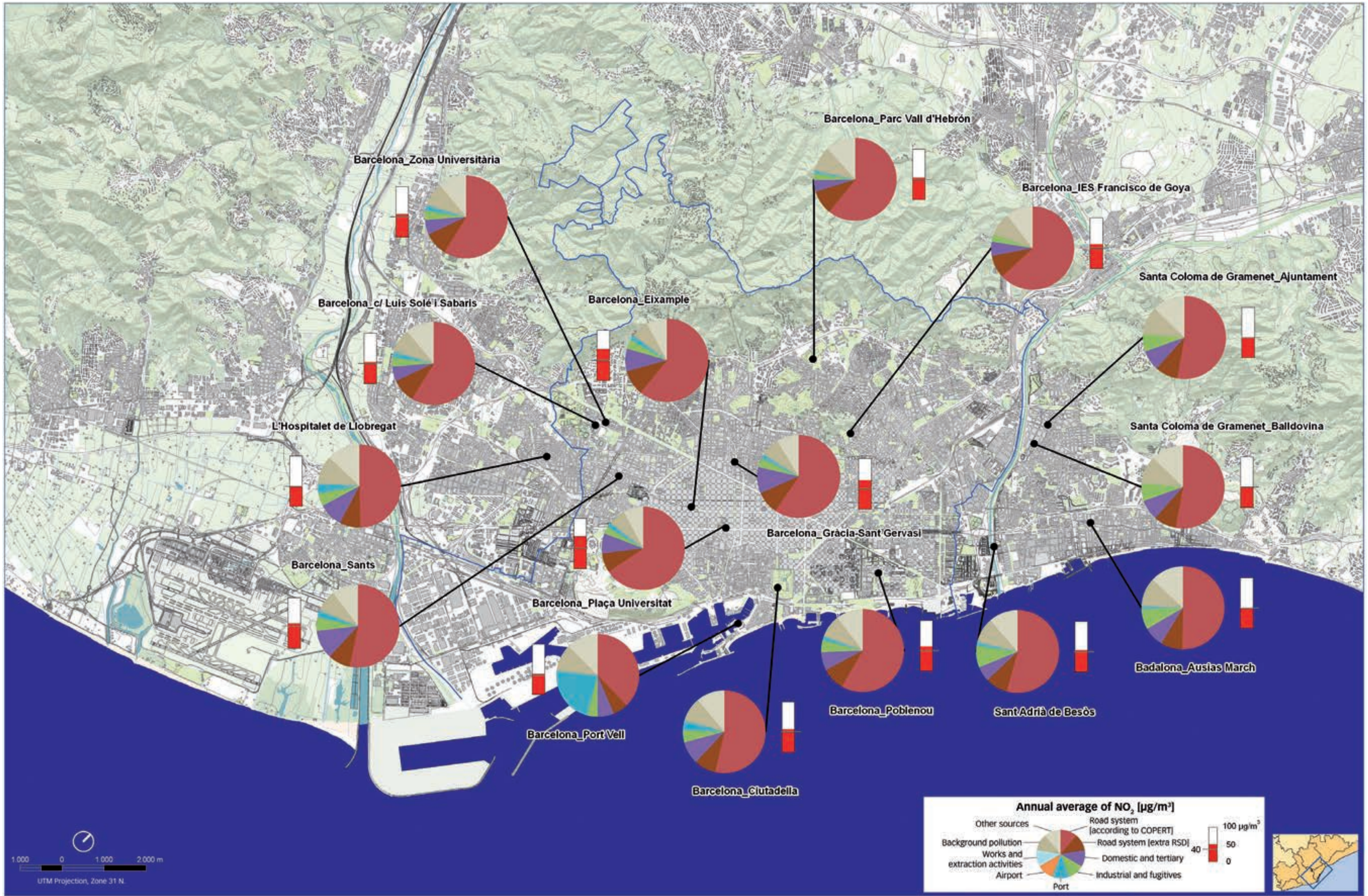


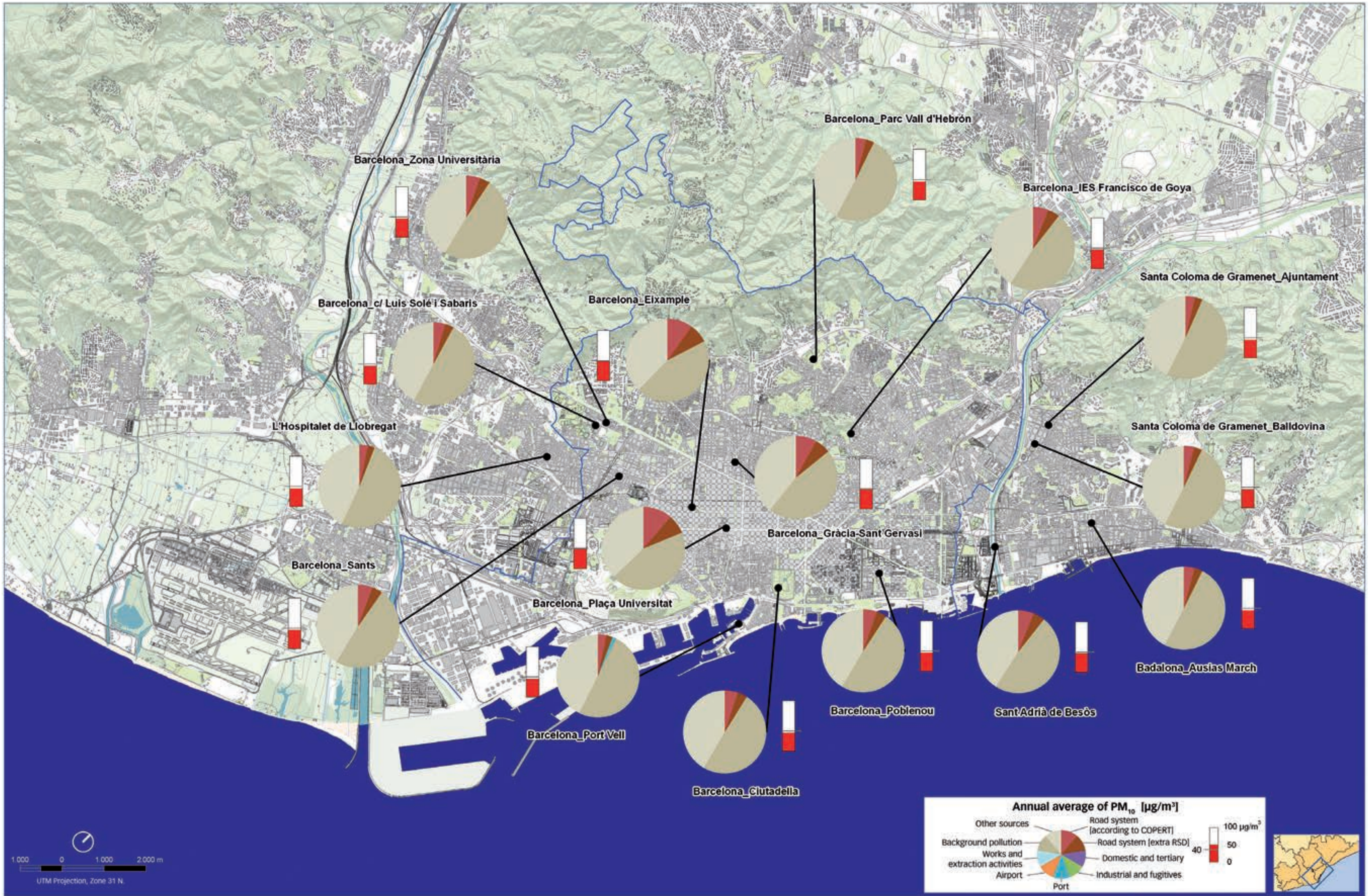
FIGURE 125 | DISTRIBUTION OF THE AVERAGE OF PM_{10}, BY SECTOR(2008)





Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Origin of NO_2 immissions in XVPCA's measurement stations in 2008



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Origin of PM_{10} immissions in XVPCA's measurement stations in 2008

AGÈNCIA D'ENERGIA DE BARCELONA
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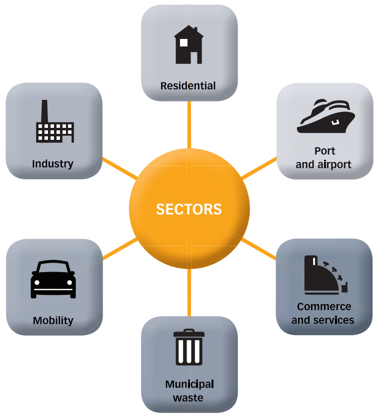
2.8 - Analysis by sectors

An analysis of the evolution of energy consumption of each of the sectors over recent years – residential, commercial and services, industrial, mobility, waste and major infrastructures- provides an excellent overview of the evolution of the relationship between the economic and social fabric of the city and energy and also the influence of the changes on the perception and use of these resources and the various situational changes on an international level.

In this respect, the relative importance of each sector in global energy consumption over the years has varied to the same extent as the city of Barcelona and its economic model. Thus, while during the early nineties the industrial sector accounted for the chief percentage of consumption, it is currently the residential, commercial, services and mobility which have gained weight.

This is the result of, amongst others, the decline in the industrial sector and the improved efficiency of production processes, the growth of the services section, increased tourism and phenomena related to individual behaviour in energy use, such as a stronger demand for mobility or climate control and the increasing use of electrical appliances.

FIGURE 126 | THE SECTORS STUDIED



2.8.1 - THE RESIDENTIAL SECTOR

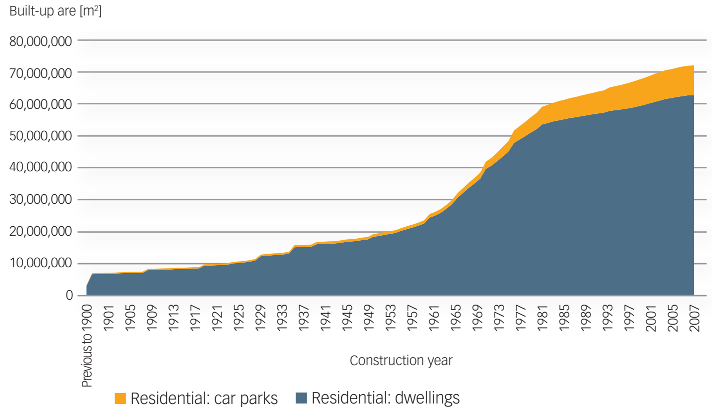
The housing stock of the city

Barcelona has a residential land space of 62.7 million square metres[30], more than half the total surface area of the city. The stock of residential buildings and car parks shows highly significant growth from the end of the forties of the last century with a sustained growth until the end of 2007.

Therefore, one of the main courses of action of this PECQ to reduce energy consumption and the associated emissions is to ascertain the characteristics of this housing stock, diagnosing the trends and deficiencies of the sector. The PECQ continues the study of the residential sector carried out in the Barcelona Energy Improvement Plan (PMEB), analyses the evolution of the housing stock since the year 1999, detects the new construction trends and assesses the changes in consumption habits.

The city's land register shows that residential buildings have an average age of 63 years, and prospective studies reveal that there will be a progressive ageing of the stock due to the scarcity of free land and refurbishment activities which prolong their useful life. A more detailed analysis of the refurbishment licences issued by Barcelona City Council in three districts shows considerable refurbishment work with approximately 11,600 licences issued in ten years. These figures place building refurbishment as a fundamental factor to be taken into account in the strategic analysis to enhance energy efficiency in the residential sector in Barcelona..

FIGURE 127 | ACCUMULATED DISTRIBUTION OF BUILT UP LAND SPACE FOR RESIDENTIAL USE IN BARCELONA BY AGE (1901-2007)



Source: Land Register 2007

The implementation of the Solar Ordinance of Barcelona, the Decree on eco-efficiency and, more recently, the Technical Building Code have changed the standards of new buildings since the PMEB was drafted, and therefore during the formulation of the PECQ, the energy and environmental implications of these new standards have also been analysed together with the affects on actual construction, studying the improvements they bring and the possibilities of going further towards more sustainable building. This, for the residential sector, the PECQ stresses as key challenges:

- Characterisation, from the energy viewpoint, of the current housing stock of Barcelona.
- Definition by type and energy study of newly built housing.
- Analysis of energy improvements in refurbishment work.

30. Without counting the surface area for parking spaces in most residential buildings (9,346,247 m²) or the communal areas of the buildings (stairways, meter rooms, etc.).

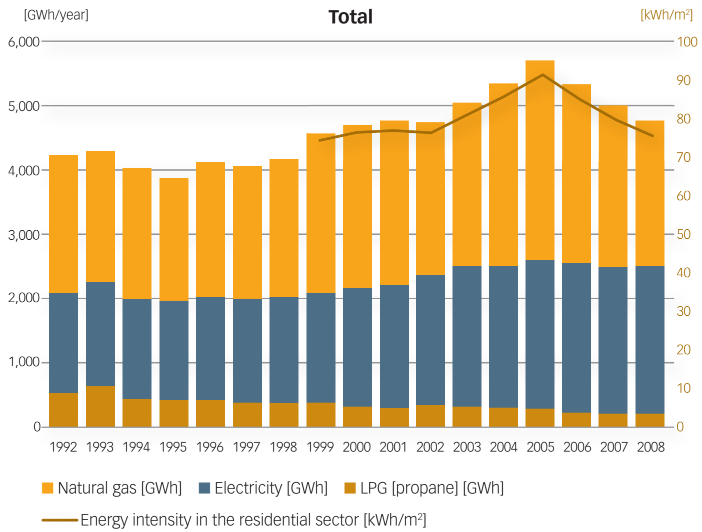
Evolution of consumption

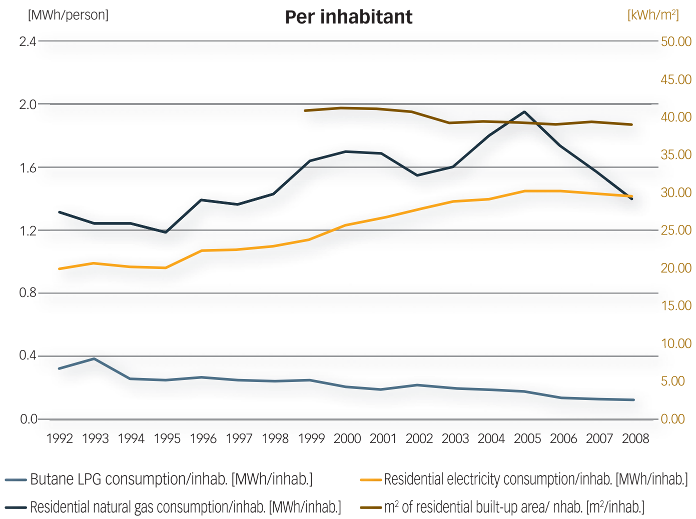
In 2008, the residential sector in Barcelona consumer 4,794 GWh, 28% of final energy. This consumption was distributed almost equally between electricity and natural gas (48%, approximately of each energy source), while the remaining consumption was of liquefied petroleum gases LPG (butane), an energy resource which is progressively declining year after year.

Consumption records point to sustained growth in electricity consumption over recent years, due to the higher number of electrical appliances in homes (computers, dishwashers, air-conditioning...). The consumption of natural gas is also highly variable, due mainly to weather variations between years-, although demand for this energy source shows an upward trend.

Despite the reduction in residential land space per inhabitant – due to the construction of smaller flats and the increase in the number of occupants-, energy consumption per inhabitant has increased over recent years. This consumption, however, has varied from year to year due to fluctuations in natural gas demand.

FIGURE 128 | EVOLUTION OF FINAL ENERGY CONSUMPTION BY THE RESIDENTIAL SECTOR IN BARCELONA, TOTAL AND PER INHABITANT (1992-2008)





Source: ICAEN

CHARACTERISATION OF THE BUILDING STOCK

In order to gather more detailed information on the characteristics of the building stock of Barcelona and its thermal behaviour, the Energy Improvement Plan (PMEB) included a characterisation project via an analysis of the construction, architectural, urban and functional specificities and use of the housing and office stock. The use of a Geographic Information System (GIS) allows cross-referencing of parameters with the cartographic information of the city.

The methodology applied to characterising the housing stock, the definition of newly built buildings by type and the analysis of energy improvements in building refurbishment were as follows:

DIAGRAM OF THE CHARACTERISATION PROCESS AND ANALYSIS OF MEASURES

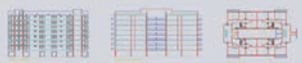
CHARACTERISATION OF THE RESIDENTIAL SECTOR

Definition of types of existing and newly erected buildings in Barcelona. Based on SIG data from the Land Registry and a series of architectural and urban-planning designs depicting the building reality in the city.

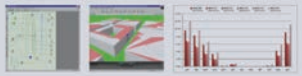
Determining energy demand by types of buildings. Analysis of the thermal behaviour of various types by using transient system simulation tools (TRNSYS).

Determining energy consumptions by types of buildings. The various types of energy systems are considered in order to obtain the corresponding consumption levels. Consumption levels for other uses such as lighting, facilities and other are also determined.

Determining energy consumptions in the construction sector in Barcelona. Global city emissions and consumption values are obtained on the basis of the characterisation made for each of the building types and of the extrapolation made in the scope of the city with SIG tools and the total consumptions of the sector.



Details of architectural designs by type of "post-war dwelling"



Details of simulation tools and resulting demands by type of building

Consumption matrix and representation by sources and uses by type of building

SIG map of city emissions

ANALYSIS OF MEASURES IN THE RESIDENTIAL SECTOR

Setting proposals for refurbishment and actions in new developments. Refurbishment measures are proposed with regard to the three most representative types of existing buildings. Such measures are defined from an architectonic and building perspective but they also include measurements. Similarly, proposals for improvement measures are made relating new developments (H9).

Evaluation of thermal demands (heating and cooling) in refurbishment and improvement actions. Each of the refurbishment and improvement measures are evaluated quantitatively.

Determining the savings in consumption (energetic, economic) and in emissions associated to the various refurbishment and improvement proposals for new development buildings.

Updating the characterisation of energy consumption of the building sector in Barcelona and new scenarios and policies for the future. The new characterisation of energy consumption of this sector in Barcelona, the future scenarios and the baseline for strategic city lines are determined on the basis of data resulting from previous stages and the analysis of works bids during the last few years.

The types of buildings

To conduct an energy characterisation of the residential buildings in the city, first it is necessary to ascertain their historic evolution. Until the unification of Barcelona with nearby municipalities (Gràcia, Sarrià, Les Corts, etc.) the City Plan of Barcelona was occupied by the old quarters of these towns, separated by fields and agricultural land.

To analyse the evolution of the buildings since that time down to the present, five major historic periods have been established which act as the starting point for a subsequent study of the different types of buildings currently to be found:

- FIRST PERIOD (UNTIL THE 19th CENTURY)
  In the old urban quarters- and particular that of Barcelona which was walled in-, the street plan was irregular, with narrow streets in which plots were opened with a small façade but with great depth. Originally, they followed the guild model, with space for the economic activity on the ground floor and dwellings on the upper floors. In many cases, the buildings were built upon or replaced.
  Construction methods evolved towards mud and irregular masonry bearing walls until, at the start of the 19th century, solid brick work became popular. Ground floors, however, continued to use Montjuïc stone masonry to prevent damp. Roofs were made with wooden beams with crossbeams made of plaster or ceramic tiles.
  From the thermal viewpoint, housing of this type is not well ventilated and the size of façade openings and the narrow streets did not make for proper lighting within the rooms. In winter they suffer the cold due to the lack of sunlight and low quality of the woodwork, although the compactness of the buildings signified they had little contact with the exterior.
  Dwellings located under the roof underwent greater cold in winter, while in summer they are very hot due to the lack of roof insulation.

- SECOND PERIOD (19th CENTURY- CIVIL WAR)
  With the approval of the Cerdà Plan in the mid 19th century and the subsequent aggregation of neighbouring municipalities, the city broke out of the limits which confined it and the Barcelona Plan takes shape. With the opening of new streets, the Eixample is built over the agricultural parcels, giving rise to larger plots than the old quarters although these were sometimes irregular.
  The larger plots and ordinances of the Cerdà Plan (despite the initial ordinances hardly being applied) led to buildings in which the construction techniques still resembled the earlier methods (brick bearing walls, wooden beams), but with improved quality of the finished product. The enlargement of parcels made it possible to build houses with a double orientation with better ventilation and offer greater alternate sunlight of rooms. Interior patios began to appear, which ventilated the interior areas, the beams were covered over with suspended ceilings, and galleries appeared in the centre of the building and buildings gained in height. As the 20th century progressed, in a manner similar to the change in architectural styles and tastes, construction technology also evolved together with certain building elements.
  There was no great change in construction methods or the construction sites themselves. The Eixample grew, but construction took place in the areas of the old quarters, and therefore the plots available had the traditional characteristics. There were also operations to dignify the old quarters (opening of Via Laietana, Passeig de les Drassanes, Ferran-Comerç…) which used the *"Eixample"* method in these areas.
  From the energy viewpoint, the Cerdà Plan had a very important advantage: the green space in the interior of the buildings which provide a highly favourable micro-climate in the summer months. Unfortunately, this idea was lost due to the building pressure, which is why the trend towards recovering the interiors of this area as public green spaces is so highly considered.
  The typical dwelling in the Eixample, arranged around a long passageway from façade to façade, works fairly well in terms of natural ventilation, despite the depth. In the case of large units which have subsequently been subdivided, the air flows cease to exist due to the separations built. The width of the streets makes for good sunlight and illumination of the rooms on the upper floors, while the dimensions of the patios do not make for good lighting of the interior rooms, especially on the lower

floors. In winter the dwellings are temperate, as the sun always shines on one of the two facades (except those near the corners of the interior patio), despite the lack of specific insulation signifying that the facades receiving little sunlight continue to be cold. They are cool in summer, as they can be well aired and solar protection is more effective. Only the rooms facing west on the upper floors have a tendency to heat up as the façade without insulation accumulates the heat during the afternoon. Dwellings located under the roof suffer greater cold in winter due to the lack of insulation of the Catalan roofs.

- THIRD PERIOD (POST-WAR – 70's)

The civil war signified a very important economic rupture and social and technological regression. The post-war period continued with traditional construction methods, based on the disappearance of prior assays and the scarcity of many material, especially steel, cement and energy.

In particular, as from the end of WWII and the autarky of Spain over several years (coinciding with the change of decade 1940-1950), there was an incipient economic recovery accompanied by migratory flows related to the growing industrialisation of the city's area of influence which led to swifter construction of buildings.

As from 1945 and until the sixties, there arose the figure of the *"polygon"* as a global form of urbanisation and construction, generally simple, small, inexpensive houses but in groupings of up to 4,000 dwellings, developed by official bodies or private companies and designed to absorb the immigrant labour.

The concrete structure model became consolidated (initially coexisting with bearing walls), closures were lightened (the air chamber took on the role of insulation which until then was provided by the façade thickness), windows became larger, the suspended ceilings were replaced by prefabricated plaster fillings, etc. These were years of great activity and also speculation, in which new technological methods and low cost construction materials appeared.

From the planning viewpoint, the District Plan in 53 raised the regulatory height and build on existing structures to avoid land saturation.

By type, and unrelated to the variety present in the polygons, dwellings became smaller, being reduced parallel to the facades. Thus, the same staircase gave onto four dwellings, two looking onto the street and the other two onto the interior patio. The patios went from playing a role as an ancillary element to being an essential source of ventilation and light for the dwellings.

Bearing walls virtually disappeared at the end of the sixties while cap and reticular roofs appeared together with flat beams instead of girders. Aluminium carpentry made its first appearance, although it was to coexist with wooden carpentry for many years, while steel ceased to be used.

The division into interior and exterior dwellings prevents direct cross ventilation which only takes place between the façade and the interior patios, without positive results. The patios in general are too small in proportion to the height to be ventilated, and especially to be illuminated. Each dwelling faces only one way, and its behaviour therefore depends on this orientation. The width of the streets makes for good sunlight (according to the orientation) and illumination of the rooms on the upper floors, yet the dimensions of the patios do not make for good lighting of the interior rooms, especially on the lower floors. The general lack of insulation and larger glass surfaces make the dwellings colder in winter, except for those receiving a large amount of sunlight. In summer they are hot, as the difficulty in ventilating them is compounded by the lack of insulation and the little effectiveness of certain types of protection from the sun. Dwellings located under the roof suffer greater cold in winter, while in summer they are very hot due to the lack of roof insulation. The low original quality of the exterior woodwork signifies there are many leaks.

- FOURTH PERIOD (1970-2000)

In the mix-sixties, a new General Plan came into effect which reduced the possibilities of building densification allowed under the previous Plan; it reduced the regulatory height, prohibited upward construction, increased the size of the patios and limited the construction depth.

The most standard dwellings lost in surfaced areas – together with the family units becoming smaller – to a size of some 90 m^2, with four rooms.

In 1979, due to the 1973 oil crisis, the first and only state thermal standard was approved (NBE-CT-79) which sought energy saving, especially with regard to the heating of buildings.

Despite the initial reluctance, the lack of proper compliance in many cases and the weak demands of the insulation standards, the habitability of the dwellings improved, especially the most exposed cases (those highly affected by sunlight located below the roof, etc.). Socially, insulation and double glazing were perceived as quality values and used as sales arguments.

In general terms, the shortcomings in thermal performance of buildings from the earlier period continued. The division into interior and exterior dwellings prevented direct cross ventilation. The patios continued to be too small in proportion to the height of the building for ventilation and lighting purposes, especially when covered by skylights. Despite there usually being solar protection, it often prevented simultaneous ventilation as it could not be regulated (folding blinds).

In parallel, the end of the *"development"* stage of the Franquist regime led to smaller population flows which started to achieve a higher standard of living. It was no longer a case of finding a home in whatever manner. The population started to demand a certain *"quality"*, assisted by advertising campaigns of brands of insulation, carpentry, etc.

The errors and shortcomings in the quality of the construction started to appear, especially in the polygons, which saw a more active resident movement to achieve a minimum quality level. During these years construction methods barely evolved, and with the exception of the improved insulation, they continued to be built in the same manner as before.

In Barcelona, construction emigrated to the neighbouring municipalities. Only specific areas of the city centre saw any activity to substitute obsolete constructions or to use up the few remaining building sites.

Property prices rose during the mid-eighties, probably as a result of economic movements related to the Olympic Games of 92 (the designation was made in 1986). Preparations for the Games led to one of the most active periods of the century: Opening up of the Ring roads, the transformation of Poble Nou, the Olympic Village… In the Olympic Village (and also in Vall d'Hebron), the global concept of the district and the lack of time imposed the adoption of new building and technological models: Small partitions, dual orientation without patios, plasterboard partition walls, centralised refuse collection systems, urban service galleries…

Once the Olympics had concluded, building within the city returned to its earlier pace with the normal economic fluctuations. This period was, however, marked by two factors: There was increasingly less free land at higher prices. This affected the final price of the dwellings, although the improved communications – the Ring roads and trains or buses- led part of the population to live outside the city, while others did likewise for reasons unrelated to housing prices.

- CURRENT AND FUTURE TRENDS

Sociological changes over recent years have led to the appearance of different types of housing users which entails diversified demand. From dwellings occupied by a single person, single-parent families or traditional family units to dwellings with excessive occupancy as a result of immigration.

We should, however, underline that construction methods have also undergone a significant change thanks to various standards and directives which have addressed the subject of energy saving and efficiency in building.

In the EU, we should note Directive 2002/91CE of the European Parliament and Council dated 16 December 2002 on energy efficiency in buildings. Its objective is to take action in relation to energy calculations and minimum efficiency requisites, energy certification and regular inspection of boilers and air-conditioning systems.

The Technical Building Code (approved by Royal Decree 314/2006, 17 March and partially amended by Royal Decree 1371/2007, 19 October), is the legal framework which regulates the basic quality requirements which buildings must comply with, including installations so as to meet the basic safety and habitability requisites. Some of the basic requirements regulated are safety in the event of fire, soundproofing and energy saving.

On an autonomic level, we should highlight the Eco-efficiency Decree (Decree 21/2006, 14 February). This decree contained environmental and eco-efficiency parameters (for water, waste, construction materials and systems) in newly constructed buildings, those older buildings which are reconverted and major refurbishment work. It also affects buildings used as housing, for collective residential and administrative, teaching and health purposes.

Since 1999 Barcelona has had the thermal solar Ordinance (which forms part of the general Ordinance on the urban environment), with the aim of promoting and regulating, via local legislation, low temperature solar energy installations to produce hot water for buildings. This legislation on thermal solar capture was amended in March 2006.

The emergence of new requisites and the directives mentioned above have also led to the compulsory conditions and accessibility of roofs, if only for the maintenance of the installations which are an increasingly common feature in buildings. This has created a new means of reusing rooftops, traditionally used for hanging out clothing but underutilised or inaccessible in the more recent types.

Based on this analysis of the evolution of construction throughout history in Barcelona, a proposed classification of buildings is made which are mostly used for residential purposes into different building types, in accordance with the period constructed and other parameters (planning, construction, operational). The thermal performance of the buildings is also simulated, taking into account the technology available in the dwellings, the consumption habits of their inhabitants and the influence of the building envelope and neighbouring buildings.

Of the land space in Barcelona (62,774,888 m²), 89.4% is represented by five defined building types (56,133,904 m²), while the remaining 10.6% (6,640,984 m²) are mostly residential buildings which do not correspond to any defined profile type. By analysing the cartographic database and the data of the land register, the type H6 stands out as the most common type, accounting for 51% of the square metres of dwelling land space in Barcelona.

TABLE 33 | THE CHIEF TYPES OF BUILDINGS IN BARCELONA

TYPE	Short description	Construction period
H1 and H2	Dwelling in the old part of town	Specially up to the end of the 19th Century, although more recent ones can be found in areas where plot division made it easy.
H3 and H4	Pre-Civil War dwelling (Eixample area)	From the beginning of Barcelona's expansion to the Eixample (mid 20th Century) up to 1930's.
H5 and H6	Post-Civil War dwelling (development and expansion in housing estates)	From the post-war reconstruction period (1940) up to Late-Development Policy (1979)
H7	Post-thermal rules dwelling	Post-thermal rules dwelling
H8	Dwelling following the year 2000 trends	2000-2007
H9	Post-Technical Building Code building	Buildings erected according to CTE regulation

FIGURE 129 | DISTRIBUTION OF BUILDINGS IN BARCELONA BY TYPE

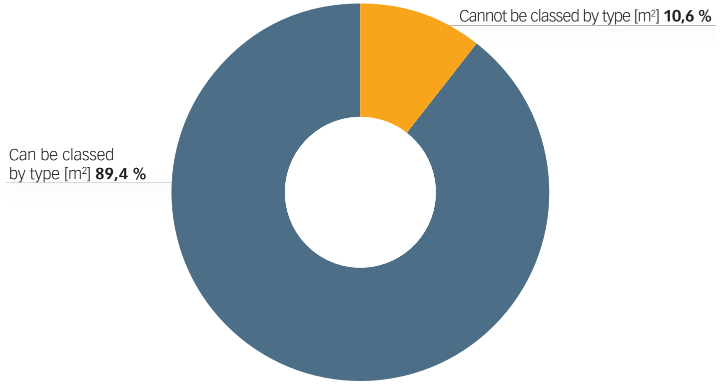
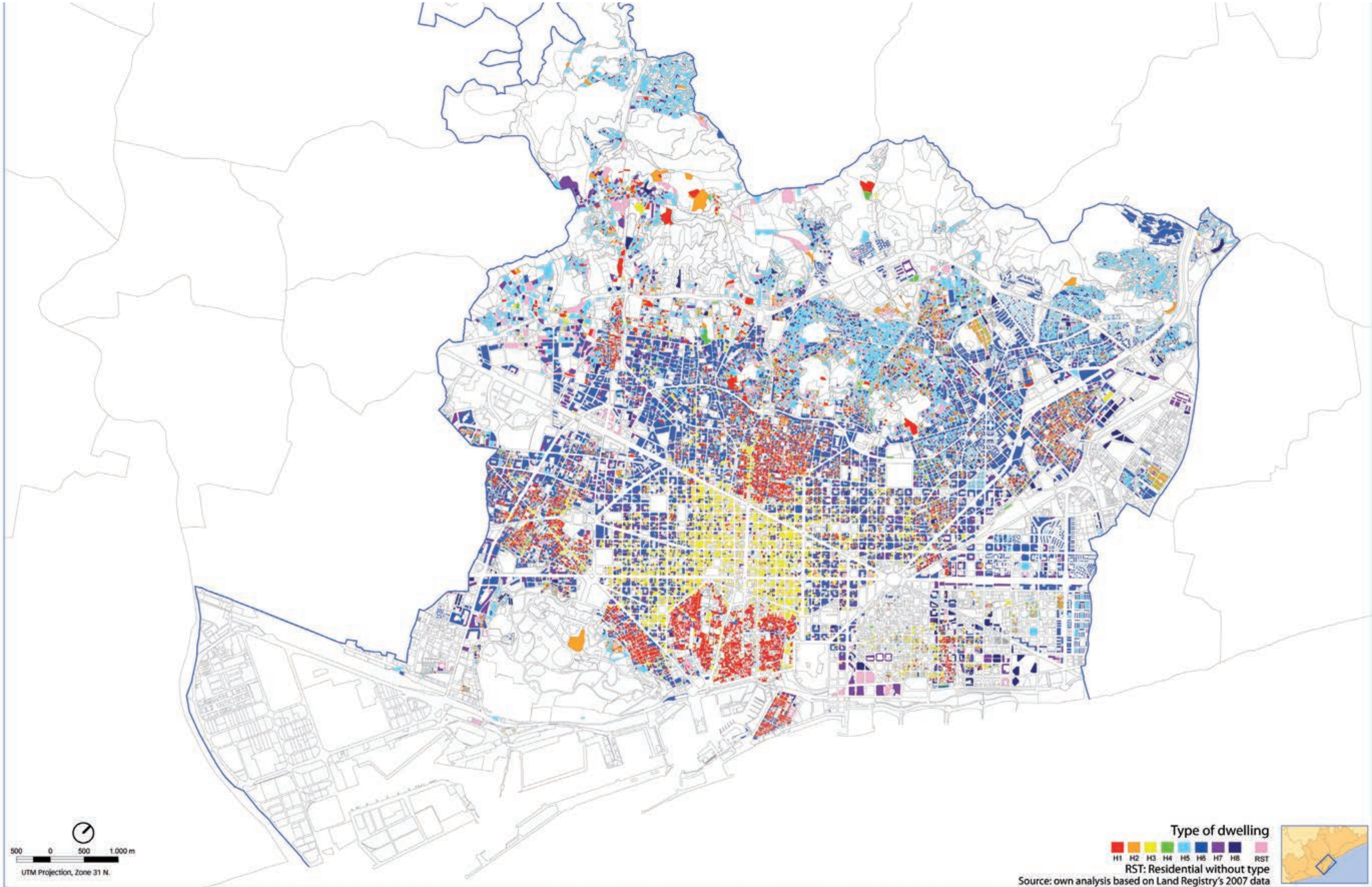


TABLE 34 | DISTRIBUTION OF BUILT UP LAND SPACE IN BARCELONA BY TYPE

	m² dwellings	%	number of dwellings	%
H1	5,257,842	9%	79,607	11%
H2	642,895	1%	10,667	1%
H3	7,304,277	13%	84,315	12%
H4	136,048	0%	2,041	0%
H5	5,701,109	10%	87,023	12%
H6	28,566,816	51%	358,393	50%
H7	6,544,407	12%	72,975	10%
H8	1,980,510	4%	24,894	3%
Total	**56,133,904**		**719,915**	

Source: Municipal Statistics Institute Land Register 2007



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Modelling of consumption and demand

A more accurate picture of the distribution of consumption in the residential sector is made using the modelling of thermal demand and consumption in different types of buildings (simulations carried out using the TRNSYS application in the types defined in the PMEB and PECQ), and by means of calibrating the real energy consumption of the city.

The analysis shows that the consumption is highly distributed between hot water consumption, heating and appliances. The data relating to hot water include the energy from solar panels, which since the approval of the solar Ordinance are compulsory in newly constructed buildings.

FIGURE 130 | DISTRIBUTION OF RESIDENTIAL ENERGY CONSUMPTION, BY USE (MODELLING)

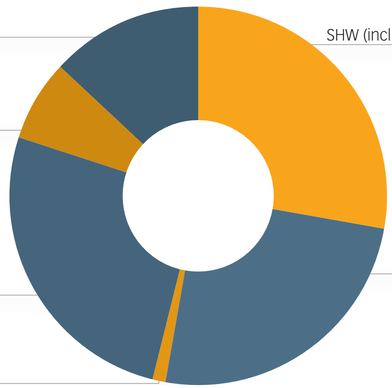


FIGURE 131 | DISTRIBUTION OF RESIDENTIAL ENERGY CONSUMPTION BY BUILDING TYPE (MODELLING)

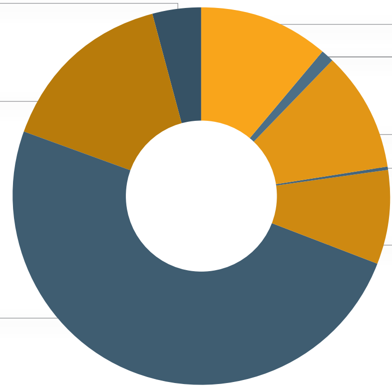


FIGURE 132 | EVOLUTION OF THE DEMAND AND CONSUMPTION OF HOT WATER, BY TYPE (MODELLING)

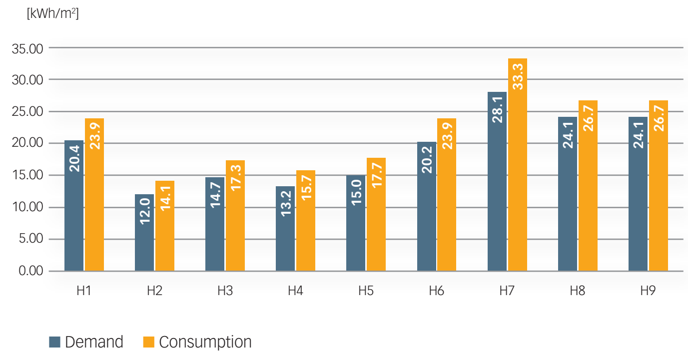


FIGURE 133 | EVOLUTION OF THE DEMAND AND CONSUMPTION OF HEATING, BY TYPE (MODELLING)

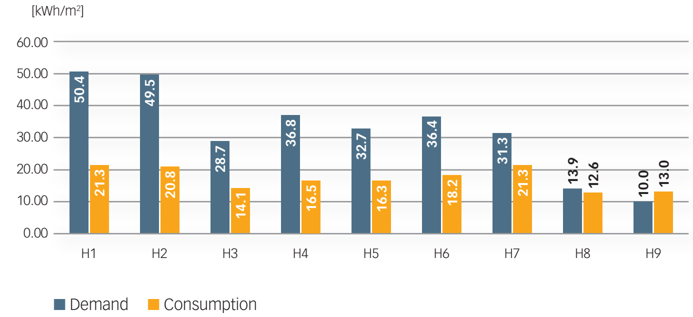


FIGURE 135 | EVOLUTION OF THE DEMAND AND CONSUMPTION OF HEATING, BY TYPE (MODELLING)

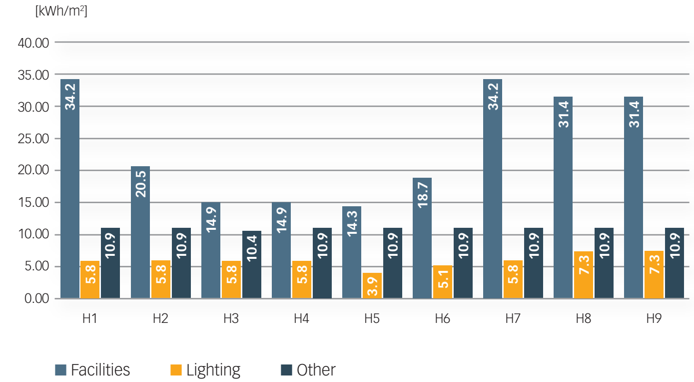


FIGURE 134 | EVOLUTION OF THE DEMAND AND CONSUMPTION OF COOLING, BY TYPE (MODELLING)

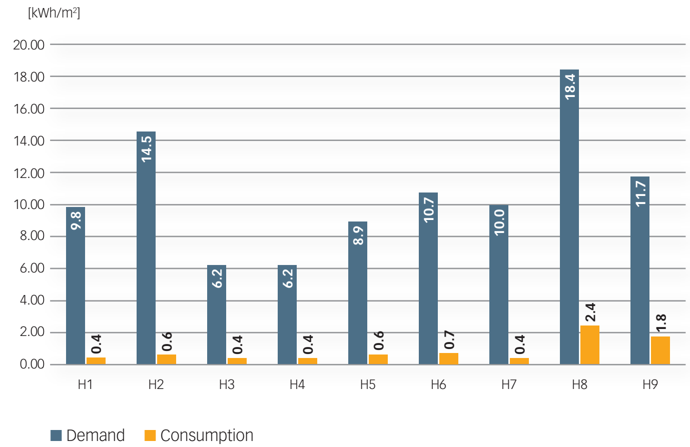
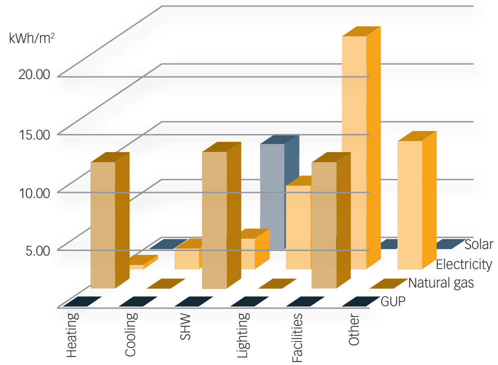


FIGURE 136 | ENERGY CONSUMPTION BY SOURCE AND USE IN NEW DEVELOPED BUILDINGS



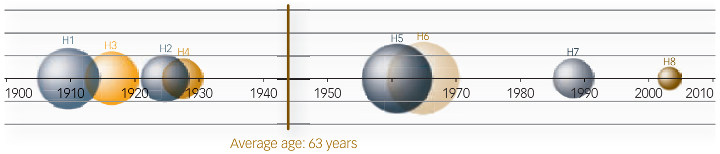
▲ The changes in construction use and methods signify that new buildings have different demands and consumption from the existing types of building in the city.

Refurbishment in the residential sector

The evolution of land space in Barcelona has not ceased to grow over recent years, with an increase of 1.4 million m² between the years 1999 and 2007. Notwithstanding this, the built up land space in those eight years accounts for only 2% of the total residential land space in the city.

If we analyse the current housing stock by age, according to the type of building to which it belongs, we find it is quite old, as a large number of buildings were built prior to 1900 (13%). These data coincide with those furnished by the Department of Statistics of Barcelona City Council, formulated using the Population and Housing Census. The average age of the building stock, as mentioned earlier, is 63 years.

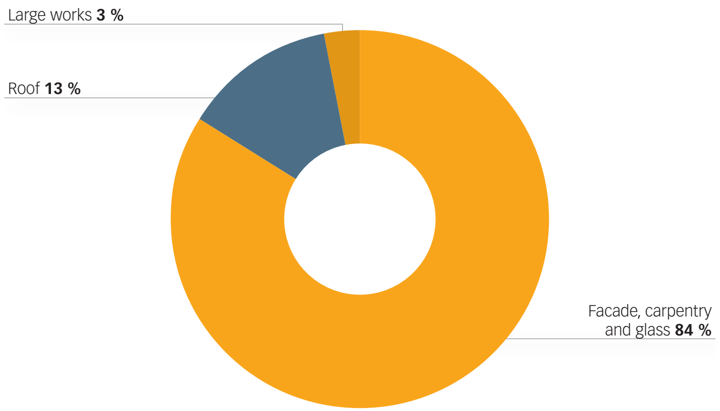
FIGURE 137 | AVERAGE AGE OF THE HOUSING STOCK OF BARCELONA BY NUMBER OF BUILDINGS



In order to detect the most usual reforms carried out in the city, an exhaustive study was made of the works licences processed between the years 1999 and 2009 in the three districts with the largest number of refurbishments according to the land register data (Ciutat Vella, Eixample and Nou Barris). During the ten years analysed, 11,600 refurbishment licences were issued in these three districts: 84% were minor works with improvements to facades which affected the envelope – interior or exterior - 13% refer to the roof and 3% to minor works.

Based on this information, the various energy improvements were analysed which were carried out during the most usual refurbishment work, evaluating the impact, economic cost and saving on energy bills.

FIGURE 138 | TYPE OF WORKS LICENCES PROCESSED (1999-2009)



Priorities for action in the sector

The analysis of the sector shows a great potential for action in energy efficiency in three specific areas:

- Action in current buildings
  Barcelona has a large stock of old buildings which could be refurbished, to a greater or lesser extent, in line with their age and degree of repair so as to reduce their energy demand. The actions proposed are related to the following elements:
  - Facades: By improving the conditions of thermal transmission to reach the values set forth in the Technical Building Code (TBC) and in the Eco-efficiency Decree, energy savings of between 9 and 14% can be achieved, together with a reduction in GHG emissions of between 10 and 15%, depending on the construction type.
  - Woodwork, windows and shutters: By improving the condition of these elements and achieving the values set forth in the TBC and Decree 21/2006, savings of between 7 and 12% of final energy are obtained, which result in reductions of greenhouse gases of between 4.5% and 7%.

- Refurbishment of buildings: By complying with the levels provided in the TBC and the Eco-efficiency Degree, both in the facades, roof, floor structure and openings, achieving the TBC levels, savings of between 14 and 19% of final energy can be reached and between 15.4 and 21.5% reduction of GHG emissions.

- Action in future buildings
  Barcelona plans to carry out major urban transformations which will, to a large extent, define the city of the future and the buildings of the coming decade. They therefore not only have to include energy efficiency criteria, thus reducing the energy demand of new buildings, but also take into account alternatives for utilising sustainable resources and analyse new, more efficient production alternatives.
  The City Council will not only monitor the application of the TBC in future buildings, but will also study the feasibility of drawing up a new building energy Ordinance. This ordinance, amongst others, will offer an overview of the territory's resources and the technological options depending on the use of each building. Likewise, it will require a justification of the chosen alternative, in line with the global criteria for GHG emission reduction and primary energy using fossil fuels.

- Actions in social behaviour with regard to energy
  As important as improving efficiency in buildings and home appliances to reduce energy consumption is to foster rational use of energy resources and renewable energy production facilities among the public (see section 2.1.6. Social behaviour).
  In this respect, one of the aspects underlined by the PECQ is to influence the management of energy demand using projects which also involve the general public.

2.8.2 - COMMERCE AND SERVICES

Consumption of final energy in 2008 by the business and services sector was 5,083.79 GWh, of which 81.6% was electricity consumption. Despite the growth rate between the years 1999 and 2008 being 2.56% a year, two stages can be differentiated: the first, between 1999 and 2004, characterised by a sharp increase of 4.08%; and the second, between 2004 and 2008, with weaker growth but more sustained, of 0.69%. It is precisely as from 2004 that the energy intensity of the sector also fell in a sustained manner, revealing the greater energy efficiency of the sector.

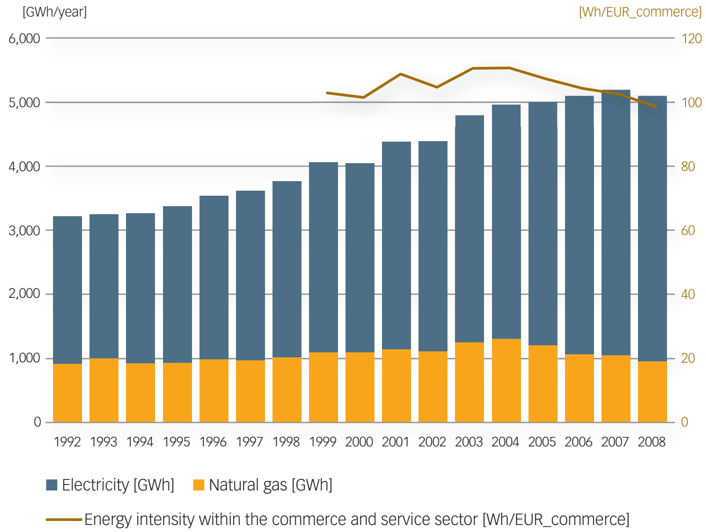
The commercial and services sector in 2007 had a stock of built-up land space of 20,141,305 m^2 (1,012,689 m^2 in municipal buildings), which accounted for 16% of the total land space in the city. By use, 25.4% of the built-up land space was used for offices with a surface area of over 500 m^2, located in 1,994 buildings (of the total 70,825 in the city) and therefore have an average surface area of 2,566 m^2/buildings.

The next largest type in built/up surface area were businesses with over 500 m^2 which accounted for 21.2% of the land space of the sector; they were located in 3,220 buildings and had an average surface area of 1,325 m^2 business/building. Businesses smaller than 500 m^2 which accounted for 19.5% of the land space were located in 23,429 buildings and had an average surface area of 168 m^2 business/building.

The remaining types were sports centres without swimming pools (6.66% of the total land space of the sector), healthcare buildings and clinics (6.54%) and municipal buildings (5.03%).

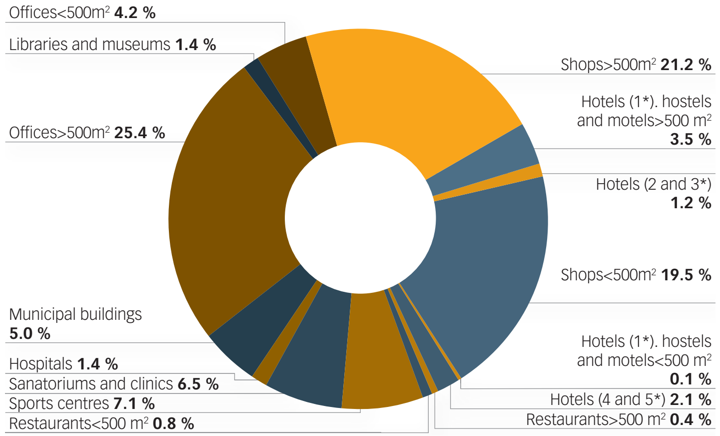
An analysis of the land space area by use of buildings shows that hospitals and four and five start hotels are those with the largest ratio, although they account for only 1.43% and 0.35% respectively of the total surface area. The types with the highest consumption are offices (29.66%) and businesses (38.85%).

FIGURE 139 | EVOLUTION OF FINAL ENERGY CONSUMPTION BY THE BUSINESS SECTOR IN BARCELONA (1992-2008)



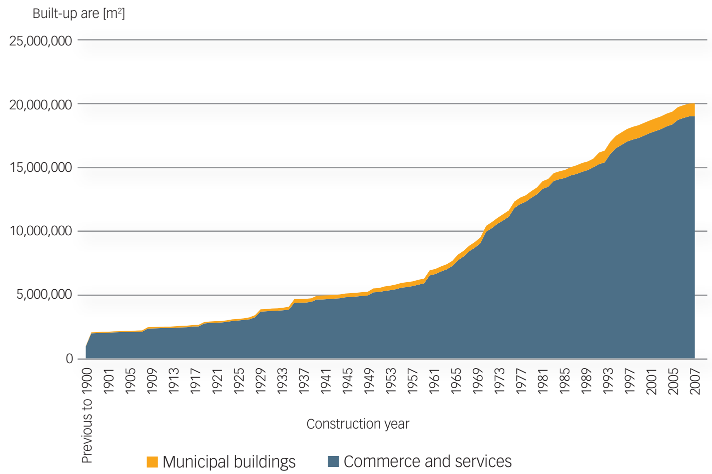
Source: ICAEN

FIGURE 140 | DISTRIBUTION OF USE OF THE LAND SPACE OF THE BUSINESS AND SERVICES SECTOR IN BARCELONA (2007)



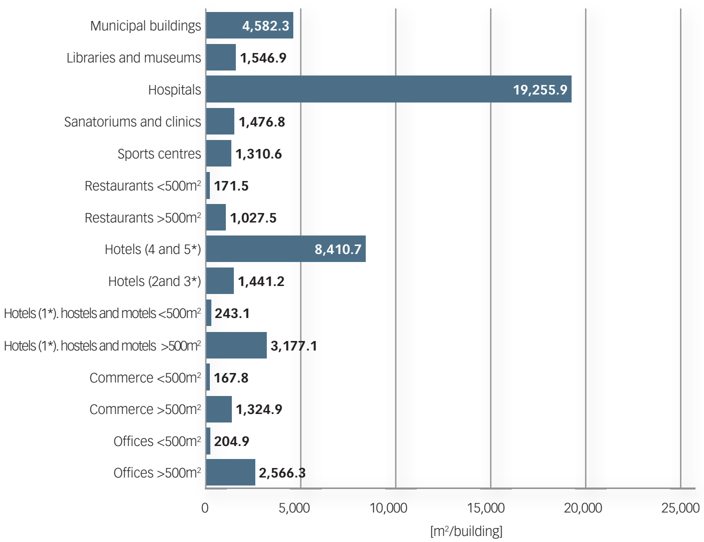
Source: Land Register

FIGURE 141 | ACCUMULATED DISTRIBUTION BY AGE OF THE BUILT-UP LAND SPACE OF THE BUSINESS AND SERVICES SECTOR IN BARCELONA (1901-2007)



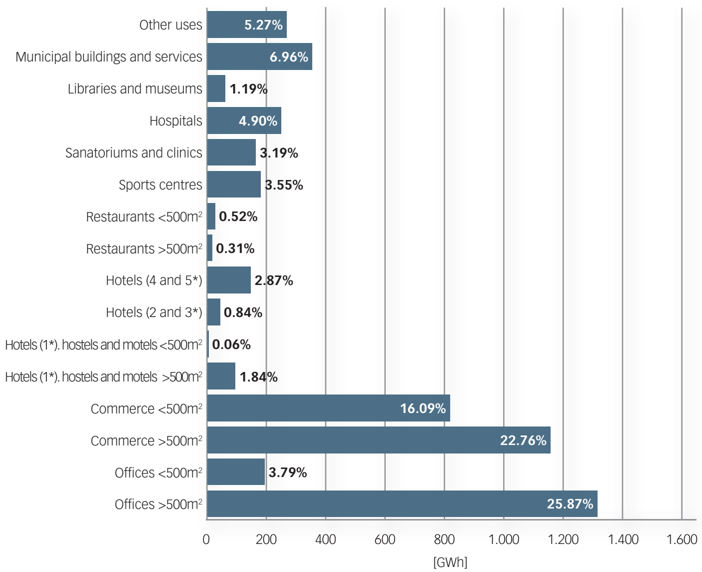
Source: Land Register

FIGURE 142 | AVERAGE SURFACE AREA PER BUILDING ACCORDING TO THE BUSINESS AND SERVICES SECTOR IN BARCELONA (2007)

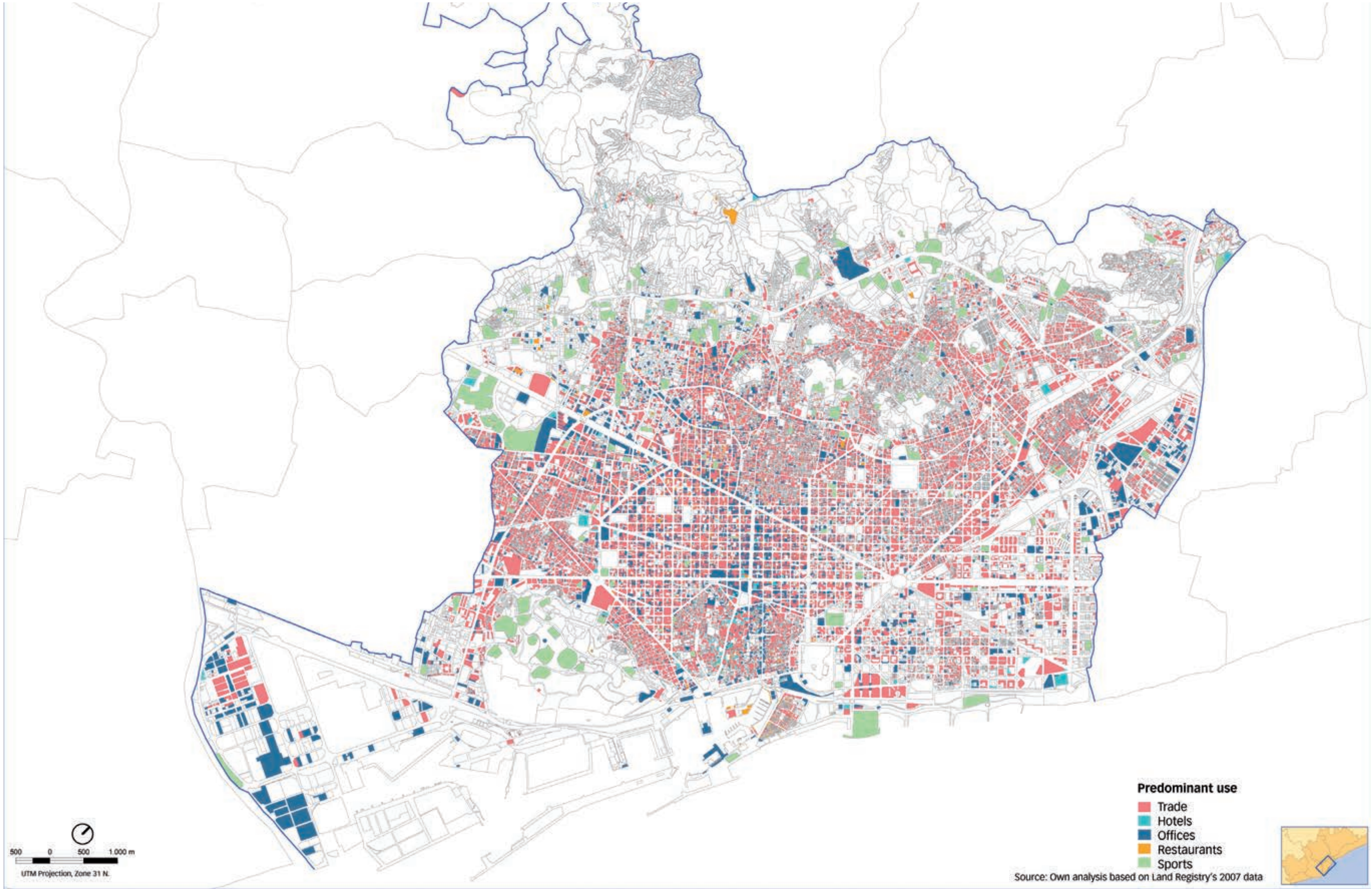


Source: Land Register

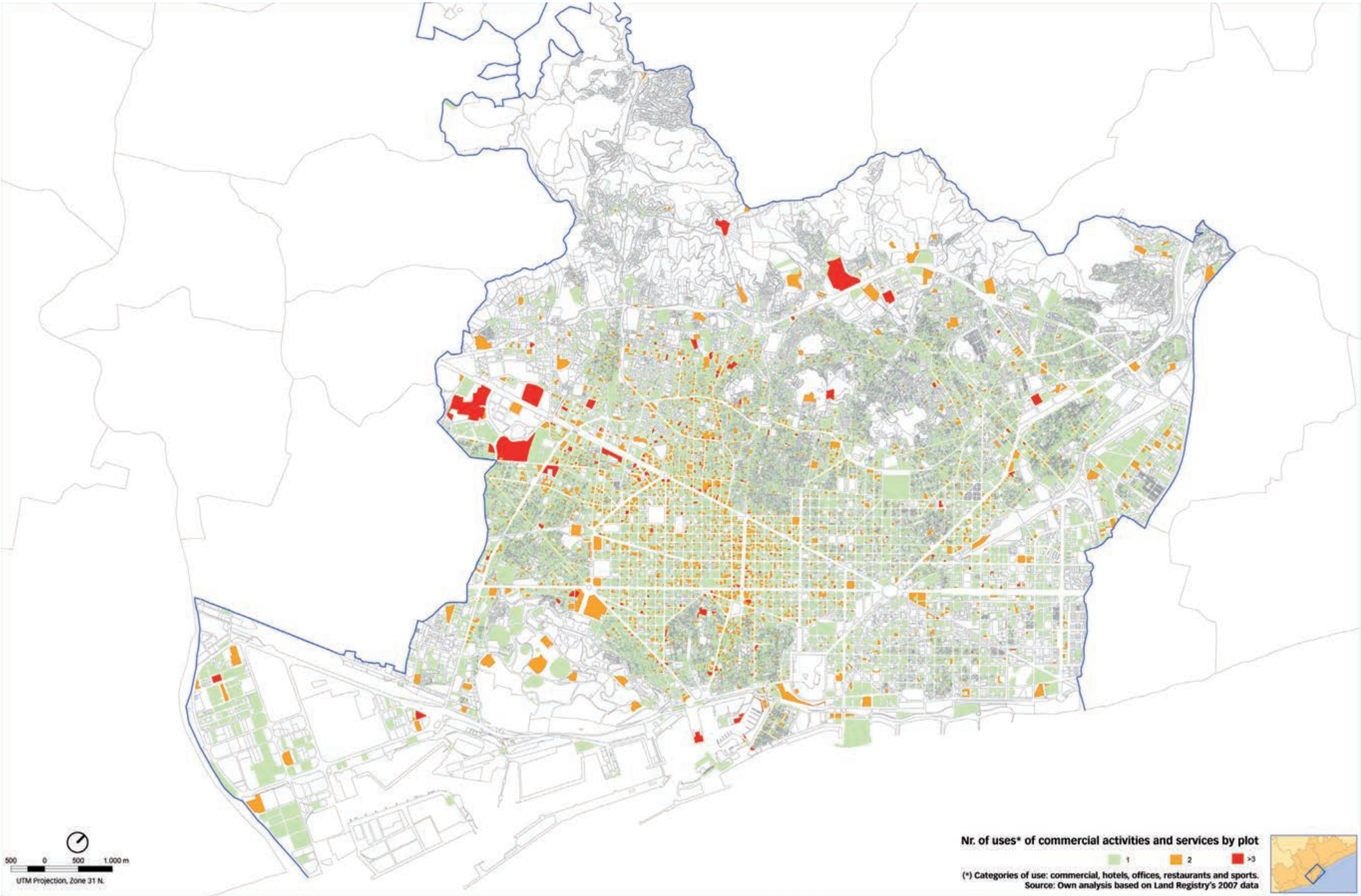
FIGURE 143 | ESTIMATION OF ENERGY CONSUMPTION BY TYPE OF THE BUSINESS AND SERVICES SECTOR OF BARCELONA (2008)



Source: Land Register



Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Distribution of commercial and services built-up area in Barcelona by type



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Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Commercial and service activities by plots in Barcelona.

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2.8.3 - INDUSTRY

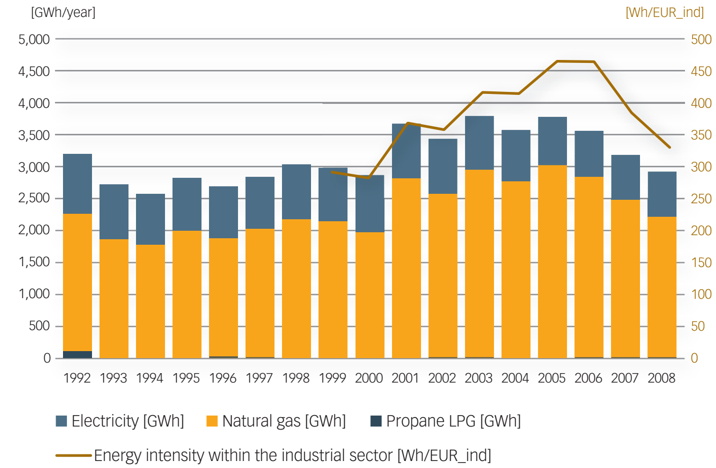
Consumption data

The consumption of final energy by the industrial sector in 2008 was 2,929.76 GWh, 74.8% natural gas, 24.3% electricity and 0.9% LPG. The evolution of energy consumption between 1999 and 2008 was a negative rate of -0.24% a year, as in 1999 2,993 GWh were consumed.

As with other sectors, 2005 saw a maximum peak in natural gas consumption, but subsequently this fell to levels below those of 1999. Energy intensity – the energy efficiency ratio of the necessary energy to produce one unit of GDP – also saw sustained growth until 2005 at which time it started to decree to levels well below those of 1999.

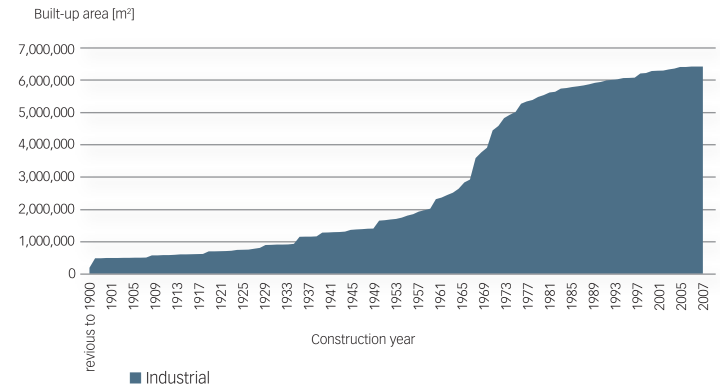
The number of subscribers to the industrial electricity rate was 6,137 in 2007 (no data are available for 2008), a figure similar to previous years.

FIGURE 144 | EVOLUTION OF FINAL ENERGY CONSUMPTION BY THE INDUSTRIAL SECTOR IN BARCELONA (1992-2008)



Source: ICAEN

FIGURE 145 | ACCUMULATED DISTRIBUTION BY AGE OF THE BUILT UP LAND SPACE OF THE INDUSTRIAL SECTOR IN BARCELONA (1992-2008)



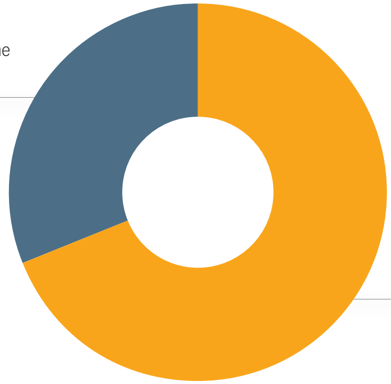
Source: Land Register

Potential energy saving

When evaluating the potential energy saving in the industrial sector as a whole, the diversity of the existing companies and variety of subsectors must be taken into account, for which reason when drafting the PECQ the analysis was focused on a specific set of industries which account for 31% of the sector's consumption.

Of the selected industries – medium/large size with data available on energy consumption and an audit conducted by the company itself – an analysis was performed of the audits of the three preceding years and the measures proposed, both those implemented and those pending implementation. Visits are also made to the industries to ascertain their production processes and conduct personalised interviews with the heads of maintenance and/or managers of the processes of each one. After gathering all the information, a set of feasible, practical and realistic measures to be applied was proposed to enhance the efficiency of the various production activities studied.

FIGURE 146 | ENERGY CONSUMPTION BY THE SET OF INDUSTRIES ANALYSED COMPARED TO TOTAL CONSUMPTION BY THE INDUSTRIAL SECTOR (2008)



This set of proposals shows that the potential for final energy consumption reduction is 57.18 GWh/year (77% in natural gas and 23% in electricity), a saving which accounts for 1.95% of consumption by the industrial sector in 2008.

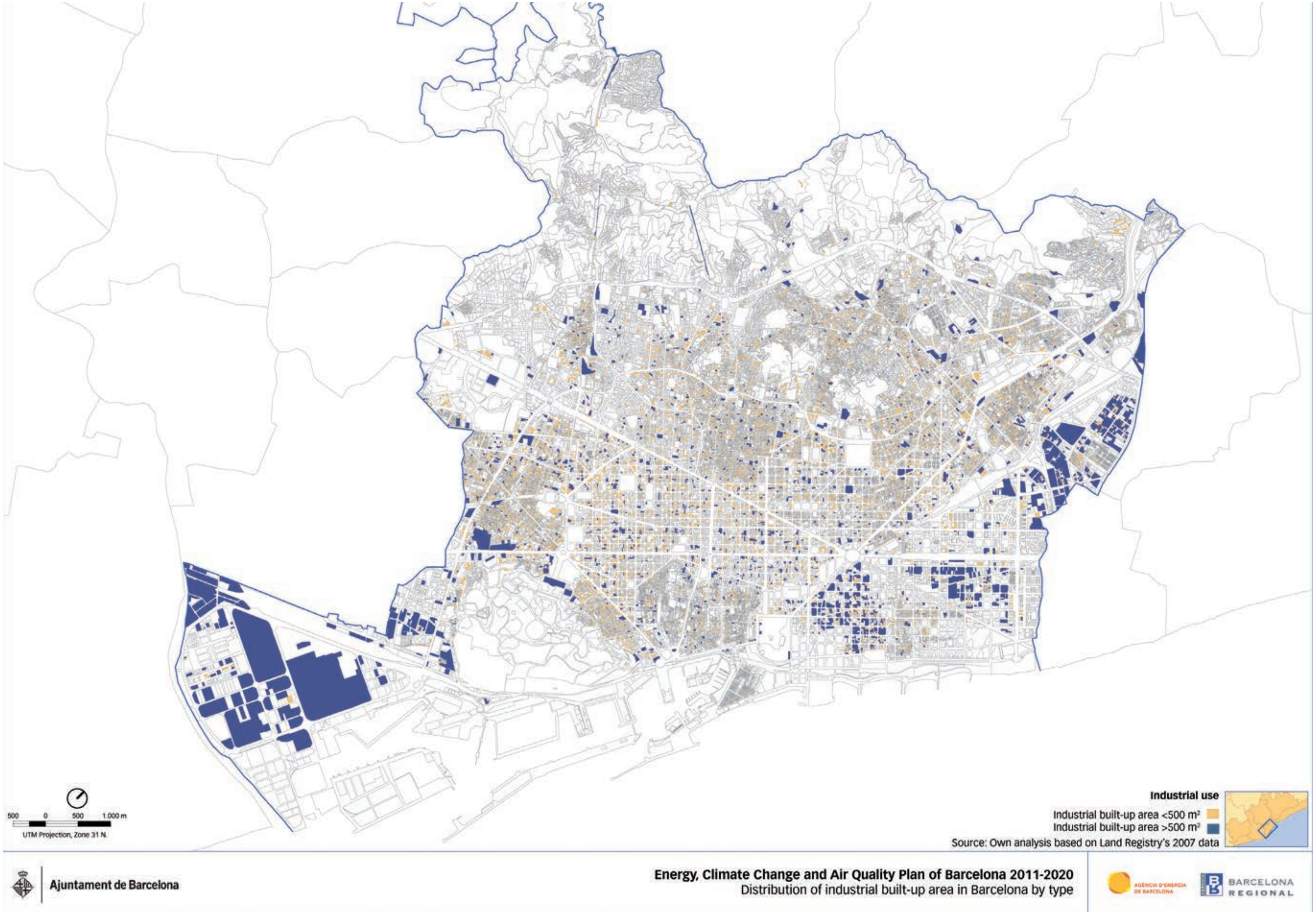
The analysis also includes other electricity production measures using renewable energies and more efficiency systems. Total production would be 32.26 GWh/year (4.5% of the electricity consumption in 2008), distributed as follows: photovoltaic technology (13%), cogeneration (86%) and small-scale hydraulics (1%). With regard to thermal energy production, the proposals would represent the production of 35.45 GWh/year of useful heat (1.8% of the equivalent consumption of natural gas in 2008): cogeneration (99%) and sludge to energy recovery (1%).

This reduction in final energy and electricity production using renewable or more efficient systems would lead to a saving of 173.86 GWh of primary energy consumption and the non-emissions of 15,572 t of GHG (2.8% of GHG emissions from the industrial sector in 2008). Yet as this is only a part of the total industries in the city, the potential saving would be greater although no direct extrapolation is possible given the lack of uniformity of the sector.

Priorities for action in the sector

Based on the study of the potential energy saving of the industrial sector conducted as part of the PECQ, different proposals have been put forward:

- **Implementation of energy efficiency management systems**
  It is proposed to create a project to promote these management systems, provided they are associated with specific energy reduction objectives and with the strategic plan of the company itself. The management system would need to contain the necessary measurement methods to define, in terms of energy, the various stages of the processes.
- **Introduction of heat recovery systems**
  One proposal is to achieve energy saving by means of recovering the heat from combustion fumes.
- **Pinch analysis for certain processes**
  The integration of industrial processes can generate major improvements in energy efficiency. Pinch analysis – the Pinch method for designing processes or technology -, allows the optimization of energy recovery in industrial processes, minimising investment as it establishes a thermodynamic link between the cold and hot flows.
- **Outsourcing of energy services with cogeneration systems between others**
  Together with the Service Platform of the Zona Franca, it is proposed to support the companies with technical advice, encouraging contacts between energy service companies and energy consuming companies.
- **Photovoltaic solar energy on industrial roofing**
  It is proposed to take advantage of the potential of solar roofing by means of the advice and administrative support so as to facilitate the implementation of photovoltaic energy on certain industrial roofs – either owned or rented – by contributing solutions to possible barriers, such as the temporary nature of the rental of industrial land and the depreciation period of the photovoltaic system.
- **Sludge drying for energy use**
  It is proposed to analyse the real possibility of introducing sludge drying systems which could be used energetically such as biomass in certain industries.
- **Increase energy efficiency in production processes**
  In conjunction with the Catalan Energy Institute (ICAEN) and the Services Platform of the Consortium of the Zona Franca, it is proposed to design support strategies for these industries to improve their energy efficiency and make them more competitive.
- **Energy saving in paint booths of vehicle workshops**
  Energy efficiency in car paint booths can be improved by using a new technology applicable to paint booths. This new system can be adapted to any conventional or newly built paint booth and consists of equipment which speeds up the evaporation of the water in the paint, considerably reducing the energy consumption and emissions of CO_2.


500 0 500 1.000 m
UTM Projection, Zone 31 N.
Industrial use
Industrial built-up area <500 m²
Industrial built-up area >500 m²
Source: Own analysis based on Land Registry's 2007 data
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Distribution of industrial built-up area in Barcelona by type
Agència d'Energia de Barcelona
Barcelona Regional

2.8.4 - MOBILITY (I): CHARACTERISATION OF MOBILITY AND TRANSPORT

The demand for mobility and modal distribution

In Barcelona, six million trips are made every day, according to data from 2008; 4.3 million are internal trips and 1.7 million internal-external.

In 2008, 32.7% of the internal trips were by public transport, 51.5% on foot and bicycle and only 15.8%, in private vehicles. As regards external-internal trips (1.7 million), private vehicles account for 47.5%, public transport 49.5%, and journeys on foot or bicycle 3%. Public transport, however, has grown in importance over recent years instead of private vehicles for this type of journey.

In general, private means of transport, except the bicycle, have decreased in the total number of journeys in favour of collective public transport and mobility on foot

Mobility in Barcelona must be interpreted by considering the city and its metropolitan area. Although inter-municipal journeys account for just a third of the total, over half of the private vehicles in circulation on working days come from other municipalities.

When analysing the data, however, we must differentiate between journeys and stages of journeys. The first refer to a direct journey between the point of origin and final destination, while the latter consider the pauses during the journey to carry out other activities (shopping, collecting children from school, accompanying relatives...).

In non-motorised journeys, the public in Barcelona mostly travel on foot, which is the most common form of transport in the city. The bicycle is the only private means of transport which has seen an increase over recent years, especially as a result of the Bicing system which has been a major success.

As regards collective public transport, the most common in staged journeys, the Metro is the most highly used transport for internal travel such as entering and leaving Barcelona. Buses, on the other hand, which are the most common form of transport for internal journeys, have lost users to the local rail network for internal-external travel. Lastly, trams are the public transport which have gained the most passengers, even though this is linked to the fact that they were introduced relatively recently.

Cars are by far the most common means of transport in private vehicles, especially for internal-external travel, as they usually cover large distances. Motorcycles have also seen a significant increase to the extent they now account for 32.2% of the internal journeys in Barcelona. Both means of transport have a similar occupancy ratio, of approximately 1.18 persons, for which reason most journeys are made with a sole occupant. Vans and lorries also account for a percentage of journeys in private vehicles -15% of the internal and 26.6% of the internal-external, although they transport not passengers but freight.

In general, private means of transport, except the bicycle, have decreased in the total number of journeys in favour of collective public transport and mobility on foot.

TABLE 35 | NUMBER AND MODAL DISTRIBUTION OF JOURNEYS IN BARCELONA (2008)

Number and modal distribution of journeys in Barcelona						
Journeys	Internal		Connection (Internal – External)		Total	
Public transport	1,428,856	32.7%	822,984	49.5%	2,251,840	37.3%
Private vehicle	691,993	15.8%	789,780	47.5%	1.481,773	24.5%
On foot and by bicycle	2,253,024	51.5%	50,346	3.0%	2,303,370	38.2%
Total	**4,373,873**	100%	**1,663,110**	100%	**6,036,983**	100%

Source: Mobility Services Dept. Barcelona City Council (2008)

TABLE 36 | NUMBER AND MODAL DISTRIBUTION OF STAGES OF JOURNEYS IN BARCELONA (2008)

Number and modal distribution of stages of journeys in Barcelona						
Journey stages	Internal		Connection (Internal – External)		Total	
Public transport	1,712,106	35.2%	1,433,979	48.1%	3,146,085	40.1%
Private vehicle	930,764	19.1%	1,296,639	43.5%	2,227,403	28.4%
On foot and by bicycle	2,226,268	45.7%	251,217	8.4%	2,477,485	31.6%
Total	**4,869,139**	100%	**2,981,834**	100%	**7,850,973**	100%

Source: Mobility Services Dept. Barcelona City Council (2008)

FIGURE 147 | MEANS OF TRANSPORT IN INTERNAL TRAVEL STAGES, WORKING DAYS (2008)

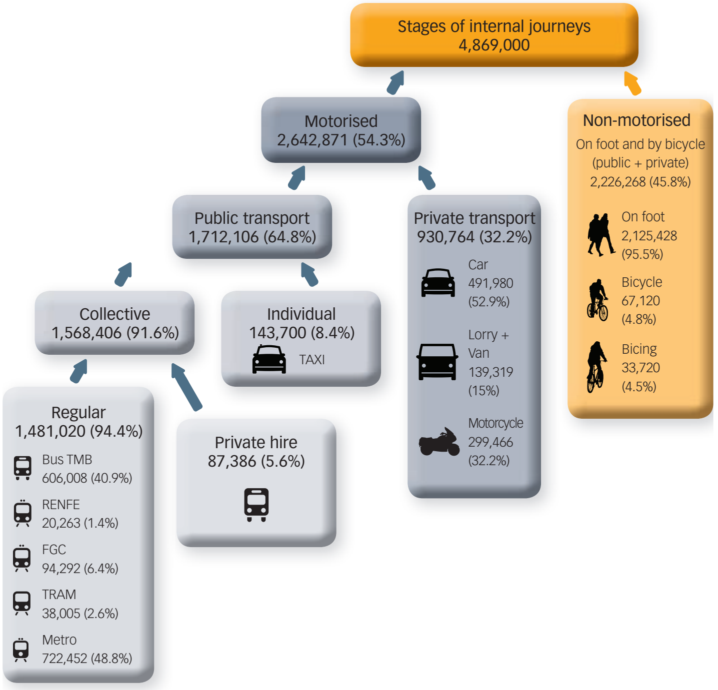
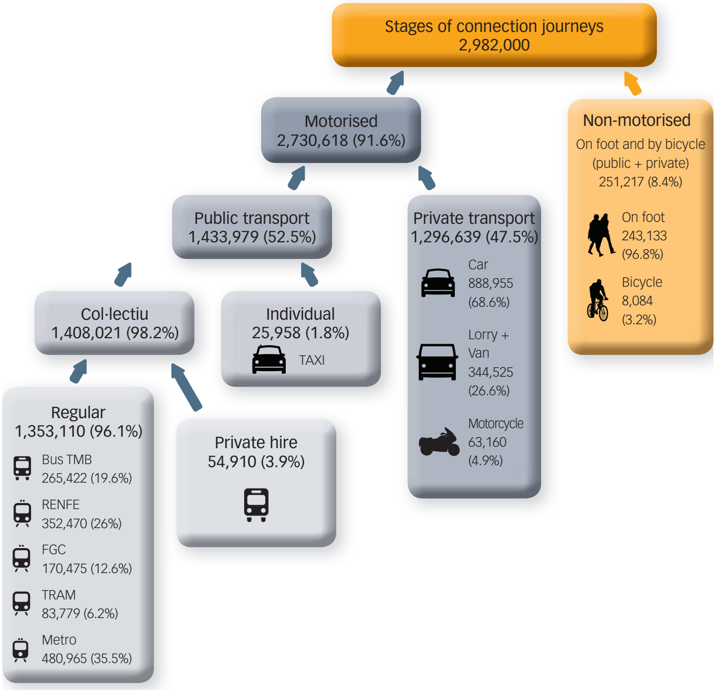


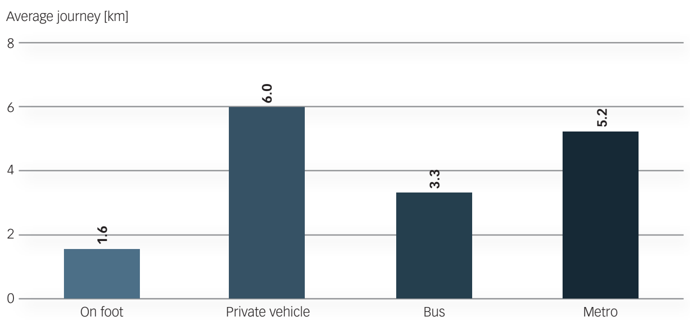
FIGURE 148 | MEANS OF TRANSPORT IN CHANGEOVER TRAVEL STAGES, WORKING DAYS (2008)



The reason for the journey and the distance travelled are characteristics of journeys which complete the characterisation study of mobility. According to the data of the Working Day Mobility Survey - EMEF 2008 (Metropolitan Transports of Barcelona), if we consider mobility according to the reason for travelling on working days, those which are compulsory (work or study) represented 24.7%, and non-compulsory (shopping, leisure, sport, dining, etc.) 30.2%; the rest are returns trips home (pendularity). As regards the number of journeys per person, the average was 3.31 on working days and 2.40 on holidays.

As regards journeys by bicycle, the average distance covered is some 1,600 m, in approximately twenty minutes assuming a speed of 5.14 km/h. On a bicycle, at an average speed of 20 km/h, the distance covered in ten minutes is 3.2 km. In public transport, the average distance is 3.3 km in the case of buses and 5.2 km in the case of the metro, with speeds of 11.7 km/h and 27.28 km/h respectively. For private vehicles, the usual distance is estimated to be up to 6 km, with average speeds of 56.3 km/h on the Ring roads and 21.3 km/h in the rest of the city.

FIGURE 149 | AVERAGE DISTANCE COVERED BY DIFFERENT MEANS OF TRANSPORT (2008)



Source: Barcelona City Council

TRENDS IN MOBILITY IN EUROPE

An efficient and flexible system –both for freight and passengers- is basic for the socio-economic growth of a territory and to ensure the standard of living of its inhabitants.

In Western Europe, transport has seen significant growth over the past forty years, especially by road and air. All the short-term forecasts point to mobility demands (travellers-km and t-km) will continue their sustained growth which will be locally affected by the usual fluctuation of economic cycles, but not as regards the global trend. This stems from mobility being a phenomenon associated with human behaviour and psychology, the cultural habits of society and the income level, among other factors.

Despite this, the transport sector is one of the main emitters of greenhouse gases - CO_2, chiefly, and polluting compounds - nitrogen oxide, particles in suspension, volatile organic compounds – due to large-scale use of fossil fuels (see chapter 2.7. Air quality). For this reason, over recent years measures and initiatives have been fostered to minimise the environmental, social and economic impact of both passenger and freight transport.

Thus, transport policies throughout the European Union acknowledge the need to impose limits on superfluous transport growth – without adversely affecting the mobility of the public and the transport needs of companies – by increasing the market shares of the most efficient, healthy means of transport. Efficient pricing, internalisation of the environmental and social costs, accurate selection of investments and integrated territorial planning, mobility and infrastructures are some of the tools which can help to overcome this challenge.

The collective public transport network

Barcelona and its area of influence have a collective public transport network comprising buses, metro, railways, local trains, trams and taxis. The chief collective public transport operators are: Transports Metropolitans de Barcelona - TMB (bus and metro), Ferrocarrils de la Generalitat (FGC), the Metropolitan Transport Authority (trams) and RENFE (local trains).

In 2008, metro travellers accounted for 48% of collective public transport and buses, 25%. Both means of transport are operated by TMB, making this company the most important transport operator in Barcelona and its Metropolitan area (73% of journeys).

The operators Authosa and Transports Lydia engage in their activity solely within the municipal boundary of Barcelona, and connect districts with a special orography such as Ciutat Meridiana and Carmel. On the other hand, of the twenty-two lines operated by Mohn only seven provide service inside the city of Barcelona, four of which reach Pl. Espanya, two the Rda.Universitat and one more to Pl, Reina Maria Cristina.

Of the twelve lines operated by Oliveres, only the L70 and the L72 enter Barcelona and reach Pl. Espanya, from L'Hospitalet de Llobregat. A similar situation occurs with the Rosanbus lines, which chiefly service L'Hospitalet but which as a municipality bordering on Barcelona, has five lines which also have a stop, with relatively short journeys. Tugsal is the company which operates the most journeys inside Barcelona: three stop at the periphery (B16, B19 and B23), five reach Pl. Catalunya (B20, B21, B24 and B25), and one more finalises in Hospital de Sant Pau (B22).

The services of Transport Ciutat Comtal link the chief landmarks of the city, such as Pl. Catalunya and Tibidabo (at 30-40 minute intervals), Paral·lel and ZAL-Barcelona, and Pl. Catalunya and the Airport. Soler i Sauret serves Esplugues de Llobregat, Sant Just and Sant Feliu de Llobregat, there is only one line which extends to the University Area (EP1).

Therefore, if we consider all the bus companies which serve the inner metropolitan ring, TMB is that which accounts for 71% of the users of this means of transport. This percentage is even greater if we consider only the travellers travelling from or to Barcelona, given that most of the lines of the other companies operate outside the municipality of Barcelona. The improved night bus service has also led to an increase in the number of users over recent years, by 42.4% since 2005 (5.9 million passengers), with a growth in the vehicle fleet of 62.5% (up to 130 units).

The local network of overground collective public transport also includes the Tram (inaugurated in 2004) and the metro network will be expanded in future with the coming into operation of line 9.

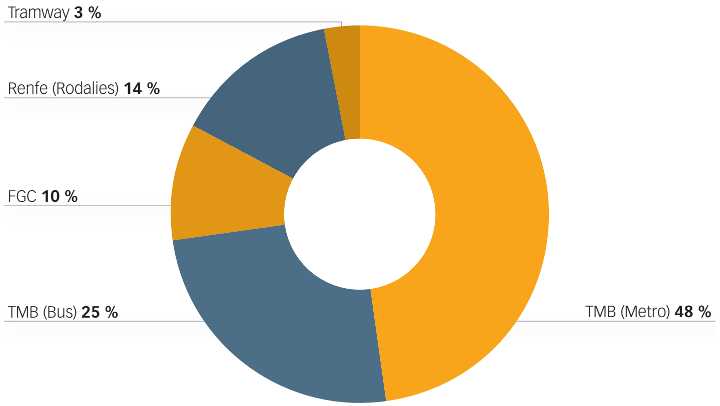
Individual public transport, taxis, use a fleet which remains constant at 10,400 vehicles; transports 107 million passengers a year and has 174 tax ranks.

TABLE 37 | BASIC DETAILS OF COLLECTIVE PUBLIC TRANSPORT OPERATORS IN THE INNER METROPOLITAN RING (2008)

Basic details of collective public transport operators in the Inner metropolitan ring – 2008				
PUBLIC TRANSPORT	Line length (km)	Lines	Passengers (millions)	Δ08/07 (%)
TMB (Metro)	88.4	6	376.4	2.7%
FGC	143.3	4	81	2.5%
RENFE (Rodalies)	529.6	6	114.4	-2.3%
Tramvia	29.1	6	23.2	11.1%
TMB (Autobús)	915.2	108	194.9	-7.4%
Authosa	8.6	2	2.7	
Transports Lydia	20.5	4	0.4	
Mohn	380.8	22	15.2	
Oliveras	112.7	12	6.9	
Rosanbus	89.6	9	9.5	4.0%
Tusgsal	484.2	41	34.7	
TCC	40.6	3	3.5	
Soler i Sauret	38.8	7	1.5	

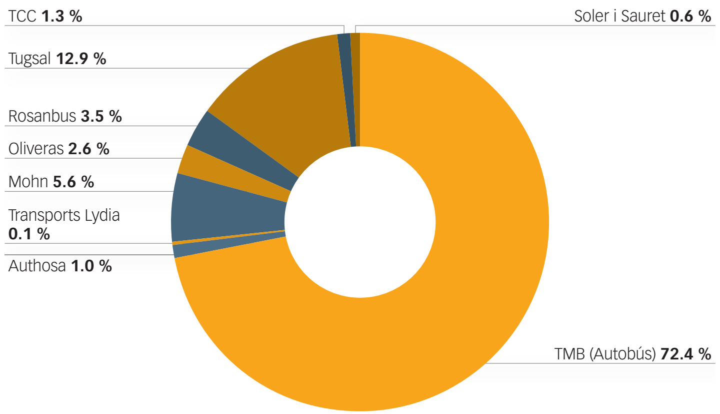
Source: 2008 Annual Report (ATM, 2009)

FIGURE 150 | DISTRIBUTION OF PASSENGERS OF THE MAIN COLLECTIVE PUBLIC TRANSPORT OPERATORS (2008)



Source: TMB, FGC and RENFE

FIGURE 151 | DISTRIBUTION OF PASSENGERS OF THE MAIN BUS AND COACH OPERATORS (2008)



Journeys on foot and by bicycle

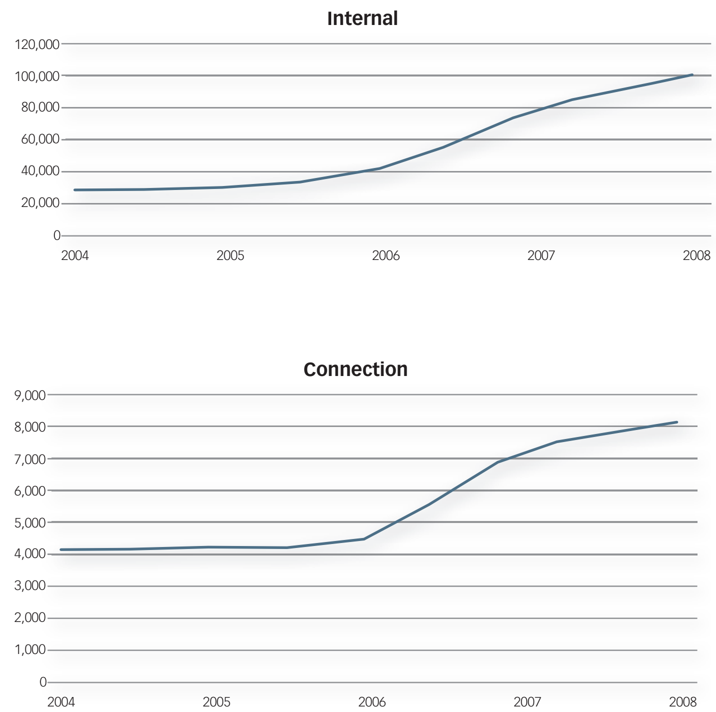
Barcelona occupies a surface area of 101 km^2, of which 17% are squares and streets. 0.7% (69 hectares) corresponds to the pedestrian priority areas of which 31% is located in the district of Ciutat Vella.

As regards the bicycle, the length of cycling lanes has increased progressively in the city, from 7.3 km in 1990 to the current 140 km (12.2 km are circuits and 17.5 km are cycling priority lanes). The building of car parks has evolved in parallel to the increase in cycling lanes and, in four years, has increased by 2.6 to 17,502 parking spaces.

The significant increase in this form of transport over recent years is shown in the increased number of journeys between 2007 and 2008; 27% of the internal journeys and 13.59% of connection journeys. As regards the number of bicycles, it saw an increase of 26.7% over the same period, with the Bicing service accounting for 46.56%.

The Bicing service, introduced in March 2007, completed its rollout in 2008, with 6,000 bicycles and 390 bicycle stations. The number of subscribers increased over the past year by 80%, to 181,962 and the number of bicycles by 30.1%. The average number of journeys on working days is 37,669, a figure which drops by approximately 30% on holiday.

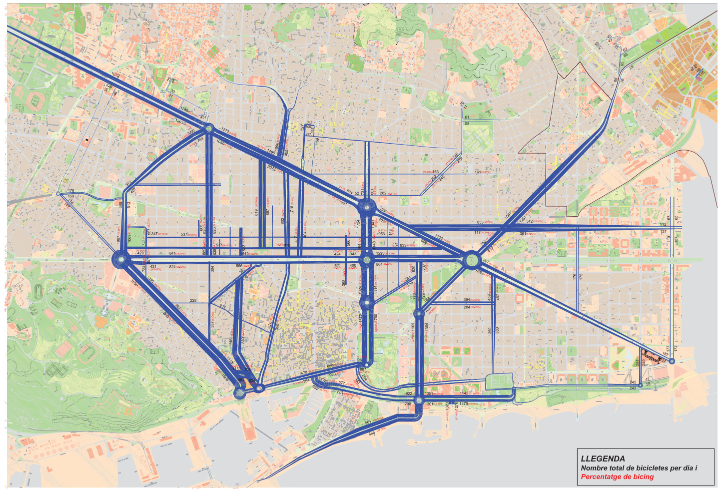
FIGURE 152 | EVOLUTION OF BICYCLE JOURNEYS IN BARCELONA: INTERNAL AND CONNECTION JOURNEYS (2004-2008)



Source: Mobility Services Dept. Barcelona City Council

▲ 33.5% of the 100,000 internal bicycle journey stages in 2008 used the Bicing service.

FIGURE 153 | VOLUME OF BICYCLE TRAFFIC IN BARCELONA (2008)



Source: Mobility Services Dept. Barcelona City Council

▲ 45% of the traffic uses bicycle lanes.

Road traffic

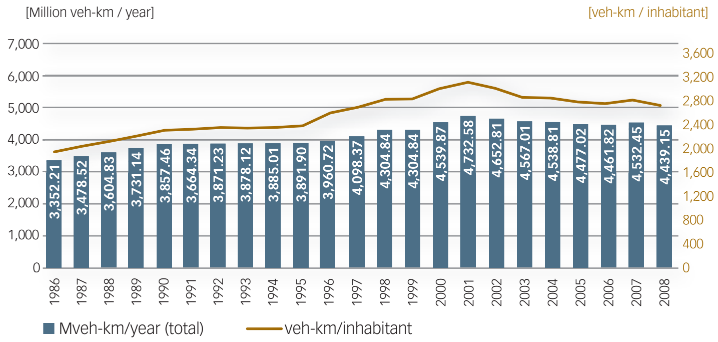
In 2008 in Barcelona, 13,234,210 veh-km/working day were covered, according to the Mobility Services Dept. of Barcelona City Council. When analysing the traffic on different days of the week at different points throughout the city, it can be concluded that the annual traffic in Barcelona in 2008 was 4,439.15m veh-km/year.

The evolution of road traffic over recent years shows signs of stability due to the road congestion at certain peak times. This is, however, a different trend to that detected as from 1992, when there was a rise in traffic due to the greater road capacity created by the Upper and Lower Ring roads (Dalt and Litoral.).

Despite this trend towards stability over recent years, there has been a variation in the distribution of road traffic, which has led to a reduction in the percentage of private cars and an increase in light commercial vehicles (vans).

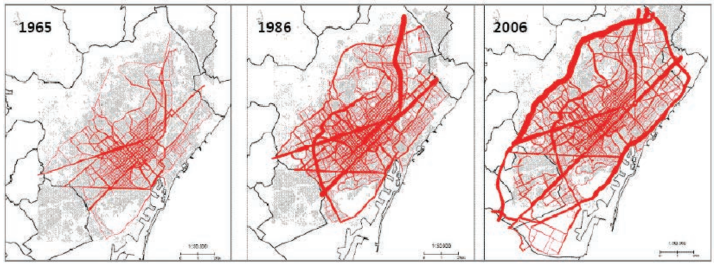
There are several causes for this change of vehicle mix: Action aimed at improving the competitiveness of public transport and other alternatives to private vehicles (via new infrastructures and improved service quality); the support for the bicycle and expansion of the bicycle lane network; and the implementation of measures to reduce the use of private cars in the city such as the enlargement of metered parking areas (Zones Blaves) and resident parking areas (Zona Verda).

FIGURE 154 | EVOLUTION OF ROAD TRAFFIC IN BARCELONA (1986-2008) AND FORECAST FOR THE FUTURE



Source: Mobility Services Dept. Barcelona City Council

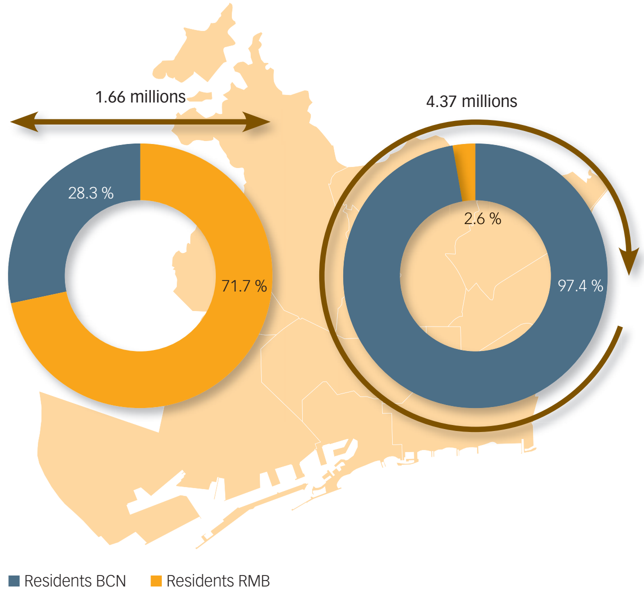
FIGURE 155 | EVOLUTION OF COMPOSITE NETWORKS IN BARCELONA (1965/1986/2006)



Source: Mobility Services Dept. Barcelona City Council

▲ In 2008, 80% of traffic was to be found in the city streets and 20% on the Ring roads of Barcelona (graphic representation of the volume of traffic on a standard working day; the thickness of the lines represents a larger flow of vehicles).

FIGURE 156 | DISTRIBUTION OF JOURNEYS IN BARCELONA, INTERNAL AND INTERNAL-EXTERNAL (2008)



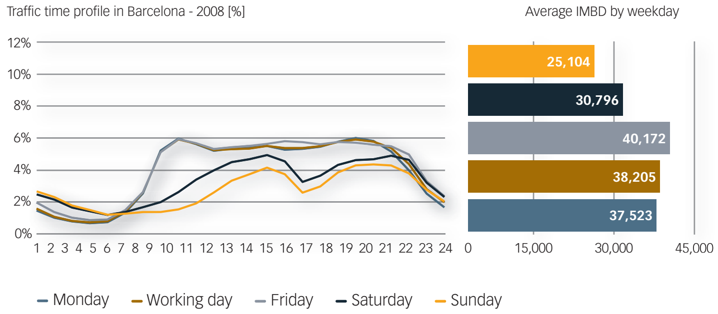
Source: Metropolitan Transport Authority

TABLE 38 | DISTRIBUTION OF THE VOLUME OF VEHICLES BY TRAFFIC CARRYING STREETS IN BARCELONA (2008)

Distribution of the volume of vehicles by traffic carrying streets (2008)			
Street	Veh-km (%)	kms network	
Ring roads	20%	24.12	1.89%
External connectivity roads	21%	43.37	3.40%
1st level internal connectivity network	14%	86.73	6.80%
2nd level internal connectivity network	14%	109.39	8.58%
3rd level internal connectivity network	13%	87.70	6.88%
Local network	18%	923.8	72.45%
Total	**100%**	**1,275.0**	**100%**

▲ 20% of the annual volume of traffic circulates via the Ring roads, despite these roads accounting for only 2% of the length of the road network in Barcelona.

FIGURE 157 | TRAFFIC TIME PROFILE IN BARCELONA (2008)



Source: Barcelona Regional, based on data from the Mobility Services Dept

▲ Road traffic in the city has time and daily cycles which are characteristic of the economic and social flux of the city, and therefore there are more intense peaks during the morning and afternoon together with differences between working days and holiday days. Below is the typical time profile for different days of the week.

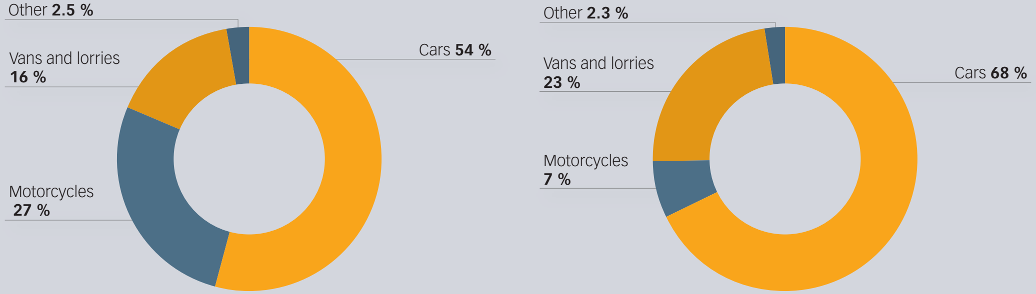
COMPOSITION OF TRAFFIC ON THE RING ROADS AND THE CITY

It should be borne in mind that the composition of the traffic in the city and the Ring roads is not the same. The most significant difference lies in motorcycle use (this group also includes mopeds) as the percentage on the Ring roads is 7% compared to 27% in the city. This is partly due to the prohibition of motorcycles on the Ring roads and the volume of internal-external journeys on these roads.

In the city, a large part of car use is replaced by motorcycles, with 54% in the city compared to 68% on the Ring roads, taking into account that cars includes passenger cars and taxis.

LCVs and lorries account for 16% in the city and 23% on the Ring roads. The group "others", referring to buses and coaches, is similar in percentage both in the city and the Ring roads.

FIGURE 158 | COMPOSITION OF TRAFFIC IN BARCELONA (LEFT) AND THE RING ROADS (RIGHT), IN 2008



Source: Mobility Services Dept. Barcelona City Council

2.8.5 - MOBILITY (II): ENERGY CONSUMPTION

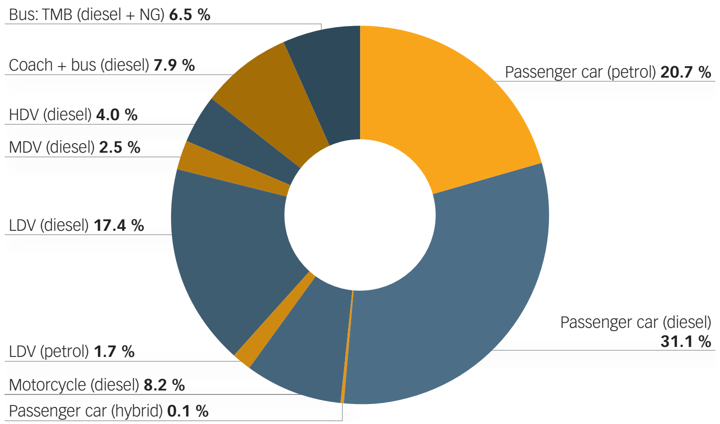
Global consumption by the vehicle population

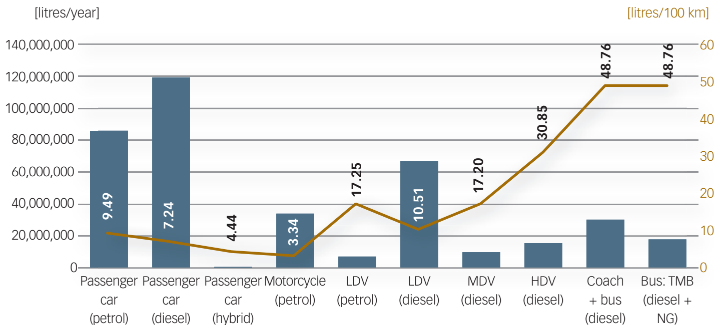
Based on the characterisation of the vehicle population, the fuel consumption associated with road traffic in Barcelona has been precisely defined. In 2008, it stood at 3,850.17 GWh, with an average of 0.87 kWh/km.

83% of this consumption took place in the streets of the city and 17% on the Ring roads, with an average of 0.91 kWh/km and 0.70 kWh/km respectively. This divergence between average consumption figures is connected to the different composition of the traffic and the higher average traffic speed on the Ring roads (56.3 km/h) than in the city (21.3 km/h).

In the case of the Ring roads, engine performance is also greater, as the speed with the lowest energy consumption per kilometres falls between 80 and 90 km/h; at lower or higher speeds, average consumption increases.

FIGURE 159 | DISTRIBUTION OF ENERGY CONSUMPTION OF TRAFFIC IN BARCELONA AND THE RING ROADS, IN PERCENTAGES AND BY TYPE OF VEHICLE (2008)





▲ In 2008, road transport in Barcelona (not counting natural gas buses) consumed 383.47 million litres of diesel (670%) and petrol (33%) with an average consumption in the city and the Ring roads of 8.64 litres/100km (9.07 and 6.96 litres/100 km respectively).

Bus service consumption (TMB)

In 2008, TMB had a total of 1,079 vehicles (850 in service) to operate over 100 lines and transport almost 190 million passengers. The vehicle distribution was as follows: 657 standard, 282 articulated, 24 microbuses, 42 minibuses, 67 double-decker buses and 7 open top buses.

Fuel consumption by buses totalled 18.17 million litres of diesel, 2.7 of biodiesel and 110.5 GWh from natural gas. Diesel consumption between 2006 and 2008 fell by 21.76% which was offset by other energy sources such as biodiesel and natural gas.

In 2006, a pilot test was launched with hydrogen, but in the short-term this energy will not be commercially applied until the technology is improved and operating costs can be brought down to an acceptable level.

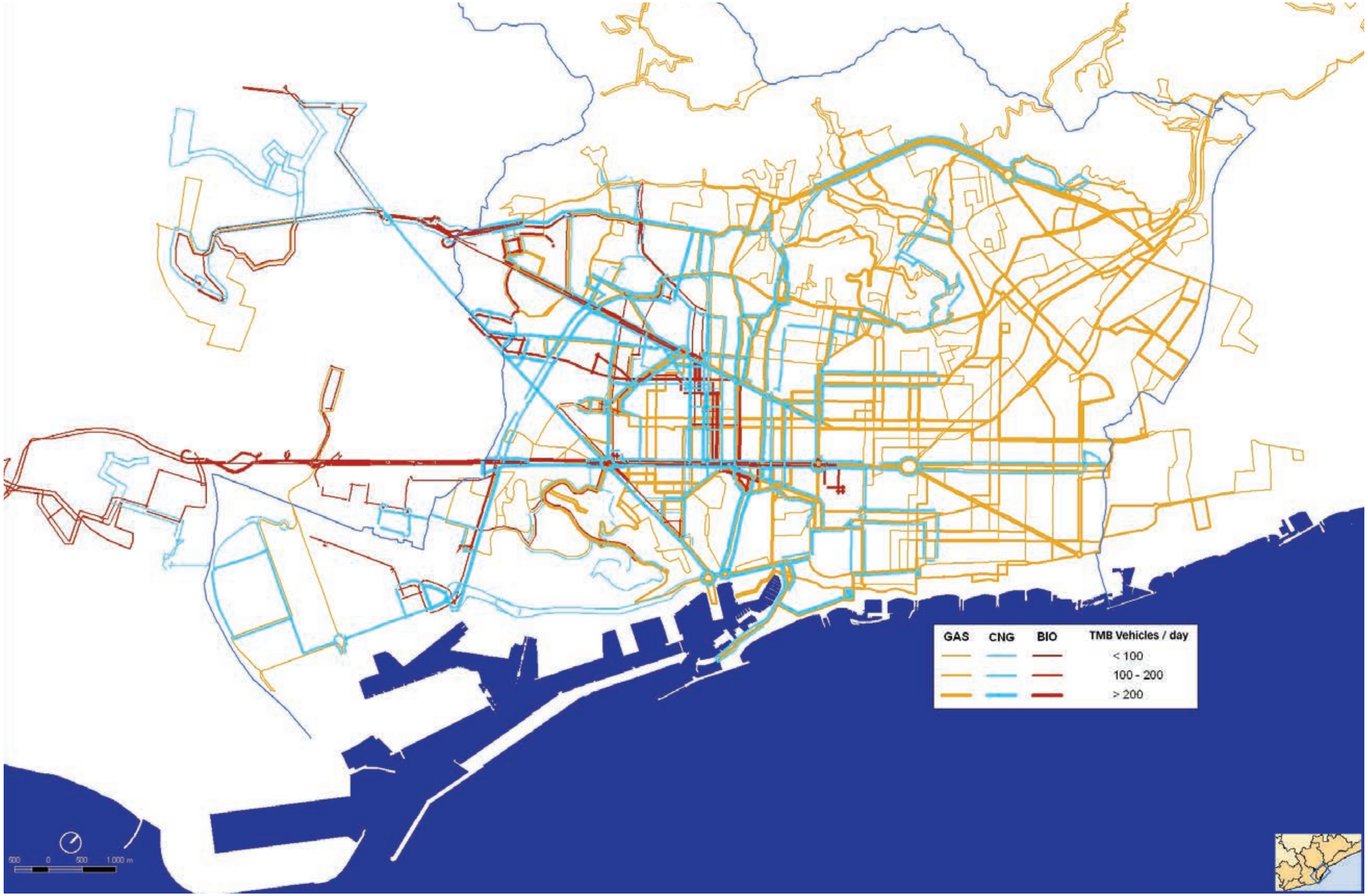
TABLE 39 | DATA ON THE TMB BUS SERVICE SUPPLY (2008)

Data on the TMB bus service supply	
Indicator	year 2008
Seats-km	3,519,410,000
Vehicles-km	41,385,440
Journeys	188,330,000
Number of routes	108
Commercial speed	11.7
Diesel vehicles	831
CNG vehicles	248
Biodiesel vehicles	116
Total vehicles	**1,079**

TABLE 40 | FUEL CONSUMPTION BY TMB BUSES (2006/2008)

Fuel consumption by TMB buses				
	2006	2008	Difference 06/08	Percentage 06/08
Automotive diesel consumption [litres]	23,222,323	18,168,392	-5,053,931	-21.76%
Vehicle's natural gas consumption [kWh]	78,637,100	110,508,000	31,870,900	40.53%
Biodiesel consumption [litres]	253,000	2,724,665	2,471,665	976.94%
Hydrogen consumption [kg]	8,762	-	-	-

FIGURE 160 | TYPE OF FUEL AND FREQUENCY OF CIRCULATION OF THE TMB BUS NETWORK



Source: TMB (2008) and Barcelona Regional

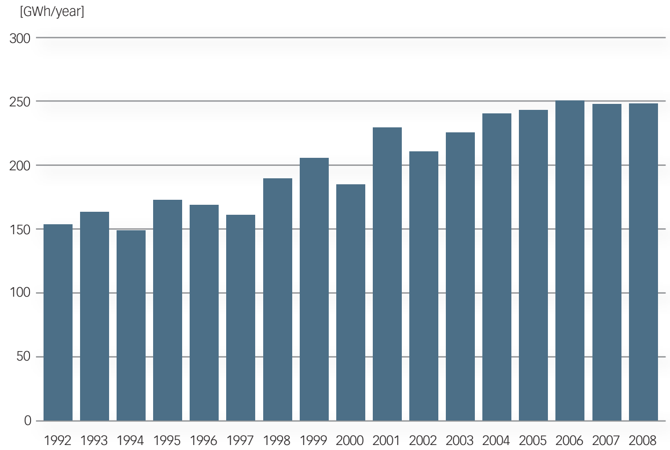
Electrically-powered public transport consumption

In Barcelona, there are three electrically-powered collective transport operators: TMB, FGC and RENFE due to the interconnection of the rail transport networks between municipalities, the energy consumption of transport within Barcelona cannot be calculated using the total consumption of each operator, and it is therefore necessary to use the consumption data provided by the electricity companies (based on the service connections in Barcelona by electrical traction tariffs).

In 2008, electricity consumption was 248.47 GWh/year, compared to 205.83 GWh/year in 1999, a period with an annual growth rate in consumption of 2.11%.

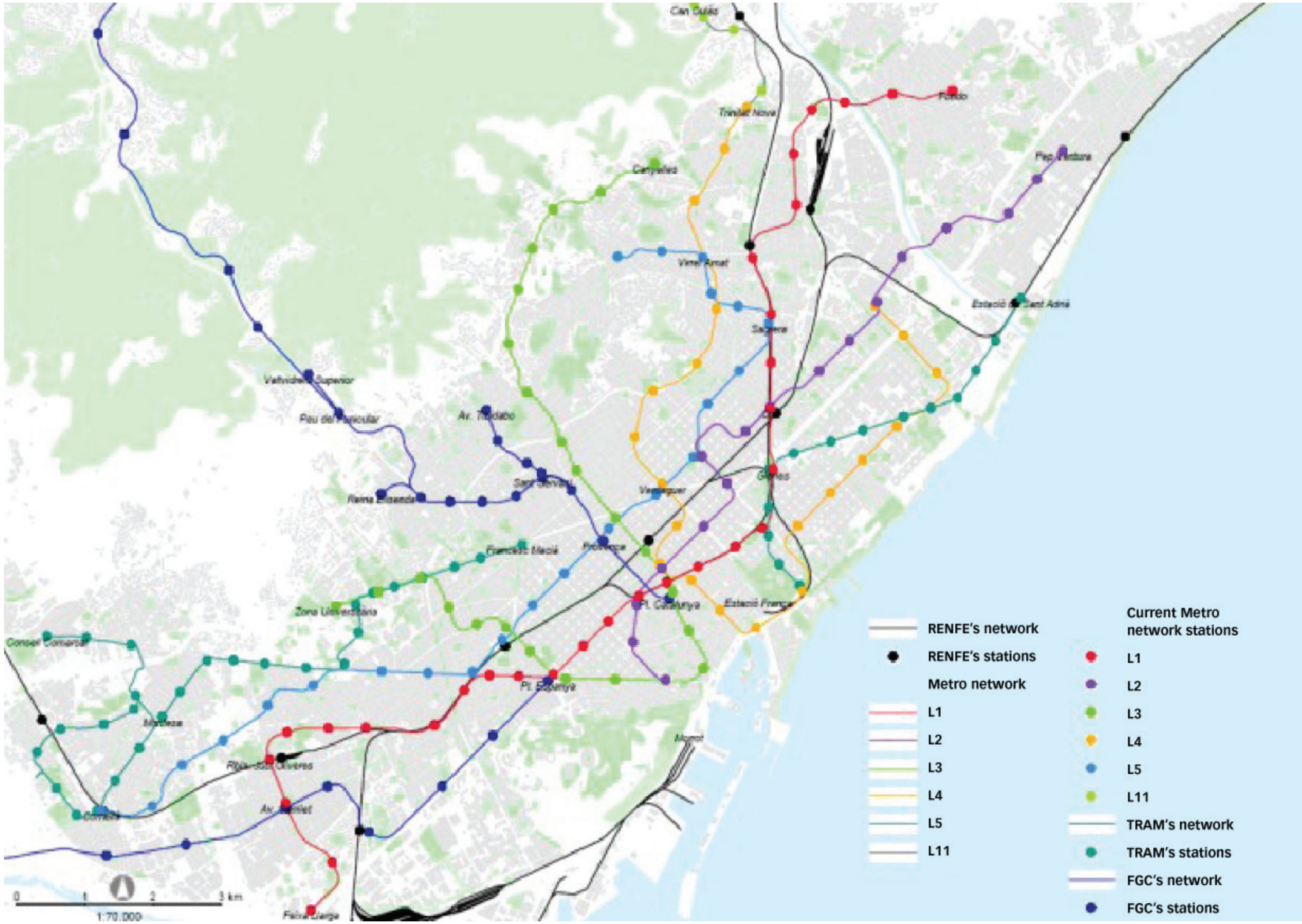
Overall, when considering mobility in Barcelona (internal and internal-external journeys), in 2008 there were 667.68 million annual journeys by metro, tram, FGC and RENFE. Average electric traction consumption is 0.388 kWh/journey.

FIGURE 161 | EVOLUTION OF ELECTRIC TRACTION CONSUMPTION (1992-2008)



Source: ICAEN

FIGURE 162 | METRO AND TRAM NETWORK



Source: Barcelona Regional

FIGURE 163 | LOCAL TRAIN NETWORK OF RENFE AND FGC

Source: Barcelona Regional

- **METRO (TMB)**

  Metro consumption in 2008 was 198,064,712 kWh (198.06 GWh/year), 8.64% more than in 2006, due to the greater number of veh-km covered. Despite this, this increase was lower than the increase in the supply of vehicles (9.7%), thanks to the reduction in unit consumption of the trains.

  On top of this consumption, we must add the power and lighting of the service, which totalled 71,637,637 kWh, for which reason the total consumption of the network was 269,702,349 kWh/year. This is the equivalent to an average traction consumption of 2.46 kWh/veh-km considering only vehicles, and 3.35 kWh/veh-km if we include power and lighting.

  This energy was used to cover 80.4, veh-km throughout the network, which also includes the municipalities of Hospitalet de Llobregat, Cornellà, Santa Coloma de Gramenet and Badalona. Given that 83.9% of the network is located inside Barcelona, the distance covered was 67.45m veh-km, with a traction consumption of 166.18 GWh/year.

TABLE 41 | EVOLUTION OF ENERGY CONSUMPTION OF THE METRO (2006/2008)

Metro's energy consumption [MWh]				
	2006	2008	Difference 06/08	Percentage 06/08
Traction	182,310	198,064.7	15,754	8.64%
Lighting	67,353	71,637.6	4,285	6.36%
Total	**249,663**	**269,702.3**	**20,039**	**8.03%**
Total within Barcelona (traction only)	-	**166,176.29**	-	-

- **METROPOLITAN TRAM**

  In 2008, the metropolitan tram (Trambaix, lines T1, T2, T3; and Trambesòs, lines T4, T5, T6) covered 2.52m veh-km. Of the 29.1 km in length of the network, 48.4% are inside Barcelona, which signifies an average of 1.22m veh-km.

  According to data of the tram operator in Barcelona, this means of transport consumes 4.56 kWh/km, so that in 2008 consumption stood at 5.55 GWh/year.

- **FERROCARRILS DE LA GENERALITAT (FGC)**

  In 2008, FGC consumed 91.63 GWh, 90.53 in traction and power supply for the vehicles, and 1.1 GWh for lighting. This energy was used to cover 32.8 million veh-km over 183 km of rail lines of the network, of which only 7.38 km run inside Barcelona.

  Despite the lack of data on veh-km in Barcelona, there is information on the number of trains, enabling us to estimate the electric traction consumption. According to data from the Metropolitan Transport Authority, there are a total of 45 trains at peak time per direction within the inner ring and 34 trains/peak time and direction on the rest of the line. Thus, consumption for the year 2008 in the city of Barcelona is 20.32 GWh/year.

TABLE 42 | **EVOLUTION OF ENERGY CONSUMPTION OF THE FGC (2006/2008)**

FGC's energy consumption [MWh]				
	2006	2008	Difference 06/08	Percentage 06/08
Traction	81,308	90,530	9,222	11.34%
Lighting	1,069	1,112	43	4.02%
Total	**82,377**	**91,642**	**9,265**	**11.25%**
Total within Barcelona (traction only)	-	**20,324**	-	-

- **RODALIES RENFE (LOCAL TRAINS)**

  The local Renfe network (447.7 km) in 2008 covered a total of 91.9m veh-km, carrying 114.4 million passengers. Rodalies Barcelona consumed 355.49 GWh, with an average value of 3.87 kWh/km. Barcelona has a network of 27.2 km.

  Considering that the train traffic in the municipality represents only 19% of total traffic, in 2008, 17.46m veh-km were covered in Barcelona, entailing a total consumption of 67.543 MWh/year.

  A total of 207.6m veh-km are covered across the entire network. Average consumption in the city of Barcelona was 2.78 kWh/veh-km.

TABLE 43 | **ELECTRICALLY-POWERED PUBLIC TRANSPORT CONSUMPTION (2008)**

Electricity consumption results: it summarises the electrical traction consumption of transport in Barcelona in 2008. Electrically-powered public transport consumption [MWh]					
	Total electricity consumption (traction) [GWh]	M cars-km travelled [5]	M cars-km travelled in Barcelona	% BCN with regard to the network [6]	Energy consumption within Barcelona [GWh]
TMB (metro)	198.06 [1]	80.4	67.46	83.9%	166.18
Tramway	11.49 [2]	2.52	1.22	48.3%	5.55
FGC	90.53 [3]	32.8	7.38	22.5%	20.32
RENFE	355.49 [4]	91.9	17.46	19%	67.54
TOTAL	**655.57**	**207.6**	**93.52**	**45%**	**259.59**

1 TMB Report
2 Calculated according to operator's data
3 FGC Report
4 Data provided by the operator
5 Figures by TransMet (ATM)
6 According to SIG calculations

Taxis

The number of kilometres covered by taxis in the Metropolitan Area in 2008 was 498,039,723 veh·km. In order to calculate the number of kilometres covered in Barcelona, we should bear in mind that 143,700 internal journey stages were covered on working days, according to the data of the City Council Mobility Service in over 25,958 connection journeys. If we consider that half of the distance covered by these journeys correspond to the streets of Barcelona, in 2008 156,679 journey stages were carried out by taxi on working days.

According to data from the Metropolitan Area of Barcelona, during the same year 197,320 services were carried out on working days, so the proportion of journey stages on working days in Barcelona compared to the total of the MAB was 79.4%.

If we consider that this proportion is the number of trips, we can extrapolate to the kilometres covered, the figure for Barcelona would be 395,461.006 veh·km (8.9% of all traffic).

2.8.6 - MOBILITY (III): LOCAL AND GLOBAL EMISSIONS

The analysis methodology

The characterisation of the vehicle population of Barcelona (see section 2.1.7) has revealed the exhaust emissions measured using the RSD or Remote Sensing Device. It was thus possible to compare these empirical data with those obtained in the simulation using the CORINAIR/COPERT methodology. This methodology has also contributed information on the vehicle population in circulation, the average monthly temperatures and average speeds of traffic in the city and on the Ring roads.

The emissions considered were as follows:

- EMISSIONS of NO_x: exhaust emissions (both hot and cold).
- EMISSIONS of PM_{10}: exhaust emissions, both hot and cold, emissions produced by braking, the tyres and abrasion of the asphalt (according to the CORINAIR/COPERT methodology); COPERT does not take into account emissions from re-suspension.

The chief conclusion of the study, considering global city traffic, is that real NO_x emissions captured with the RSD system are 16.2% higher than those provided by the model, and 76.6% higher than in the case of PM_{10}. Similar studies conducted around Europe also confirm this fact.

NO_x and PM_{10} emissions by vehicles submitted in this PECQ are the real figures recorded by the RSD system. The notation used in the figures shown are as follow: COPERT+RSD or COPERT, on the one hand, and XTRA RSD on the other, to differentiate the COPERT results and the increased to be added to approach the COPERT methodology to the real measurements detected using the RSD. In the case of GHG emissions and fuel consumption, the PECQ has only used the COPERT/CORINAIR methodology; i.e. the official European methodology.

The importance of working with measured emissions of NO_x and PM_{10} is that the dispersion of pollutants can be modelled for the entire city (together with the inventory of emissions from other sectors). Entering more real data of the dispersion model helps to obtain more accurate final results in the comparison and calibration process with the real measurement of immissions at air quality measuring stations of the XVPCA (Air Pollution Surveillance and Prevention Network).

Greenhouse Gas Emissions (GHG)

Road transport in Barcelona and the Ring roads generated 1,025,721.7 t of GHG, which includes both CO_2 and CH_4 and N_2O. The calculation was made by applying the CORINAIR/COPERT methodology and taking into consideration the vehicle characterisation data and average speeds in the city and the Ring roads.

The average traffic emission factor was 231.06 g GHG per kilometre covered. By type of passenger car, the average of diesel vehicles stood at 199 g/km, 9.5% lower than petrol driven cars. Hybrid vehicles produced 102 g/km on average, while motorcycles and mopeds, 93 g/km.

In 2008, passenger cars accounted for 51.1% of total emissions, LCVs 19.3%, buses and coaches 14%, motorcycles 9,2% and medium and heavy duty lorries (MDV and HDV) 6.5%. Although passenger cars and motorcycles are the vehicles with the lowest emissions per distance, they were those which covered the largest number of kilometres in the municipality as a whole. Buses and coaches represented a low percentage of road trips in Barcelona, but had high emissions per kilometre covered.

FIGURE 164 | DISTRIBUTION OF GHG EMISSIONS IN BARCELONA AND THE RING ROADS, BY TYPE OF VEHICLE (2008)

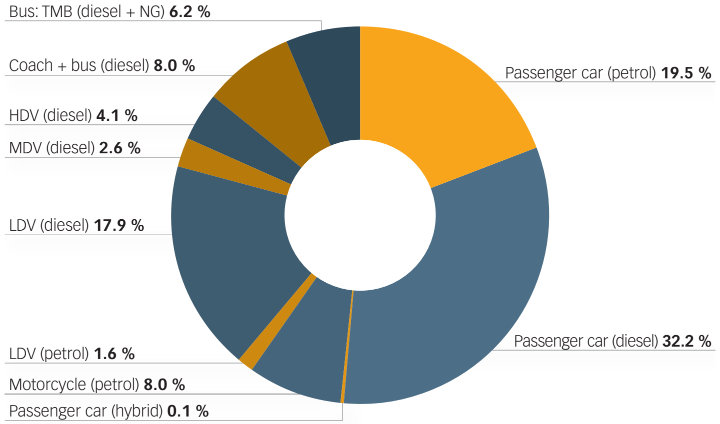


FIGURE 165 | TRAFFIC GHG EMISSIONS IN BARCELONA AND THE RING ROADS, BY TYPE OF VEHICLE (2008)

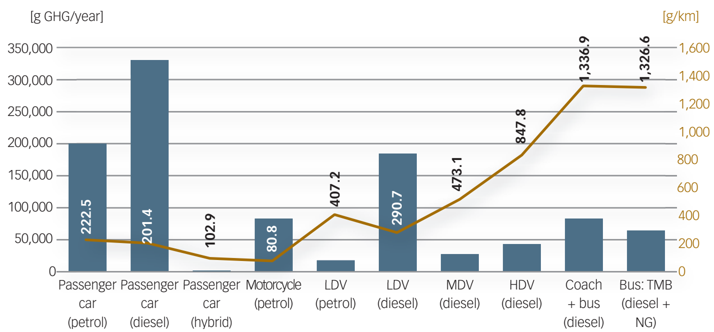
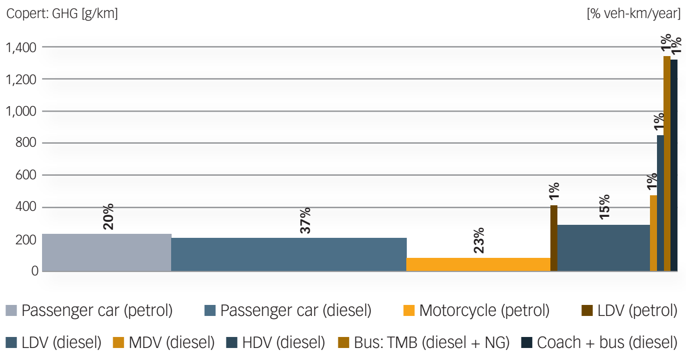


FIGURE 166 | CORRELATION BETWEEN EMISSIONS PER KM OF GHG AND DISTRIBUTION OF TRAFFIC IN BARCELONA AND THE RING ROADS (2008)



NO_x emissions

The distribution of NO_x emissions according to the type of vehicle also diverges from the GHG, as they have no direct relationship. Thus, passenger cars account for 34.2% of the total emissions, followed by vans (LCV) with 17.4%, medium and heavy duty lorries (MDV and HDV) with 15.7%, private coaches and buses with 12.2%, motorcycles with 12.3% and lastly TMB coaches and buses with 8.2%. Overall, diesel cars and vans are the vehicles which most circulate within the city and those with the highest emissions per kilometre in the weight category.

The average weighted traffic emission factor was 1.1297 g NO_x/km^2 [31]. However, there are significant differences between types of vehicles, as the average emissions from diesel cars is 3.3 times higher than petrol cars (it should be remembered that the petrol vehicles circulating in Barcelona are older than diesel versions). This shows how the increase in the number of diesel cars does not lead to improve air quality, despite reducing CO_2 emissions.

There are also high emission indices on the part of diesel vans compared to petrol versions, which increase per kilometre driven as they are heavier duty vehicles. Motorcycles and mopeds also record high emissions levels, as they lack the catalytic converters which help to reduce them in the case of cars.

TMB buses, on the other hand, produce fewer emissions per kilometre than private buses and coaches as a result of TMB's environmental policy of using less polluting fuels (buses with natural gas emit 81% less NO_x than the average for petrol), the improved technology of the existing fleet and a newer fleet than the private sector, according to registration data.

The unit factors of NO_x emissions together with the distribution of the distance covered in the city and the Ring roads offers a clear overview of the environmental effect the vehicle segment produces in emissions.

31. It should be remembered that the EURO standards which limit NO_x and PM vehicle emissions refer to a driving cycle determined by the standards themselves and are used to regulate the vehicles under the same conditions. This driving cycle does not match the real cycle in any city and therefore the EURO limits are not comparable to the real ones. In addition to this, the real values comprise different aspects such as the type of driving, vehicle maintenance, etc.

FIGURE 167 | DISTRIBUTION OF NOX EMISSIONS IN BARCELONA AND THE RING ROADS, BY TYPE OF VEHICLE (2008)

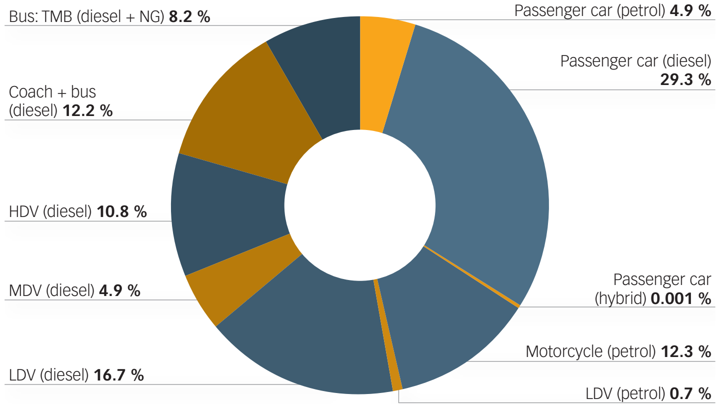


FIGURE 168 | TRAFFIC GHG EMISSIONS IN BARCELONA AND THE RING ROADS, BY TYPE OF VEHICLE (2008)

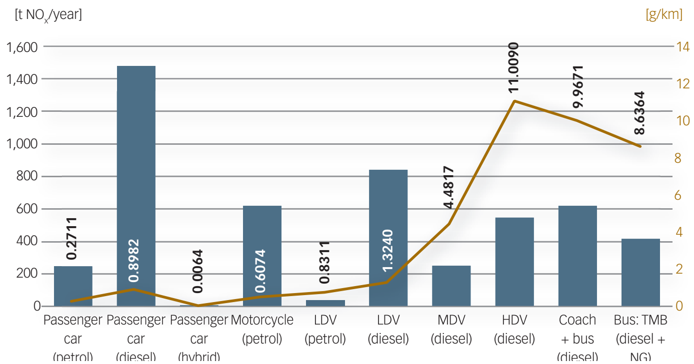
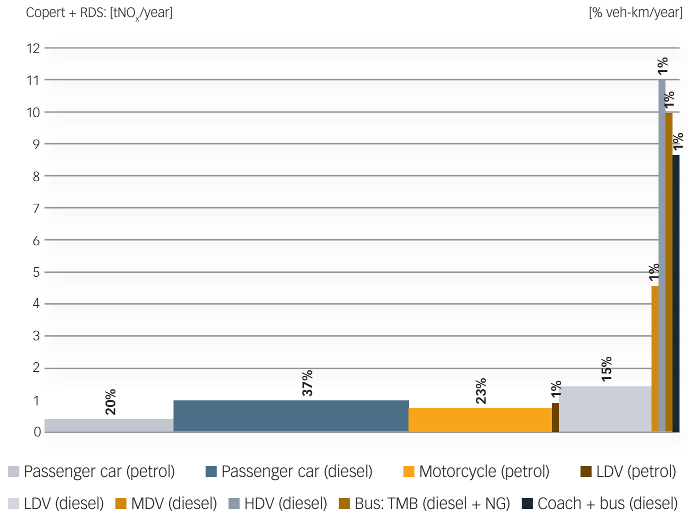


FIGURE 169 | CORRELATION BETWEEN EMISSIONS PER KM OF GHG AND DISTRIBUTION OF TRAFFIC IN BARCELONA AND THE RING ROADS (2008)



PM_{10} emissions

The distribution of PM_{10} emissions by type of vehicle differs compared to that of NO_x as the motorcycle and moped segment has a high level of emissions. Thus, passenger cars, vans and motorcycles are the main emitters of solid particles, with 39.6%, 21.6% and 16.7% respectively. Medium and heavy duty lorries (MDV and HDV), account for 8.5% of the total volume of emissions, private buses and coaches 8.3%, and TMB buses 5.3%.

The average weighted traffic emission factor in Barcelona and the Ring roads in 2008 was 0.1032 g PM_{10}/km. As occurs with NO_x, the average emissions of PM_{10} from diesel cars are 2.7 times higher than petrol versions. The motorcycle and moped segment also shows a high rate of emissions, especially vehicles with two stroke engines, as they lack the filters to reduce particle emissions. Also, diesel vans (LCV) emit 2.9 times more particles than petrol versions per kilometre.

As regards public transport, the TMB bus fleet has lower levels of emissions per kilometre than private company buses and coaches as part of the fleet operates with natural gas (they produce 74% fewer emissions than diesel) and all the vehicles have particle filters.

Overall, diesel cars, motorcycles and vans are the vehicles which most circulate within the city and those with the highest emissions per kilometre in the lightweight category. Diesel cars are the type of vehicle with the highest level of PM_{10} emissions, followed by motorcycles and diesel vans.

FIGURE 170 | DISTRIBUTION OF PM_{10} EMISSIONS IN BARCELONA AND THE RING ROADS, BY TYPE OF VEHICLE (2008)

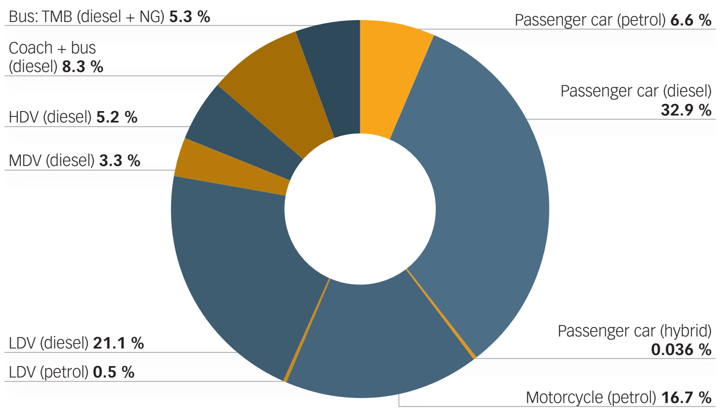


FIGURE 171 | TRAFFIC PM_{10} EMISSIONS IN BARCELONA AND THE RING ROADS, BY TYPE OF VEHICLE (2008)

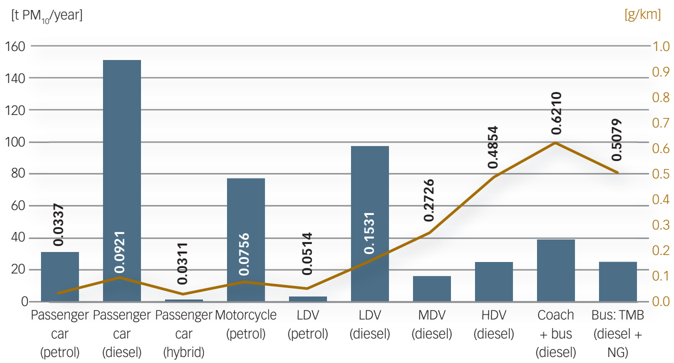
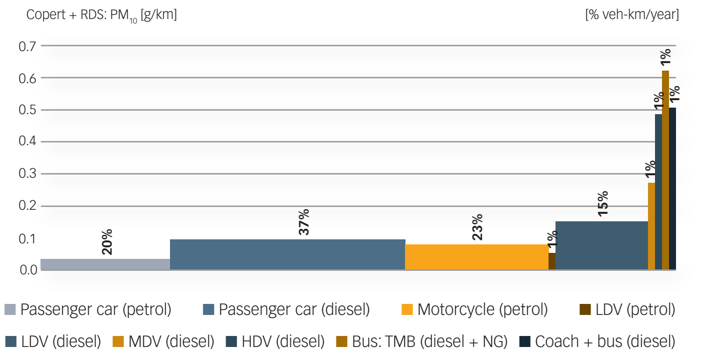


FIGURE 172 | CORRELATION BETWEEN EMISSIONS PER KM OF PM_{10} AND DISTRIBUTION OF TRAFFIC IN BARCELONA AND THE RING ROADS (2008)



THE RATIO BETWEEN MOBILITY AND EMISSIONS

If we correlate the mobility data of persons (journey stages) with local polluting emissions, the vehicle segment with the highest emissions of NOx are diesel cars. To cover 29.3% of the journey stages they need to cover 36.9% of the total kilometres, contributing 29.3% and 33.0% of NOx emissions and particles respectively.

On the other hand, TMB buses to cover 25.6% of the journey stages of the city need to cover 1.1% of the total kilometres, contributing 8.2% and 5.3% of NOx emissions and particles respectively. Collective public transport is therefore more efficient and produces lower emissions than private motor vehicles.

FIGURE 173 | DISTRIBUTION OF MOBILITY BY TYPE OF VEHICLE, JOURNEY STAGES AND EMISSIONS IN BARCELONA AND THE RING ROADS (2008)

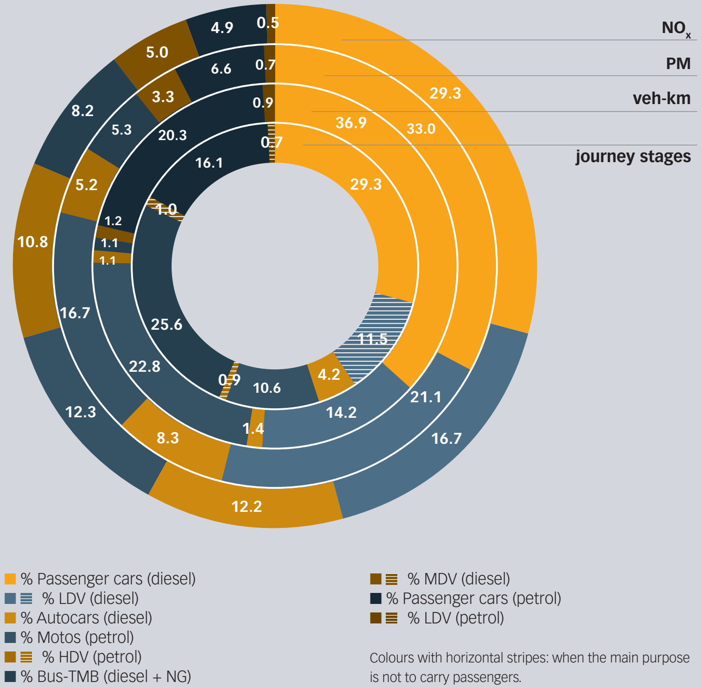
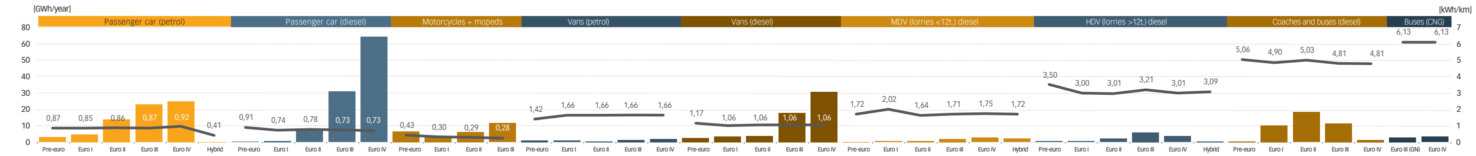
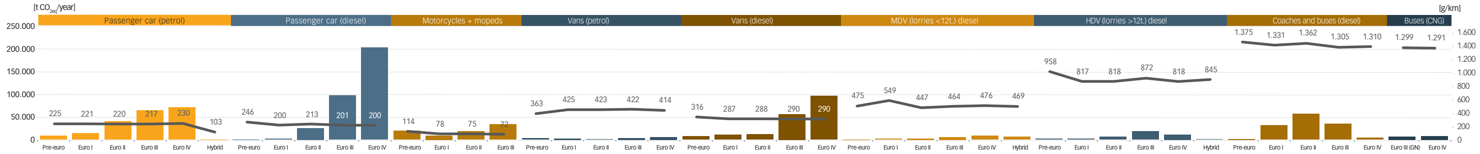


FIGURE 174 | MAP OF ENERGY CONSUMPTION AND TRAFFIC EMISSIONS IN BARCELONA AND THE RING ROADS BY TYPE OF VEHICLE AND EURO CLASSIFICATION

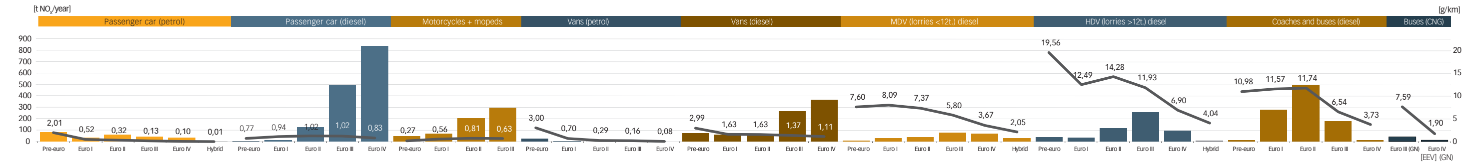
Fuel consumption (petrol and diesel) of traffic in Barcelona and the Ring roads by Euro classification (2008)



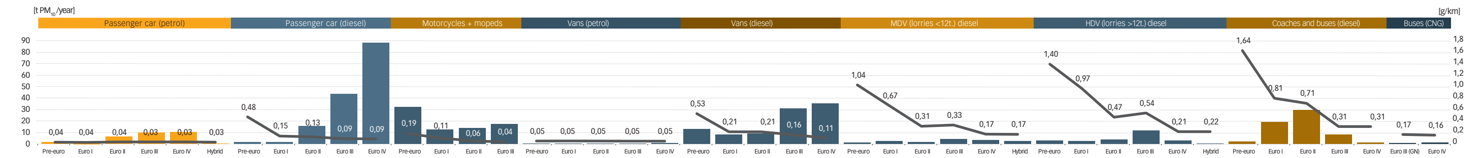
CO_{2eq} emissions in Barcelona and the Ring roads of vehicles by Euro classification (2008)



NO_x emissions in Barcelona and the Ring roads of vehicles by Euro classification (2008)



PM_{10} emissions in Barcelona and the Ring roads of vehicles by Euro classification (2008)



2.8.7 - MUNICIPAL WASTE

Waste management programmes

The collection and processing of waste in Barcelona and the municipalities within the metropolitan area conforms to the European, Spanish and Catalan laws. The chief legislative reference point is Directive 2008/98/CE which sets forth the measures aimed at environmental and health protection via prevention, reduction of generation and suitable processing of waste.

The Metropolitan of Hydraulic Services and Waste Treatment (EMSHTR) is responsible for treating the waste from Barcelona and the other municipalities and it operates in accordance with the principles and aims of the municipal waste management programme 2009-2016 (PMGRM; approved by the Metropolitan Council on 8 October 2009), and by the following planning schemes of the Catalan Government:

- **Municipal waste management programme of Catalonia 2007-2012 (PROGREMIC)**, initially approved by the Governing Council of the Waste Agency of Catalonia (ARC) on 29 October 2007.
- **The territorial sectoral municipal waste management infrastructure plan of Catalonia 2005-2015 (PTSIRM)**, approved by the Governing Council of the ARC on 3 April 2009.
- **The industrial waste management programme of Catalonia 2005-2012 (PROGRIC)**, approved by the Governing Council of the ARC on 3 April 2009.

Given that the waste treatment and management is over a supra-municipal nature, it is necessary to consider future scenarios within the framework of analysis defined in the aforementioned plans and programmes. Although some of these programmes have a time horizon of 2012, the forecasts reach 2016, which has allowed the evolution of the Barcelona waste management and treatment to be projected until 2020, the final scenario of this PECQ.

Waste generation and evolution by type of collection

In 2008, Barcelona generated 887,515 t of municipal waste. The ratio of waste per inhabitant/day was 1.50 kg, lower than during the period 2002-2008, when it stood at 1.53 kg (at the end of the nineties it ranged between 1.3 and 1.4 kg/inhab-day).

The composition of the waste analysed in Barcelona is that considered in the PMGRM 2009-2016, which reports 36% of organic matter, 18% paper and cardboard, 12% containers, 7% glass and 27% other fractions, which include large size and materials recovered from refuse sites such as scrap iron, wood, rubble, special waste, electrical apparatus and appliance waste, tyres, oils, plywood, etc.

As regards selective collection, there was a significant increase until 2008 in the percentage of the total municipal waste collected, as it totalled 34% (in 1999 the figure was 12%). By fractions, the collection of organic matter increased at a rate of 27% a year, paper and cardboard by 17%, small containers by 15%, large size by 10%, glass by 9.7%, and scrap and other fractions 7% each. This increase was the result of the policies promoted by Barcelona City Council and the relevant authorities in waste management and treatment.

In 2000 a new contract commenced for the period 2000-2009 which entailed considerable improvements, both in collection and in cleaning. Until mid-2007, selective collection increased to 30% of the total municipal waste collected, a figure which in 2001 stood at 13%. Paper and cardboard was the most important fraction of selective collection by weight, followed by the organic fraction, large size, glass and containers.

During these years, commercial, selective collection of door to door markets spread and became consolidated, totalling over 30,500 businesses which were major producers of fractions or which were located in the main commercial roads and markets of the city; the fractions collected were remains or rejects, organic, glass and paper-cardboard. Refuse and the organic fraction were also collected at forty municipal markets. Commercial and door to door market collection accounted for 10% of the tonnes collected during 2006, and led to an increase in the collection of cardboard, organic matter and glass, with a relatively low level of erroneous waste.

House collection accounted for 83% of the total waste in 2006 and the collection of large size was 4%. The house waste collection model in Barcelona is carried out mostly using containers in the street for four or five fractions, according to the area of the city: remains, paper-cardboard, containers, glass and organic matter. As regards pneumatic collection, in 2007 7,147.2 tonnes of waste were collected (6,414.35 t with fixed collection and 732.85 t with mobile collection), an amount which represented 0.7% of the total waste collected; it provided this service to approximately 60,000 inhabitants.

The introduction of selective house collection of the organic matter coincided with the start of the contract in 2000, with 4,100 dual-compartment containers located in Sants-Montjuïc, Les Corts, Horta-Guinardó, Nou Barris and Sant Andreu.

As regards waste collection elements, in 2009 the city had installed almost 22,000 litter bins and 23,600 containers, of which some 7,000 were for selective collection of paper, glass and containers, some 4,200 dual-compartment containers of organic matter and remains and 12,400 only for the remains fraction. There were also 33,500 deposits in shops, shopping areas and markets in the city and 640 more for door to door collection.

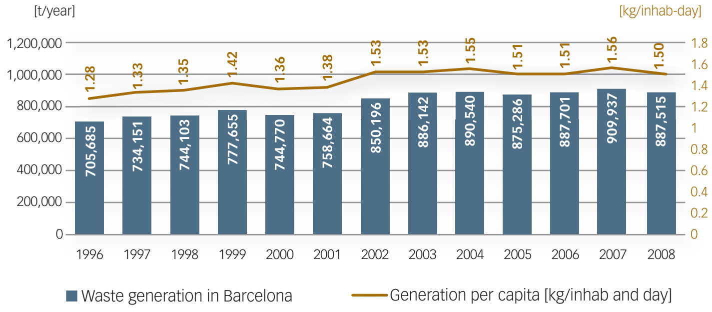
MUNICIPAL WASTE COLLECTION SYSTEMS

The systems used in Barcelona for municipal waste collection are the containers located in the streets, door to door collection and pneumatic collection. The selective collection model separates the following fractions: glass, paper and cardboard, light containers (ERE), organic matter (FORM or organic fraction of municipal waste) and the remainder (including street cleaning waste). Other fractions are collected from landfills or via the municipal collection service for furniture and old objects.
Other specific collection takes place in Barcelona with the support of entities, companies, foundations and social players with which the City Council enters into cooperation agreements (batteries, electrical appliances, paper and cardboard, clothing...).

TABLE 44 | EVOLUTION OF THE SELECTIVE COLLECTION MODEL IN BARCELONA (2000-2009)

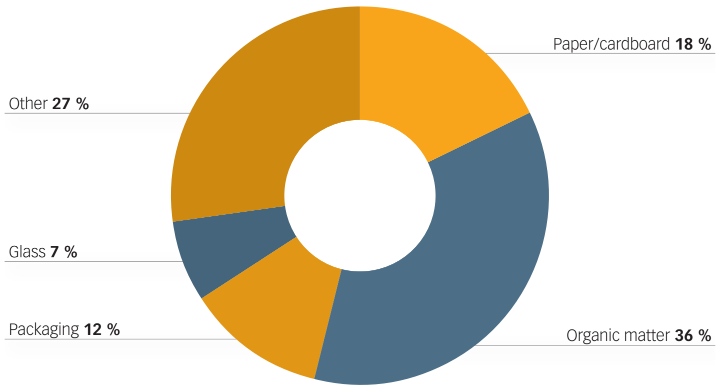
Evolution of the selective collection model in Barcelona 2000-2009		
Objectives	Where were we (2000)	Where are we now (2009)
Selective	· Fostering non-house collection services (commercial, green areas network) · Start of waste recycling · 10% of selective collection, 90% of refuse	· Consolidation of selective collection services · Waste recycling and valorisation · 34% of selective collection, 66% of refuse
Organic	Partial implementation of organic matter collection (2002)	Extension of organic matter collection, 27.5%
Inappropriate matter		31.6% of inappropriate matter mixed with organic matter in house collection
Containers	5,531 selective, 15,387 refuse	7,174 selective (3-container areas + organic matter), 4,164 two-compartment containers, 12,270 refuse
Vehicles	Functional efficiency 889 vehicles	Functional efficiency 949 vehicles (90% petrol / gasoil, 7% gas, 3% electric / hybrid)
Street cleaning	Service mechanisation	Service quality increase

FIGURE 175 | EVOLUTION OF THE WASTE GENERATION IN BARCELONA (1996-2008)



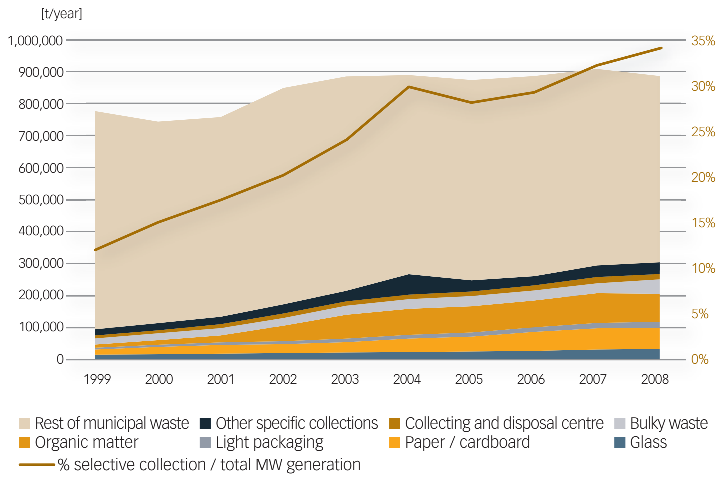
Source: EMSHTR

FIGURE 176 | COMPOSITION OF MUNICIPAL WASTE IN CATALONIA



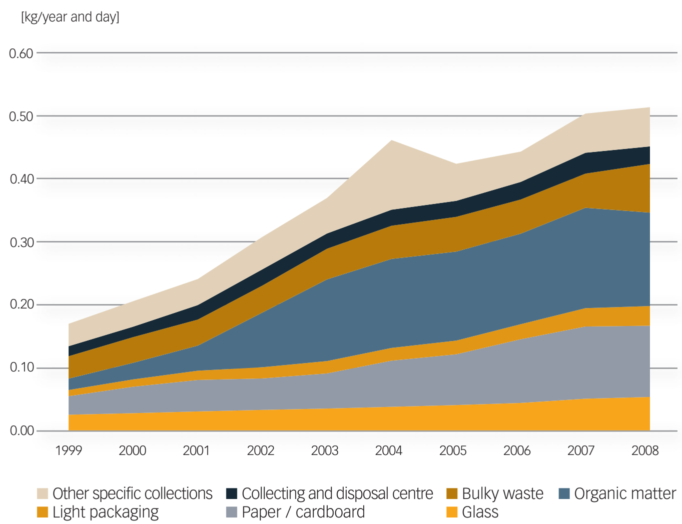
Source: PROGREMIC 2007-2012

FIGURE 177 | EVOLUTION OF MUNICIPAL WASTE IN BARCELONA, BY FRACTION (1999-2008)



Source: EMSHTR

FIGURE 178 | EVOLUTION OF SELECTIVE COLLECTION IN BARCELONA, BY INHABITANT AND DAY (1999-2008)



Source: EMSHTR

THE WASTE TREATMENT SYSTEMS AND FACILITIES

The treatment systems used on the various waste fractions and the facilities where they take place are as follows:

- Glass treatment is operated by authorised recovery companies. The material collected is crushed and the undesirable items are released to be used by manufacturers of other glass products.

- Paper and cardboard (P/C) are also treated by authorised recovery companies. Most of the fraction collected is taken to paper manufacturers or recycling plants which separate the undesirable elements to obtain clean matter with a higher commercial value.

- Light packaging (LP) is separated by fractions from plastics, metal and cartons under the agreement with Ecoembes. The selection plants are based on mechanical selection systems and have different levels of automation. The treatment facilities are the metropolitan selection plant at Gavà-Viladecans, and the temporary plants in Sant Feliu and the Zona Franca. The selected material is taken to authorised recovery facilities.

- Possible treatments for Organic matter (OM) are composting and anaerobic digestion. The composting plants (compost production) are Eco park 1, Eco park 2 and Eco park 4. Anaerobic digestion (methane production) is also performed at Eco parks 1 and 2.

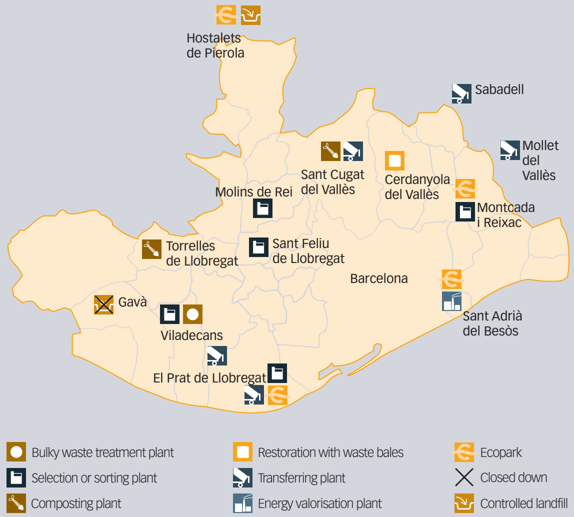
- Bulky waste (BW) is carried to the selection facility at Gavà-Viladecans, where it is classified by type for recycling (metal items, for example) or subjected to special treatment (for example, refrigerators). Certain waste is crushed for recycling or for final treatment.

- The rest, the main objective of management improvement according to the PMGRM, is fully treated for energy recovery or final disposal. The facilities where this process is carried out are Eco Parks 1, 2, 3 and 4.

As the treatment systems applied to the various fractions generate refuse, this is taken to final treatment plants: energy recovery of controlled landfill. Final treatment plants are as follows:

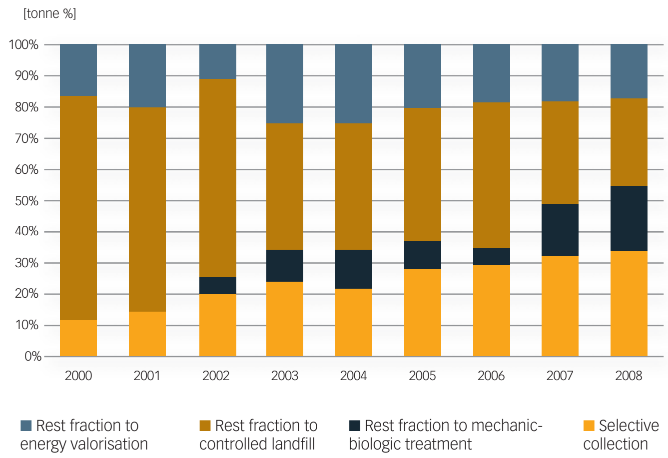
- Energy recovery plant in Sant Adrià del Besòs: Mass waste incineration facility using roller grate technology and energy recovery in the form of steam and electricity. Part of the electricity and steam are consumed by the plant itself and the rest exported. The plant has a gas and emissions scrubber system in compliance with the law.
- Controlled landfills: Can Mata, Hostalets de Pierola, Baled waste restoration of Argilera Elena.

FIGURE 179 | LOCATION OF METROPOLITAN WASTE TREATMENT INFRASTRUCTURES (JANUARY 2009)



Source: EMSHTR

FIGURE 180 | EVOLUTION OF THE DISTRIBUTION OF MUNICIPAL WASTE OF BARCELONA, ACCORDING TO TREATMENT (2000-2008)



Source: EMSHTR

▲ The percentage of waste taken to controlled landfills has fallen over recent years, mainly due to selective collection and mechanical-biological treatment (MBT), while energy recovery has remained stable throughout the period.

TABLE 45 | DIFFERENT SYSTEMS AND COMBINATIONS OF WASTE TREATMENT

Waste treatment options	
Process	Description
1- Untreated waste disposal in controlled landfill	Unsorted waste is directly disposed of in controlled landfills. Landfill gas extraction and exploitation is taken into consideration as well as sealing the landfill when closed down.
2- Mass waste energy valorisation	Mass combustion with energy recovery (electricity or electricity + heat).
3- Combining a mechanic-biologic treatment with final disposal in controlled landfill of the generated waste	Municipal waste or waste which can rot, after a mechanic separation of those that can be recovered, are digested or stabilised with a later metal separation treatment. The generated waste in the process is disposed of in a controlled landfill.
4- Combining a mechanic-biologic treatment with energy valorisation of the generated waste	Same mechanic-biologic treatment as previous one but waste now is energy valorised.
5- Composting	Aerobic process considered per fraction separated at origin (OFMSW), considering the composting options in open or closed process.
6- Anaerobic digestion	Biologic decomposition of the waste under anaerobic conditions of fractions segregated from the production of methane-rich biogas.
7- Recycling	Separation management and reuse of different fractions that can be valorised from waste disposed of in mass or selectively collected.

2.8.8 - MAJOR INFRASTRUCTURES: THE PORT AND THE AIRPORT

Barcelona Airport

Although the Prat Airport is not actually located in the municipality of Barcelona, it does offer synergies between this infrastructure and the city's production activity, with the following impacts:

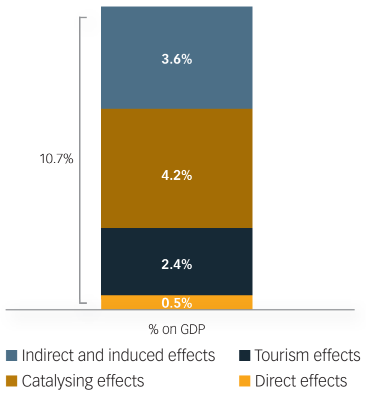
- **Direct**: Employment and economic activities generated in the airport vicinity.
- **Indirect**: Employment and revenue generated by the chain of goods and services linked to the direct activities.
- **Induced**: Employment and revenue generated by the direct and indirect impact.
- **Effects of tourism**.
- **Catalysing effects**: Employment and revenue generated in the economy due to the attraction, retention or expansion of production activities.

Of these various impacts, we should highlight those related to tourism, as 45% of the tourists arriving in Barcelona do so by plane (see section 2.1. Economic factors). In addition, this is a type of visitor with an above average level of spending; it is estimated that tourists arriving by plane spend 15% more than average (Tourist spending survey by the Ministry of Industry, Tourism and Commerce), and account for 55% of tourist spending.

The Airport also has a catalysing effect (although less concentrated) on the rest of the economy, as it contributes to increasing productivity and the internationalisation of the production system, drawing in investments thanks to the closer connections with the global economy and the reduction of transport costs. The larger the number of destinations and the more competitive the passenger prices, the more intense this effect becomes. Thus, the existence of the Airport boosts a full range of activities which would otherwise be difficult to carry out.

If we take into account all these positive impacts, the Airport is estimated to contribute approximately 10.7% of the city's economy, and a similar percentage of jobs. It is clearly essential to enable an infrastructure of this kind to lever all its potential.

FIGURE 181 | THE IMPORTANCE OF BARCELONA AIRPORT FOR THE CITY'S ECONOMY (2008)



The port of Barcelona

Another key infrastructure of the city is the Port of Barcelona which, over recent years, has progressively increased its capacity in line with the volume of activity, despite the recent decline due to the economic crisis. In 2008, the port ranked seventh in Europe for container traffic.

The new international trade routes place the Mediterranean ports in a strategic position in relation to the flows from the Far East. This situation affords the ports of Barcelona and Tarragona the opportunity to become the logistic centres of southern Europe, as is Rotterdam (with eight times the traffic) of the north.

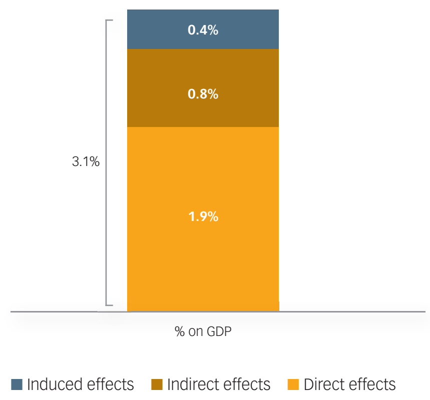
In order to be operational, a port needs two key elements: A logistic platform for the provision of port activities and a speedy, effective freight transport network. The construction of a specific goods train line and a large ancillary inland logistic zone in addition to the Zona Franca – a dry port - are fundamental to a medium to long term competitive strategy.

As regards rail connections, the FERRMED project (Great Axis Rail Freight Network and its area of influence, Ferrmed, 2009) seeks to create a major railway hub to link the Iberian Peninsula with the Scandinavian Peninsula running through the centre of Europe with full interconnection to become the chief freight transport channel of Europe. In the case of the Iberian Peninsula, FERRMED is committed to the Mediterranean axis and international gauge as core elements. This decision would boost the role of the various Mediterranean ports as logistic centres, especially that of Barcelona which would increase its competitiveness compared to the ports of Northern Europe.

As with the Airport, the Port of Barcelona is a transversal activity in the territory which entails, in addition to the direct impact on the economy, indirect, induced and catalysing effects.

In order to measure the activity created by the Port, the indicator used is the percentage accounted for by logistic activities (i.e., those generated by the Port) of the total value of the products which pass through. International studies set this percentage at 4% of the value of the goods. Thus, the Port of Barcelona as a whole represents 3.1% of the city's GDP, of which 1.9% are the result of direct activities and the remainder to indirect or induced effects.

FIGURE 182 | IMPORTANCE OF THE PORT OF BARCELONA IN THE CITY'S ECONOMY (2008)



2.9 - Future plans and projects

2.9.1 - PLANNING IN LINE WITH ENVIRONMENTAL CRITERIA

At present, cities have a great responsibility in consumption of energy, water resources, generation of emissions and waste and reveal the need to adopt measures to progress towards a more efficient, healthy model. In this respect, the new urban transformations and new districts must be planned, designed and managed in keeping with sustainability criteria, so as to reduce the consumption of material resources, water and energy and their environmental impact.

Barcelona, aware of the relationship between city planning and energy consumption (and climate change) has innovated for years when incorporating new elements into its projects, such as the centralized climate control networks or the Solar Thermal Ordinance, amongst others. It is now necessary to move beyond this and reflect on new forms of intervention and understand urban development, especially from the viewpoint of energy and its relation with the climate and air quality.

It is therefore necessary that the urban and planning projects promoted include in their priority challenges achieve the most efficient use possible of energy resources so as to minimise the global and local impact of inefficient energy consumption. The real application of this idea commences with a sound concept of the urban approach and continues with the implementation of environmental criteria in design and subsequent development.

Despite there being procedures and guidelines to enhance these aspects based on current legislation, there is yet to take place a transformation of the standards towards the optimal common criteria of the various scopes of action to be included in the planning, including energy efficiency.

In this respect, after the legal changes in construction matters, the next natural step would be a change in the way of thinking and regulating urban planning. It should be remembered that the difficulty this change entails means that it must be of a transitory nature, assessing in detail the various aspects and factors which converge (planning, social, economic, environmental and energy-related), so as to set minimum, maximum values, ranges or boundaries.

One of the aims of this PECQ is to drive and accelerate this transition towards a more aware approach to energy issues.

It is therefore necessary that the urban and planning projects promoted include in their priority challenges achieve the most efficient use possible of energy resources so as to minimise the global and local impact of inefficient energy consumption

2.9.2 - NEW PLANNING PROJECTS

Areas of action

The urban planning of Barcelona for the next ten years is heavily concentrated in what is known as the *"Eastern triangle"*, the area defined by the Av. Meridiana, Av.Gran Via de les Corts Catalanes and the river Besòs. A substantial transformation of this area is planned, both as regards the current usage and its physical configuration, as it would change from an industrial area to new residential districts. A district located at the southern tip of the city, Marina, is also undergoing the same process.

These transformation operations can be grouped by:

- **Major urban operations**: These entail changes in land use and the large scale appearance of new buildings; the end result is a radical change in the morphology of the city and they share the scale of the scope of the transformation.
- **Urban projects**: These have a lower profile but are important given their position in the urban fabric or the desire to drive the transformation of the sector where they are implemented.

All these projects will have a significant impact on energy demand and consumption in the city.

In all the planned actions, all the built-up space will be practically new, as the remodelling will entail a change from industrial to service sector and residential use. It should be borne in mind that 22@ is approximately 40% at present, and therefore only 60% is pending execution. This means that the data for the new land space in the period 2009-2020 (without the industrial sector) will be 7,173,624 m^2, of which 3,907,771 correspond to the services and facilities sectors and 3,265,854 m^2 to the residential sector, with 42,666 new dwellings.

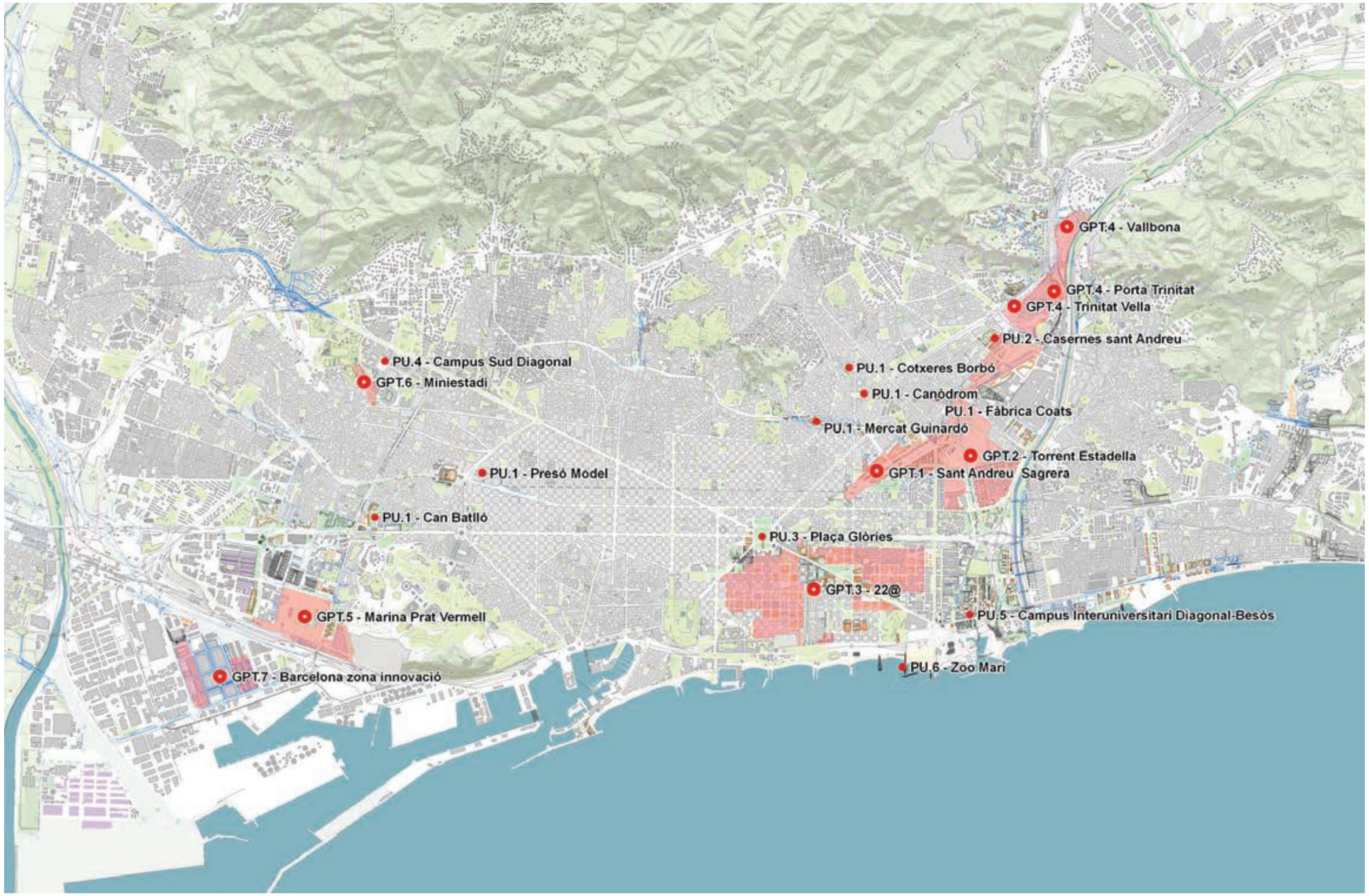
TABLE 46 | URBAN AND PLANNING TRANSFORMATION PROJECTS PLANNED FOR BARCELONA OVER THE COMING YEARS

	Project	Total area [m^2]	Green area [m^2]	Used area (built-up + street) [m^2]	Facilities built-up area [m^{2}st]	Residential built-up area [m^{2}st]	Dwellings	Tertiary built-up area [m^{2}st]	Industrial built-up area [m^{2}st]	Total built-up area [m^{2}st]
1. Large transformations										
GPT1	La Sagrera:	940,000	489,212	450,788		812,000	10,150	440,000		1,252,000
GPT2	Torrent Estadella	581,837	109,960	219,246		663,876	8,293	284,518		948,394
GPT3	22@	1,982,600	114,000	1,868,600	145,000	509,976	6,375	3,435,426		4,090,402
	Trinitat Vella	59,000	23,775	35,225		41,532	519			41,532
GPT4	Vallbona	326,000	51,561	274,439	0	169,600	2,120	0		169,600
	Porta Trinitat	37,097	3,867	33,230	6,000	6,000	75		8,508	20,508
GPT5	Marina Prat Vermell	724,692	24,396	700,296		869,237	10,865	315,420		1,184,657
GPT6	Mini estadi	159,904	29,400	130,504	11,200	145,000	1,650	8,000		164,200
GPT7	Innovation area in Barcelona	437,132	-	-		0	0	70,000	455,000	525,000
	Partial addition for transformations	**5,248,262**	**846,171**	**3,712,328**	**162,200**	**3,217,221**	**40,047**	**4,553,364**	**463,508**	**8,396,293**
2. Urban projects										
PU1	New city facilities	264,000	120,500	143,500	167,800	151,500	1,893,75	18,000		337,300
PU2	Casernes Sant Andreu	110,000	40,000	70,000	84,000	181,000	2,263			265,000
PU3	Plaça Glòries	378,019	192,169	185,850	3,000	81,000	1,013	9,000		93,000
PU4	Campus Sud Diagonal	134,100	33,479	100,621	15,000		0			15,000
PU5	Campus Diagonal-Besòs	77,332	30,875	22,546	88,606			59,660		148,266
PU6	Zoo Marí	81,785	58,756		18,434					18,434
	Partial addition for urban projects	**1,045,236**	**475,779**	**522,517**	**376,840**	**413,500**	**5,169**	**86,660**	**0**	**877,000**
Total		**6,293,498**	**1,321,950**	**4,234,845**	**539,040**	**3,630,721**	**45,216**	**4,640,024**	**463,508**	**9,273,293**

TABLE 47 |

	Project	Facilities built-up area [m²st]	Residential built-up area [m²st]	Dwellings	Tertiary built-up area [m²st]	Total built-up area excluding industrial [m²st]
1. Large transformations						
GPT1	La Sagrera:		812,000	10,150	440,000	1,252,000
GPT2	Torrent Estadella		663,876	8,293	284,518	948,394
GPT3	22@ [pending 60%]	87,000	305,986	3,825	2,061,256	2,454,241
GPT4	Trinitat Vella		41,532	519		41,532
	Vallbona	0	169,600	2,120	0	169,600
	Porta Trinitat	6,000	6,000	75		12,000
GPT5	Marina Prat Vermell		869,237	10,865	315,420	1,184,657
GPT6	Mini estadi	11,200	145,000	1,650	8,000	164,200
GPT7	Innovation area in Barcelona		0	0	70,000	70,000
	Partial addition for transformations	**104,200**	**3,013,231**	**37,497**	**3,179,194**	**6,296,624**
2. Urban projects						
PU1	New city facilities	167,800	151,500	1,893,75	18,000	337,300
PU2	Casernes Sant Andreu	84,000	181,000	2,263		265,000
PU3	Plaça Glòries	3,000	81,000	1,013	9,000	93,000
PU4	Campus Sud Diagonal	15,000		0		15,000
PU5	Campus Diagonal-Besòs	88,606			59,660	148,266
PU6	Zoo Marí	18,434				18,434
	Partial addition for urban projects	**376,840**	**413,500**	**5,169**	**86,660**	**877,000**
Total (excluding industrial)		**481,040**	**3,426,731**	**42,666**	**3,265,854**	**7,173,624**

FIGURE 183 | MAP OF FUTURE URBAN DEVELOPMENTS IN BARCELONA



The Strategic Residential Area of Vallbona

This new district has been planned from a global viewpoint because it includes criteria for sustainability and reduction of the environmental impact from the initial design and conceptualisation stages.

The Strategic Residential Area[32] of Vallbona is an urban transformation project with a surface area of 32.6 ha which will lead to the creation of 2,120 dwellings. This SRA is located on the municipal boundary between Barcelona and Montcada i Reixac and the right bank of the Besòs. It is surrounded by major road, rail and service infrastructures which create a physical barrier that has given rise to problems accessing its surroundings, together with certain structural shortcomings in collective transport.

The future Vallbona district will be built in line with environmental and energy efficiency criteria, optimising the use of local resources (land, water, green areas and waste) and minimising their emissions, while increasing the quality of life and fostering respect for the natural surroundings. To comply with the general criteria set forth, specific objectives have been defined for the various vectors: Mobility, energy and service infrastructures, green spaces and agricultural zone, water and waste and public space and social environment:

- **Objectives of the mobility vector**: To streamline the mobility flows; recover public space for the citizens; enhance the connectivity with the urban fabric of the rest of the city (especially Trinitat Vella and Montcada); reduce the use of private vehicles.
- **Objectives of the energy vector and service infrastructures**: Minimise the energy demand per inhabitant in the building sector, use renewable energies maximising local energy sources; streamline service infrastructures.
- **Objectives of the green spaces and agricultural zone vector**: Conserve the agricultural mosaic as a distinctive landscape features; boost the Rec Comtal as a structural hub; conserve and recover local biodiversity; design new green spaces in line with sustainability criteria; introduce a participative management model in non-professional kitchen gardens.
- **Objectives of the water and waste vector**: Streamline the water cycle; diversify the supply sources; adapt the quality to the use made and take advantage of local resources; maximise selective waste collection; meet the demand for compost in the agricultural zone from the plant closest to Vallbona.
- **Objectives of the public space and social environment vector**: Create a quality public space, integrated with the current town centre of Vallbona; foster the wealth of relationships in public areas.

Urban processes follow a cyclic progression which undergoes several stages. Once the planning has been defined for a new area, this reveals itself in the architectural design and construction of the space. After completion, the management of the district is essential for it to function correctly and to progress in achieving the planned objectives. In the case of the SRA of Vallbona, this entails grouping the activities into three proposed stages: Actions during the planning stage; in the architectural design and construction stage and in the management stage.

Some of the thirty-four actions included in the planning stage are as follows:

- **Mobility**
  The road and collective public transport are improved; spaces are defined lending priority to pedestrians and cyclists; a network of bicycle lanes is created inside the district connected with the current network and the distribution of parking spaces for private vehicles is determined with the aim of recovering space for people and achieving a reduction in private vehicle use.
- **Energy and Infrastructures**
  The energy demand of the buildings is minimised by means of different strategies, including that of achieving a very high Solar Capacity Index[33] (SCI) in most directions and buildings, with an average of 84% during

32. The Strategic Residential Areas (SRA) are an urban feature created as an emergency measure by the Catalan Government, for the purpose of compensating the lack of residential land. The chief objective of the SRAs is affordable dwellings, including sustainability criteria in their urban development.

33. The Solar Capacity Index (SCI) is an indicator which measures the hours of direct sunlight on the building island compared to the ideal maximum of a building island (without its own shade or that of the surrounding buildings).

the summer months and 65% in winter thanks to the general orientation of the district following the north-south axis and the large number of blocks having facades facing southeast and southwest.

To reach this solution it was necessary to analyse and model the amount of solar radiation of the various layouts and shapes which have, by using the most appropriate modifications, obtained an optimal result for the dwellings from an energy and natural lighting viewpoint. The radiation has also been analysed during summer to detect the facades which require a solar protection system to avoid or reduce the demand for cooling, with the aim of residential buildings not requiring any cooling system. Cross-ventilation of the future dwellings is also maximised as the plan includes a distance between them of 13 m and by limiting the maximum distance to 16 m, in addition to taking into account the heat island effect.

The use of autochthonous energy resources is prioritised, such as solar radiation, while introducing solar thermal capture systems which exceed the levels provided in the Ordinance. In addition to covering a large part of the demand for hot water, heating and climate control are also covered by means of 10,570 m^2 of solar thermal vacuum panels (approximately double that provided in the Ordinance, with flat panels). These panels would occupy 36% of the total surface area of the roofs of the district (48% of the useful available surface area) and be connected to the centralized climate control system of the district. Overall, solar coverage would account for practically 72% of the total thermal energy for heating and cooling of the buildings, which would signify a primary energy saving of 58% compared to the conventional solution (and therefore a saving of 58% of GHG emissions). This system has helped to achieve the objective for the district in its entirety in which newly-constructed buildings obtain an energy certificate of the TBC of at least level B in 90% of the buildings and level A in the remaining 10%. Additionally, acoustic panels will be installed and facades given special treatment to reduce the noise from the nearby motorway.

- **Green spaces and agricultural zone**

  It is proposed to conserve the maximum surface area of the current agricultural mosaic, as Vallbona has the last remaining agricultural areas of Barcelona which have been conserved for their intrinsic characteristics. The total surface area is 2.4 ha.

  The Rec Comtal is also promoted as the structural axis of the SRA (now that it has been recovered as an important element of the cultural heritage of the city) and green spaces are designed from a sustainable viewpoint.

- **Water and waste**

  Suitable sources are diversified for each specific use, analysing the various supply and exit points, the various possible networks (rain, waste and underground), and the other elements available (tanks), and including in the water cycle reutilisation systems of grey waters and efficient consumption systems.

  One proposal is to create a separate rainwater network, connect to the underground network, continue to utilise the water from the Rec Comtal for irrigation purposes and build rainwater regulation tanks (antiDSU or Unitary Discharge Systems and rain-underground water tanks).

  Another proposal is to relocate the Punt Verd (collection point) of the area and build a multifunctional Eco-landfill to foster correct waste management.

- **Public space and social environment**

  To create a higher quality public space and reduce the effect of the various infrastructures near to the SRA, acoustic screens are planned for roads and railway lines.

  Guidelines have also been defined for the use of street furniture using environmental criteria, such as the prioritisation of low impact materials.

Project 22@ and the new strategic axes

The aim of the urban renovation programme of the 22@ is to promote the service sector transformation of Poblenou, after over one hundred years acting as the industrial driver of Barcelona. The area in question is 198 hectares in extension.

The project commenced in 2000 and has seen swift urban management. The area to be developed is some 198 hectares (1.98 million m^2) which has been allocated a buildable potential of up to 4 million m^2, of which over 80% corresponds to economic activities. The activities are selected via a specific planning regulation so as to transform the area into an international platform in the creation and development of an innovative corporate fabric.

The execution of project 22@ commenced with little or underused industrial land 100% privately owned with part still to be developed. Via urban planning, urban management, infrastructure and refurbishment planning, in 2007 a compact model for the city was achieved, together with high added value and more jobs in knowledge intensive activities.

Faced with the low density of traditional industries, a decision was made to create a dense, complex urban area. The increased buildability gives rise to capital gains which are the driver of the transformation, as virtually all of the land is under private ownership.

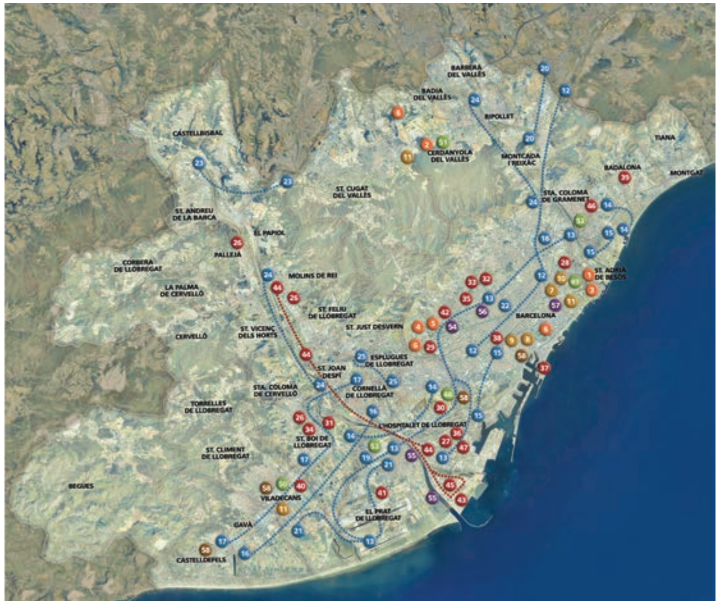
The facilities of the 7@ are the solution of project 22@. 10% of the transformed land is expected to pass into public ownership and be earmarked for training, research and dissemination activities relating to new technologies. This system is expected to create 145,000 m^2 of new facilities, which will attract corporate activities, areas for new employment, local development agencies, etc. A study conducted by the Economics Institute of Barcelona which analyses the introduction of economic activities reveals that over half of the two thousand companies registered at the end of 2007 had been set up in the period 2000-2007 and had created 25,800 jobs.

Service companies have displaced industrial firms, which were predominant until the end of the nineties. Within the services sector, the activities of 22@ gained in importance to slightly over 50% of the total as from 2005. At present, over 90% of the companies were established subsequent to 1980. Of the 40,000 persons working there, 65% belong to the service sector and 24.7% to the manufacturing sectors, basically pre-existing companies. As the final objective is to reach 130,000 employed, it has already covered a third of its corporate evolution. From the beginning, clustering, specialisation and innovation policies have been introduced to boost the convergence of science, technology and business.

The renovation work on the Zona Franca estate continue the 22@ model. The creation of the corporate Barcelona Zona Innovació platform (with the participation of the Consortium of the Zona Franca) seeks to reconvert this area by promoting activities based on knowledge and technology.

To achieve this, agreements have been entered into with companies from three key sectors: science, food and audiovisual, with the aim of creating 400 new companies and some 20,000 jobs. The 3,000 million euro investment in development, the proximity to the Port of Barcelona and the Airport and the connection with the metro service are key factors in the promotion of this area.

FIGURE 184 | STRATEGIC PROJECTS PLANNED IN THE STRATEGIC METROPOLITAN PLAN OF BARCELONA



▲ 22@ plays a core role in the transformation of the production activities of the city, which include the proposals for the Vallès (Sincrotró, Parc Tecnològic, Projecte Alba, Parc de Recerca de la UAB) or the measures in Hospitalet along the Gran Via Axis which also consolidate this change in production model during the period 2010-2020.

The future district heating and cooling networks

Barcelona is firmly committed to district heating and cooling networks using residual or renewable energy (see section 2.3.3. Efficient production systems). There is currently a DHC network in the Llevant area (under expansion), which uses the residual heat from the waste recovery-to-energy plant in the Besòs.

Barcelona City Council has also promoted the introduction of a climate control plant and district heating and cooling network in the Zona Franca and the La Marina del Prat Vermell. The scope of the concession also takes in part of the municipality of Hospitalet. Although this project is still at the construction stage, it can be considered complete as regards the planning and concept as such.

This project, under construction since the start of 2010[34], entails building and installing an energy plant in the Zona Franca of Barcelona connected to a new heating and cooling network which would supply energy to the Zona Franca in Barcelona and Hospitalet de Llobregat. The project rests on two fundamental pillars from the viewpoint of energy generation by using efficient systems of residual and renewable energy:

- Construction of a recovery plant for the biomass obtained from the green waste from park and garden maintenance and conservation in Barcelona (together with forest biomass from other available sources) with which to generate electricity and heat.
- By taking advantage of the residual cold from the Regasification plant in the Port of Barcelona, which is generated from the liquefied natural gas shipped in when it passes from a liquid to a gaseous state. This LNG arrives at very low temperatures and very high quality cold can therefore be recovered which can be used not only for climate control but also for industrial uses.

34. Certain facilities which form the system as a whole are scheduled to come into service at the start of 2011.

It should be noted that, unlike other climate control systems in the city, this network is expected to supply not only service sector buildings but also residential buildings, and is even intended to be the chief supply for the Barri de la Marina.

The connection to the climate control network will not release the buildings from the obligation to comply with the solar thermal Ordinance; on the contrary, efforts will be made to integrate these renewable generation systems within the network to optimise their use. Thus, it is expected to implement a total of some 13,000 m^2 solar thermal panels in the Marina as a whole with the ensuring saving of primary energy and emissions.

When the project is fully implemented, this system will account for a primary energy saving of 67,060 MWh/year and a reduction in emissions of CO_2 of 13,412 t/year compared to conventional climate control systems.

TABLE 48 | PLANNED NETWORK IN THE PONENT

DHC planned grid in the Ponent area	
Planned grid length [km]	8-10
Expected heating power subscribed [kW]	90,000
Expected cooling power subscribed [kW]	94,000
Expected heating power installed [MW]	47*
Expected cooling power installed [MW]	75**
Expected biomass-based electricity power [MW]	1.3
Expected heating demand [MWh/year]	57,500
Expected cooling demand [MWh/year]	62,500

* 12 MW in the Marina Plant and 35 MW in the Zona Franca Plant.
** 24 MW in the Marina Plant, 21 MW in the Zona Franca Plant and 30 MW to the cold recovery system of the regasification plant.

FIGURE 185 | DEVELOPMENT OF THE NETWORK OF THE ZONA FRANCA AND THE MARINA DEL PRAT VERMELL

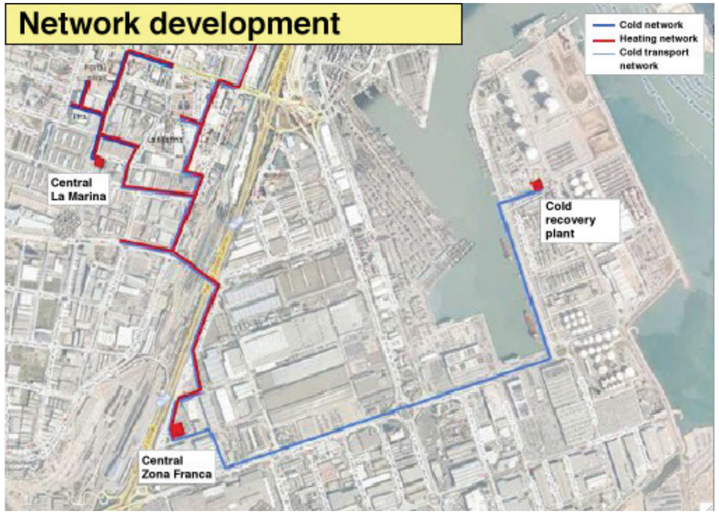
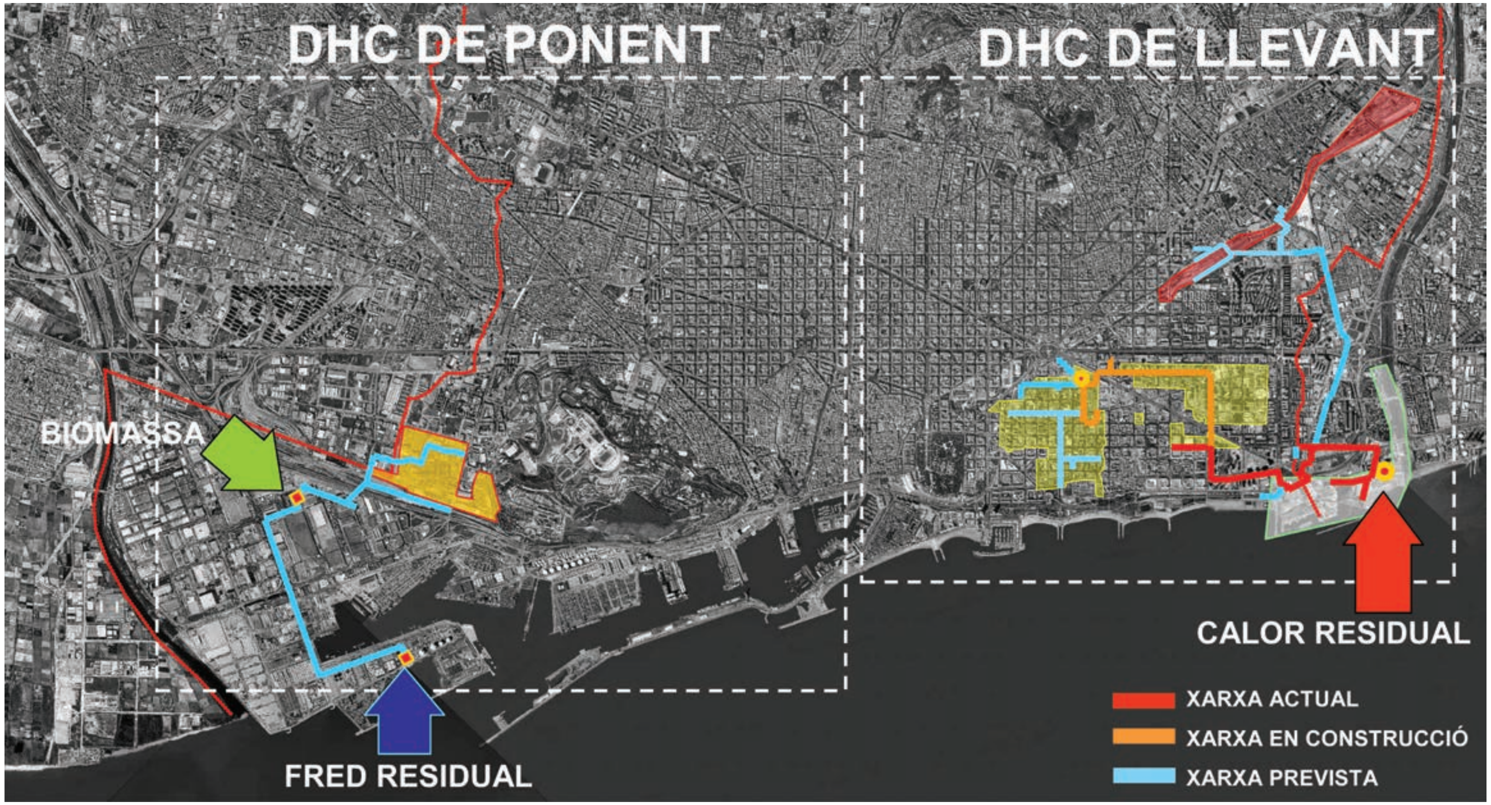


FIGURE 186 | THE DISTRICT HEATING AND COOLING NETWORKS IN BARCELONA



2.9.3 - TRANSPORT INFRASTRUCTURES

The strong increase in demand for mobility in the Metropolitan Region of Barcelona over recent years has given rise to certain dysfunctions caused by the increase of private motor vehicle use for daily travel such as the increase in polluting emissions from energy consumption and road congestion problems.

This increased mobility, due largely to the decentralisation of the population and of economic activities since the seventies-eighties, has encouraged intermunicipal travel, thus increase average travel distances in private vehicles to the detriment of non-motorised means or collective public transport.

Given this context, over recent years there has been a firm decision to achieve a modal change towards more efficient, sustainable mobility, enlarging the public transport network, introducing streamlining measures for private vehicle use (especially parking policies), and utilising strategic planning instruments for mobility purposes.

The planning of the public transport network

The chief public transport network planning programme of the Metropolitan Region of Barcelona is the Infrastructure Master Plan (PDI), approved in 2002 for the period 2001-2010, and revised and updated in 2009 for the period 2009-2018.

The revision of the PDI shaped a new investment programme, while continuing with the proposals of the previous plan and now proposes new measures which require promoting until 2018. This will bring to completion the most important investment programme in public transport of recent years.

The PDI 2009-2018, prepared in conjunction with the territorial metropolitan plan and the PITC (which also includes proposals for the local transport plan[35]), expects to invest 25,242 million euros in enlarging , modernising and improving the public transport network in the Metropolitan Region until 2018. It includes new measures and also others which were included in the previous IMP, leading to the construction of:

- FGC, metro and tram: 158 new kilometres of railway and 173 stations and modernising and improving the current network.
- National railway network: 202 new kilometres (including duplications) and 44 stations and modernising and improving the current network.
- Improving the existing connections.
- 12 ride & park centres in FGC and 46 in the local network.
- Various HOV bus lanes (high occupancy vehicles).

All these measures are planned to provide service for 1.4 million new daily public transport users throughout the RMB.

The action planned for Barcelona and the core of the metropolitan area signify almost doubling the metro network and connecting the two tram networks, providing extra accessibility to different points within the territory which lacked then and creating a true integrated transport network. This measure, together with the improvement and enlargement of the FGC lines, the local rail system and bus service create a scenario which will boost modal passenger flows towards collective public transport both for internal journeys and connection journeys.

35. The Local Railway Plan, drawn up by the Ministry of Public Works and approved in 2009, is the document which defines and programmes the measures in the local railway network. It provides for an investment of 4,000 million euros. The overall objectives of the Plan are to increase service quality via the modernisation of the infrastructure, increase the transport capacity by enlarging the current network, more daily ring routes and higher capacity trains; and the optimisation of the service system with a new operating plan for the network.

FIGURE 187 | LENGTH OF THE METRO, TRAM AND FGC NETWORKS IN BARCELONA

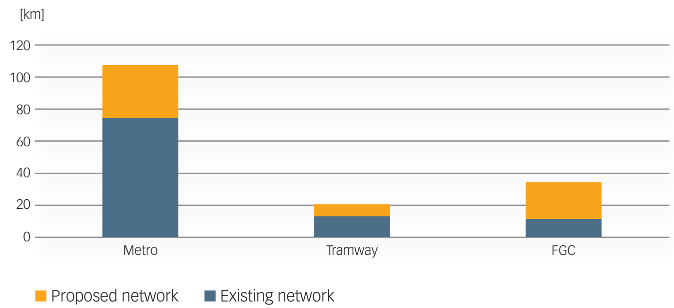
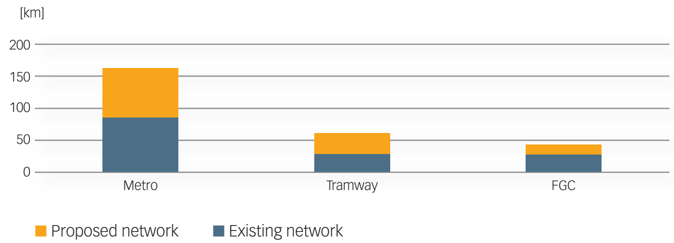


FIGURE 188 | LENGTH OF THE METRO, TRAM AND FGC NETWORKS WITHIN THE SCOPE OF THE METROPOLITAN TRANSPORT COMPANY



Mobility planning

In June 2003, the Catalan Parliament approved the Mobility Law, the chief point of reference in mobility planning, to work towards a new, more sustainable, safe and efficient mobility model which prioritises collective means of public transport and those with a low environmental and social impact, such as journeys on foot or bicycle.

This law provides various planning instruments which in Barcelona take the form of the Mobility Master Plan (PDM) of the Metropolitan Region of Barcelona, drawn up by the ATM, and the Urban Mobility Plan of Barcelona (PMU), drafted by Barcelona City Council, together with the new Infrastructures Master Plan (PDI). The PDM, definitively approved in 2008, sets out guidelines for action in the field of mobility management in RMB with the aim of creating this new mobility model and it is now the framework document in which various measures are proposed, which specific instruments, such as the PMU of Barcelona are to include.

As regards the specific contents of the Barcelona Mobility Plan, this document proposes undertaking an ambitious change in the mobility patterns of the city so as to achieve a significant reduction in greenhouse gas emissions and local pollutants (NO_x and PM_{10}), and to ensure mobility with tolerable levels of traffic congestion. In short, the aim is to shape a mobility model in which the public transport network and journeys on foot and bicycle absorb approximately 95% of the increase in mobility expected for 2018; some 2.4 million journeys.

In order to reverse the current trend, the PMU proposes a reduction in the use of private means of transport and fostering the share of *"eco-mobility"* (on foot or bicycle) so as to achieve a new modal distribution by 2018: 35% on foot or bicycle, 38% by collective public transport and 27% by car. To achieve this aim, measures will be necessary in the following areas:

In internal journeys:
- Increase mobility on foot or bicycle by over 50% (1,200,000 journeys).
- Increase the use of public transport (400,000 journeys).
- Reduce private transport mobility by 9% (100,000 journeys).

In connection journeys:
- Increase the use of public transport by 70% (800,000 journeys).
- Contain journeys in private vehicles.

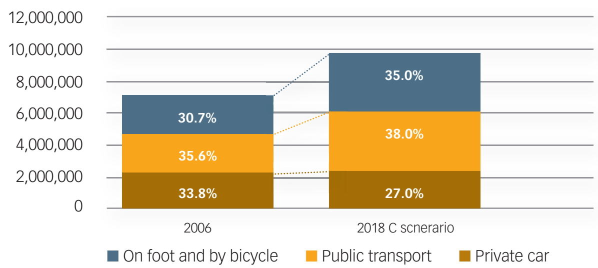
From the socio-environmental viewpoint, achieving these objectives will signify:
- An increased importance of public, non-motorised passenger transport of up to 73%.
- An increase in public transport of up to 38% of the total.
- A reduction in mobility energy consumption per inhabitant of 11.49% compared to 2006.
- Reduce carbon dioxide emissions by 27.03%.
- Reduce fatal casualties in road accidents by 25%.

TABLE 49 | ESTIMATION OF THE PROGRESS OF THE EXECUTION OF THE TRAM, METRO AND FGC NETWORKS

	Municipality de Barcelona				EMT			
	Existing network		Proposed network		Existing network		Proposed network	
	Length [km]	Stops [n]	Length [km]	Stops [n]	Length [km]	Stops [n]	Length [km]	Stops [n]
Tramway	14	27	6.7	10	29	56	36	40
Metro	74	93	36	42	86	121	77	80
FGC	13	21	18	16	23	26	18	18
RENFE					467*	107*	202*	44*

*data extending to the whole of the Metropolitan Region of Barcelona

FIGURE 189 | TARGET MODAL DISTRIBUTION OF THE PMU OF BARCELONA



Source: Barcelona City Council

FIGURE 190 | MAPS OF THE FUTURE RAILWAY INFRASTRUCTURES IN BARCELONA

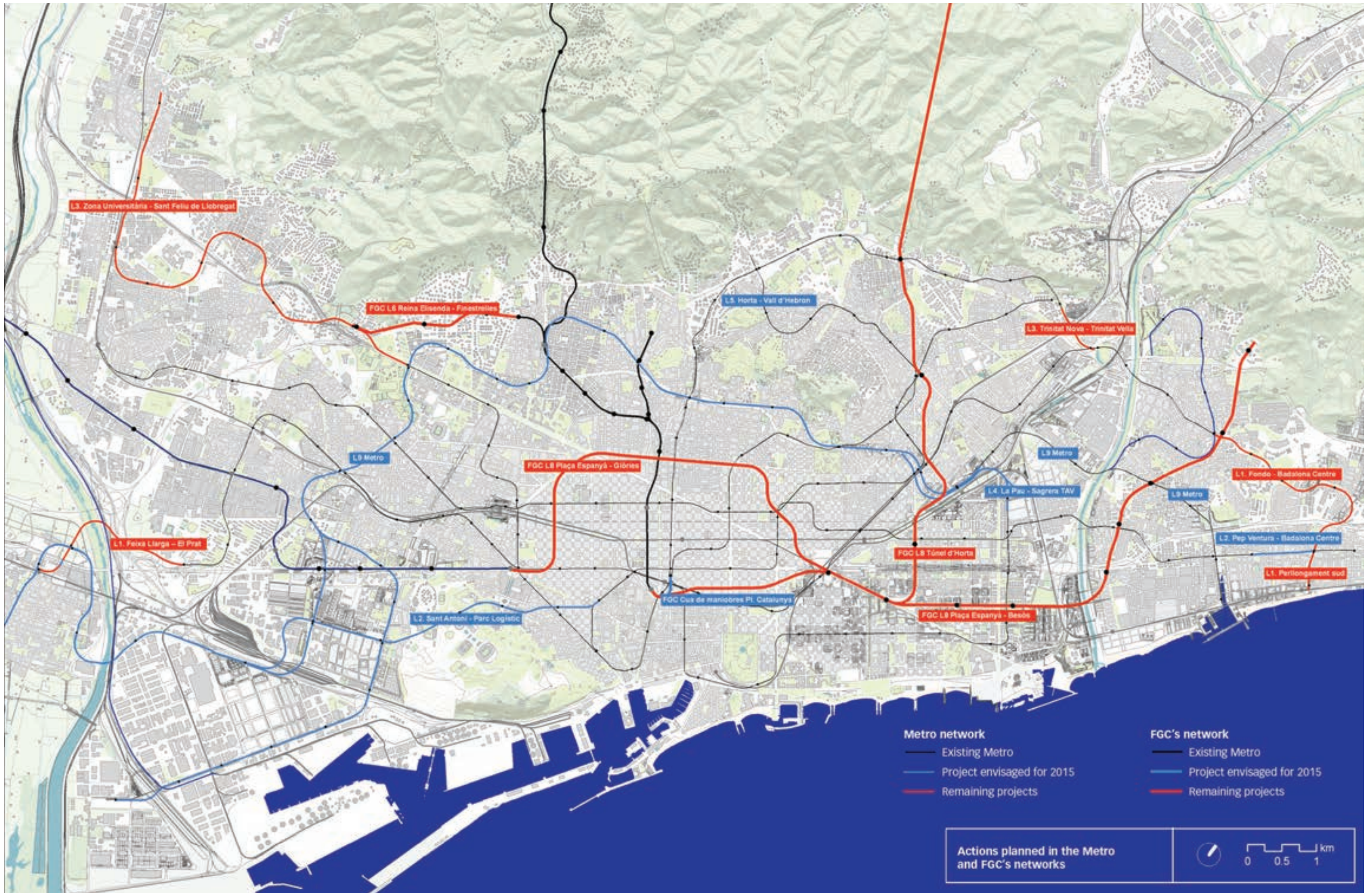


FIGURE 191 |

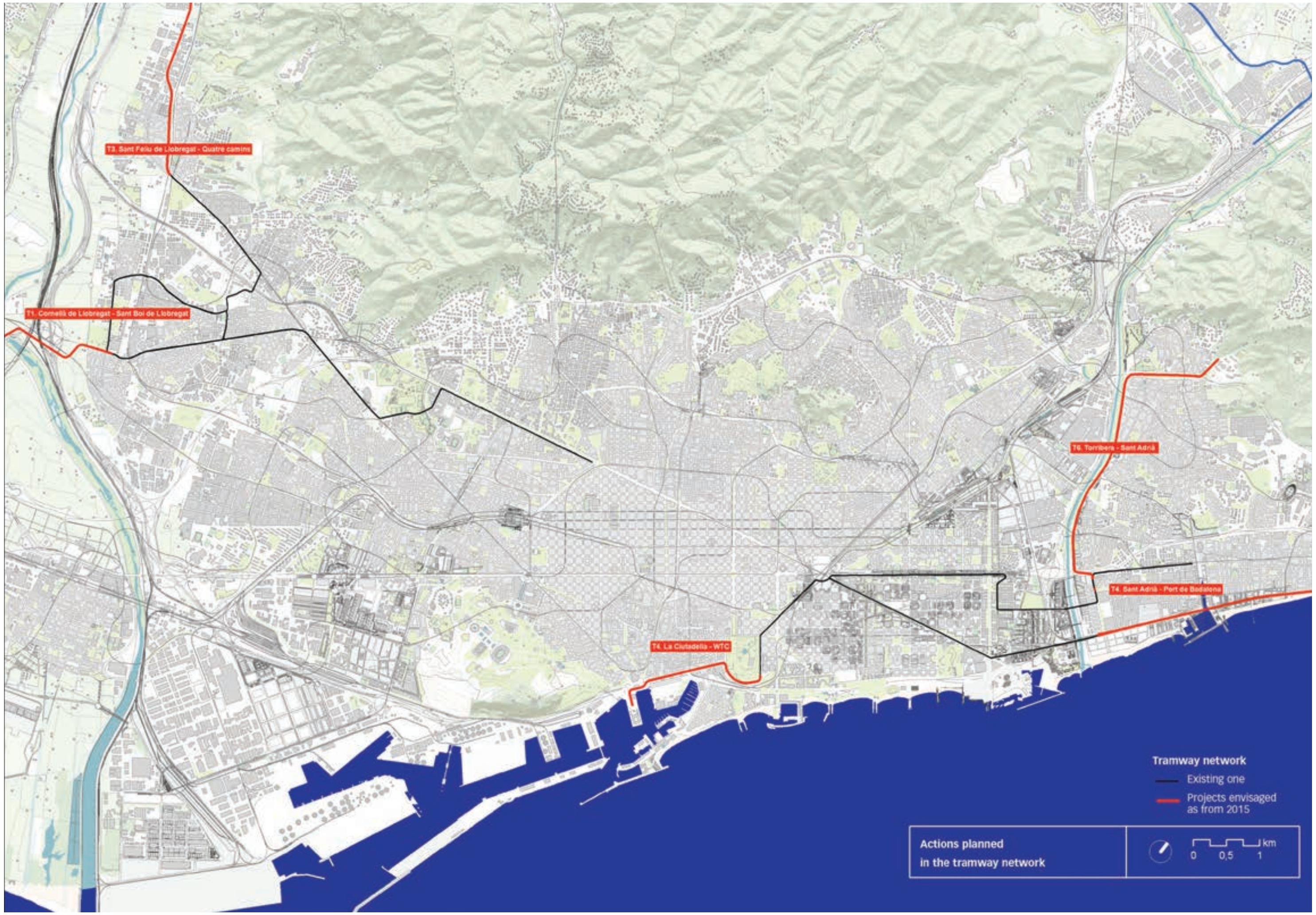
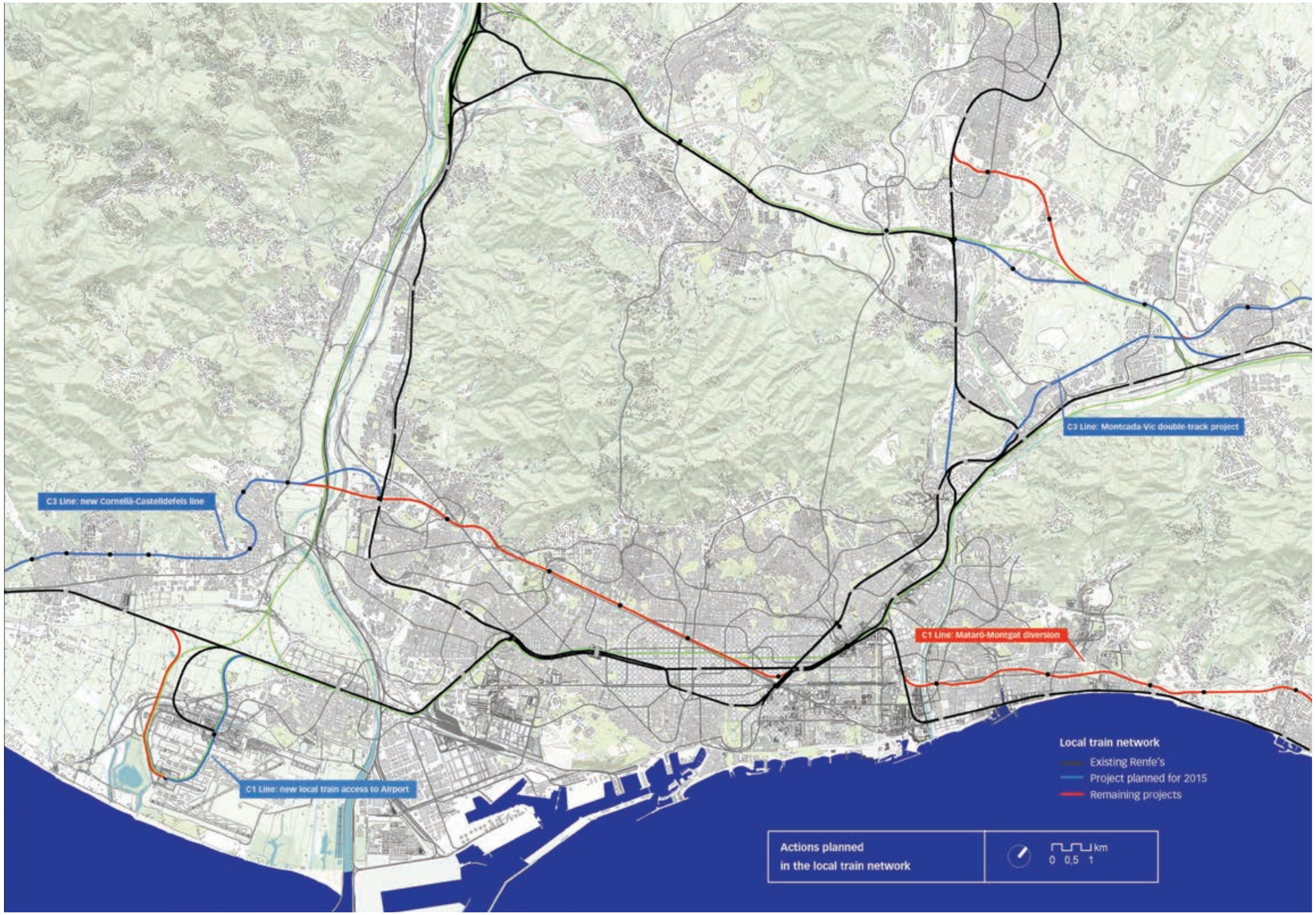

T3. Sant Feliu de Llobregat - Quatre camins
T1. Cornellà de Llobregat - Sant Boi de Llobregat
T6. Torribera - Sant Adrià
T4. Sant Adrià - Port de Badalona
T4. La Ciutadella - WTC
Tramway network
Existing one
Projects envisaged as from 2015
Actions planned in the tramway network
km
0
0,5
1

FIGURE 192 |


C3 Line: new Cornellà-Castelldefels line
C3 Line: Montcada-Vic double-track project
C1 Line: Mataró-Montgat diversion
C1 Line: new local train access to Airport
Local train network
Existing Renfe's
Project planned for 2015
Remaining projects
Actions planned
in the local train network
km
0 0,5 1

2.9.4 - WASTE TREATMENT INFRASTRUCTURES

The Facilities Plan of the Metropolitan Municipal Waste Management Programme 2009-2016 (PMGRM) is the document which proposes the interventions to be carried out over this period with regard to waste management and treatment facilities in the territory. The measures planned are as follows:

- Measures regarding the current facilities:
  - Different actions aimed at the Eco parks 1 and 2 to maximise their MWOF treatment capacity (municipal waste organic fraction).
  - Different actions regarding Eco park 1 to adapt the facility to its educational function.
  - Improvements to the adaptation of the Waste-to-Energy Plant (WEP) to equip it with the capacity to recover the refuse from eco parks.
- New proposed facilities
  - Two mobile disposal sites and promotion of fixed disposal sites.
  - Centre for private exchange of objects.
  - New metropolitan selection plant of LP (light packaging).
  - New metropolitan plant for bulky waste treatment.
  - New refuse treatment plant (non-treated flows).
  - Enlargement and modernisation of the energy-to waste function and other measures to treat surplus refuse not treated in the WEP.
  - Baled waste quarry restoration.

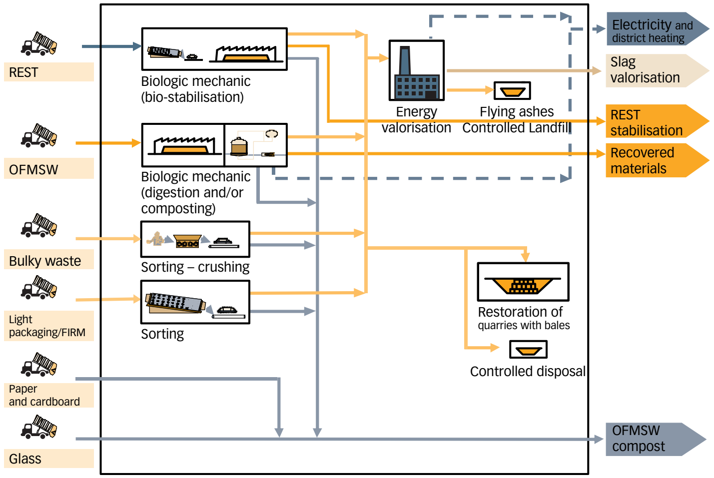
These new facilities, together with the measures set forth in the Municipal Waste Management Programme of Catalonia 2007-2012 (PROGREMIC), are in line with the objectives to be achieved in selective collection contained in the scope of the same Catalan programme.

TABLE 50 | ENERGY-TO-WASTE OBJECTIVES AND OTHER OBJECTIVES OF PROGREMIC 2007-2012

Energy-to-waste objectives of PROGREMIC 2007-2012	
MO	55%
P/C	75%
Glass	75%
ERE	25%
Other	25%

Other objectives of PROGREMIC 2007-2012	
Other	40% of selective collection
RVOL	20% of material valorisation
Batteries	25% of selective collection
RAEE	Royal Decree 208/2005 objectives

FIGURE 193 | OVERALL MODEL OF WASTE TREATMENT OF THE EMSHTR



Source: EMSHTR

For each of the different basic fractions, and in keeping with the objectives of the Metropolitan Municipal Waste Management Programme (PMGRM).

THE NEW WASTE COLLECTION MODEL

In 2009, the City Council promoted a new contract for cleaning and waste management for the period 2009-2017 which boosted selective collection and reduction of the refuse fraction. It increases the number of containers for paper, glass and packaging by over 50% and organic collection is rolled out to the entire city with a separate container to minimise the percentage of undesirable material.

It also supports the environmental commitment to improve the efficiency and effectiveness of the processes and move forward in utilising resources which have not completed their lifecycle. It also proposes using loss polluting fuels for the vehicle fleet (biodiesel, natural gas, hybrid technology, electrical) and increasing the use of water from alternative resources not suitable for human consumption (underground water), reduce the noise level and make progress in leveraging the available technological enhancements.

The new contract simplifies the disposal of municipal waste in containers (especially in selective collection) with a ratio of one container for paper, glass and packing for every 500 inhabitants. Likewise, it uses ergonomic containers, with opening, handle and pedal heights to make opening them easier to use for persons with reduced mobility or movement.

The rollout of organic matter collection in the city as a whole is performed using separate containers (5,400 in total) which have increased the capacity from 2,718 m^3 to 9,722 m^3. Dual compartment containers are not included in this rollout.

As regards commercial collection, the aim is to incorporate the collection of the organic fraction for all producers: restaurants, fruit shops, markets, schools, etc.- with 2011 as the time horizon for achieving full implementation. As regard to market collection, a new waste management model has been fostered for the forty markets in the city.

TABLE 51 | FUTURE SITUATION OF SELECTIVE COLLECTION 2009-2012

Future situation of selective collection 2009-2012		
Objectives	Where are we now (2009)	Where do we go to (2012)
Selective	· Consolidation of selective collection services · Waste recycling and valorisation · 34% of selective collection, 66% of refuse	· Service sustainability: <emissions (CO_2, acoustic, polluting gases) and water consumptions · Waste minimisation · 50% of selective collection, 50% of refuse
Organic	Extension of organic matter collection, 27.5%	Increase in organic collection, 55%
Inappropriate matter	31.6% of inappropriate matter mixed with organic matter in house collection	<15% of inappropriate matter mixed with organic matter in house collection
Containers	7,174 selective (3-container areas + organic matter), 4,164 two-compartment containers, 12,270 refuse	10,710 selective (3-container areas), 5,401 organic matter, 10,803 refuse
Vehicles	Functional efficiency 949 vehicles (90% petrol / gasoil, 7% gas, 3% electric / hybrid)	Environmental efficiency 1,140 vehicles (35% biodiesel, 35% gas, 3% electricity)
Street cleaning	Service quality increase	Co-responsibility and sustainability. Service flexibility

OBJECTIVES AND OBLIGATIONS OF THE SELECTIVE COLLECTION MODEL

The Action Plan for the Municipal Waste Management Programme in Catalonia 2005-2012, and the Municipal Waste Management Programme (PROGREMIC 2007-2012), set out waste-to energy objectives for the year 2012 so as to progress towards selective collection of all the fractions and gradually reduce the refuse fraction (55% for organic matter, 75% for paper, 75% for glass and 25% for light packaging). The Metropolitan Municipal Waste Management Programme (PMGRM) sets out recovery or recycling objectives which are similar to those of the PROGREMIC.

Catalan Law 6/1993, which regulates waste and its subsequent modifications, sets forth the obligation to carry out separate collection of the organic fraction and also the responsibility of businesses in the management of the waste they produce. Royal Decree 208/2005 on electrical and electronic appliances and resulting waste compels municipalities to selectively collect four kilos per inhabitant and year of this waste produced in the home.

Diagnosis - BLOCK 3

The Municipal Programme

3.1 - Scope of the analysis

The study approach

Municipal services and facilities provide the scope for the diagnosis and analysis in this chapter. The appraisal process also included specifying the elements and tools for action required to define a sustainable energy strategy that is consistent with the targets to which the city has committed itself at international level.

Although the study focuses on energy, the analysis was approached from a cross-cutting perspective that sought to incorporate into the process the various sectors and departments involved. Thus, during the preparation of the plan, account was taken of all the other plans and programmes run by the Council that have an energy dimension to them (Green Space planning, the Urban Mobility Plan, the Infrastructure Master Plan, the Energy Supply Quality Assessment Project, the Tourism Plan and the +Sustainable City Council Programme, amongst others) in order to define the most consistent municipal strategy possible.

The following sectors are included: buildings and equipment, vehicle fleets (belonging to the Council or to municipal contractors), public lighting, fountains, sewers, and any infrastructure or service aimed at the general public. For each one, the necessary data has been compiled in order to carry out a careful assessment and to propose measures aimed at reducing consumption, improving efficiency and minimising their impact. These inventories were carried out using information supplied by the various Council departments[36].

36. It should be noted that it was not always possible to access the data and that the quality of the data differs depending on its origin and function. For this reason, a process of homogenisation was undertaken prior to processing the data and preparing ratios and comparisons.

Criteria

In order to carry out the activities that fall within its remit, Barcelona City Council uses a network of facilities distributed throughout the city - offices, schools, sports centres, museums, etc. – comprising buildings, owned or rented by the Council, that are managed by local services or municipal undertakings.

In the past, information about the consumption of these premises was taken from global consumption figures for the buildings studied, from overall invoicing data for the city and also from simulations. However, differentiating between city consumption and municipal consumption when preparing the PECQ helped ensure greater accuracy when collecting and analysing the data needed for the diagnosis. Thus, for 2008 (the baseline year for the PECQ), the data was obtained from centralised invoicing data from Barcelona City Council's General Services Sector and other municipal units that carry out their own energy consumption monitoring procedures. This approach made it possible to obtain a more precise picture of the actual situation.

It should be noted that most of the institutions that are principally run by the Council have their own management systems that are not always easy to access. For this reason, over the years to come, work must continue in terms of data research so as to improve the precision of the information and of the final energy balances.

The consumption data provided later in this report shows that this sector has one of the highest levels of potential in terms of savings, efficiency and introducing renewable energy. With this in mind, a specific, separate action plan has been prepared: the Energy Savings and Improvement Plan for Municipal Buildings (PEMEEM). The PEMEEM, which occupies a section of its own within the PECQ, has, thus, became one of the Council's areas of strategic action, and the measures and proposals it sets out are designed to lead to significant reductions in municipal emissions involving a reasonable economic investment.

When considering municipal vehicles, it is important to distinguish between Council vehicles (such as cars and vehicles for Council representatives, traffic police vehicles, and fire service vehicles) and vehicles used by contractors to provide public services - for example, lighting, waste disposal and cleaning. As the latter category has a greater impact on energy consumption and GHGs, it is treated separately from other municipal fleets. In order to prepare the energy balance, data was collected about specific consumption of liquid fuels (in litres or Nm^3) and electricity consumed by vehicles in service. This made it possible to identify easily those uses that could be reconsidered and to calculate the associated CO_2 emissions. Consideration was also given to specific consumption and the number of kilometres travelled.

Finally, regarding the remaining services – lighting, traffic lights, road signs, fountains, sewers, green spaces and beaches – invoices for energy use were the principal data source.

3.2 - Energy consumption

3.2.1 - ENERGY CONSUMPTION BY SECTOR AND BY ENERGY SOURCE

Analysing energy performance for a specific human system is a complex task and involves a degree of objectivity that is influenced by the physical limits of the area under study. Thus, to analyse the consumption of a subsystem (municipal services for the city, in this case) can result in conflicting conclusions.

In 2008, municipal services consumed 472,250.98 MWh, equivalent to 2.78% of the city's total consumption. In terms of greenhouse gas emissions, the impact on the city as a whole was 2.09%, i.e., 84,799.71 t of greenhouse gases. Although in relative terms these figures are not excessively high, they are high in absolute terms. It is, therefore, necessary to investigate further to find out more about energy performance and to improve the efficiency of these services. Most of this energy (52%) was consumed by municipal buildings. The other consumption figures were: public lighting (20.1%), waste collection vehicles (15.8%), municipal services (8.8%) and other vehicles (3.4%).

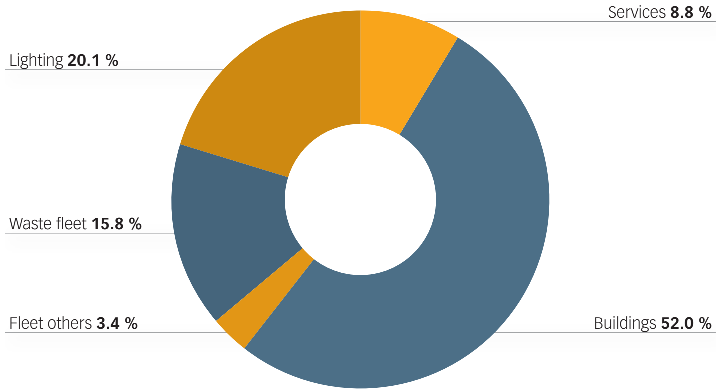
The high percentage of buildings – mainly due to the large number of municipal facilities provided - leads to the conclusion that this area could be the source of significant savings. Lighting, services and vehicles, on the other hand, have been progressively reducing consumption thanks to maintenance work carried out over recent years and to the technological upgrading of the various materials and elements used. It should be noted that this ability to incorporate the best available technology is less flexible in buildings for a number of reasons, most of them economic. This has led to stagnation in the sector that is verging on endemic inefficiency.

FIGURE 194 | COMPARISON OF MUNICIPAL CONSUMPTION WITH CONSUMPTION OF THE CITY AS A WHOLE

f the analysis is undertaken by energy source, electricity was the most-used vector (58.3%) – a proportion that is consistent with the level of energy consumed by buildings, lighting, and the majority of public services (traffic lights, pumping, etc.). Natural gas represented 24.6%, mainly due to consumption in buildings and by waste collection vehicles. Diesel accounted for 13.6% - it is the most common fuel for municipal vehicles, although it is also used in a number of heating systems. Liquefied natural gas (1.8%) and petrol (0.4%), both of which are used exclusively in vehicles, accounted for marginal levels of consumption. Noteworthy is the figure for solar thermal energy (1.4%), not an insignificant contribution, bearing in mind that it is basically used to produce hot water.

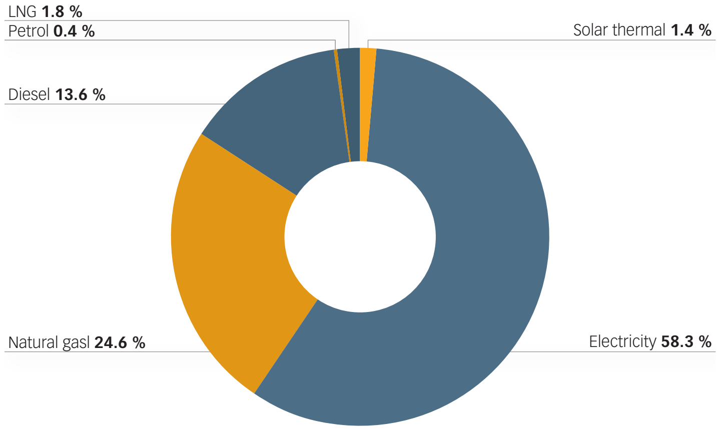
The generalised use of diesel in municipal vehicles is a reflection of the general trend that has affected vehicles in general. The intensive dieselisation seen over recent years has improved energy efficiency on the whole (the diesel cycle is thermodynamically more efficient than the Otto cycle, which is used in engines powered by petrol or natural gas), although it has led to a worsening of air quality owing to concentrations of NO_x and PM_{10}, in particular. As with other sectors, this represents a potential policy platform that can be used to set an example to members of the public.

FIGURE 195 | DISTRIBUTION OF MUNICIPAL ENERGY CONSUMPTION BY SECTOR (2008)



Total energy consumption of the Municipal Programme [MWh]		
Services	8.8 %	41,328.81
Buildings	52.0 %	245,464.53
Fleets others	3.4 %	16,042.93
Waste fleet	15.8 %	74,402.49
Lighting	20.1 %	95,012.22
Total		**472,250.98**

FIGURE 196 | DISTRIBUTION OF MUNICIPAL ENERGY CONSUMPTION BY ENERGY VECTOR (2008)



Total energy consumption of the Municipal Programme		
Vector	Consumption [MWh]	Fraction
Electricity	275,141.61	58.3 %
Natural gas	116,006.30	24.6 %
Diesel	64,165.43	13.6 %
Petrol	1,799.49	0.4 %
LNG	8,496.11	1.8 %
Solar thermal	6,642.03	1.4 %
Total	**472,250.98**	

FIGURE 197 | DISTRIBUTION OF MUNICIPAL ELECTRICITY CONSUMPTION BY SECTOR(2008)

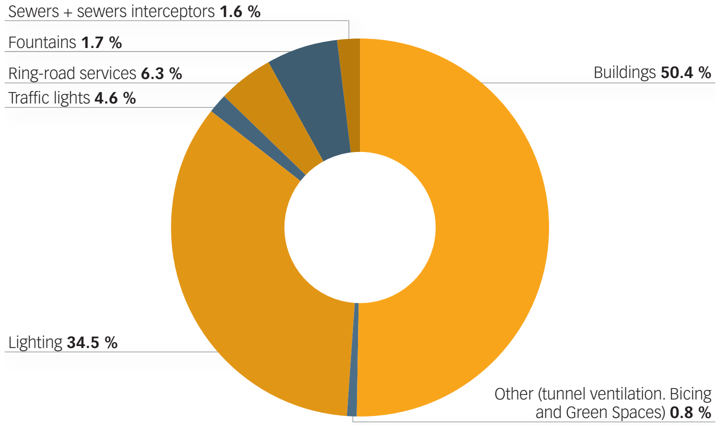
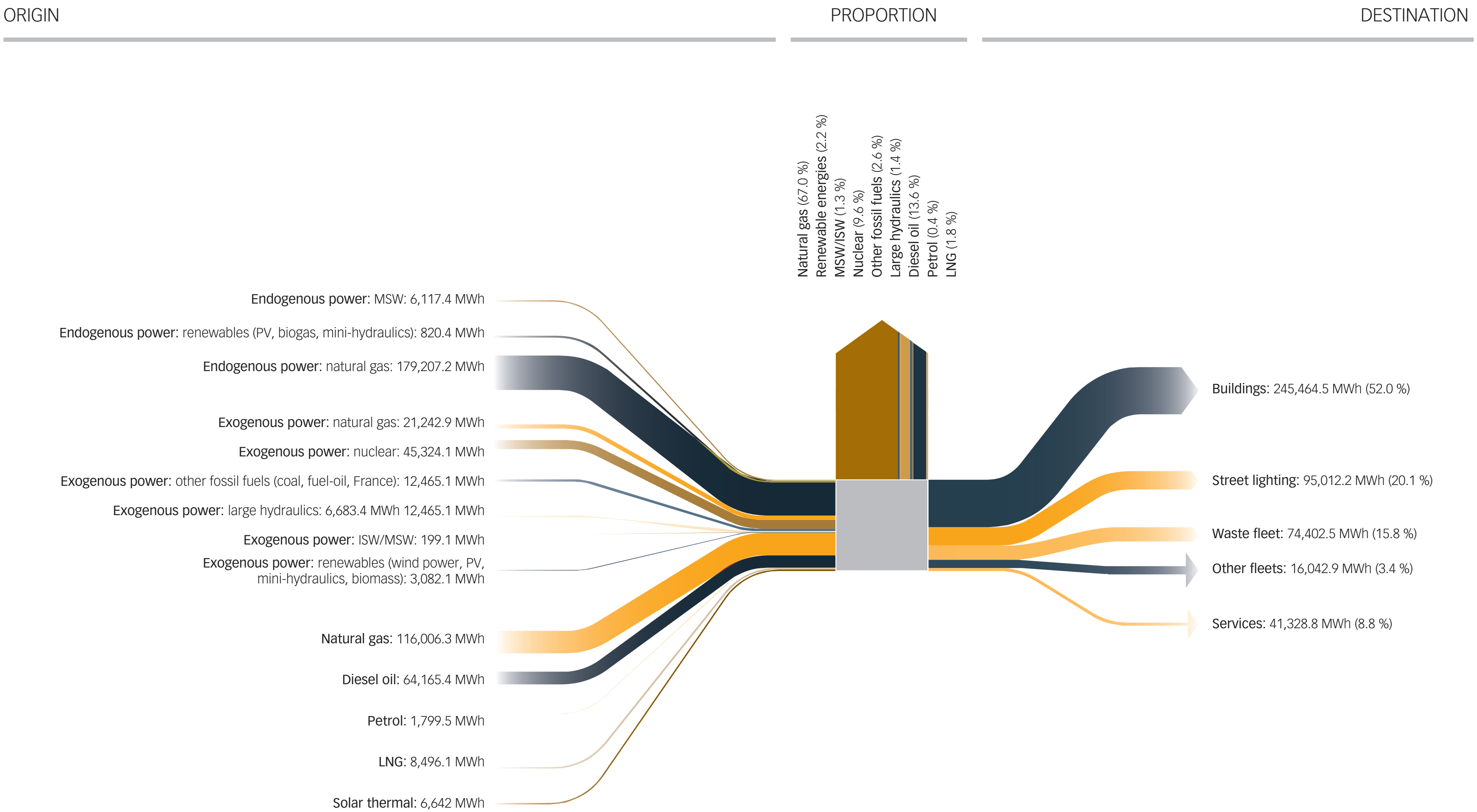


FIGURE 198 | SOURCE OF ENERGY CONSUMED BY MUNICIPAL SERVICES IN BARCELONA, BASED ON THE MIX IN CATALONIA. DIAGRAM BY SANKEY (2008)



3.2.2 - TRENDS IN CONSUMPTION

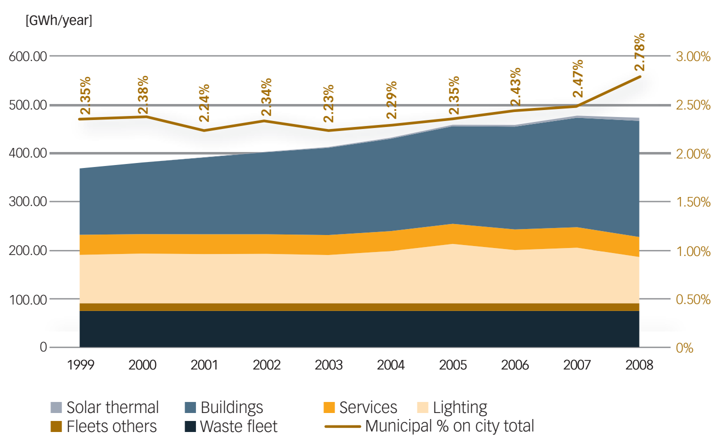
Overall, Barcelona has a high level of dependency on natural gas. This is mainly due to the combined cycle power plants in the city or within its administrative boundaries that use natural gas. The upside of this is that it increases the proportion of self-generated electricity[37] to up to 68%, although it highlights the low level of diversification in the local energy mix, which mainly comprises fossil fuels.

Given that the ability of the Council to take action with regard to local or national electricity mixes is limited, policies to improve energy efficiency and incorporate new sources of renewable energy from the bottom up (i.e. initiatives from the public or from the local administration) into municipal services are key factors in reducing energy dependency. The standardisation of solar thermal and photovoltaic technologies, with the backing of the City (as evidenced by the bylaws approved over recent years) has dramatically changed the perception of the potential of these energy sources. Advantage needs to be taken of this so as to make further progress in renewable self-sufficiency.

If consumption from the baseline year of 2008 is compared with the figures for preceding years, a growth trend of up to 28% can be observed between 1999 and 2007. Essentially, this increase took place in the buildings sector - as the area occupied by services increased, so did the associated energy consumption. By contrast, energy consumption for public lighting has decreased on account of technological changes and improvements, despite increases in installed power. With regard to vehicles, for methodological reasons, consumption is considered to have remained stable on the whole over recent years, with levels equivalent to those of 2008. In any event, the bulk of the consumption is attributed to waste collection vehicles, which have been operated by the same contractor since 2001 with annual energy consumption remaining, by and large, unchanged.

This shows that energy consumption by municipal services is moving forward at the same pace as the city's overall energy consumption. Municipal consumption accounts for approximately 2.5% of the total, with little variation from one year to the next. In 2008, however, the proportion was slightly higher than average, mainly due to the overall reduction in city consumption and to the fact that municipal consumption levels remained the same. From an energy point of view, therefore, the city responds to the need for services as it grows.

FIGURE 199 | CHANGES IN MUNICIPAL CONSUMPTION AND ITS PROPORTION OF TOTAL CITY CONSUMPTION (1999-2008)

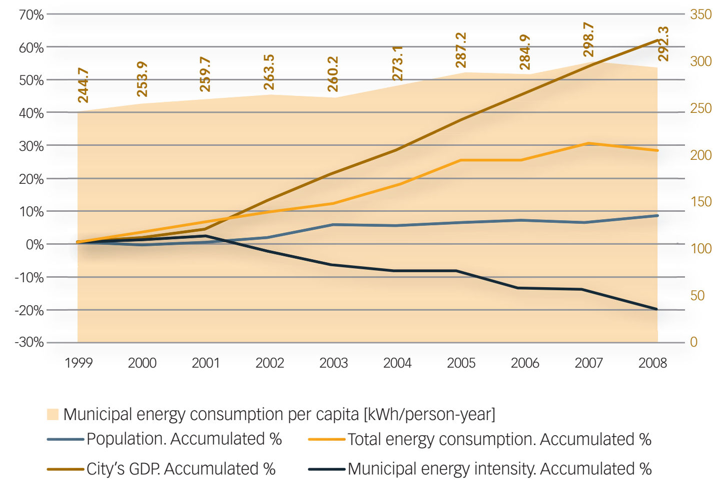


This shows that energy consumption by municipal services is moving forward at the same pace as the city's overall energy consumption. Municipal consumption accounts for approximately 2.5% of the total, with little variation from one year to the next

37. The term "self-generation" applies to the electricity generated in electricity power stations operated in Barcelona and at the Besòs river mouth at Sant Adrià (Zona Fòrum).

The rise in energy consumption accompanies increases in other indicators that measure city activity. Over the last ten years, the population has increased by 7.5%, while GDP has grown by 58.8%. This trend explains the greater demand for public services and the consequent added energy expense. This higher growth of GDP over energy consumption, however, has a positive impact in terms of lower energy intensity for municipal services. Although municipal energy intensity should not be interpreted in the same way as overall energy intensity, it remains a positive piece of data.

FIGURE 200 | CHANGES IN SOCIOECONOMIC INDICATORS IN THE CITY AND MUNICIPAL ENERGY CONSUMPTION PER CAPITA (1999-2008)



3.3 - Energy generation

3.3.1 - ENERGY SHARE FROM SELF-GENERATION

Self-generation covers the production of electrical or heat energy in facilities, usually buildings, managed by the Council. By 2008 solar thermal and photovoltaic facilities - as well as small-scale wind turbines producing small amounts of energy – were contributing to self-generated municipal energy.

These kinds of installation can cover electricity demand (making use of the grid for storage) and a proportion of heat requirements in buildings (hot water, heating and cooling). This diagnosis does not, for this reason, include energy consumption associated with vehicle fleets because local self-generation installations are not designed to provide fuel for the transport sector. The scope of this study is, therefore, limited to municipal buildings and services.

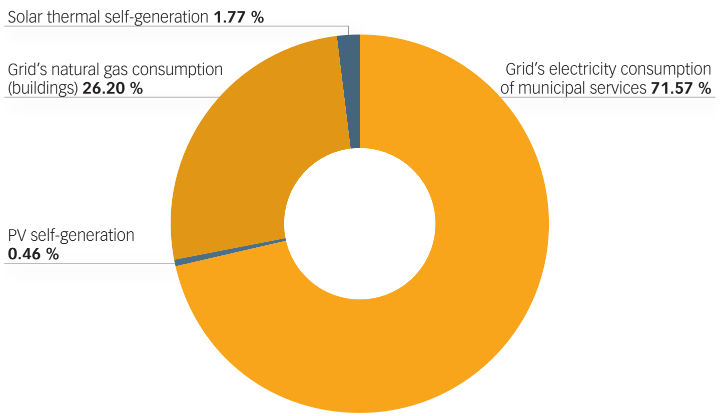
TABLE 52 | SHARE OF SELF-GENERATED ENERGY IN MUNICIPAL BUILDINGS AND SERVICES (2008)

Municipal Services and Buildings Consumptions - 2008	
	[MWh]
Grid-purchased electricity consumption	270,230.92
Grid-purchased thermal consumption (natural gas in buildings)	98,290.57
Solar thermal generated in municipal facilities	6,642.03
PV generated in municipal facilities*	-1,731.34
Total consumption of sectors	**373,432.19**

* Generation transferred to grid

Self-generation contributes 2.24% of energy produced in municipal solar thermal and photovoltaic facilities. The energy demands (heating, refrigeration, hot water) of municipal buildings are usually covered by natural gas boilers and heat pumps fitted with electric compressors.

FIGURE 201 | THE SHARE OF SELF-GENERATED ENERGY IN MUNICIPAL BUILDINGS AND SERVICES (2008)



3.3.2 - CONTRIBUTION FROM RENEWABLE ENERGY SOURCES

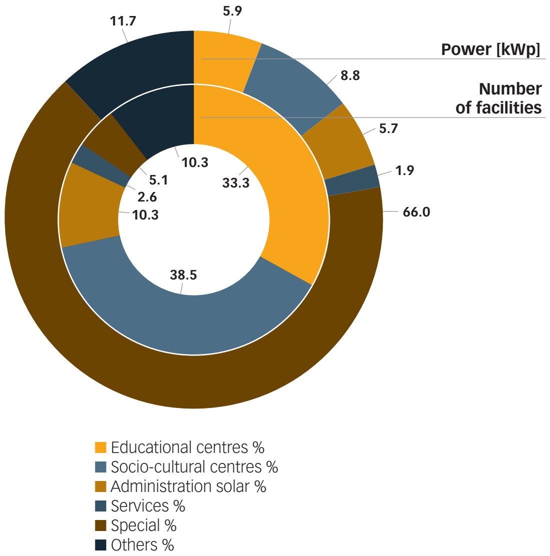
Solar photovoltaic energy

By 2008, there were 39 solar photovoltaic energy installations in municipal facilities with a total power output of 1.6 MWp producing 1,700 MWh of electricity a year. This energy is exported to the grid for the appropriate economic consideration.

Most of these installations are located in socio-cultural and educational centres (libraries, civic centres, schools, etc.) in order also to take advantage of their educational and demonstrative value vis-à-vis the general public.

Although the flexibility of the technology makes it possible to diversify and atomise total power output in small power stations throughout the city, the main proportion of the installed power comes from the photovoltaic pergola located at the Forum – classified as *"Singular"* - that accounts for 66% of output and the resultant production.

FIGURE 202 | **MUNICIPAL SOLAR PHOTOVOLTAIC INSTALLATIONS IN BARCELONA (2008)**



Type of location	Number [n]	Power [kWp]
Educational centres	13	97.58
Socio-cultural centres	15	145.03
Administration solar	4	93.34
Services	1	32.00
Special	2	1,090.00
Others	4	192.60
Total	**39**	**1,650.55**

Solar thermal energy

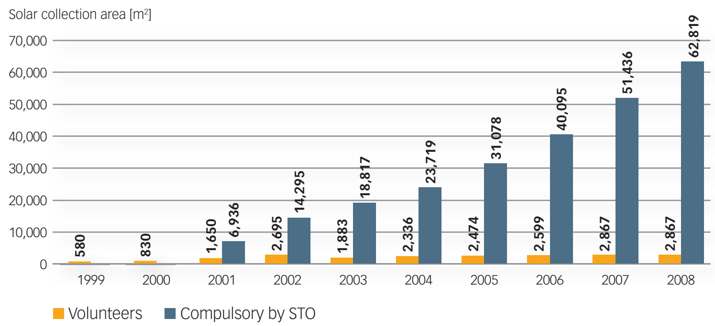
The regulations about meeting hot water requirements using thermal solar energy in buildings are stricter in Barcelona than at state level. This is because Barcelona introduced the Solar Thermal Ordinance (OST) in 2000 in the framework of the General Urban Environment Ordinance of Barcelona.

The approval of, and compliance with the OST has meant standardising the presence of solar thermal energy within the city, with the installation of more than 60,000 m^2 of solar panels over a ten-year period. At the same time, the OST has led to a domino effect of solar ordinances throughout Spain, culminating, in 2006, in the requirement to install solar thermal systems, as set out in the Technical Building Code.

This has led to a growing number of energy harnessing systems in municipal buildings that have either been built or rehabilitated over the last decade. It is also important to note the large number of solar thermal installations undertaken on a voluntary basis, even prior to the entry into force of the OST, when Barcelona had 1.650 m^2 of panels. Such systems have been promoted by various municipal bodies - such as the Municipal Housing Trust – or as part of campaigns such as *"Barcelona, posa't guapa"* (Barcelona Make Yourself Beautiful).

Included in the list of voluntary installations are those that were designed to meet demand over and above hot water requirements, such as heating or refrigeration using absorption chillers. Such installations have a clear demonstrative, investigative and developmental vocation directed at studying their viability and replicability in more favourable market conditions. By 2008, there were 110 municipal thermal installations of this type covering 8.233 m^2 – more than 10% of the city total.

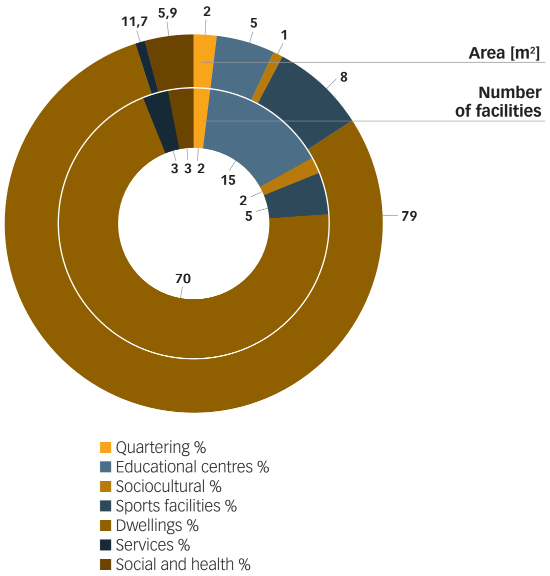
FIGURE 203 | SURFACE AREA COVERED BY SOLAR THERMAL PANELS IN THE CITY OF BARCELONA (1999-2008)



A significant part of the surface area of municipal solar thermal installations is located in buildings and public housing. However, the PECQ only takes into consideration consumption that is invoiced to the Council. Therefore, in absolute self-generation terms alone, it can be concluded that 21% of this thermal energy (that which is not located on public housing) represents a real reduction in energy bills relating to municipal buildings and facilities.

However, it is important not to overlook the efforts on the part of builders of public housing to integrate renewable energy and energy efficiency into their designs. For this reason, this analysis also recognises the total thermal solar surface area and production installed in these buildings.

FIGURE 204 | MUNICIPAL SOLAR THERMAL INSTALLATIONS IN BARCELONA AND PLANNED PROJECTS (2008)



	Number	Collection area [m²]	Production [kWh/year]
Quartering	2	123.20	98,560
Educational centres	17	367.80	294,240
Sociocultural centres	2	117.00	93,600
Sports facilities	6	665.00	593,200
Dwellings	77	6,540.55	5,226,440
Services	3	119.25	95,400
Social and health	3	300.74	240,592
Total	**110**	**8,233.54**	**6,642,032**

Small-scale wind energy

Unlike solar energy, there has been no regulatory framework governing small-scale wind energy that has helped promote it. Added to this are the constraints inherent in the technology, such as the vibrations caused to the building structure when the turbine is in use, or the greater degree of complexity in the technological development of wind turbines compared with other systems.

In this regard, in 2007 a pilot project was carried out involving the installation of a mixed wind energy-photovoltaic system on the roof of a public housing building. The 10 kWe wind turbine and 34 kWp photovoltaic panels are expected to be replicated elsewhere in the future.

3.4 - Greenhouse gas emissions

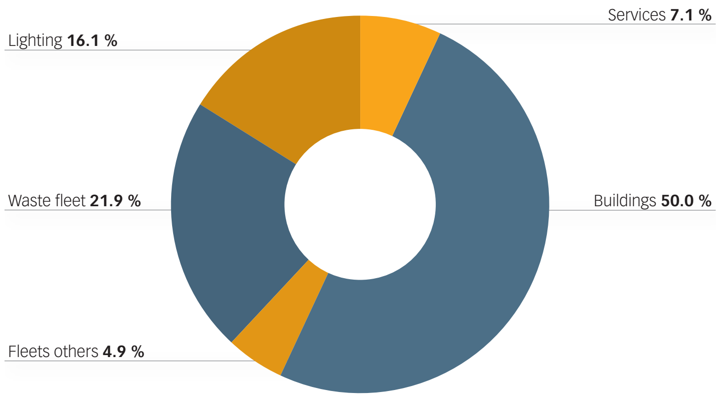
As a signatory to the Covenant of Mayors[38], Barcelona City Council has committed itself to cutting greenhouse gas emissions (GHGs) by 20% in the services that it manages directly. In order to establish the reduction scenario, 2008 was taken to be the baseline year.

That year, municipal services produced 84,402.6 t, 50% of which came from consumption in buildings. By energy vector, electricity consumption accounted for almost 60% of emissions, whilst natural gas and diesel accounted for approximately 20% each. Diesel, however, represented 14% of the energy consumed.

The parallel between municipal energy consumption and GHGs is significant. However, emissions grew by 24% between 1999 and 2008, whilst consumption increased by 28%. This difference can be explained by technological changes introduced in new services and buildings that have reduced emissions rates per unit of energy consumed. With regard to the increase in GDP, the intensity of emissions from municipal services has reduced progressively over recent years. This has offset the increase in municipal emissions per capita.

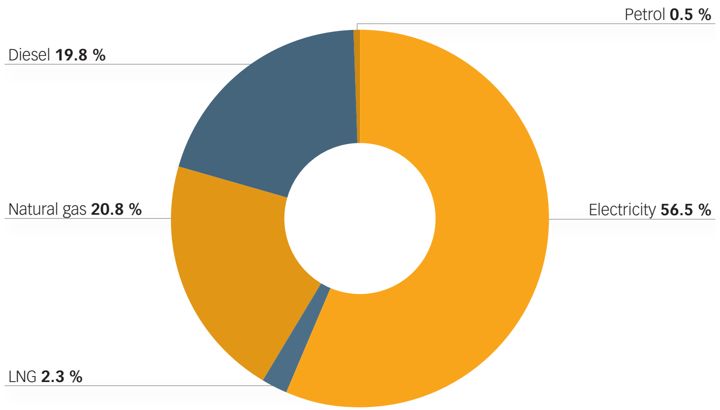
38. In March 2007, the European Union adopted a package of measures called Energy for a Changing World, which involved a commitment unilaterally to reduce CO_2 emissions by 20% by 2020, increase energy efficiency by 20%, and ensure that 20% of energy supplied comes from renewable sources. As a result of this commitment, the European Commission implemented the Covenant of Mayors - an initiative that aims to take this challenge down to local level, with the active participation of society as a whole. The Covenant was the result of an informal consultation process between a large number of European cities and is open to all cities, irrespective of their size.

FIGURE 205 | EGHGS ARISING FROM MUNICIPAL SERVICES BY SERVICE TYPE (2008)



Municipal Services GGE Emissions - 2008		
Area		[tCO_2/year]
Services	7.1 %	5.988.42
Buildings	50.0 %	42,394.86
Fleets others	4.9 %	4.126.80
Waste fleet	21.9 %	18,254.44
Lighting	16.1 %	13,638.05
Total		**84,402.58**

FIGURE 206 | GHGS ARISING FROM MUNICIPAL SERVICES BY ENERGY VECTOR (2008)



Municipal Services GGE Emissions - 2008		
Vector		[MtCO2/year]
Electricity	56.5 %	47,664.19
Natural gas	20.8 %	17,588.23
Diesel	19.8 %	16,727.28
Petrol	0.5 %	460.27
LNG	2.3 %	1,962.60
Total		**84,402.58**

FIGURE 207 | RELATIONSHIP BETWEEN ENERGY CONSUMPTION BY MUNICIPAL SERVICES AND GHGS (2008)

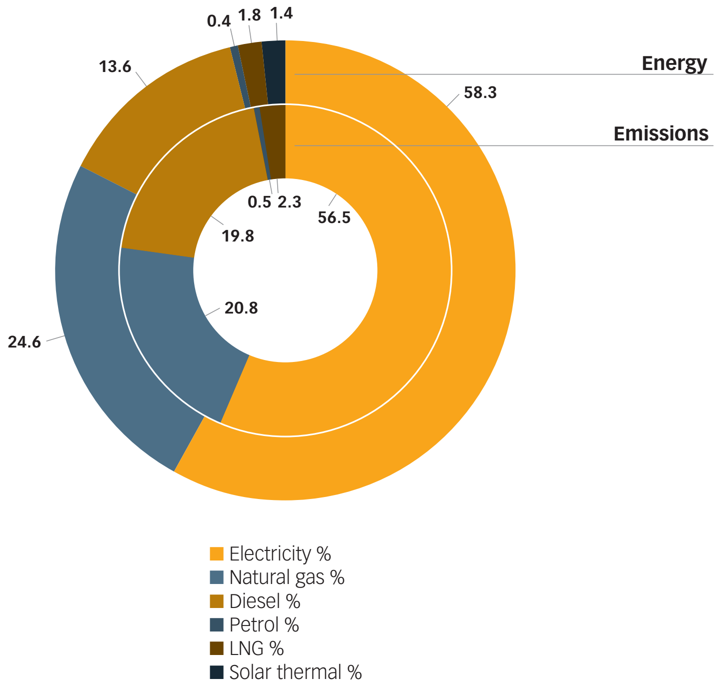


FIGURE 208 | TRENDS IN GHGS IN THE MUNICIPAL SECTOR AND THEIR PROPORTION OF TOTAL EMISSIONS IN THE CITY (1999-2008)

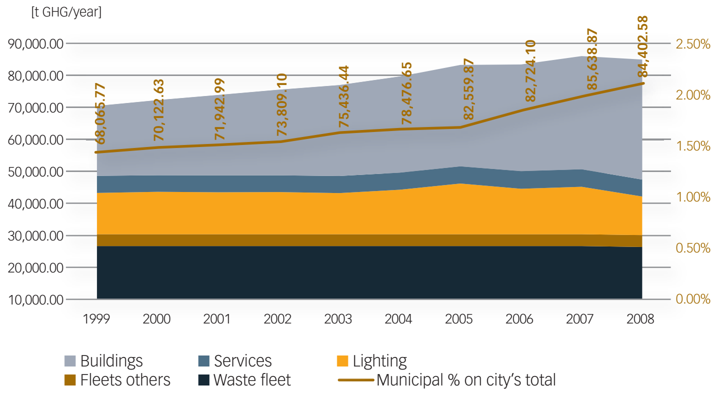
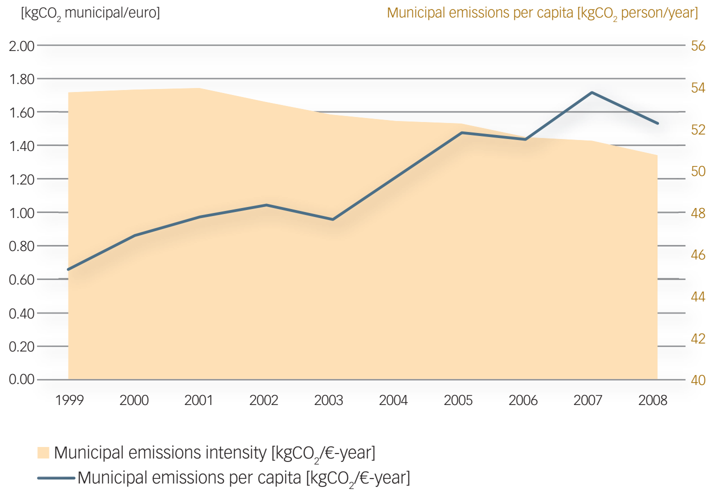


FIGURE 209 | MUNICIPAL EMISSIONS PER CAPITA AND EMISSIONS INTENSITY (1999-2008)



3.5 - Analysis by sector

3.5.1 - MUNICIPAL BUILDINGS (PEMEEM)

Context and background

The energy consumption of Barcelona City Council buildings and facilities represents almost 52% of the total consumption of municipal services. The sector has, therefore, a relatively high potential for taking action aimed at making savings and improving efficiency and is one of the cornerstones of the PECQ's Municipal Programme. With regard to this, although buildings and municipal facilities are covered in this Plan, they are the subject of a document called the Energy Savings and Improvement Plan for Municipal Buildings (PEMEEM). The PEMEEM is a separate document containing specific objectives regarding energy savings and CO_2 emissions. It forms the basis of this section of the PECQ. The PEMEEM objectives are also incorporated into the PECQ and cover improving efficiency and energy savings in buildings, along with building work aimed at improving efficiency, and installations of renewable energy systems.

The PEMEEM was drawn up based on the specific demands of the sector. During 2009, a number of diagnostic tasks were carried out and information was compiled: identification of buildings to study, coordination with districts, technical, economic and viability analyses previous to promoting a range of projects, and running pilot projects that make it possible to replicate experiences over the years to come. Policies from the previous administration were also integrated into the plan, such as installing photovoltaic systems in municipal facilities and monitoring renewable energy installations.

Similarly, the PEMEEM took into consideration proposals from the Barcelona Energy Improvement Plan (PMEB), covering the 1999-2010 period, such as that of improving and updating energy management in public buildings.

There are a number of measures that were started in the PMEB and that, given their nature, are continued in the PEMEEM. Others, however, are no longer applicable in the current context. The current juncture and state of the art of technologies calls for new measures that make it possible to reach the objectives and savings set down in this Plan.

The development of the PEMEEM is based on a Government Measure on energy savings and efficiency in municipal facilities, approved in 2009 - a cross-cutting tool that serves as the basis for implementing the Plan. The measure involves all departments and areas within the Council and has become the main mechanism by which the Energy Saving Working Group coordinates the efforts of building energy managers when carrying out the policies set down in the PEMEEM.

PMEB PROPOSALS (1999-2010)

The 1999-2010 Barcelona Energy Improvement Plan (PMEB) put forward a number of measures for municipal buildings and facilities aimed at saving energy and improving energy efficiency, reducing energy consumption and introducing renewable energies:

- Improve and update energy management in public buildings
- Introduce energy management programmes in schools and universities
- Improve carpentry and window glass
- Improve insulation in existing buildings
- Introduce systems to heat water in sports centres
- Install co-generation systems in sports centres
- Install photovoltaic systems for offices > 1,500 m^2
- Install medium-temperature solar systems for heating and air conditioning in offices
- Install co-generation systems in offices > 4.000 m^2
- Update thermal mass in new offices
- Review energy standards in new builds and office rehabilitation projects
- Energy certification of buildings
- Distribute learning content to education centres

The current situation

As at March 2008, Barcelona City Council managed 2,015 installations, of which 645 were managed by the Council's General Services Sector.

TABLE 53 | REGIONAL DISTRIBUTION OF PROPERTY OWNED BY BARCELONA CITY COUNCIL (2008)

District	Number of properties
Without district allocation	13
Ciutat Vella	405
Eixample	152
Gràcia	113
Horta-Guinardó	201
Les Corts	76
Nou Barris	209
Sant Andreu	195
Sant Martí	249
Sants - Montjuïc	261
Sarrià - Sant Gervasi	127
Total Barcelona	**2,001**
L'Hospitalet de Llobregat	2
Montcada i Reixac	4
Sant Cugat del Vallès	2
Sant Hilari Sacalm	1
Sant Adrià del Besòs	5
Total outside Barcelona	**14**
Total properties	**2,015**

Municipal buildings have been classified as follows in order to conduct a sectoral analysis:

TABLE 54 | MUNICIPAL BUILDING TYPES

Type code	Type name	Description
AQA	Quartering	City's Police Corps and City's Fire Brigade
CEPS	Educational Centres	Kindergartens, primary education schools, secondary education schools, specialised schools (photography, music, arts), etc.
CSC	Sociocultural centre	Social activities and meeting facilities: libraries, market places, foundations, neighbourhood associations, social organisations, leisure centres, etc.
CULT	Cultural centre	Specialised cultural centres: monuments, museums, exhibition rooms, theatres, etc.
EQES	Sports facilities	Sports centres, municipal sports facilities and outdoor sports facilities, playgrounds, etc.
HAB	Dwelling	Municipal dwellings and student's residences
OFIC	Administrative offices	Municipal administration's own buildings
PKG	Parking	Outdoor and underground car parks
SERV	Services	Public areas, public toilets, dogs' homes, green points, waste collecting and storing centre, warehouses, etc.
SING	Special	Zoo, Olympic Stadium, Palau Sant Jordi, Biomedical Research Park and Tibidabo
SSAN	Social and health	Public Health Agency of Barcelona, day care centres, primary health care centres, hospitals, first-aid posts, etc.
ALT	Other	Available information does not allow relating them with any of the previous categories.

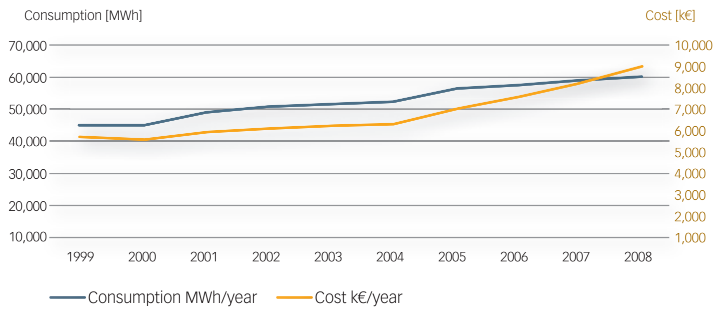
Energy consumption and emissions

In 2008, the electricity consumption of municipal buildings stood at 138,800.59 MWh/year. This consumption has grown steadily over recent years, at a year-on-year rate of 3.98% (1999-2008). Consumption of natural gas was 100,021.91 MWh/year, with an annual growth rate of 2.10% (1999-2008).

Other consumption emerging from the analysis applied to diesel (871.74 MWh/year) and solid urban waste used in district heating and cooling networks (3,606 MWh/year). The sum of this consumption produced GHGs of 40,394 t, split between electricity consumption and natural gas consumption in very nearly equal parts.

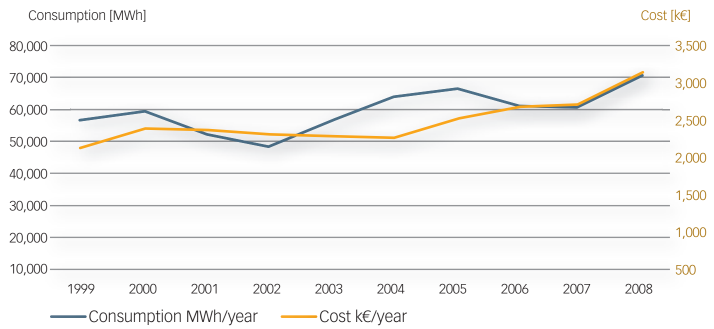
Also included in the analysis was the consumption of electricity and natural gas on an aggregate basis by building type as classified by the Council. Using the available data, it is possible to build a distribution of consumption by type according to total consumption and to the number of buildings considered.

FIGURE 210 | CHANGES IN ELECTRICITY CONSUMPTION IN GENERAL SERVICES BUILDINGS (CONSUMPTION RELATING TO 625 ESTABLISHMENTS AND 853 CONTRACTS FOR 2008)



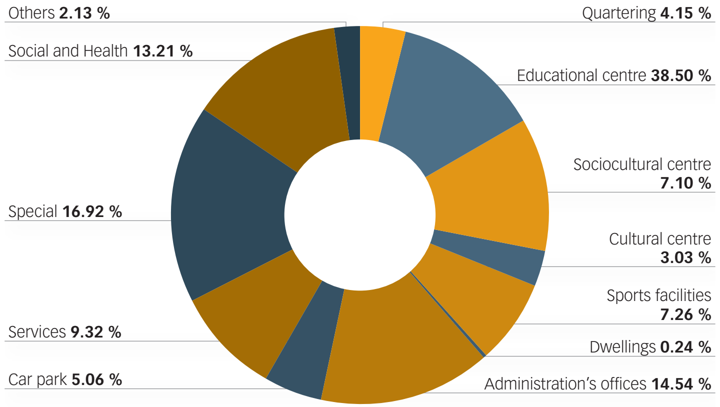
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Consumption MWh/year	41,023	40,747	45,410	47,321	48,276	49,232	53,612	55,311	56,698	58,271
Cost k€/year	5,205	5,108	5,446	5,656	5,761	5,866	6,630	7,276	7,993	8,855

FIGURE 211 | CHANGES IN NATURAL GAS CONSUMPTION IN GENERAL SERVICES BUILDINGS (CONSUMPTION RELATING TO 341 ESTABLISHMENTS AND 386 CONTRACTS FOR 2008)



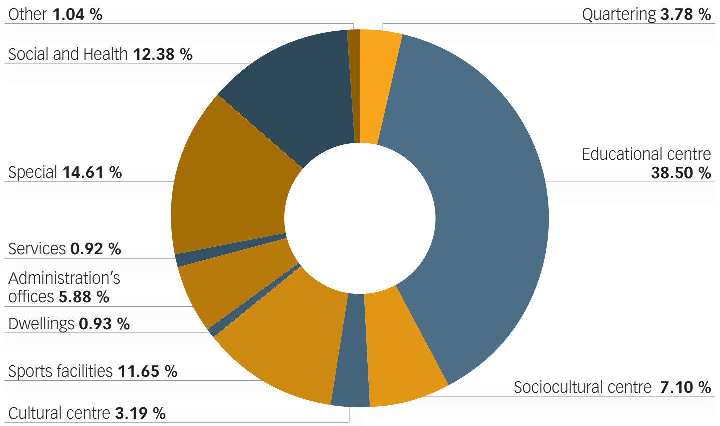
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Consumption MWh/year	53.12	56.18	48.48	43.95	52.62	61.30	64.18	58.44	58.16	69.40
Cost k€/year	1,879	2,180	2,172	2,107	2,075	2,042	2,337	2,532	2,581	3,082

FIGURE 212 | ELECTRICITY CONSUMPTION IN MUNICIPAL BUILDINGS AGGREGATED BY TYPE (2008)



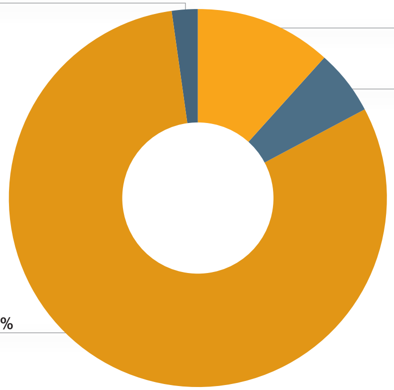
Type name	Electricity consumption [MWh]	%
Other	2,952	2.13 %
Quartering	5,766	4.15 %
Educational centres	17,571	12.66 %
Sociocultural centres	15,944	11.49 %
Cultural centre	4,207	3.03 %
Sports facilities	10,072	7.26 %
Dwellings	337	0.24 %
Administration's offices	20,176	14.54 %
Car park	7,029	5.06 %
Services	12,932	9.32 %
Special	23,484	16.92 %
Social and Health	18,332	13.21 %
Total	**138,801**	

FIGURE 213 | NATURAL GAS CONSUMPTION IN MUNICIPAL BUILDINGS AGGREGATED BY TYPE (2008)



Type name	Natural gas consumption [MWh]	%
Other	1,043	1.04 %
Quartering	3,776	3.78 %
Educational centres	38,512	38.50 %
Sociocultural centre	7,105	7.10 %
Cultural centre	3,192	3.19 %
Sports facilities	11,656	11.65 %
Dwellings	931	0.93 %
Administration's offices	5,883	5.88 %
Services	923	0.92 %
Special	14,618	14.61 %
Social and Health	12,384	12.38 %
Total	**100,022**	

FIGURE 214 | DIESEL CONSUMPTION IN MUNICIPAL BUILDINGS AGGREGATED BY TYPE (2008)



Type name	Consumption [MWh]	%
Other	102	11.67 %
Sociocultural centre	50	5.68 %
Cultural centre	701	80.43 %
Administration's offices	19	2.22 %
Total	**872**	

Irrespective of what this analysis shows, the need to index consumption so that it shows the specific consumption of each building is more important than aggregated consumption by type. It can then be seen that those buildings that account for the highest electricity consumption are those found within the Singular category (Zoo, Parc Tibidabo, Palau Sant Jordi and the Barcelona Biomedical Research Park) followed by car parks and socio-medical buildings (hospitals and medical centres managed by the Council). In terms of natural gas, consumption is highest amongst the Singular category, followed by socio-medical buildings.

It is for this reason that it is important to prepare consumption ratios and indicators so that it is possible, for example, to make comparisons between consumption related to buildings of the same type vis-à-vis the sector average, or to discover which types have the highest consumption in terms of floor space. Such an analysis would make it possible to design policy actions that are more appropriate to the current context, prioritising studies and the carrying out of work on those buildings with above-average consumption (for their type) and in accordance with their energy consumption-to-floor area ratio.

In this regard, a database has been set up to collect all the information relating to a particular building, including energy consumption data and data on the physical characteristics of the property, in order to come up with ratios and to carry out comparative analyses of municipal buildings. This will facilitate the decision making process when investing in energy efficiency and renewable energy systems.

Thus, all the targets for energy saving and GHGs included in the PEMEEM entail being in possession of detailed knowledge of consumption in municipal facilities. They also entail involving all workers in the municipal buildings plan, by means of participation, awareness, communication and orientation to act in a cross-cutting manner.

The PEMEEM will be implemented gradually, with objectives set for 2020. It will be rolled out by means of three action plans, each with its own time frame. The 11 projects proposed in the Plan are included in the global projects in the PECQ and have the same savings and timing objectives.

ACTION PRIORITIES IN THE SECTOR

1. Promote the role of an energy manager for municipal buildings and create a network of municipal energy managers. Create an energy saving working group to coordinate the policies to be carried out.
2. Acquire thorough knowledge of the City's buildings and facilities in terms of their constructional and energy properties in order to obtain energy ratios that make it possible to focus and prioritise both energy saving and improvement actions and also renewable energy systems.
3. Carry out energy monitoring exercises in municipal buildings and facilities and centralise energy consumption data in a single platform that makes it possible to monitor consumption properly whilst, at the same time, evaluating the impact of efficiency measures that are introduced into each building.
4. Improve thermal envelopes on municipal buildings and facilities to reduce their energy requirements.
5. Introduce energy saving and improvement systems in thermal plants.
6. Introduce energy saving and improvement systems in lighting plants.
7. Introduce high-efficiency energy generation systems.
8. Introduce renewable energy systems and systems that use residual energy.
9. Promote a model of energy service companies in municipal buildings and facilities.

3.5.2 - PUBLIC LIGHTING

The context

An essential public service in terms of quality of life and human safety in urban centres is public lighting, which needs to offer sufficient levels of light whilst causing the least possible environmental impact. In general, out of the services provided by the Council, lighting accounts for a high energy consumption. It is, therefore, fundamental to manage it efficiently in order to reduce consumption and the associated GHGs.

In the case of Barcelona, public lighting currently accounts for 20.4% of the total energy consumption of municipal services. However, technological innovations are making it possible to reduce consumption significantly. Nevertheless, advances achieved in the future in terms of savings and energy efficiency will be very much dictated by the effective application of existing regulations that set down specific values with respect to safety, uniformity, lighting intensity, and light pollution, etc.

The legal framework governing public lighting policies is made up of a number of laws and regulations: the Energy Efficiency Regulations for Exterior Lighting Installations (Ministry of Industry, 1890/2008), Law 6/2001 on regulations for lighting to protect the night environment (Generalitat de Catalunya), and Decree 82/2005 (also from the Generalitat). Towns and cities must, therefore, act in accordance with this legal framework that lays down guidelines to follow so that municipalities have lighting systems that are effective, efficient, and environmentally progressive.

The Barcelona Lighting Improvement Plan, covering 2009-2011, served as a benchmark for the PECQ. The measures put forward have made it possible to meet the commitments to reduce GHGs whilst ensuring that lighting is of high quality and efficient.

PMEB PROPOSALS (1999-2010)

The Barcelona Energy Improvement Plan 1999-2010 (PMEB) had already put forward a set of measures to improve lighting in the city and reduce its energy consumption:

- Reduce installed power by replacing mercury vapour lamps with high-pressure sodium vapour lamps.
- Renew light fittings, allowing for the installation of products that offer higher performance.
- Install new instrument panels fitted with flow reduction systems.
- Standardise the use of centralised management systems in public lighting, improve and update the current centralised IT control system by means of the installation of new programmes and monitoring systems.
- Manage and reduce the number of connections to optimise power and reduce consumption.

The implementation of the PMEB measures since 2002 has made it possible to:

- Reduce the installed power per light fitting.
- Increase power using a flux regulator.
- Increase dynamic control power.
- Carry out pilot tests involving new technologies that are available (for example, LED bulbs in street lighting).

Consumption and emissions

In 2008, public lighting consumed 95 GWh of electricity, equivalent to 20.4% of municipal energy consumption and 0.6% of the city's total. After public buildings, public lighting was the second-highest consumer of electricity, far ahead of all other areas associated with municipal services.

Over recent years, the number of individual light fittings in Barcelona has been increasing, not just in terms of street lighting and tunnel lighting but also in terms of decorative lighting. More than 7,400 new light fittings (4.63% of the total) were added in 2008, taking the total to 160,631 units with an installed electrical power of 23,656 kW. Decorative lighting comprises 3,800 lighting points, most of which are metal halide lamps. Sodium vapour technology is the most widely used in the City on account of the lamps' relative efficiency and longer life.

TABLE 55 | DISTRIBUTION OF STREET LIGHT FITTINGS BY TECHNOLOGY USED (2008)

Current light fittings	Total	Fraction
Sodium vapour	93,485	63.4%
Mercury vapour	20,086	13.6%
Other types of fluorescence	27,082	18.4%
Metal halides	6,883	4.7%
Total	**147,536**	

TABLE 56 | DISTRIBUTION OF TUNNEL LIGHT FITTINGS BY TECHNOLOGY USED (2008)

Current light fittings	Total	Fraction
Sodium vapour	6,066	65.5%
Mercury vapour	17	0.2%
Other types of fluorescence	3,172	34.3%
Total	**9,255**	

TABLE 57 | NUMBER OF LIGHT FITTINGS INSTALLED AND OVERALL CONSUMPTION FOR PUBLIC LIGHTING IN BARCELONA OVER TIME (2001-2008)

Year	Fitted units [u]	Unit installed power [kW/u]	Lighting global consumption [GWh/year]
2001	131,806	0.161	95.96
2002	134,620	0.160	96.52
2003	137,047	0.158	96.29
2004	139,261	0.158	101.37
2005	139,639	0.157	110.38
2006	140,681	0.155	102.38
2007	153,190	0.140	99.01
2008	160,631	0.129	95.01

▲ Although there are a number of oscillations from year to year, the overall trend in consumption - and also in the number of fittings installed - is one of growth. However, average unit consumption has fallen by 10.7% because new and replacement fittings are more energy efficient.

The successive energy balances in the city performed over recent years have made it possible to monitor the actual impact of the various measures introduced to improve the quality and energy efficiency of exterior lighting. Thus, a study of the energy indicators over time shows that:

- Between 2001 and 2008, the specified output per light fitting reduced by an average of 3% a year - a cumulative total of 19.9%.
- The number of light fittings installed throughout the city grew by 3% a year between 1999 and 2008 (a cumulative total of 30.6%).
- Overall lighting consumption increased by 1.4% a year during that period (a cumulative total of 10.7%).

Developments in technology have, therefore, improved the efficiency of installations - energy consumption increased during that period by less than the increase in the number of light fittings. However, there is still room to continue to adapt and modernise current installations, tighten up the related regulations, improve maintenance, optimise the time the lights are on and, ultimately, to rationalise consumption.

The successive energy balances in the city performed over recent years have made it possible to monitor the actual impact of the various measures introduced to improve the quality and energy efficiency of exterior lighting

With regard to GHGs, public lighting produced 13,638 t of emissions in 2008, equivalent to 16% of total emissions from municipal services. The trend of these emissions over recent years was similar to that of energy consumption, in that both values include the Catalan electricity mix as a proportionality factor.

3.5.3 - MUNICIPAL VEHICLE FLEETS

When considering action strategies for vehicles in a city, consideration needs to be given to the fact that the most efficient solutions from an energy perspective are not necessarily the most suitable from an environmental point of view. For example, a number of policies for cutting greenhouse gases may be counterproductive at local level in reducing polluting emissions.

In this regard, for a number of years now, administrations have been working on directives and regulations at European, state, national and local level, to design and promote cleaner, more efficient vehicles, and to promote the use of less-polluting fuels. Towns and cities, in line with these higher-level regulations, are introducing clauses in contracts so that economic as well as energy efficiency and environmental parameters are taken into account when decisions are made to acquire vehicles used by the city to provide its services.

In Barcelona, the Energy Improvement Plan 1999-2010 already covered both the introduction of more energy-efficient vehicles and the definition of a number of standards covering consumption and emissions with regard to municipal vehicles. These objectives have been included in the PECQ so as to move towards establishing energy criteria and limiting emissions of municipal vehicles, whether under direct or indirect management.

In 2008, the Council had more than 1,070 vehicles counting cars, vans, lorries, off-road vehicles, motorbikes and special vehicles, etc., including the Council's own vehicles and those belonging to sub-contractors providing municipal services. This figure does not include vehicles associated with refuse collection. As these are the most numerous category, they are treated separately. Vehicles considered when preparing this report were those required for: the Bicing service, fire prevention and fire fighting, B:SM, sewers, lighting, structures, fountains, traffic police, green spaces and representation.

In 2008, these vehicles consumed 16 GWh of energy (3.38% of the total of municipal services), resulting in 4,126 t/year of GHGs, along with the following local pollutant emissions: 26,000 kg of NO_x and 814 kg of PM_{10}.

With regard to the fuel used, municipal vehicles use different fuels depending on the function and type of vehicle and of the service provided. The main ones are petrol, diesel and natural gas, with bio fuels and electricity accounting for an almost-negligible amount. The trend for the next few years is for clean fuels to replace more polluting ones in line with the vehicle environmentalization strategy promoted in different municipal programmes and by the Plan itself.

With regard to the composition of the Council's vehicle fleet, each fleet comprises a different number of vehicles and different vehicle types depending on vehicle features, the service they provide and their annual mileage. Overall, more than 95% of municipal vehicles run on petrol or diesel. By vehicle type, some 30% are petrol motorcycles included in the fleets for B:SM, the local police and green spaces. Diesel vehicles (vans, cars and lorries) account for 57%.

Local police, green spaces, B:SM and sewers account for 90% of the energy consumption of municipal vehicles. Diesel is the most widely used fuel (83.8% of total energy consumption of municipal vehicles), whilst petrol accounts for 11.2%. The use of liquefied natural gas, electricity and bio fuels in municipal vehicles is currently negligible. This differs from the situation with waste collection vehicles, which use a higher proportion of liquefied natural gas and bio fuels.

TABLE 58 | DISTRIBUTION OF MUNICIPAL VEHICLES BY FLEET AND VEHICLE TYPE

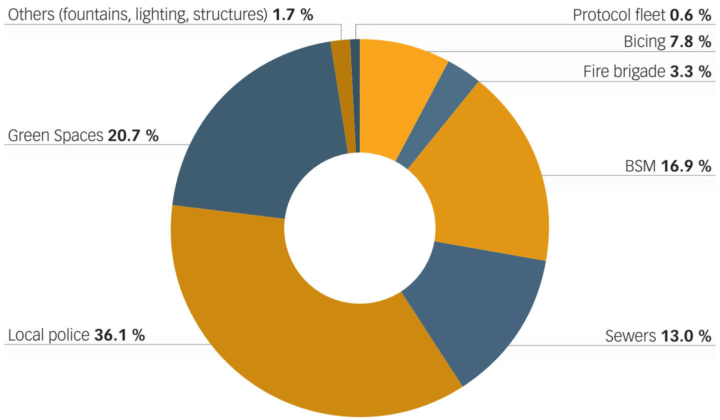
Bicing fleet			
Light truck	Gasoil	7	182,246.40
Van	Gasoil	33	1,070,595.90
	Total vehicles	**40**	**1,252,842.30**
Fire brigade fleet			
Passenger car	Gasoil	20	533,009.70
Van	Gasoil	27	0.00
Lorry	Gasoil	31	0.00
	Total vehicles	**78**	**533,009.70**
BSM fleet			
Motorcycles	Petrol	49	130,674.16
Passenger car	Gasoil	4	10,645.14
Passenger car	Petrol	9	27,817.75
Light truck	Gasoil	27	225,094.03
Light truck	Petrol	1	285.96
Van	Gasoil	50	2,312,131.60
	Total vehicles	**140**	**2,706,648.65**
Sewers brigade fleet			
Van	Gasoil	29	351,889.02
Lorry	Gasoil	5	1,062,984.77
Lorry	LNG	9	606,233.88
Boats	Gasoil	1	62,718.39
	Total vehicles	**44**	**2,083,826.06**
Lighting brigade fleet			
Passenger car	Petrol	1	171.06
Light truck	Gasoil	13	5,766.14
Van	Gasoil	17	8,284.38
Lorry	Gasoil	15	11,159.34
	Total vehicles	**46**	**25,380.91**
Structures brigade fleet			
Passenger car	Gasoil	2	12,712.50
	Total vehicles	**2**	**12,712.50**
Fountains brigade fleet			
Passenger car	LNG	5	0.00
Light truck	LNG	16	452.30
Van	Gasoil	1	0.00
Lorry	Gasoil	1	37,771.38
Lorry	LNG	4	189,566.58
	Total vehicles	**27**	**227,790.26**
Local police fleet			
Motorcycles	Petrol	248	982,088.30
Passenger car	Gasoil	181	3,575,151.63
Light truck	Gasoil	3	126,179.19
Van	Gasoil	44	1,099,732.95
Lorry	Gasoil	2	3,651.03
	Total vehicles	**478**	**5,786,803.10**
Green spaces fleet			
Motorcycles	Petrol	18	526,402.96
Passenger car	Petrol	2	131,600.74
Light truck	Gasoil	138	1,859,376.02
Light truck	Petrol	1	0.00
Van	Gasoil	20	265,625.15
Lorry	Gasoil	39	531,250.29
	Total vehicles	**218**	**3,314,255.15**
Protocol fleet			
Passenger car	Gasoil	14	99,666.00
	Total vehicles	**14**	

TABLE 59 | DISTRIBUTION OF MUNICIPAL VEHICLES BY VEHICLE TYPE AND FUEL USED

	Number	Energy consumption	Fraction on total	Fraction on/total
	[veh]	[kWh]	% [veh tip/veh tot]	% [kWh tip/kWh tot]
Passenger car Diesel	221	4,231,185	20.3%	26.37%
Light truck Diesel	188	2,398,662	17.3%	14.95%
Van Diesel	221	5,108,259	20.3%	31.84%
Boat Diesel	1	62,718	0.1%	0.39%
Lorry Diesel	93	1,646,817	8.6%	10.27%
Motorcycles Petrol	315	1,639,165	29.0%	10.22%
Passenger car Petrol	12	159,590	1.1%	0.99%
Light truck Petrol	2	286	0.2%	0.00%
Lorry LNG	13	795,800	1.2%	4.96%
Passenger car LNG	5	0	0.5%	0.00%
Light truck LNG	16	452	1.5%	0.00%
	1,087	**16,042,934.63**		

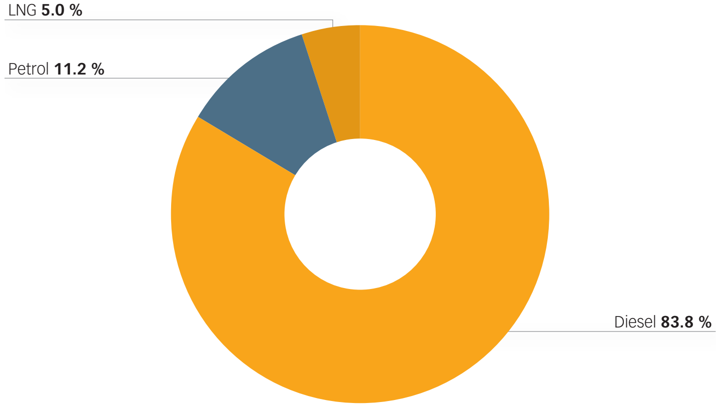
▲ GO: Diesel; GASL: Petrol; GNL: Liquefied Natural Gas; GNC: Compressed Natural Gas

FIGURE 215 | DISTRIBUTION OF ANNUAL ENERGY CONSUMPTION BY FLEET



▲ The cleaning and waste collection fleet is treated separately and not included here.

FIGURE 216 | DISTRIBUTION OF VEHICLE CONSUMPTION BY FUEL TYPE (2008)

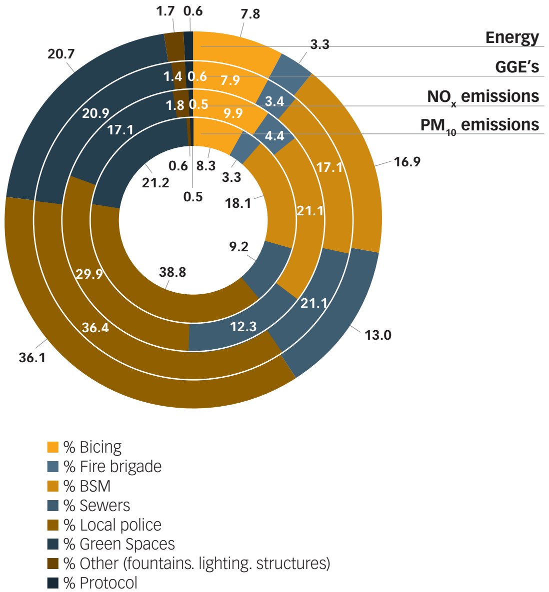


With regard to GHGs and compounds and gases that affect air quality (NO_x and PM_{10}), four fleets account for almost all emissions: local police, green spaces, B:SM and sewers.

The use of natural gas to power vehicles in the sewers and fountains fleets means that PM_{10} emissions are lower per kilometre travelled. By contrast, PM_{10} emissions from local police vehicles are slightly higher than what may have initially been expected. This is because the standard emissions-accounting methodology used to calculate the values for motorcycles (the local police use a great number of them) is far less accurate than for other vehicles. This leads to distortions in the final results.

In general, acquisitions have been made over recent years of vehicles that offer improved environmental performance, although there is still room for improvement. There is also potential to improve engine efficiency and, therefore, optimise fuel consumption. In this regard, as the emissions of both greenhouse gases and local pollutants are sufficiently significant, efforts must continue to be directed towards the use of alternative fuels, hybrid vehicles, electric vehicles, etc.

FIGURE 217 | DISTRIBUTION OF ENERGY CONSUMPTION AND EMISSIONS OF GREENHOUSE GASES, NOX AND PM_{10} FROM MUNICIPAL VEHICLES (2008)



3.5.4 - WASTE COLLECTION

In 2001, a 20-year cleaning and waste collection contract came into force. Even though this was replaced by a new contract in 2009 (see section 6.2.1 – New Projects in the PECQ), the PECQ uses data from the first contract on account of the fact that the baseline year was 2008.

There were 799 vehicles in the waste collection fleet in 2008, of which 308 were large lorries powered by diesel or natural gas used either as mobile recycling points or to collect rubbish from bins or pick up large items. The remaining 491 vehicles were used for street cleaning, which is less intensive in terms of the distance travelled each day compared with the lorries – a fact that is reflected in the final energy consumption figures.

The large number of vehicles, and the number of kilometres covered by municipal fleets, was accounted for mainly by waste collection, with the consequent impact on total energy consumption. Paradoxically, the fleet for street cleaning comprised more vehicles. However, as the number of kilometres travelled was lower, so was final energy consumption, it should be noted that waste collection vehicles follow longer routes and need periodically to empty their containers - one for each of the four different waste types.

TABLE 60 | FLEET FOR CLEANING AND WASTE COLLECTION

Type	Number
COLLECTION - total	**308**
Door-to-door collection vehicles 1100-1700 l	57
Door-to-door container cleaning vehicles 1100-1700 l	12
Door-to-door collection vehicles 3200 l	57
Door-to-door container cleaning vehicles 3200 l	12
Selective collection vehicles	27
Selective collection and door-to-door vehicles	57
Bulky waste collection vehicles	37
Commerce collection vehicles	31
Other (inspection, collection …)	14
Mobile recycling points	4
CLEANING - total	**491**
Sweepers	83
Flushers	47
Inspection vehicles	0
Auxiliary vehicles	22
Hermetic boxes	1
Snow vehicles	1
Brigades	88
Beach cleaning	9
Other	10
Paper basket collection vehicles	149
Inspection and other vehicles	81
Total	**799**

FIGURE 218 | COMPOSITION OF THE FLEET FOR CLEANING AND WASTE COLLECTION BY ENERGY SOURCE (2008)

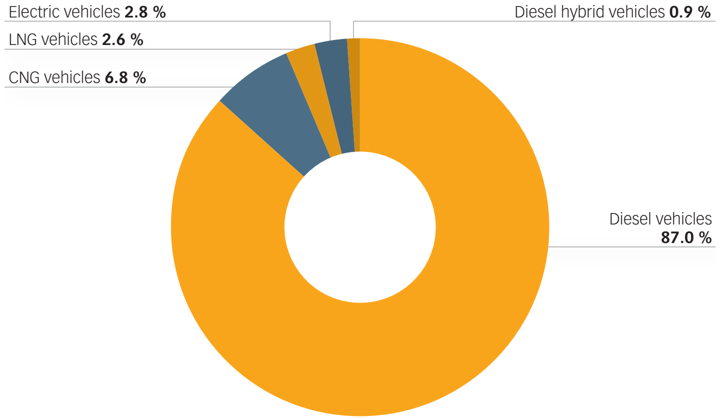


FIGURE 219 | RELATIONSHIP BETWEEN VEHICLE NUMBERS, ENERGY CONSUMPTION AND ANNUAL MOBILITY (2008)

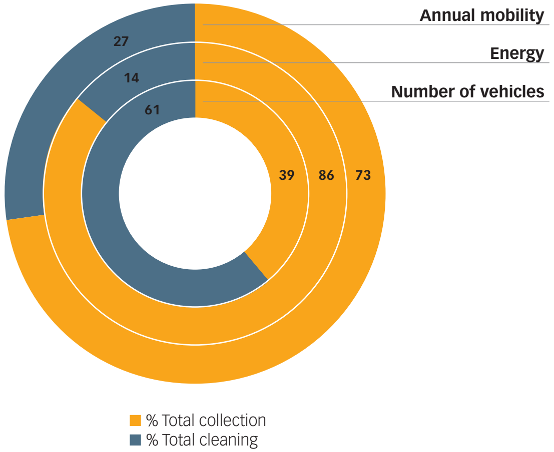


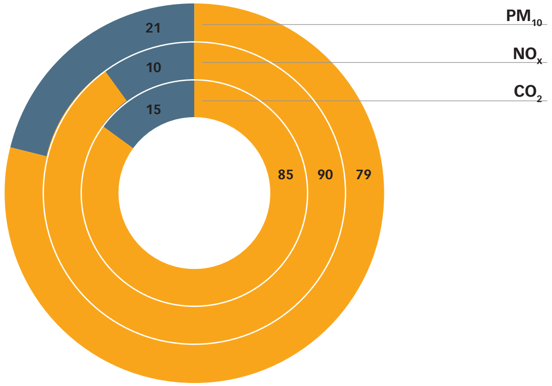
TABLE 61 | ENERGY CONSUMPTION AND ANNUAL KILOMETRES TRAVELLED BY CLEANING AND WASTE COLLECTION VEHICLES (2008)

Type	Number	Energy consumption [kWh]	
Collection - total	308	66,469,699.59	85.9%
Cleaning - total	491	10,950,779.50	14.1%
Total	**491**	**77,420,479.09**	**100%**

TABLE 62 | DISTRIBUTION OF POLLUTANT EMISSIONS BY SERVICE TYPE

Type	[MtCO_2/year]		NO_x [gr/year]		PM_{10}[gr/year]	
Collection	15,572.54	85.31%	70,582,632.71	89.56%	4,971,638.17	79.01%
Cleaning	2,681.90	14.69%	8,227,144.76	10.44%	1,321,072.28	20.99%
Total	**18,254.44**	**100%**	**78,809,777.47**	**100%**	**6,292,710.44**	**100%**

FIGURE 220 | DISTRIBUTION OF POLLUTANT EMISSIONS BY SERVICE TYPE



▲ The cleaning and waste collection fleet is the leading emitter of NOx and PM_{10} out of all municipal services. For this reason, efforts to change this are of vital importance.

3.5.5 - OTHER MUNICIPAL SERVICES

In addition to the municipal services considered in previous sections, there are others that, although they are less important in terms of energy consumption and total GHGs, are fundamental to ensure the city runs smoothly.

They include municipal fountains, ventilation equipment and other services for tunnels and ring roads, sewer installations and equipment, sewer pumps and coastal interceptors, city traffic lights, and consumption associated with beach and Bicing services.

In 2008, energy consumption for these services was 41,328.81 MWh, with associated emissions of 5,988.42 t of GHGs. These represent 8.75% and 7.1%, respectively, of the global figures for consumption and emissions from municipal services.

Scenarios and action strategies - BLOCK 4

THE SCENARIOS

4.1 - Scenario definitions

When analyzing the future evolution of energy consumption of and emissions associated with Barcelona, two scenarios are proposed:

- Starting scenario - TREND: Scenario game - trend: in which we study how the situation in Barcelona would be if no corrective measures to reduce energy demand were applied (see Section 4.2).
  Although the word trend is used, this scenario has not been defined following the exact trends of recent years; instead, other technological trends and other changes that are forecasted for Barcelona in the future, that don't have to follow a written historical pattern, have been taken into consideration. To facilitate the reading of the results, one single trend scenario (Business as usual) is proposed: a more probabilistic one, avoiding the classic high, medium and low setting trio.
  Overall, the applied methodology is based on examining the evolution of the main historical ratios of energy consumption and emission, and on predicting their most likely evolution in the coming years. Regarding socio-economic indicators they have been analyzed according to forecasts and expectations in terms of macroeconomic variables.
- Finishing scenario - PECQ 2020: where this evolution is analyzed taking into account the results achieved with the implementation of projects and measures proposed in the PECQ strategic action (see Section 4.3).

PERFORMANCE OF THE COVENANT OF MAYORS

Complementary scenario linked to the commitment adopted in 2007 by the European Commission (Covenant of Mayors). The European Union approved this year the set of measures "Energy for a changing world", which pledged unilaterally to reduce CO_2 emissions by 20% by 2020, increasing energy efficiency by 20% and getting 20% of the energy supply to come from renewable sources.
In this sense, the Scenario for the Covenant of Mayors refers to the reduction in emissions that would provide the sum of reductions associated with the proposed projects in the Municipal Programme in respect of the reference year, disregarding the growth trend. This method of presenting results is optimal to track the incidence of each of the measures proposed, and is the one proposed by the European Commission when evaluating sustainable energy action plans required with the signature of the Covenant of Mayors.

4.2 - Starting scenario: trend

4.2.1 - INITIAL CONTEXT

Decisive factors

Barcelona is undergoing an intense transformation of its productive and commercial activities. To determine the evolution of the economy of the city as part of this PECQ, a prospective analysis using 2020 as a time frame has been developed, and a unique socio-economic trend scenario has been designed to estimate the expected evolution of the city given the current dynamics.

To define this setting, and regarding the short term, 2009-11, the key tool used was regional forecasts of economic growth by sectors carried out by Hispalink[39] (data that enables the incorporation of the current situation). From 2012 and until 2020, the long-term forecasts prepared by the European Union by countries and sectors were used. This report is the most important one since it provides a recovery from the crisis and continued growth. The effects of the crisis on the Catalan economy are still strong, especially due to the industrial situation, but within ten years it is considered that the Catalan economy will have regained its leading position.

It is important to note that, at present, economic growth in Barcelona is conditioned by three determining factors:

- Development of tourism, which is manifested in a continued increase in the supply of hotel rooms in Barcelona.
- Evolution of tertiary processing technology, based on the creation of jobs in high productivity advanced services.
- Evolution of transport infrastructures, especially the Port of Barcelona and Barcelona airport, but also those that are related to access to the city and to large areas of land. These infrastructures will eventually enhance logistical activities and relationships with the outside world.

It is anticipated that these sectors will maintain their productivity increases and their growing dynamics from recent years, a trend that applies from 2011. Projects in progress in these areas, for instance, hotel rooms planned or ongoing investment have also been accounted for. So the forecasts are based on the hypothesis of compatibility between the three sectors, which requires proper management in terms of city planning, infrastructure and training. Under this premise, the trend scenario was drawn up, which has not opted for any of the different productive activities, but rather for the coexistence of the three.

39. Line of investigation in applied economics led by a series of Spanish universities.

However, no structural change has been taken into account; instead, the promotion of some of the activities that are within the city has simply been emphasized. The model assumptions used are as follows:

- The situation of the building sector will remain negative in the short term and in fact it will be difficult it recovers the level of 2007-08.
- In the case of industry, there is a differentiation made between the traditional type, which will continue to lose weight as has happened in recent years, and new industry, which will likely gain participation in a sustained way. The new offer of available land has also been considered.
- As for services, three categories have been considered: those services related to people (public services, personal services, and part of the trade), which follow a similar development to demographic forecasts; services related to tourism, in which a forecast has been made of 4,200 places planned until 2012; and professional services, in which case the dynamics of emerging industries have been taken into account.
- Regarding productivity, the statistics used show different situations, with low growth at the beginning of this decade, and significant increases over the last two years. It was decided to apply an average growth of productivity, maintaining similar growth figures for the different types of services.

FIGURE 221 | APPLIED METHODOLOGY IN THE CREATION OF THE TREND SCENARIO

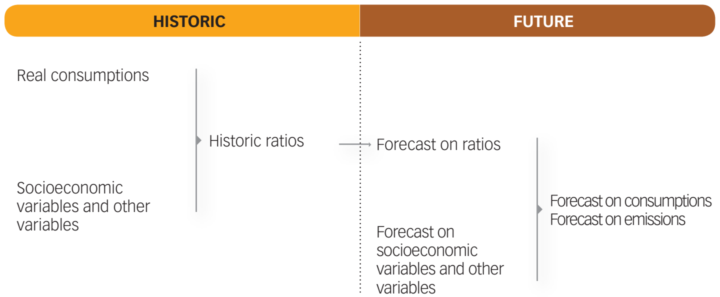


TABLE 63 | VARIABLES USED IN THE DEFINITION OF THE TREND SCENARIO

Socio-economic and other variables

- Population.
- Municipal GDP.
- Percentage of GDP in the service sector.
- Percentage of GDP in the industrial sector.
- Build-up land space area.
- 2020 forecast of annual road traffic in Barcelona (veh-km/year) according to the trend scenario of the 2018 PMU.
- Type of vehicles according to a natural fleet renewal maintaining the current average age.

Socio-economic and functional structure ratios

- Veh-km per inhabitant.
- Veh-km per unit of GDP.
- Residential built-up area per capita.

Energy consumption ratios

- Power consumption (by energy sources and sectors) per inhabitant.
- Commercial energy intensity (by energy sources).
- Industrial energy intensity (by energy sources).
- Consumption of fuels (by energy sources) and other energy by traction, by distance travelled, and per capita.

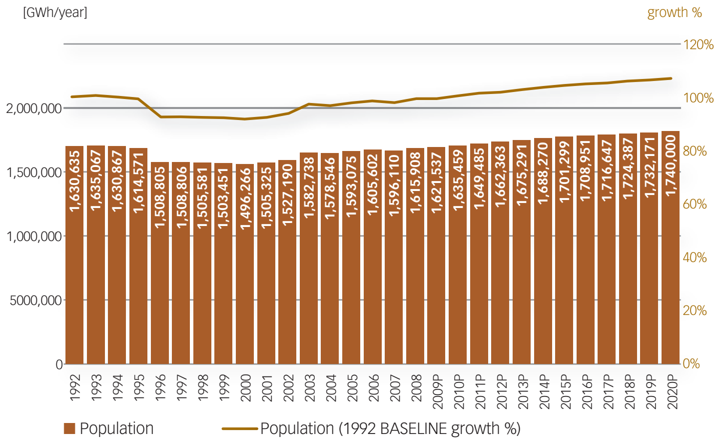
Ratios of municipal waste generation

- To estimate the future evolution of mass waste generation, the methodology applied in the 2009-2016 Metropolitan Waste Management Programme for the medium scenario is adopted and adapted to the waste generation ratio of the city of Barcelona.

Ratios of pollutant emissions

- Emission factors for NO_x and PM (by energy sources) per unit of energy consumed.
- Forecast for electricity mix to determine the GHG factor.
- Waste generation and treatment according to metropolitan forecasts.

FIGURE 222 | HISTORIC EVOLUTION (1992-2008) AND FORECAST (2009-2020) OF THE BARCELONA POPULATION IN THE TREND SCENARIO



▲ The demographic evolution has been estimated based on the future urban transformation of the city, the result for 2020 being of a population of 1,74 million, an increase that will be accompanied by a growth in the number of dwellings (following the guidelines of the current reuse of industrial land for a residential and production mixed land). This provision has been compared to the one made by the Programming Technical Office of the Barcelona City Council[40] which, in its most optimistic scenario, reaches the figure of 1,740,000 inhabitants in 2020, virtually identical to the value found in the PECQ.

The economic development of Barcelona

Across socio-economic data collected in the prospective analysis, we obtained a trend future scenario that would entail Barcelona's GDP to grow at an average of 1.8% in 2015, and 2.3% in 2020.

These figures are much lower than in recent years, but they are above the long-term estimates for the Spanish and Catalan economy. Obviously, if the recovery of the international economy were to be slower than as currently forecasted by the European Union, this would affect the economic growth of Barcelona.

In terms of sectors, it is expected to see an increase in the weight of the tertiary sector, following a trend that has been given continuously in recent years. The largest increase occurs in the segments of professional services and tourism activities.

The increase in the number of jobs is maintained, but less so in proportion to the economic growth due to productivity improvements. As the sectors of the future are more closely related to industries and services with greater added value, and adding that there is a lower population growth, increased productivity tends to be superior.

This job creation, superior to demographic growth, will continue to affect work mobility. Therefore the needs for transport services within the whole metropolitan area will increase.

40. Maria Antònia Monés i Josep Maria Carrera, La Barcelona Metropolitana els propers 20 anys, (Metropolitan Barcelona in the next 20 years) Gabinet Tècnic de Programació de l'Ajuntament de Barcelona, 2003

FIGURE 223 | ECONOMIC GROWTH FORECAST IN BARCELONA (PERCENTAGE OF AVERAGE ANNUAL GROWTH IN REAL TERMS)

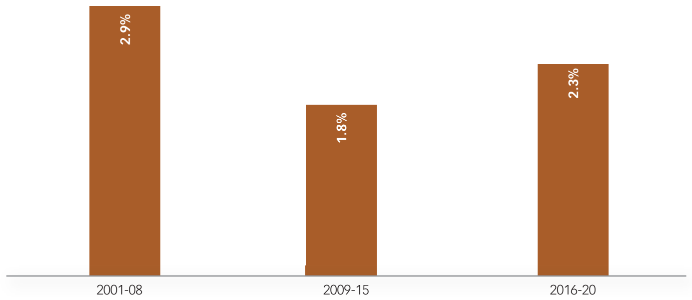
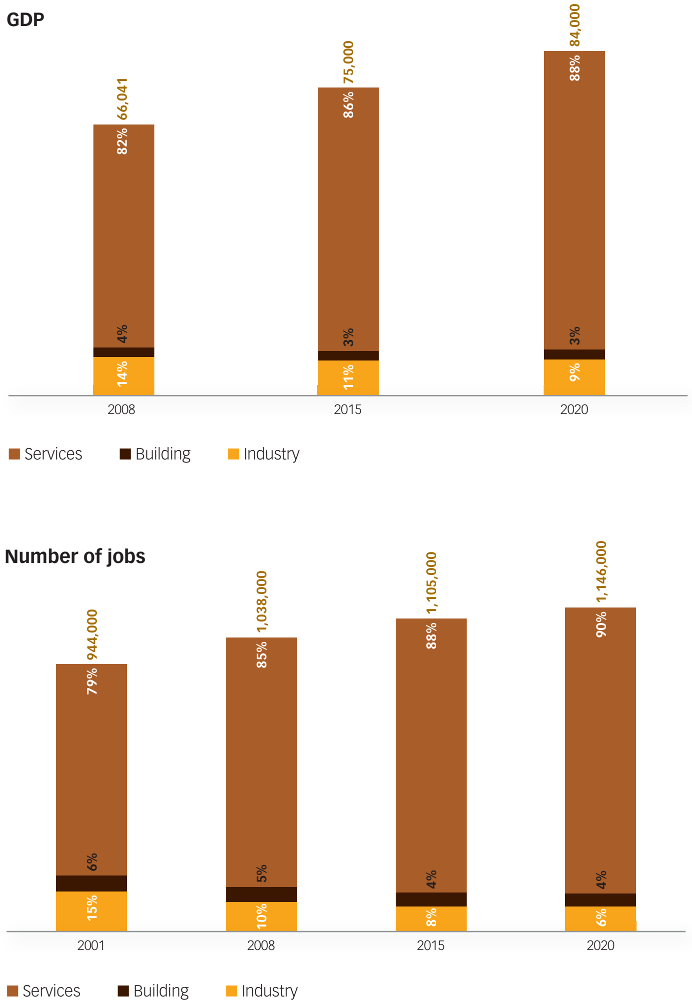


FIGURE 224 | DISTRIBUTION OF SECTORAL GDP IN BARCELONA AND NUMBER OF JOBS FORECASTED



▲ In 2008 constant million euros and percentage distribution

4.2.2 - EVOLUTION OF THE PORT AND AIRPORT ACTIVITY

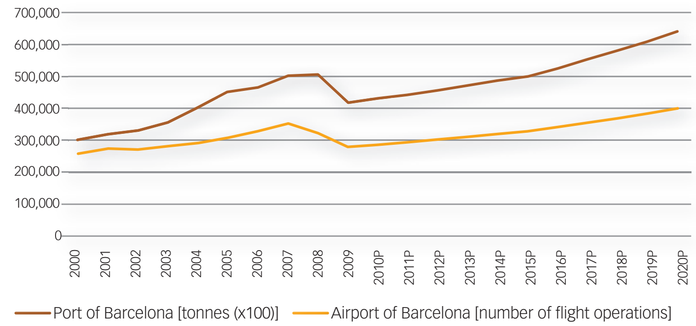
The growth of freight at the Port of Barcelona has been in recent years up to 50.55 Mt in 2008, with a cumulative annual growth rate of 6.67% (three times the GDP), while last year the effects of the economic crisis began to be noticed. 2009 was the first year of negative growth, with a volume of goods transported of 41.79 Mt (a 17% drop from on 2008).

However, despite the crisis, the Port began a process of enlargement which will place it among the top five ports of Europe, and will consolidate it as the great southern gate of entry of goods into the continent. It will this way achieve freight greater capacity, reaching 130 Mt and 10 million TEUs[41], while the current capacity is around 50 and 2.6 million respectively, which implies 160% increase in load capacity. This expansion will imply an increase in occupation area from 932 hectares (558 on land and 374 on the sea) to 2,051 ha (1,265 hectares on land and 786 on the sea).

Although it is difficult to predict the growth rate of freight at the Port of Barcelona, an average annual growth of 3% has been estimated for the period 2009-2015, and 5% for the period of 2015-2020.

As for Barcelona Airport, AENA expects a 2.7% annual increase in flights between 2008 and 2015 and 4% from 2015, which is less than the 4.6% figure for the period 2000-2008, which was marked by the growth of low-cost carriers. It must be said that in June 2009 the new airport terminal was inaugurated and launched, which has meant a capacity increase up to 50 million passengers annually and 90 operations per hour.

FIGURE 225 | HISTORIC EVOLUTION (2000-2009) AND FORECAST (2010-2020) OF BARCELONA PORT AND AIRPORT USE GROWTH



41. Twenty feet equivalent unit: unit of measure of naval shipping capacity

4.2.3 - ROAD TRAFFIC EVOLUTION

To estimate the evolution of road traffic in Barcelona in 2020 (without applying further measures of modal shift to public transport) the Barcelona 2008 Urban Mobility Plan (PMU) trend scenario has been taken into account, extending the series until 2020. The main premise considered in this PMU is that the future trend of generating travel per means of transport will be similar to that of the last six years. It is expected therefore that the annual road traffic in the city of Barcelona and the Barcelona ring-roads will be 5,624.66 million veh-km/year, a figure that implies a growth rate of 2% per year compared to 2008.

In order to estimate future emission factors, a scenario of the mix of vehicles until 2020 has been developed, considering that there will be a natural vehicle renewal. It should be noted that in this period two new European regulations will apply to reduce emissions from passenger cars and commercial vehicles: Euro V, which entered into force on 1 September 2009 and Euro VI, which will on 1 September 2014. These regulations have, however, a time of moratorium, so the application has been effective on 1 January 2011 for Euro V, and shall be 1 January 2015 to Euro VI.

Forecasts of future vehicle fleet have been calculated from the current age, which was 5.6 years in the city overall. Given the natural renewal of vehicles, it is estimated that the average age of 5.6 years will remain until 2020. This way, the percentage of vehicles of older categories will decrease while there will be more efficient and less polluting vehicles, as set by the European standards.

Apart from this hypothesis of natural renewal, an increase in the number of hybrid cars has also been estimated in accordance with trends of recent years. Although, at present, they only account for 0.21% of passenger cars, it is expected that technological advances and changes in people's consumption habits will favour a rate increase to 10% of passenger cars. In the specific case of purely electric vehicles no estimate has been made for the future, since it is not forecasted in the definition of the trend scenario.

FIGURE 226 | HISTORIC EVOLUTION (1999-2008) AND FORECAST (2009-2020) OF ROAD TRAFFIC IN BARCELONA, ACCORDING TO THE TREND SCENARIO

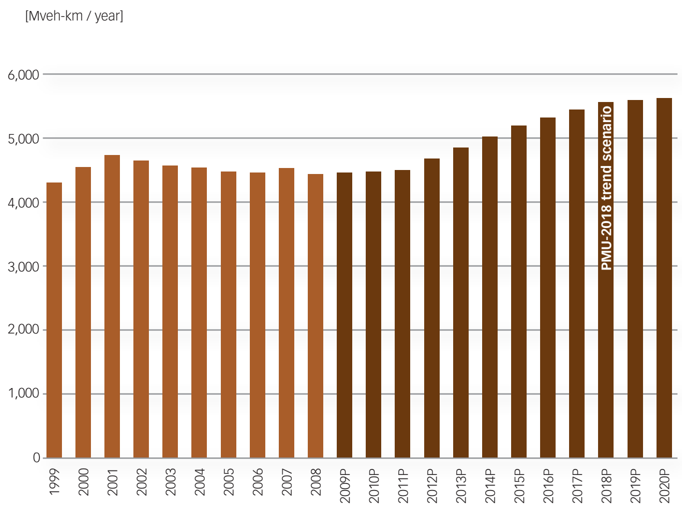
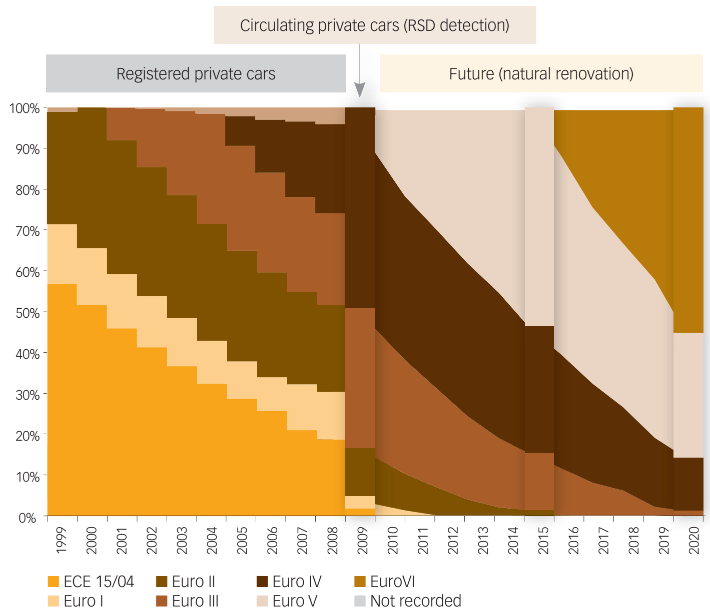


FIGURE 227 | REGISTERED PASSENGER CARS (1999-2008), CHARACTERIZATION AND EVOLUTION OF THE MOBILE FLEET (2009/2009-2020)



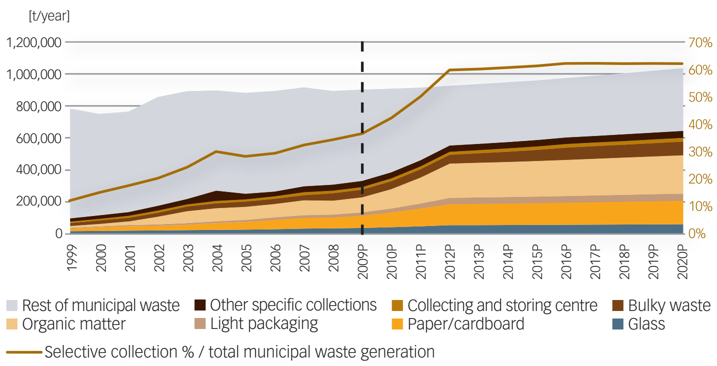
▲ Includes vehicles which will comply with the European regulations Euro V (2011) and Euro VI (2015).

4.2.4 - EVOLUTION OF WASTE GENERATION

One of the goals in the forecast of total future waste generation is to know the specific production of each of the fractions. The methodology applied in the Metropolitan Waste Management Programme 2009-2016 (PMGRM) has been used to stage an average scenario -with a ratio of increased generation of 0.62% annually -, tailored to the city of Barcelona and to the temporality of PECQ. The resulting figure is 1,029,248 t in 2020.

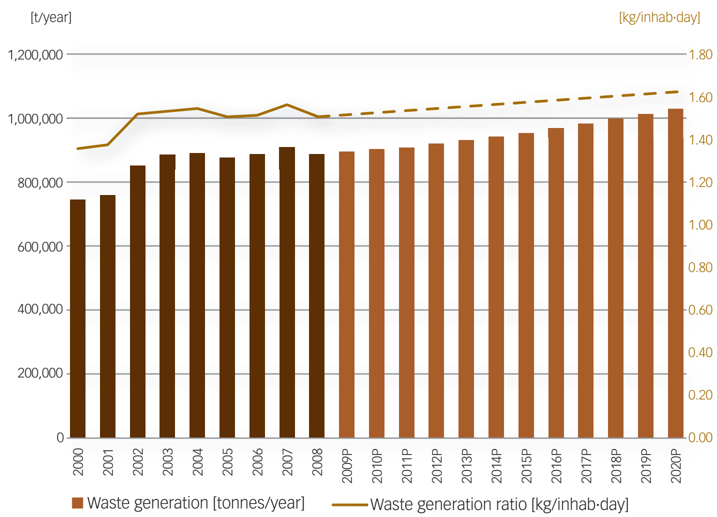
The objectives set out for selective collection in 2012 have been defined in PROGREMIC 2007-2012, while from this year until 2016, the trend set in PMGRM 2009-2016 has been followed. For the period 2016-2020, it was considered that the selective collection objectives proposed in this programme remain constant. The result implies a selective collection of 62% for 2020, with a ratio of selective generation of 1 kg / inhab · day.

FIGURE 228 | HISTORIC EVOLUTION AND FORECAST OF MUNICIPAL WASTE IN BARCELONA, BY FRACTIONS SOURCE: 2009-2016 PMGRM



Source: PMGRM 2009-2016

FIGURE 229 | HISTORIC EVOLUTION (2000-2008) AND FORECAST (2009-2020) IN WASTE GENERATION IN BARCELONA, ACCORDING TO THE TREND SCENARIO



4.2.5 - ENERGY CONSUMPTION ESTIMATION

Consumption by energy sources

The intersection of socio-economic data with the forecasts of other future variables such as city projects, forecasted traffic and consumption ratios, provide a picture of what the energy consumption trend scenario or *"business as usual"* may become.

This scenario results in a final energy consumption of 21,826.9 GWh by 2010, with a ratio of 12.54 per MWh /person. By sources of energy, this consumption is distributed as follows: 45.3% of electricity, 32.8% of natural gas, 21.3% of automotive fuels (diesel, petrol and natural gas) and 0.6% of liquefied petroleum gas or LPG.

A 2.10% annual increase in energy consumption has been estimated, much of which is directly related to the increased use of natural gas consumption, which is expected to regain in 2015 the consumption levels of the period 2001-2005. A 2.29% annual increase in electricity consumption is also expected, due mainly to the increase in the number of electrical appliances in homes. As for LPG, demand is expected to continue decreasing, while petrol for cars will grow at the annual rate of 1, 58% unless the provisions of the Barcelona Urban Mobility Plan (PMU) are applied.

TABLE 64 | FORECAST FOR FINAL ENERGY CONSUMPTION IN BARCELONA, ACCORDING TO THE TREND SCENARIO (2020)

Trend scenario: forecast on final energy consumption in 2020 Barcelona							
	1992 [GWh]	1992 - 1999	1999 [GWh]	1999 - 2008	2008 [GWh]	2008 - 2020	2020 [GWh]
Electricity	5,029.18	2.12%	5,824.20	2.91%	7,536.66	2.29%	9,890.94
Natural gas	5,204.02	1.31%	5,699.67	-0.64%	5,381.83	2.40%	7,150.56
LPG	660.73	-6.43%	414.98	-6.21%	233.12	-4.32%	137.25
Automotive	3,298.07	1.76%	3,725.93	0.37%	3,850.17	1.58%	4,648.18
Total	**14,192.00**	**1.42%**	**15,664.78**	**0.91%**	**17,001.78**	**2.10%**	**21,826.93**
Total [MWh/ inhab.]	**8.70**	**2.60%**	**10.42**	**0.11%**	**10.52**	**1.47%**	**12.54**

FIGURE 230 | HISTORIC EVOLUTION (2000-2008) AND FORECAST (2009-2020) OF ENERGY CONSUMPTION IN BARCELONA BY ENERGY SOURCE, ACCORDING TO THE TREND SCENARIO

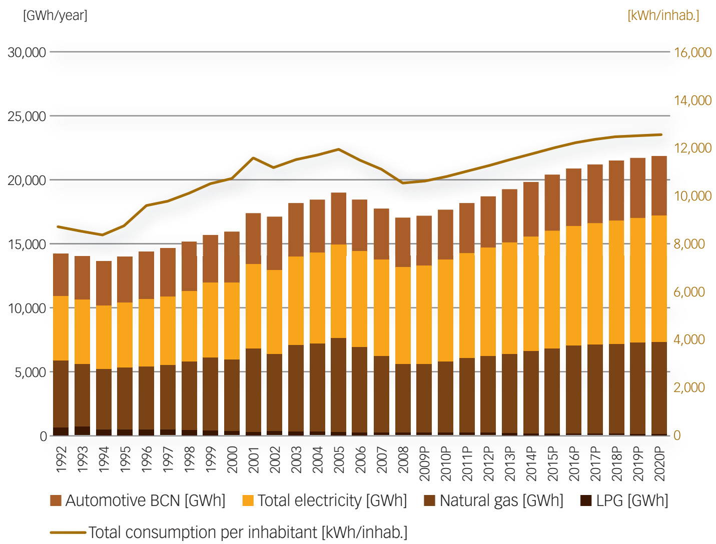
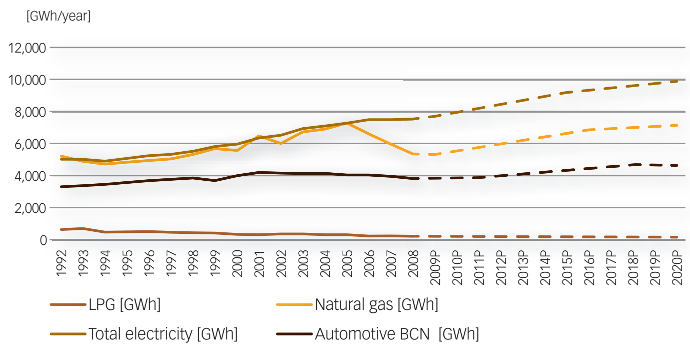


FIGURE 231 | HISTORIC CONSUMPTION (1992-2008) AND FORECAST (2009-2020) OF ENERGY CONSUMPTION IN BARCELONA BY SOURCE - TREND SCENARIO



Consumption by sectors

As for energy consumption by sector, an annual growth of 2.59% was estimated for the trade and services sector, a trend which will make this sector the largest energy consumer in Barcelona. Historically, the main consumer of energy was the residential sector, but in 2007 the trend was reversed. However, a 2.04% annual increase in consumption in the residential sector has been forecasted.

With regard to industry and transportation, increases of 1.83% and 1.69% annually, respectively, have been provided for. The *"Others"* sector, including primary, energy and construction sectors, will experience an annual growth of 3.14%, although it is worth noting that this sector only represents 0.9% of total consumption in the city.

TABLE 65 | FORECAST FOR FINAL ENERGY CONSUMPTION IN BARCELONA, ACCORDING TO THE TREND SCENARIO (2020)

Trend scenario: forecast on final energy consumption in 2020 Barcelona							
	1992 [GWh]	1992 - 1999	1999 [GWh]	1999 - 2008	2008 [GWh]	2008 - 2020	2020 [GWh]
Residential	4,225.64	1.08%	4,556.04	0.46%	4,749.34	2.04%	6,055.20
Commerce and services	3,203.79	3.40%	4,049.60	2.56%	5,083.79	2.59%	6,911.52
Industrial	3,205.19	-0.97%	2,993.50	-0.24%	2,929.76	1.83%	3,643.92
Transport	3,469.69	1.93%	3,965.88	0.37%	4,100.83	1.69%	5,016.19
Other	87.68	1.86%	99.76	3.68%	138.07	3.14%	200.10
Total	**14,192.00**	**1.42%**	**15,664.78**	**0.91%**	**17,001.78**	**2.10%**	**21,826.93**
Total [MWh/ inhab.]	**8.70**	**2.60%**	**10.42**	**0.11%**	**10.52**	**1.47%**	**12.54**

FIGURE 232 | HISTORIC EVOLUTION (2000-2008) AND FORECAST (2009-2020) OF ENERGY CONSUMPTION IN BARCELONA BY SECTORS, ACCORDING TO THE TREND SCENARIO

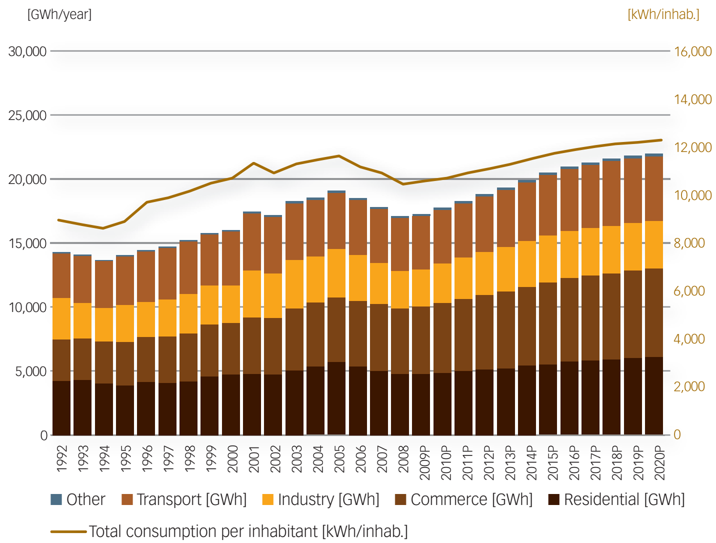
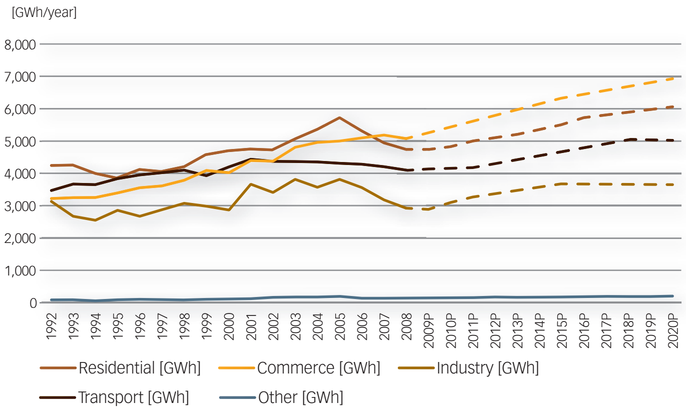


FIGURE 233 | HISTORIC EVOLUTION (2000-2008) AND FORECAST (2009-2020) OF ENERGY CONSUMPTION IN BARCELONA BY SECTORS, ACCORDING TO THE TREND SCENARIO



4.2.6 - EVOLUTION OF THE ELECTRIC GENERATION MIX

To estimate the emission factor of future greenhouse gases (GHG) the electricity generation mix also has to be forecasted. In the case of the Catalan mix, the review of the 2009 Energy Plan for Catalonia produced by the Catalan Institute of Energy was considered. Of all the scenarios analyzed, the 2015- IER and the E4 scenarios were considered for the years 2015 and 2030 respectively (the latter was also used to estimate the 2020 scenario). In the case of the Spanish electricity mix, we used information (very little) that the document *"Anticipo del Plan de Renovables 2011-2020"* (2011-2020 Forecast of Renewable Plan) provides. It is worth noting, in this sense that the discussion on the future of nuclear energy is not closed and therefore it is difficult to really determine what the future mix will be.

Either way, these electric mixes involve, for the year 2020, a forecast in terms of GHG emission factors for electricity consumption of 134.28 g and 191.87 g in the electric mix of Catalonia and Spain, respectively. The trend of the emission factor, according to the electric mix of Catalonia, is to maintain levels similar to 2008 in 2020, while in Spain they decrease thanks to the improved technology of new generation facilities and the increase in renewable energy.

TABLE 66 | FORECASTED ELECTRICITY PRODUCTION IN THE CATALAN MIX (2020)

Catalan mix				
Technology	2008 [GWh]	2015-IER [GWh]	2020 [GWh]	2030–E4 [GWh]
Coal	463	0	0	0
CHP	11,179	8,458.3	12,215	19,727.8
Nuclear	22,420	25,174.8	16,783	0
Gas turbines	454	0	0	0
Cogeneration	3,782	7,927.9	8,374	9,267.2
Other. Non-renewable	562	365.7	365.7	365.7
Hydraulics	3,958	5,863.9	5,922	6,040.8
Wind power	643	8,120.8	10,513	15,300.0
PV	141	673.0	799	954.5
Solar electro thermal	0	567.0	1,000	1,967.0
Other renewable energies	92	2,151.1	2,085	1,943.1
Total	**43,694**	**59,302.6**	**58,057**	**55,566.1**

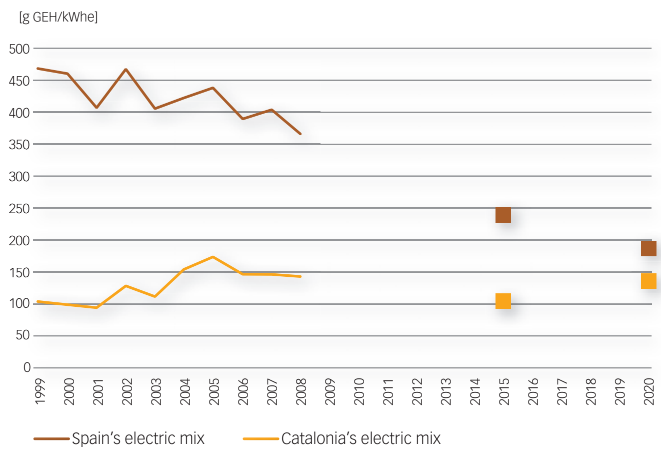
▲ In the case of the Catalan mix, the review of the 2009 Energy Plan for Catalonia produced by the Catalan Institute of Energy was considered. Of all the scenarios analyzed, the 2015- IER and the E4 scenarios were considered for the years 2015 and 2030 respectively (the latter was also used to estimate the 2020 scenario).

TABLE 67 | FORECASTED ELECTRICITY PRODUCTION IN THE SPANISH MIX (2020)

Spanish mix			
Technology	2008 [GWh]	2016 [GWh]	2020 [GWh]
Coal	46,926	23,138	5,784
CHP	91,286	120,000	146,000
Nuclear	58,973	50,000	40,000
Gas turbines	2,378	1,520	0
Cogeneration	19,260	19,260	19,260
Other, Non-renewable	4,790	2,903	1,884
Hydraulics	25,844	124,068 (36.39%)	156,068 (42.3%)
Wind power	31,393		
PV	2,812		
Solar electro thermal	0		
Other renewable energies	2,745		
Total	**286,407**	**340,889**	**368,996**

▲ In the case of the Spanish electricity mix, we used information (very little) that the document "Anticipo del Plan de Renovables 2011-2020".

FIGURE 234 | FORECASTED GHG EMISSION FACTOR FOR ELECTRICITY CONSUMPTION



4.2.7 - GREENHOUSE GAS EMISSIONS (GHG) ESTIMATION

Considering the trend scenario, greenhouse gas emissions (GHG) will reach, by 2020, 5,119.28 thousands tonnes of greenhouse gases, equivalent to 2.94 t / inhabitant. By energy sources, natural gas will represent 28.22% of emissions, electricity 25.93%, automotive oil 24.04% and liquefied petroleum gas 0.61%.

As far as GHG's by sector is concerned, transportation (including automotive petrol, electricity consumption for traction, and vehicular natural gas) will account for 25.01%; the residential sector will represent 20.29%; the commercial and the service sector 19.67%; the industrial sector 13.31%; and the Other sector (primary, energy and construction) 0.52%. The Port and Airport of Barcelona will be responsible for 14.36% and waste treatment for 6.8%.

TABLE 68 | FORECAST FOR GHG'S BY ENERGY SOURCES IN BARCELONA (2020), ACCORDING TO THE TREND SCENARIO AND THE CATALAN ELECTRIC MIX

Trend scenario: forecast for GGE's by sources in 2020 Barcelona (Catalonia's electric mix)				
[t GHG x 1,000]	1992	1999	2008	2020
Liquefied petroleum gases (LPG)	188.26	97.15	53.15	31.29
Natural gas	1,051.95	1,152.14	1,086.78	1,444.52
Electricity	877.89	610.16	1,081.44	1,327.66
Automotive oil	814.07	995.07	1,025.72	1,230.44
MSW treatment	1,320.01	1,446.40	327.58	350.00
Port and Airport	430.38	436.39	479.08	735.36
Total emissions [x1,000 t]	**4,682.56**	**4,737.30**	**4,053.77**	**5,119.28**
Ratio per inhabitant [t GHG/inhab.]	**2.87**	**3.15**	**2.51**	**2.94**

FIGURE 235 | HISTORIC EVOLUTION OF GREENHOUSE GAS EMISSIONS (GHG'S) (2000-2008) AND FORECAST (2009-2020) IN BARCELONA BY ENERGY SOURCES, ACCORDING TO THE TREND SCENARIO

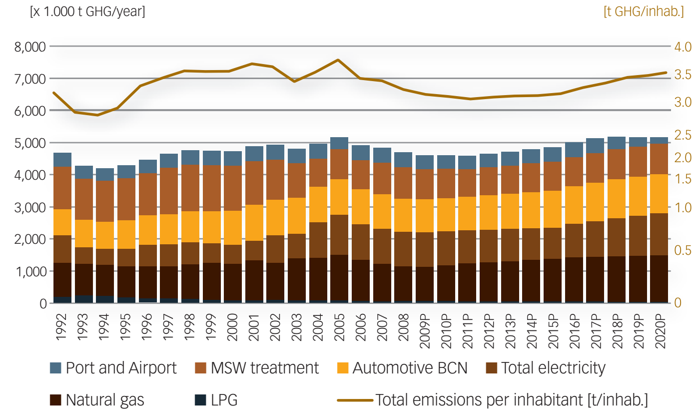
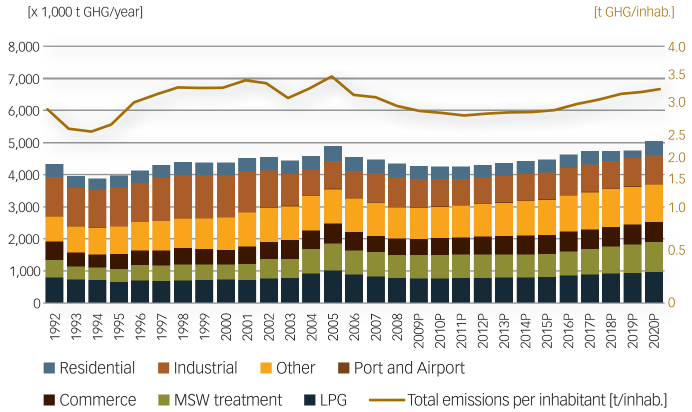


TABLE 69 | FORECAST FOR GHG'S BY ENERGY SOURCES IN BARCELONA (2020), ACCORDING TO THE TREND SCENARIO AND THE CATALAN ELECTRIC MIX

Trend scenario: forecast for GGE's by sources in 2020 Barcelona (Catalonia's electric mix)				
[t GHG x 1,000]	1992	1999	2008	2020
Residential	854.53	766.22	833.43	1,038.58
Commerce and services	584.21	530.18	785.47	1,006.98
Industry	632.09	523.05	546.50	681.38
Transport	846.03	1,024.62	1,061.89	1,280.10
Other	15.31	10.45	19.82	26.87
MSW treatment	1,320.01	1,446.40	327.58	350.00
Port and Airport	430.38	436.39	479.08	735.36
Total emissions [x1,000 tn]	**4,682.56**	**4,737.30**	**4,053.77**	**5,119.28**
Ratio per inhabitant [t CO_{2eq}/inhab.]	**2.87**	**3.15**	**2.51**	**2.94**

FIGURE 236 | HISTORIC EVOLUTION OF GREENHOUSE GAS EMISSIONS (GHG'S) (2000-2008) AND FORECAST (2009-2020) IN BARCELONA BY ENERGY SOURCES, ACCORDING TO THE TREND SCENARIO



4.2.8 - ESTIMATION OF POLLUTANT EMISSIONS

NO_x emissions

It is estimated that in 2020 Barcelona will generate 9,864 t of NO_x emissions, 17.3% less than in 2008. This information is obtained following the methodology used in calculating NO_x emissions in 2008 and the forecasted socioeconomic and energy consumption in the trend scenario.

It is important to add that the emissions that are produced within the administrative limits of the city are recorded since they are pollutants with a local effect. It is expected that the emission factors used will remain constant in all sectors except in road motor traffic, since the natural renewal of the vehicle fleet is forecasted.

TABLE 70 | FORECAST OF THE EMISSION FACTOR FOR NO_x / KM TRAVELLED IN BARCELONA - TREND SCENARIO (2008-2020)

Trend scenario: forecast of the emission factor for NO_x /km travelled in Barcelona		
[g NO_x/km travelled]	2008	2020
Total circulation in the city	1.13	0.53

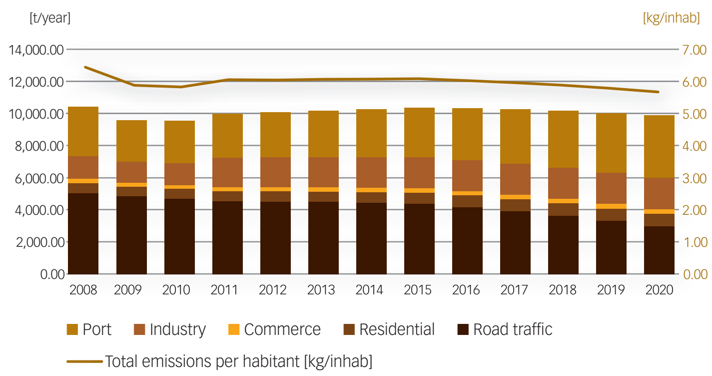
It is also expected in the trend scenario that the combined cycle power station located at the Port of Barcelona will be launched in the coming years, which will have a total power of 800 MW (2x400 MW). The construction and operation of this plant will lead -as a consequence of the implementation of the Action Plan for Improving Air Quality in the Municipalities of the Metropolitan Area- to the application of compensatory measures which will theoretically avoid emission levels higher than those derived from the operation of the plant itself. Estimations of future emissions of large electric power plants are based on historical data of the facilities currently in operation and on technical specifications of new ones.

The analysis by sector shows the great reduction in emissions that will occur in the transport and mobility sector, as it will shift from 48% of the total in 2008 to 30% in 2020. However, the industrial sector will increase its annual emissions, mostly due to the introduction of the new power plant. The domestic sector will also increase its annual emissions from 657.50 t (2008) to 785.51 t of NO_x (2020), while the commercial sector will increase up to 288.73 tonnes / year (2020). Emissions at the Port of Barcelona will grow due to expansion and expectations of increased activity, shifting from 3,078 t (2008) to 3,864 t (2020), making it the leading emission source.

TABLE 71 | FORECAST OF THE NO_x EMISSION FACTOR BY SECTORS IN BARCELONA - TREND SCENARIO (2008-2020)

Trend scenario: forecast of the NO_x emissions by sectors in 2020 Barcelona		
[t NO_x]	2008	2020
Road traffic	5,014.72	2,986.37
Industry	1,394.45	1,939.20
Residential	657.50	785.51
Commerce	268.33	288.73
Port	3,077.94	3,863.72
Total emissions [t]	**10,413**	**9,864**
Ratio per inhabitant [t NO_x/inhab]	**6.44**	**5.67**

FIGURE 237 | NO_x EMISSIONS IN BARCELONA (2008) AND FORECAST (2009-2020) - TREND SCENARIO



PM_{10} emissions

The emissions of PM_{10} are also calculated based on the trend scenario socioeconomic variables, maintaining the emission factors constant except in the case of road transport. In the case of particles, the natural renewal of the fleet also has a significant impact on reducing emissions per travelled kilometre.

TABLE 72 | FORECAST OF THE EMISSION FACTOR OF PM_{10}/KM TRAVELLED IN BARCELONA - TREND SCENARIO (2008-2020)

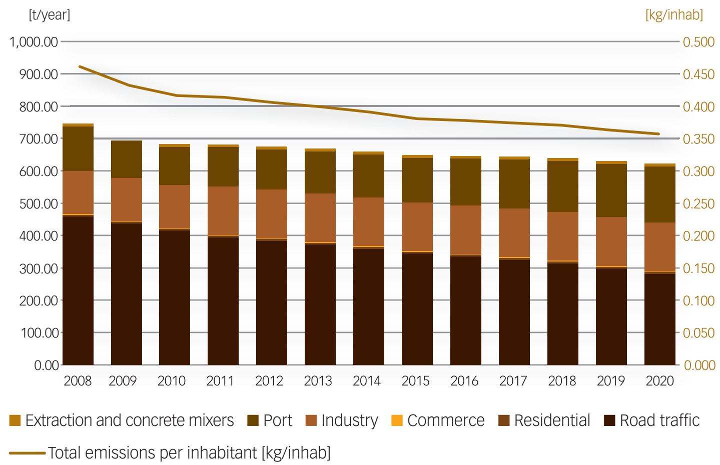
Trend scenario: forecast of the emission factor of PM_{10} /km travelled in Barcelona		
[g PM_{10}/km travelled]	2008	2020
Total traffic in the city	0.1032	0.050

This scenario for 2020 foresees a reduction of emissions by 17% over 2008, going from 457.95 tonnes to 280.18 tonnes of PM_{10} (2020). By sector, industry will increase its emissions up to 150.77 tonnes, the domestic sector up to 5.83 tonnes, and the trade sector up to 2.58 t. The Port of Barcelona will also increase its emissions due to expanding its capacity and operations from 137.31 t (2008) to 172.79 t in the trend scenario (2020). In the case of extractive activities and mixers the emissions will remain constant in 2020 compared to 2008.

TABLE 73 | FORECAST OF THE PM_{10} EMISSION FACTOR BY SECTORS IN BARCELONA - TREND SCENARIO (2008-2020)

Trend scenario: forecast of the PM_{10} emissions by sectors in 2020 Barcelona		
[t PM_{10}]	2008	2020
Road traffic	457.95	280.18
Industry	133.45	150.77
Residential	4.89	5.83
Commerce	2.36	2.58
Port	137.31	172.79
Extractions and concrete mixers	7.80	7.80
Total emissions [t/year]	**743.77**	**619.95**
Total emissions per inhab. [kg/inhab]	**0.460**	**0.356**

FIGURE 238 | NO_x EMISSIONS IN BARCELONA (2008) AND FORECASTS (2009-2020) - TREND SCENARIO



4.3 - Finishing scenario: PECQ-2020

4.3.1 - GLOBAL FORECASTS

The PECQ-2020 scenario is the result of the estimated effects of the implementation of PECQ projects on the trend scenario. Any significant economic or demographic change of the city can therefore cause certain fluctuations in the outcome.

Considering the basis of the trend scenario and the impact of the projects outlined in the PECQ action strategy (which includes 108 projects, of which 85 correspond to the City Programme and 23 to the Municipal Programme), it is expected that in 2020 there will be an increase in average yearly energy consumption close to 1.4%, equivalent to 0.8% growth in consumption per capita.

Modern society has an increasing tendency to have more electronic devices in the homes and the services sector and a greater demand for thermal comfort. This trend has so far surpassed the technological advances that improve the energy efficiency of appliances, and it is not expected to reverse by applying the measures proposed in the action strategy related to the people's energy use attitudes and habits.

Moreover, although the energy consumption in 2008 was one of the lowest in recent years -due to several temporary factors-, the most realistic possibilities of the PECQ scenario suggest that there will be a progressive growth in energy consumption until the levels go back to those of recent years. Provided, of course, there are no further reductions in consumption due to extreme climatic factors or new unforeseen local or global economic circumstances difficult to predict in a trend scenario for the future.

However, an improvement in energy intensity is also expected. While the trend scenario predicts an annual rate of -0.3%, the PECQ action strategy forecasts a -1.0%, i.e. to generate the same amount of GDP with less energy consumption.

As for the emissions of greenhouse gases, and considering the Catalan electric mix, it is expected that the average annual rate does not increase beyond 0.7%, 1.3 points below the forecast of the trend scenario. However, if we consider the Spanish electricity mix, the reduction would be 1% annually. With these ratios, emissions of greenhouse gases per capita, considering a population increase of 7.4%, would stand at 2.53 t/capita or 2.91 t/capita, depending on the Catalan or the Spanish mix, respectively.

As for the reduction of NO_x and PM_{10} emissions, the trend scenario already proposed a reduction due to technological improvements that will be introduced and to the natural fleet renewal. However, PECQ measures further reduce these emissions, with a forecast of -1.8% and -3.8% in annual rate for NO_x and PM_{10}, respectively. In short, a 1.3 and 2.3 point increase in the reductions achieved with respect to the trend stage, respectively.

It should be noted that while the PECQ scenario forecasts this vehicle emissions reduction resulting from technological improvement and renewal of the fleet, such reduction was calculated based on the 2008 fleet, reason why it will not be 100% applicable over the period of 2011-2020. Therefore, the projection of the fleet's tonnes of emissions saved in 2008 (2,742.51 tonnes/year of NO_x and 288.08 t/year of PM_{10}) in the 2020 fleet, leads to a rise to 1,451.21 and 149.82 tonnes of NO_x and PM_{10} respectively. These are precisely the figures used to estimate emissions in the 2020 PECQ scenario, as well as in its emission modelling.

TABLE 74 | CONSUMPTION AND EMISSION RATIOS UNDER PECQ SCENARIOS

RATIOS OF PECQ SCENARIOS						
Pecq-2020 Technology	2008	Trend-2020	PECQ-2020	Annual cumulative growth rate 2008-2020_trend	Annual cumulative growth rate 2008-2020_PECQ	Δ Total 2008 Pecq-2020
Final energy consumption [Gwh/year]	17,001.78	21,826.93	20,148.08	2.1%	1.4%	18.5%
CO_{2eq} emissions (Catalan mix) [t/year]	4,053,765.54	5,119,276.78	4,410,271.61	2.0%	0.7%	8.8%
CO_{2eq} emissions (Spanish mix) [t/year]	5,733,150.57	5,784,227.50	5,063,398.23	0.1%	-1.0%	-11.7%
NO_x emissions [t/year]	10,412.94	9,863.53	8,412.32	-0.5%	-1.8%	-19.2%
PM_{10} emissions [t/year]	743.77	619.95	470.13	-1.5%	-3.8%	-36.8%

Ratios of PECQ scenarios						
PECQ-2020 Technology	2008	Trend-2020	PECQ-2020	Annual cumulative growth rate 2008-2020_trend	Annual cumulative growth rate 2008-2020_PECQ	Δ Total 2008 PECQ-2020
Final energy consumption per inhabitant [MWh/inhab]	10.52	12.54	11.58	1.5%	0.8%	10.1%
Energy intensity [Wh/EUR]	269.44	259.84	239.86	-0.3%	-1.0%	-11.0%
GGE per inhabitant (Catalan electric mix) [t/inhab]	2.51	2.94	2.53	1.3%	0.1%	1.0%
GGE per inhabitant (Spanish electric mix) [t/inhab]	3.55	3.32	2.91	-0.5%	-1.6%	-18.0%
NO_x emissions per inhabitant [kg/inhab]	6.44	5.67	4.83	-1.1%	-2.4%	-25.0%
PM_{10} emissions per inhabitant [kg/inhab]	0.46	0.36	0.27	-2.1%	-4.3%	-41.3%

4.3.2 - ENERGY AND ENVIRONMENTAL IMPACT

The following quantification of the energy and environmental impact of PECQ projects is based on trend scenario values.

Overall evaluation

Given that the final energy consumption in 2008 was 17,001.78 GWh, the execution of PECQ approved projects will bring savings of 9.9% of energy consumption compared to that very year. The reduction of primary energy will account for 7% of the 30,783.60 GW consumed in 2008.

In terms of local energy generation under the special regime, PECQ expects a 139.50 GWh increase in electricity generation, from 370.01 GWh/year in 2008 to 509.51 GWh/year in 2020; in other words, a 38% increase. Since 32% of those 139.50 GWh will come from a renewable source, such 44.13 GWh/year in 2008 would become 89.18 GWh/year (an increase of 45.05 GWh/year) under the PECQ-2020 scenario.

The percentage of renewable electricity generated compared to the total electricity consumption in the city would hence grow from 0.59% in 2008 to 0.91% under PECQ-2020.

Below is the breakdown of this future power generation from renewable sources: PV would be multiplied by 3.3, an increase of 25.5 GWh/year (from 7.62 GWh/year to 33.12 GWh/year). 0.04 GWh/year would be generated at small mini-wind farms. The remaining 19.51 GWh would be generated by biogas from the treatment of the city organic fraction waste.

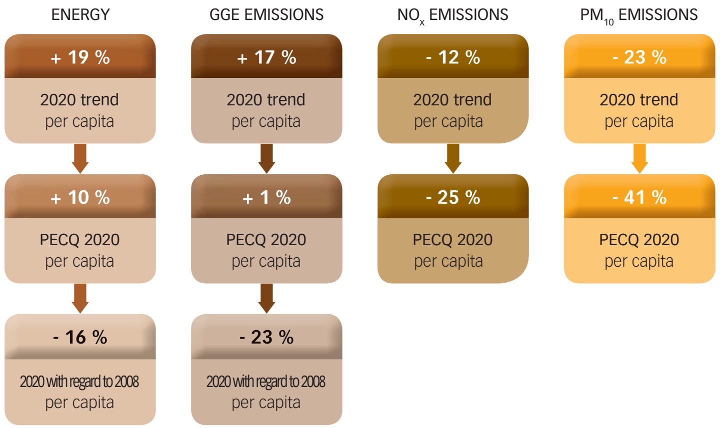
In terms of GHG reduction, according to the Catalan electric mix, when PECQ is fully implemented, it will help reduce greenhouse gas emissions to 709,005.17 t/year. Considering that in 2008 4,053,765 t/year were issued, it can be said that PECQ will help reduce GHG emissions by 17.5%.

Finally, considering that in 2008 10,412.9 t of NO_x and 743.77 t of PM_{10} were emitted in the city, the PECQ projects will help decrease NO_x and PM_{10} emissions by 26.3% and 38.7% respectively.

TABLE 75 | EVALUATION OF ENERGY AND ENVIRONMENTAL PECQ PROJECTS

PECQ project evaluation								
Technology	Nr.	Final energy savings [gwh/year]	Primary energy savings [GWh/year]	Local generation of electricity er+re [GWh/year]	CO_{2eq} reduction (catalan mix) [t/year]	CO_{2eq} reduction (spanish mix) [t/year]	NO_x reduction [t/year]	PM_{10} reduction [t/year]
City Programme	85	1,633.09	1,993.48	126.99	694,177.99	696,378.95	2,688.91	281.39
Municipal Programme	23	45.76	143.42	12.51	14,827.18	24,450.32	53.60	6.69
PECQ	**108**	**1,678.85**	**2,136.89**	**139.50**	**709,005.17**	**720,829.27**	**2,742.51**	**288.08**

FIGURE 239 | PECQ IMPLEMENTATION OVERALL RESULTS



Performance Comparison of Energy Consumption

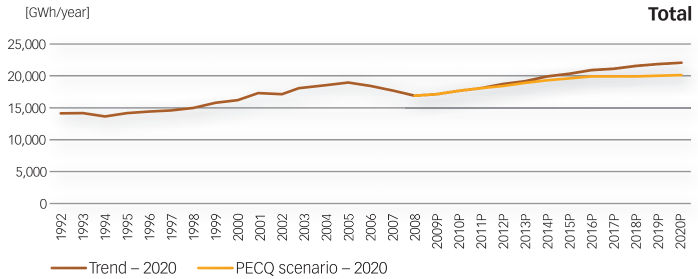
By analysing the annual forecast from the implementation of each PECQ project, we obtain the evolution of energy consumption according to the PECQ-2020 scenario compared to the trend scenario.

Considering the energy savings based on energy sources in the PECQ scenario, diesel and petrol are the greatest contributors, followed by electricity. However, because of the energy improvement oriented cogeneration and micro-cogeneration projects, natural gas involves a greater rate of consumption in the PECQ scenario than in the trend scenario.

TABLE 76 | EVALUATION OF PECQ PROJECTS FOR ENERGY CONSUMPTION

PECQ project evaluation						
Technology	Nr.	Electricity savings [GWh/year]	Natural gas savings [GWh/year]	LPG savings [GWh/year]	Petrol + diesel savings [GWh/year]	Final energy savings [GWh/year]
City Programme	85	10.02	-1.17	0.48	1,623.76	1,633.09
Municipal Programme	23	43.80	-49.34	0.00	51.30	45.76
PECQ	**108**	**53.82**	**-50.51**	**0.48**	**1,675.06**	**1,678.85**

FIGURE 240 | SCENARIOS OF ENERGY CONSUMPTION, TOTAL AND PER CAPITA



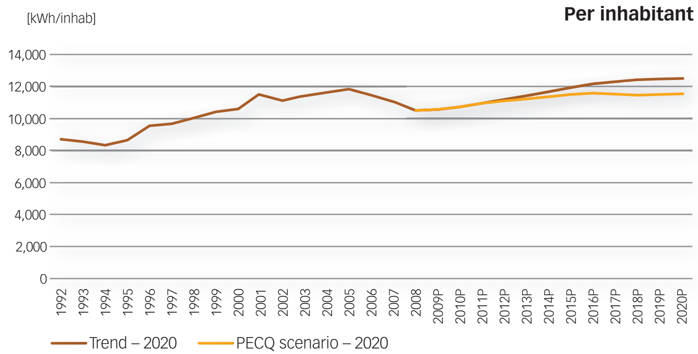
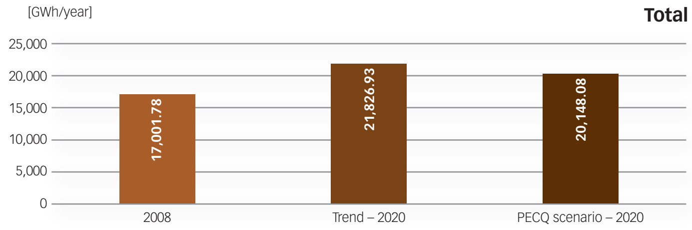
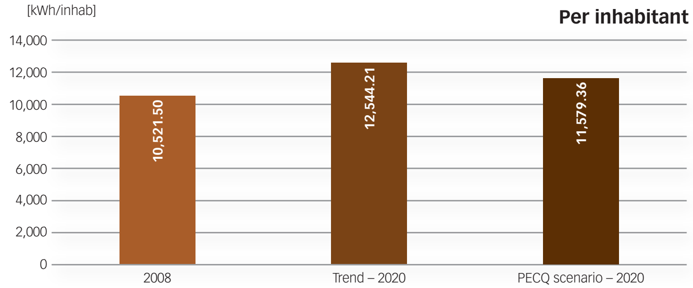


FIGURE 241 | REVISION OF FINAL ENERGY CONSUMPTION (TOTAL AND PER INHABITANT) IN BARCELONA ACCORDING TO DIFFERENT SCENARIOS (2020)



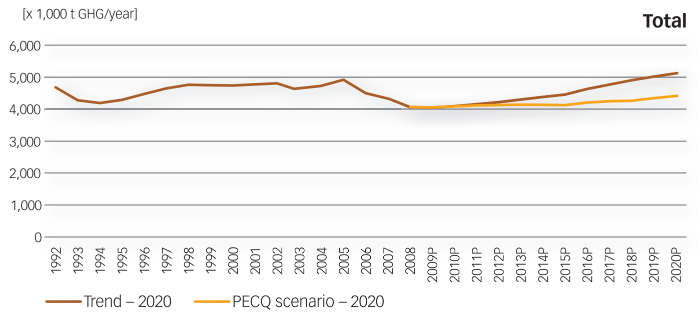


The comparative evolution of GHG emissions

By analysing the annual forecast from the implementation of each PECQ project, we also obtain the evolution of GHG emissions according to the PECQ-2020 scenario compared to the trend scenario.

It is expected to maintain per capita greenhouse gas emissions at around 2.5 t/capita-year, a level which would increase up to 2.9t/capita-year if the PECQ projects are not implemented.

FIGURE 242 | GEH EMISSION SCENARIOS, TOTAL AND PER CAPITA (CATALAN ELECTRIC MIX)



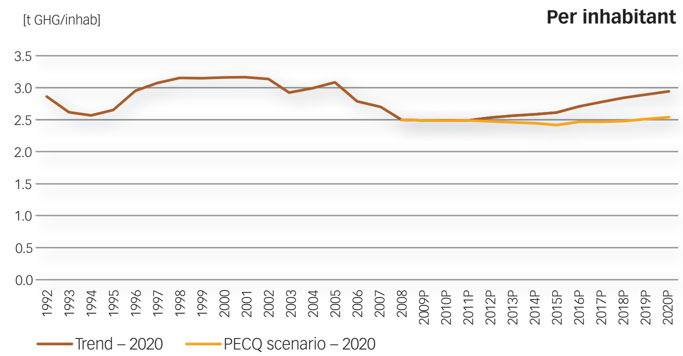
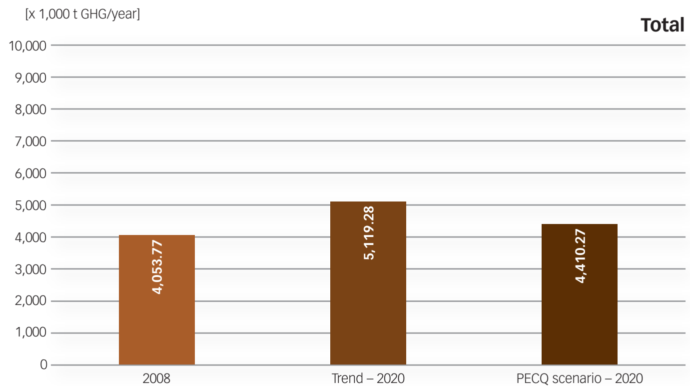
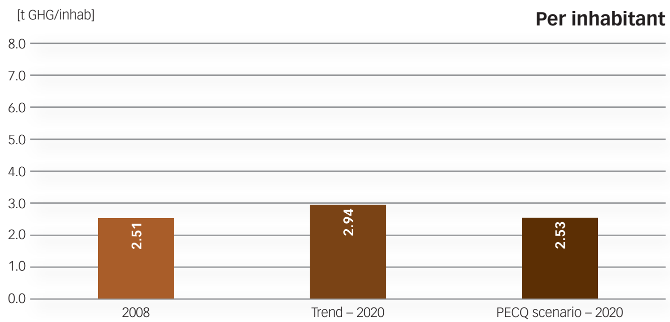


FIGURE 243 | GEH EMISSIONS FORECAST (TOTAL AND PER CAPITA) IN BARCELONA ACCORDING TO DIFFERENT SCENARIOS (2020)





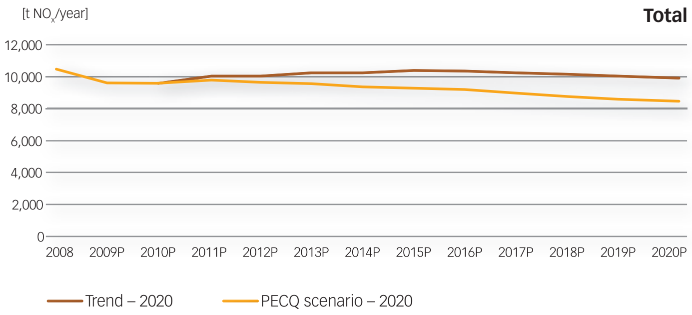
Comparative evolution of pollutant emissions

By analysing the annual forecast of the implementation of each PECQ project, we also obtain the evolution of NO_x and PM_{10} emissions according to the PECQ-2020 scenario compared to the trend scenario.

The reduction in city emissions will imply a reduction in per capita emissions of 1.6 kg of NO_x per year based on 2008, reaching emission levels of 4.84 kg of NO_x/capita in 2020.

Based on expected technological improvements, and on the implementation of PECQ projects, a reduction of 0.19 kg PM_{10}/year in per capita emissions is estimated - and up to 0.27 kg PM_{10}/capita -year in 2020.

FIGURE 244 | SCENARIOS OF NO_x EMISSIONS



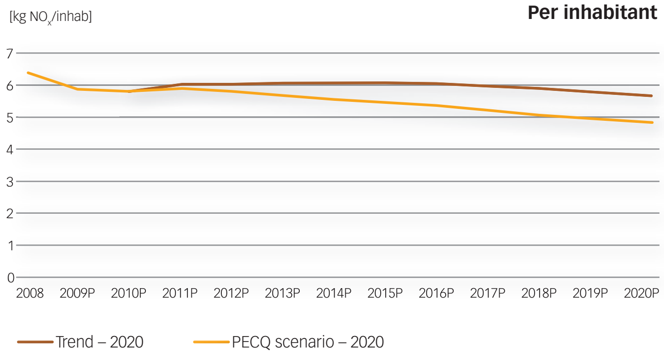
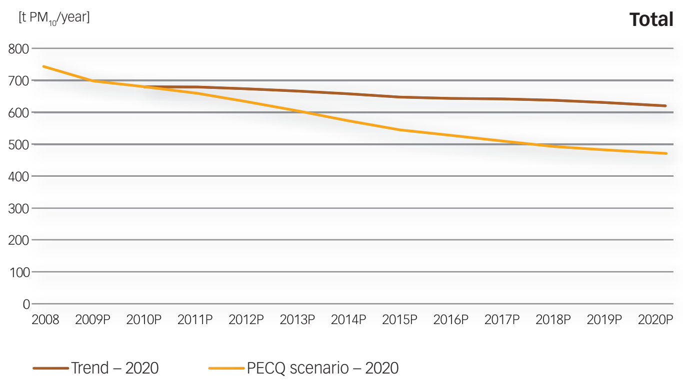


FIGURE 245 | SCENARIOS OF PM_{10} EMISSIONS



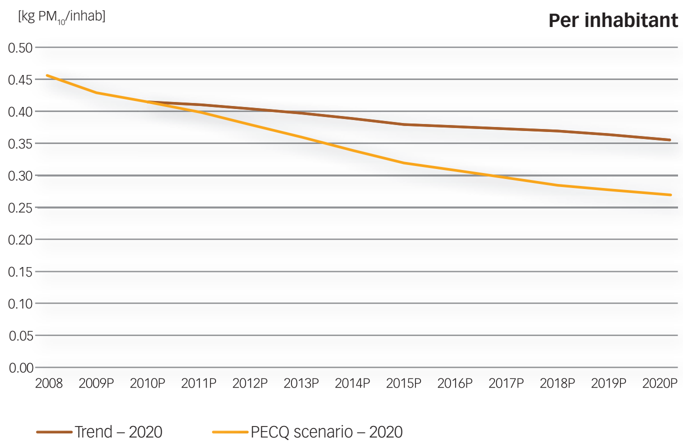
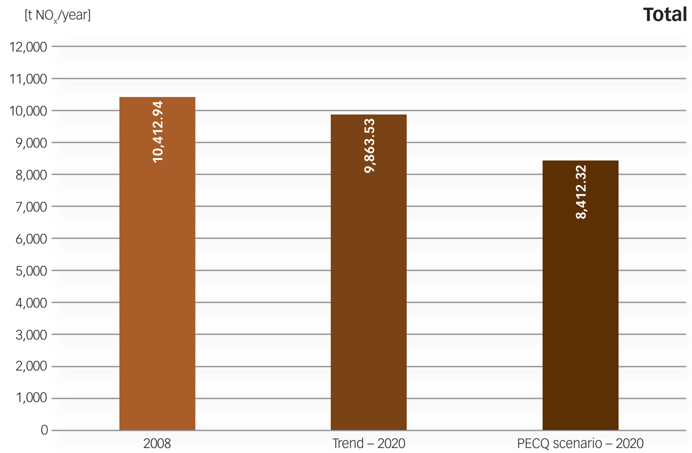


FIGURE 246 | FORECAST OF NO_x EMISSIONS (TOTAL AND PER CAPITA) IN BARCELONA ACCORDING TO DIFFERENT SCENARIOS (2020)



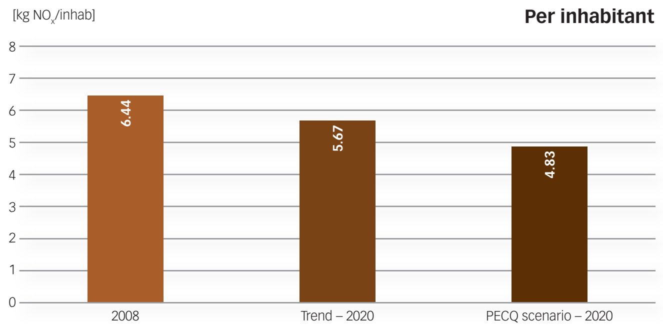
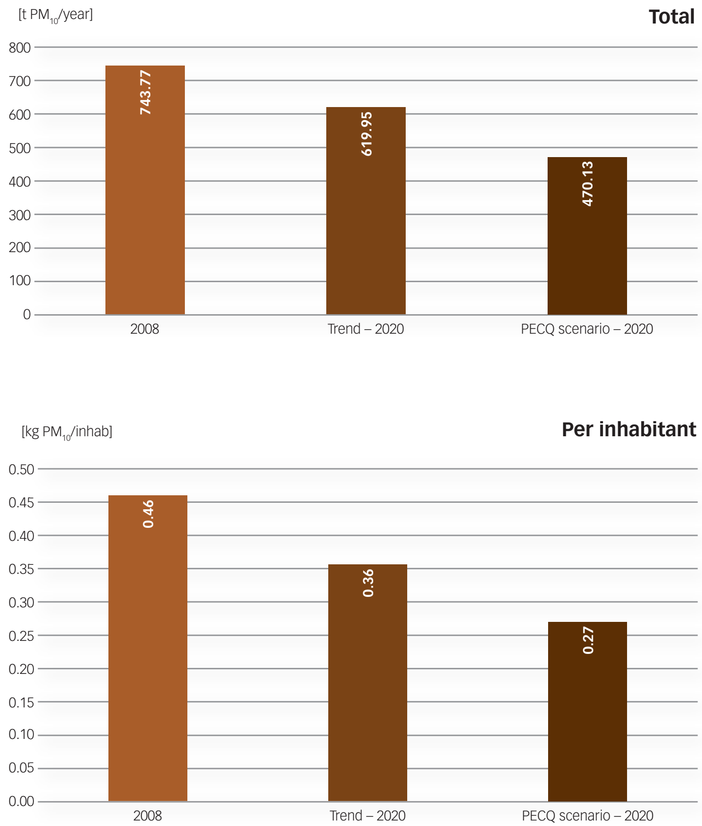


FIGURE 247 | FORECAST OF EMISSIONS OF PM_{10} (TOTAL AND PER CAPITA) IN BARCELONA ACCORDING TO DIFFERENT SCENARIOS (2020)



The development of air quality: applied methodology

The complexity of the city, the variability in climatic conditions and the physical and chemical processes in the atmosphere make it such that the emission reduction does not translate into a proportional reduction of the concentration of pollutants in the air. For that reason, when estimating the concentrations of pollutants in the air in the PECQ-2020 scenario, it was necessary to model the dispersion of pollutants with specific tools that take into account these factors and variables.

The methodology was the same as described for the study of 2008, which involved creating a new inventory of emissions, both in Barcelona city area and in all emission areas that may have an impact on air quality of the area studied. To model the hourly dispersion of pollutants in the PECQ-2020 scenario, meteorological time series data from the El Raval station (2008) were used, to obtain comparable results with the PECQ base year. The cartographic databases and land orographic information were kept constant, except in areas with large urban developments already planned, which have been incorporated into the model.

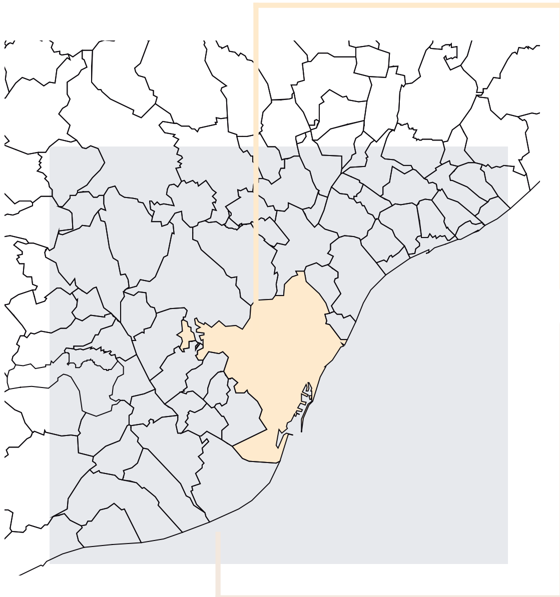
For the calculation of emission scenarios the same socio-economic hypotheses described in the methodology of the trend scenario were followed.

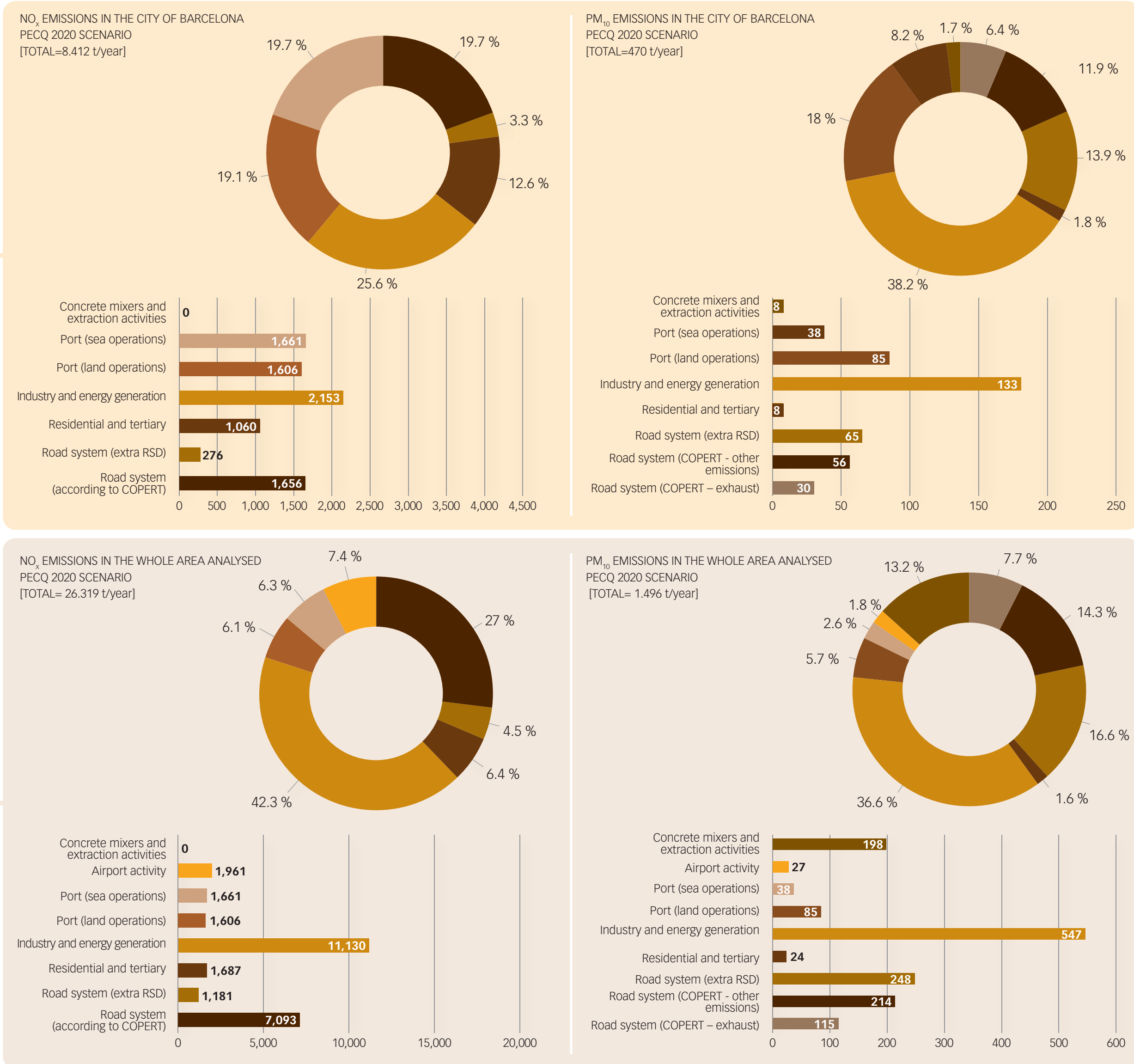
By incorporating the improvements brought into the Barcelona area by PECQ, an emissions inventory for the city was obtained (PECQ-2020 scenario) and for the whole area of analysis. The main changes in the emissions inventory under the PECQ-2020 scenario compared to the current scenario in 2008 are as follows:

- The new planned urban development areas have been taken into account, and the calculation for emissions from household and tertiary sectors have been made, based on the evolution of energy consumption associated with each sector and on the corresponding emission factors.
- Emission factors of the vehicle fleet operating in the year 2020 have been estimated, taking into account its natural upgrades and also natural penetration of new technologies.
- Industrial and power generation emissions have been updated throughout the area. The upcoming opening of the combined cycle power station at the Barcelona Port stands out among them all, as well as the replacement of the outdated gas/fuel stations in Besòs for the new combined cycle station at the same location.
- Under a conservative hypothesis, emissions from mining activities and from major projects throughout the region have been kept constant.
- A forecasted improvement in the management and treatment of waste in the metropolitan area and the new PROGREMIC equipment and facilities have been incorporated. These plants are considered, for purposes of this study, in the industrial sector.
- The emissions estimations from the Barcelona Port and Airport are based on the evolution of port and airport activity, on the emission factors established for each activity, and on the emission reduction projects that each organisation intends to conduct in the coming years.
- PECQ action strategy projects to reduce emissions of NO_x and PM_{10} in each of the sectors and areas concerned have been incorporated.

The complexity of the city, the variability in climatic conditions and the physical and chemical processes in the atmosphere make it such that the emission reduction does not translate into a proportional reduction of the concentration of pollutants in the air

FIGURE 248 | PECQ-2020 SCENARIO: INVENTORY OF EMISSIONS IN BARCELONA (IN PINK) AND THROUGHOUT THE AREA OF STUDY





Note:
"COPERT - EXHAUST" are exhaust emissions from the engine.
"COPERT - OTHER EMISSIONS" are non exhaust emissions including emissions from vehicle brake's wear. tyre wear by bearing and asphalt wear.
"EXTRA RSD" are emissions not included in the COPERT methodology detected in the measurements of vehicle emissions by means of the RSD (Remote Sensing Device) system.

BACKGROUND CONTAMINATION

To model the PECQ 2020 scenario emissions, the behaviour of two variables have been considered: the background contamination and the local background contamination. To characterise the first series the historic evolution of recent years from the Cap de Creus station has been analysed. From the empirical data of this station, the concentration trend of various pollutants such as PM10, NO_2, NO and ozone among others was studied, and a future forecast was made following the same historic pattern. The 2020 annual average concentration of background contamination is expected to be 4.42 µg/m³ in terms of NO_2 (when, in 2008 it was 4.26 µg/m³) and 12.00 µg/m³ in terms of PM10 (17.86 µg/m³ in 2008).

The evolution of the local background contamination has also been evaluated. This one includes undervalued emitting sources, regional pollution and specific episodes or patterns deviating from daily, weekly and monthly profiles as introduced in the emissions inventory. To make a prognosis on this type of pollution, the established hypothesis was that of a relationship that is directly proportional to the reduction of emissions derived from the emissions inventory for the future. From an interactive analysis of the dispersion of pollutants, it is expected that the reduction in Barcelona for 2020 will be, in the case of NO_2, 25.2% lower than in 2008, with a annual average of 3.74 µg/m³ (when, in 2008, it was 5 µg/m³). In the case of PM10, it is expected to be 16.8% lower, with an annual average of 12.48 µg/m³ (15 µg/m³ in 2008).

TABLE 77 | MODELLING THE DISPERSION OF POLLUTANTS RESULTING FROM THE EMISSION FORECASTED FOR 2020

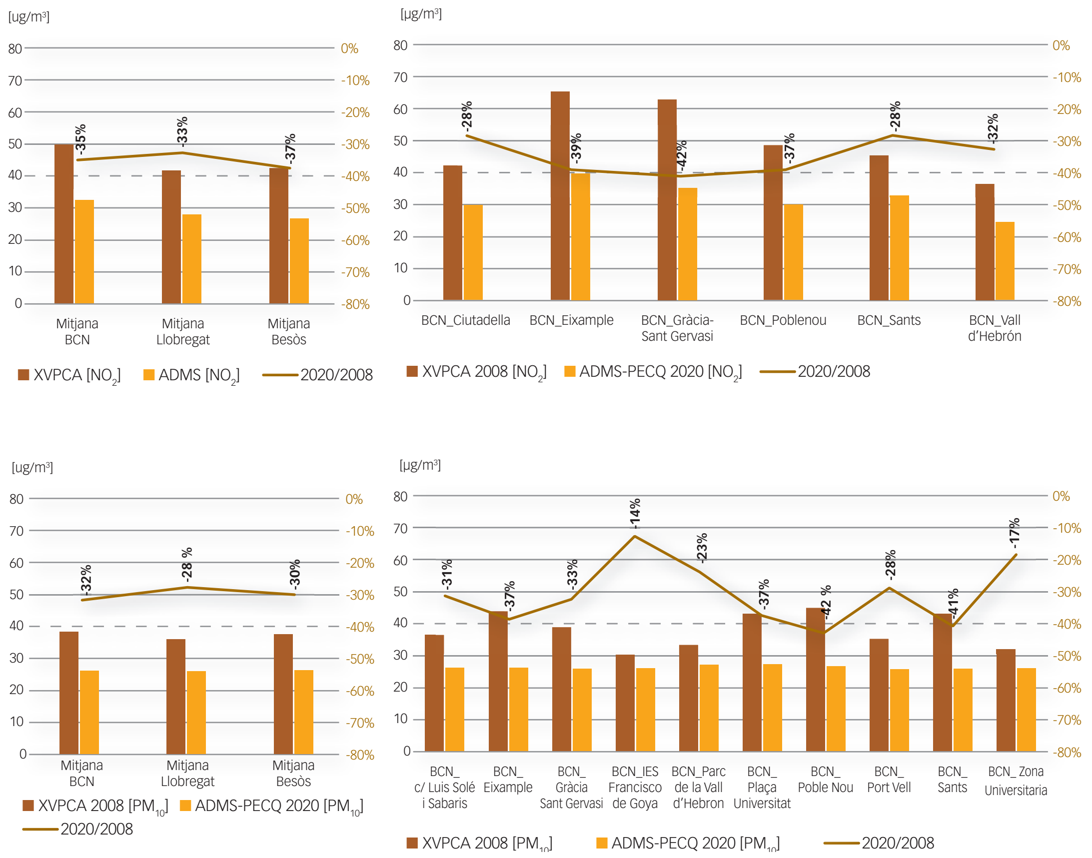
Real measurements in 2008 and PECQ-2020 scenario forecast of immission annual average in XVPCA stations in Barcelona

Station	Type of measurement according to location	NO_2		PM_{10}	
		2008 [real data] NO_2 [µg/m³]	PECQ-2020 [dades model] NO_2 [µg/m³]	2008 [real data] PM_{10} [µg/m³]	PECQ-2020 [dades model] PM_{10} [µg/m³]
CIUTADELLA	Urban background	42.3	30.3	-	-
VALL D'HEBRON	Urban background	36.5	24.6	33.3	25.6
EIXAMPLE	Very heavy traffic	65.4	39.9	43.2	27.1
PLAÇA UNIVERSITAT	Very heavy traffic	-	-	43.1	27.2
PORT VELL	Industrial	-	-	36.4	26.1
IES FRANCISCO DE GOYA	Urban background	-	-	30.1	25.9
GRÀCIA-SANT GERVASI	Very heavy traffic	62.6	36.5	39.2	26.5
POBLENOU	Moderate traffic	47.4	29.8	44.9	26.0
ZONA UNIVERSITARIA	Urban background	-	-	31.4	26.0
C/ LLUIS SOLÉ I SABARIS	Urban background	-	-	37.5	25.8
SANTS	Moderate traffic	45.3	32.7	43.9	26.1
MItjana		**49.9**	**32.3**	**38.3**	**26.2**

Source: Data 2008: Directorate of Environmental Protection, Public Health Agency of Barcelona, Department of Environment, Government of Catalonia. Data 2020: own.

In the case of NO_2, there is a considerable reduction in all points of the XVPCA measurement, arriving at 35% of the city scale. This reduction helps the annual average concentration level place below 40 µg/m³ for all measurement points, which helps meet the requirement set by the European Union. In addition, the points with the highest emission values in 2008 are where the highest reductions are achieved (39% and 42% at the stations of the Eixample and Gràcia-Sant Gervasi, respectively). This is because these measuring stations are located in areas with heavy motor vehicle traffic.

FIGURE 249 | COMPARISON OF VALUES MODELLED WITH REAL EMISSION DATA FOR NO_2 AND PM_{10}



◀ Emission values at each of the Barcelona XVPCA stations (left) and the average of the stations in Barcelona, Llobregat and Besòs (right). Also shown are the 2008 yearly average emission rate for the stations (green), and the forecast for 2020 according to the PECQ-2020 scenario.

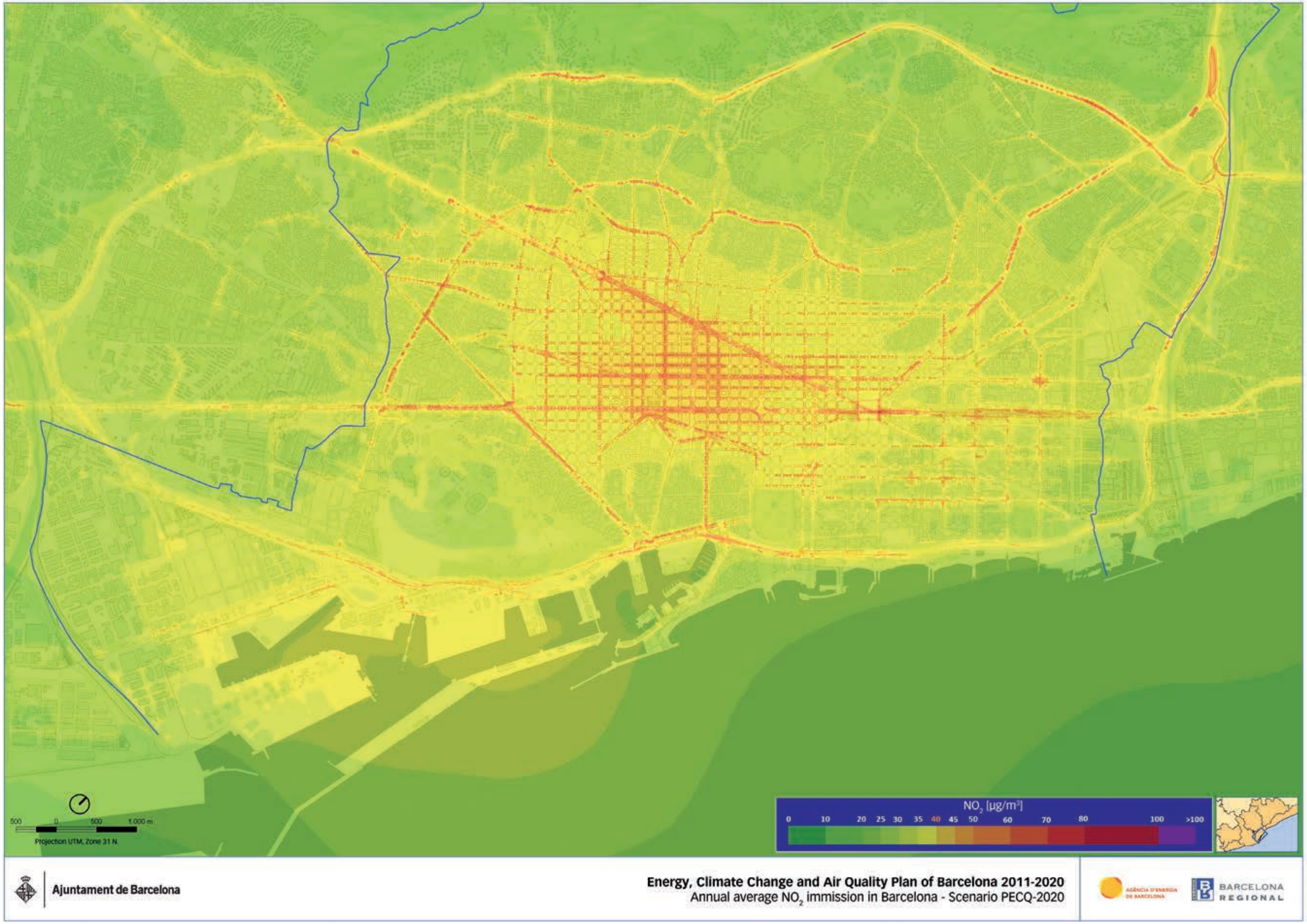
L'Eixample, Gràcia and Sant Gervasi are the most sensitive stations, or stations nearest to the annual average European threshold of 40 mg/m³; these have also high road traffic intensity. A comprehensive monitoring will therefore be of essence to see the emission evolution in the areas embraced by these stations and to even prioritise projects that can positively affect their air quality.

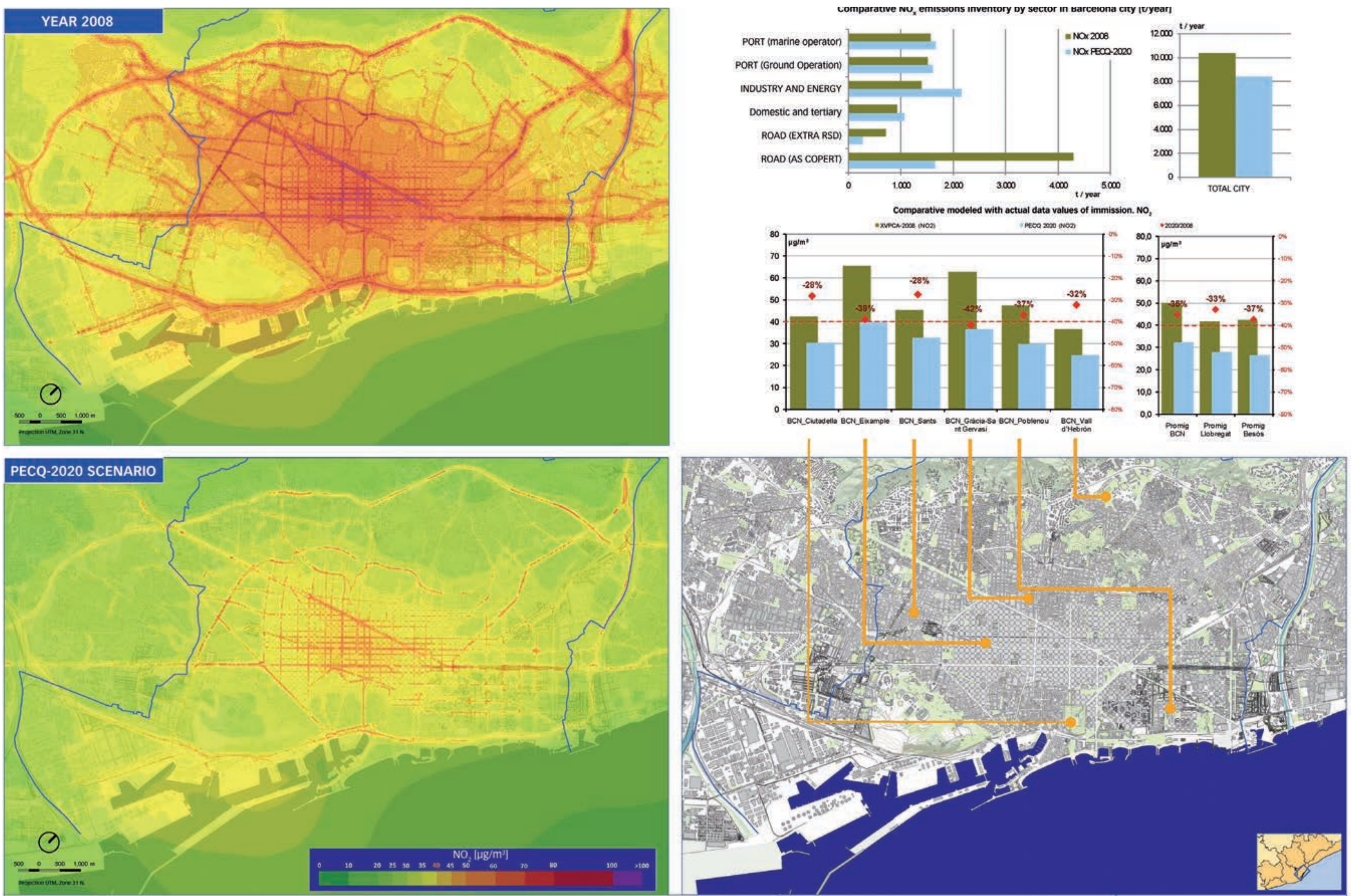
However, as with any long-term estimate, forecasts contain a degree of uncertainty resulting from the variability of the system and the various possibilities which can shape the future. Although the scenarios defined in this plan are expected to be more likely to occur, it must be remembered that the sensitivity of certain variables considered -many of them being external to the city-, can throw the most accurate forecasts, either for or against the set expectations and objectives.

In the case of PM_{10}, a reduction is also achieved in all XVPCA measurement points, reaching an annual average of 32% in the whole city. These reductions allow all points of measurement to reach values below 28 µg/m³, well below the European limit of 40 µg/m³.

The maps below show the annual average emission of NO_2 and PM_{10} as a result of the PECQ-2020 modelling. It is important to note that these maps represent the average concentration of pollutants at ground level, while the measuring XVPCA stations -such as the models made to predict emissions in these stations- have their measuring sensors located above ground level, as mandated by the European emission measuring regulation.

To facilitate comparison between the current situation emission maps and the PECQ-2020 forecasted emissions maps, they are also presented in a single image; also, for each pollutant, the emission and immission results are shown, as well as the respective emission maps, both for the PECQ-2020 scenario and for the current situation. The comparison of results from the XVPCA measuring network stations is also shown.

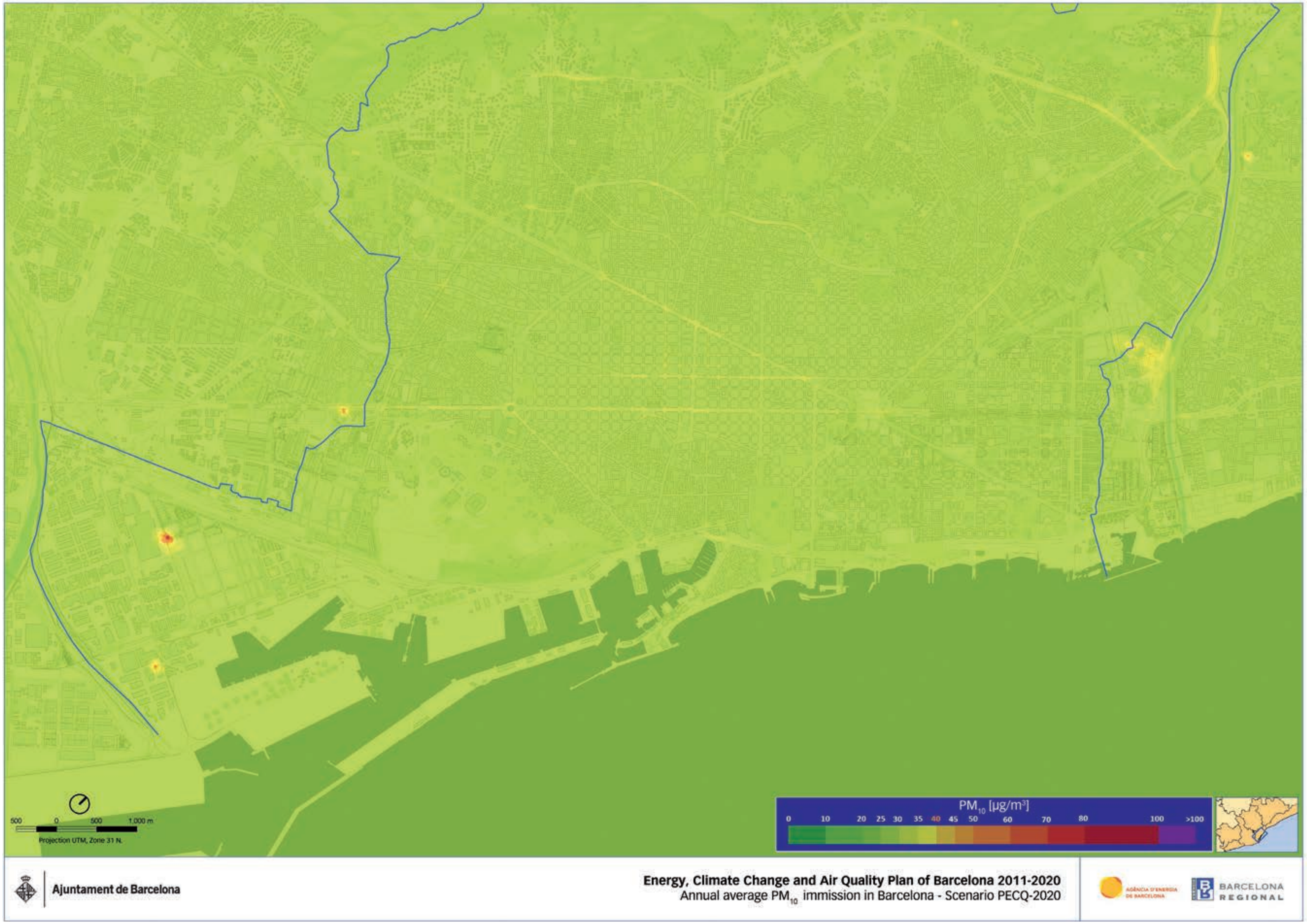

500
0
500
1.000 m
Projection UTM, Zone 31 N.
NO2 [µg/m3]
0
10
20
25
30
35
40
45
50
60
70
80
100
>100
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Annual average NO2 immission in Barcelona - Scenario PECQ-2020
AGÈNCIA D'ENERGIA DE BARCELONA
BARCELONA REGIONAL



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Comparative immission and emission of NO$_2$ in Barcelona - Year 2008 and setting PECQ-2020

Agència d'Energia de Barcelona · Barcelona Regional


500 0 500 1.000 m
Projection UTM, Zone 31 N.
PM10 [µg/m3]
0 10 20 25 30 35 40 45 50 60 70 80 100 >100
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Annual average PM10 immission in Barcelona - Scenario PECQ-2020
BARCELONA REGIONAL

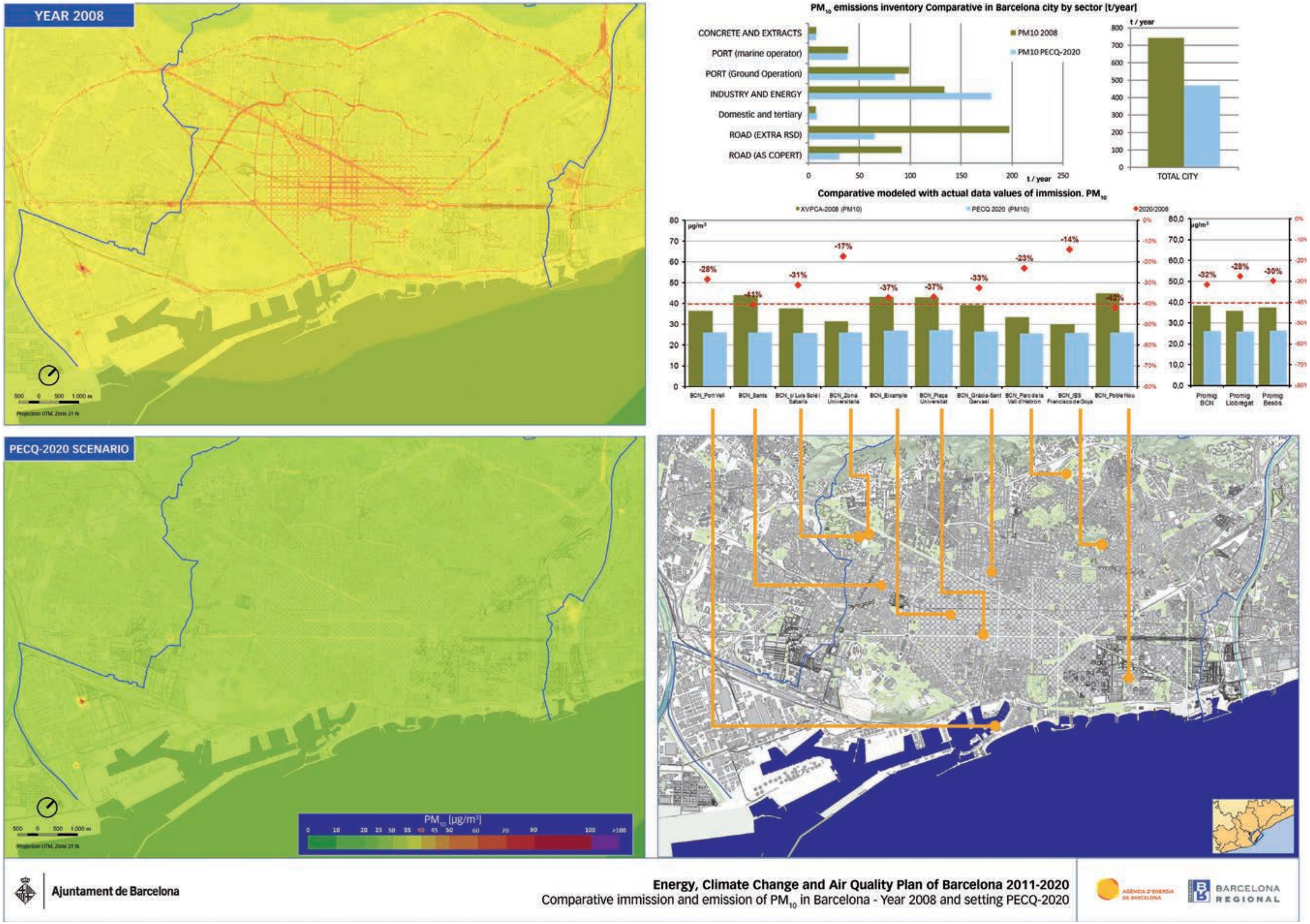
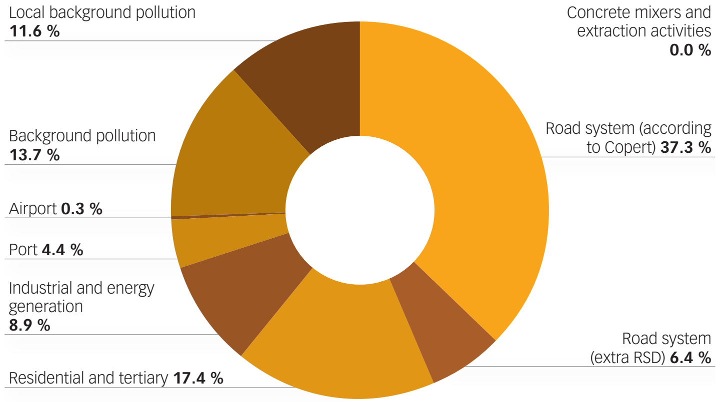
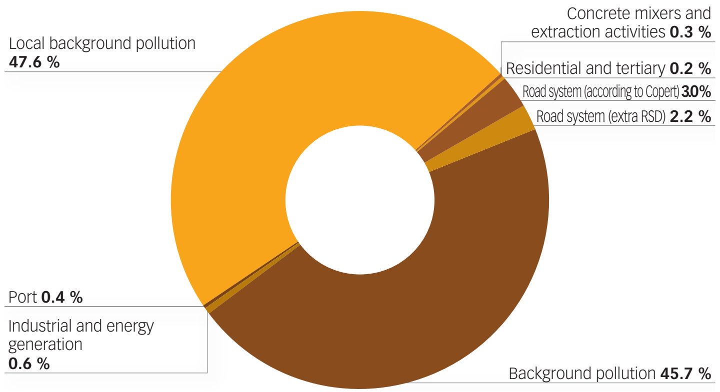

YEAR 2008
PECQ-2020 SCENARIO
PM10 emissions inventory Comparative in Barcelona city by sector [t/year]
CONCRETE AND EXTRACTS
PORT (marine operator)
PORT (Ground Operation)
INDUSTRY AND ENERGY
Domestic and tertiary
ROAD (EXTRA RSD)
ROAD (AS COPERT)
PM10 2008
PM10 PECQ-2020
t / year
TOTAL CITY
Comparative modeled with actual data values of immission. PM10
XVPCA-2008 (PM10)
PECQ 2020 (PM10)
2020/2008
µg/m³
-28%
-41%
-31%
-17%
-37%
-37%
-33%
-23%
-14%
-42%
-32%
-28%
-30%
BCN_Port Vell
BCN_Sants
BCN_c/ Luis Solé i Sabarís
BCN_Zona Universitaria
BCN_Eixample
BCN_Plaça Universitat
BCN_Gràcia-Sant Gervasi
BCN_Parc de la Vall d'Hebron
BCN_IES Francisco de Goya
BCN_Poble Nou
Promig BCN
Promig Llobregat
Promig Besòs
PM10 [µg/m³]
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Comparative immission and emission of PM10 in Barcelona - Year 2008 and setting PECQ-2020
BARCELONA REGIONAL

FIGURE 250 | SOURCE OF EMISSION SOURCES, IN AVERAGE, FOR BARCELONA, PECQ-2020 SCENARIO

NO_2 annual average [µg/m³]



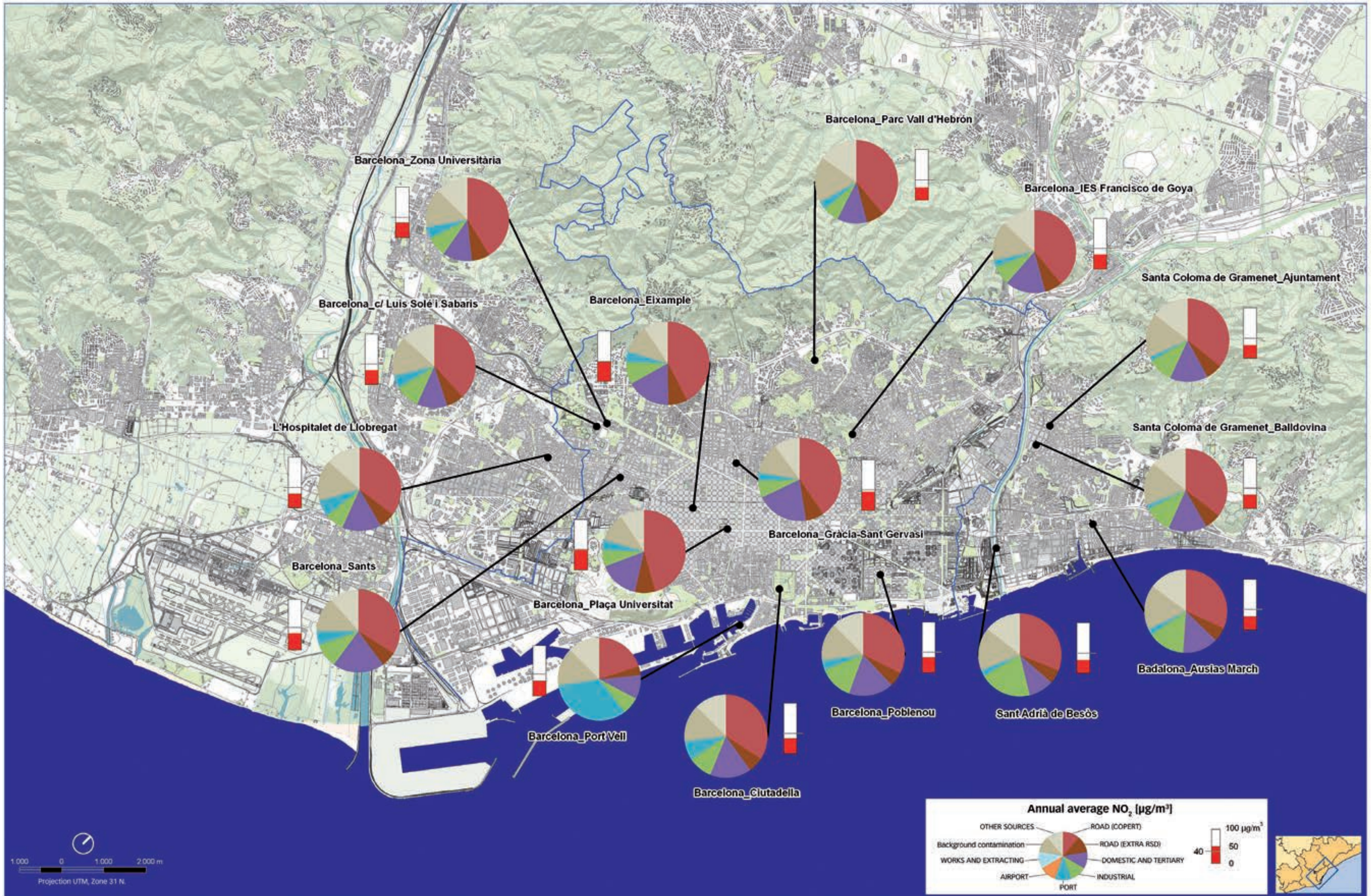
PM_{10} annual average [µg/m³]



◀ According to the modelling conducted, approximately 43.7% of the concentration of NO_2 in the Barcelona air in 2020 comes from the road traffic, 21.9 points below the 2008 levels (65.6%). Moreover, 17.4% of the immission of NO_2 comes from the domestic and commercial sectors (8.6% in 2008), 8.9% from the industry and power generation sector (4.8% in 2008). 4.4% is caused by the Port area activity and 0.3% comes from airport emissions (in 2008, the percentages were 2.1% and 0.1% respectively). The background contamination is expected to be around 13.7% (10.1% in 2008), and local background contamination near 11.6% (8.6% in 2008).

In the case of PM_{10}, background contamination is responsible for 45.7% (47.9% in 2008). As for the local background contamination, it is expected to be at 47.6% (40.2% in 2008). Analysing the immissions derived directly from the source of the emissions inventory model, road traffic stands out with 5.2% (11.0% in 2008), 0.6% is from industry and power generation (0.3% in 2008), 0.4% from port activity (0.3% in 2008), 0.3% from the forecasted major works and quarrying activities (0.2% in 2008) and less than 0.01% from the Airport.

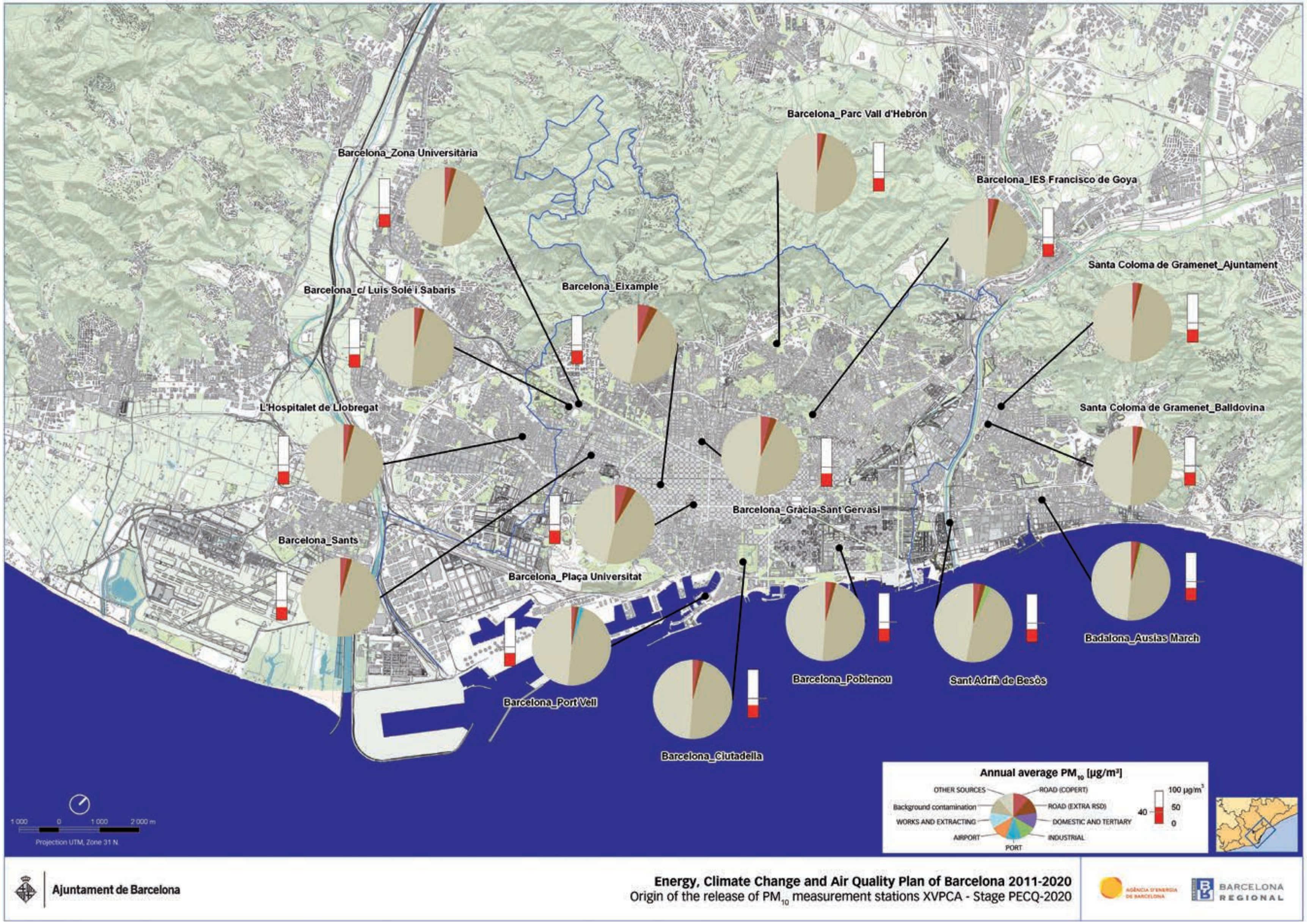
In the case of both NO_2 and PM_{10} immissions, there was a decrease in the influence of road traffic in the concentration levels present in the city, which increases the relative weight of other sectors. Yet, traffic will remain one of the sectors with greatest anthropogenic contribution to the concentration of both pollutants.



Ajuntament de Barcelona

Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Origin of the release of NO_2 in the measurement stations XVPCA - Stage PECQ-2020

Agència d'Energia de Barcelona · Barcelona Regional


Barcelona_Parc Vall d'Hebrón
Barcelona_Zona Universitària
Barcelona_IES Francisco de Goya
Santa Coloma de Gramenet_Ajuntament
Barcelona_c/ Luis Solé i Sabaris
Barcelona_Eixample
L'Hospitalet de Llobregat
Santa Coloma de Gramenet_Balldovina
Barcelona_Gràcia-Sant Gervasi
Barcelona_Sants
Barcelona_Plaça Universitat
Badalona_Ausias March
Barcelona_Poblenou
Sant Adrià de Besòs
Barcelona_Port Vell
Barcelona_Ciutadella
Annual average PM10 [µg/m³]
OTHER SOURCES
Background contamination
WORKS AND EXTRACTING
AIRPORT
PORT
ROAD (COPERT)
ROAD (EXTRA RSD)
DOMESTIC AND TERTIARY
INDUSTRIAL
100 µg/m³
50
40
0
Projection UTM, Zone 31 N.
Ajuntament de Barcelona
Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020
Origin of the release of PM10 measurement stations XVPCA - Stage PECQ-2020
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BARCELONA REGIONAL

4.3.3 - ECONOMIC AND SOCIAL IMPACT

Overall evaluation

Under PECQ, a specific study has been developed to assess the impact of the proposed action strategy measures on the economy of the city. There have been various approaches for this assessment - quantitative evaluation, economic/financial profitability and social profitability, and qualitative evaluations[42] about the business nature of some selected projects-, although only the projects that could really be assessed were taken into account.

Although most PECQ projects have been rated from the economic point of view, it has not been possible to assess them all with specific numbers[43]. In 22% of projects, the lack of evaluation had to do namely with the fact that there is not enough data available that depends on government or other institutions.

More importantly, only those that have a direct and measurable impact on energy consumption and pollutant emissions in the city were rated, and those of a more social nature were rated with zero savings because of the difficulty to assess the direct and real effect on the metabolism of the city.

It is estimated that the cost of implementing the PECQ based on the year 2008 (excluding the increases in the CPI until 2020 and VAT tax) is 2,431.74 million €, spread over 492.05 million € for the City Programme and 1,939.69 million € for the Municipal Programme. It is important to note that just the Deployment project of a new cleaning contract with a greened vehicle fleet (Municipal Programme) has a cost of 1,743.40 million €.

The cost that the City will have to assume directly, whether for investment, programmes or studies, or to encourage and motivate some projects, is estimated at 1,960.22 million € in ten years, amount reduced to 216.82 M € if the cost of the Deployment project of a new cleaning contract with a greened vehicle fleet (Municipal Programme) is deducted (20.56 and 196.26 for the City Programme and for the Municipal Programme respectively). This amount will go, therefore, towards investments and improvements of municipal buildings and facilities, and information and communication programmes for municipal workers.

Estimated cost savings and annual income derived from efficiency and local generation measures promoted within PECQ add up to 34.85 M €/year (considering 2008 energy prices).

TABLE 78 | PECQ PROJECTS ECONOMIC EVALUATION: SUMMARY TABLE

Economic evaluation of PECQ projects						
Technology	Nr.	Total cost [meur]	Economic savings / annual income [meur/year]	Council cost [meur]	Council cost [%]	Council cost per inhabitant [€/inhab]
City Programme	85	492.05	34.44	20.56	4%	12.72
Municipal Programme	23	1,939.69	0.41	1,939.66	100%	1,200.36
PECQ	**108**	**2,431.74**	**34.85 [*]**	**1,960.22**	**81%**	**1,213.08**

[*] These economic savings come from the 289 GWh of energy savings and generation of all projects that have been evaluated economically and energetically. Considering the cost savings from other projects which, even without available investment data, still involve certain savings, annual savings could exceed 200 million €.

42. Focused on six City Programme projects.

43. Both are particularly relevant: the Barcelona Urban Mobility Plan and the Port and Barcelona Airport projects, both derived from the environment of the air quality in the municipalities declared as Areas of Special Atmospheric Environment Protection (Decree 226/2006, 23 May), which do not include investment costs.

The quantitative assessment

This assessment consists in calculating the measures' impact on production, GDP and occupation in the city and the surrounding areas. The effects of demand and the effects of supply were compared, and the impact on the local economy was stressed.

The effects of demand

The total cost of running the PECQ proposals is 2,431.74 million €. The results of the input-output analysis are, therefore, that this investment will end up becoming a productive activity of 4,734 million €, which means a multiplier of 1.94. In terms of GDP, PECQ investments will lead to an increase of 1,448 million €. 43% of this impact will affect the economy of the people in Barcelona, which is 20% higher than the other areas of Catalonia; the rest will be distributed throughout the Spanish and the International economies. This impact on other economies is what is known as spill-over effects. By having a very open economy, and despite the fact that spending takes place in a given territory, the impact will spread through purchases of goods and services produced elsewhere.

Therefore, the investment generated directly by PECQ will increase the county GDP by 0.97%. It is a significant figure, and it is important to appreciate its importance, both in quantitative terms, as well as for the fact that it is the activity generated by a short-term investment plan. It is also worth noting that this increase in GDP is not consolidated, and the economic effects die out when the Plan's actions come to an end.

In terms of employment, PECQ investments will lead to the creation of 21,800 jobs[44] throughout the action Plan implementation period, 43.6% (i.e., around 9,500) of which will be created in Barcelona, another 4,350 in the rest of Catalonia, and 7,900 more outside Catalonia. It should be stressed that these are annual jobs, regardless of the number of contracts that can be carried out. These jobs are linked to planned actions and, obviously, will be created and eliminated as the planned investments from the Plan are carried out. The involvement of local initiatives in these projects will largely determine whether these results will be achieved. In Catalonia there are leading companies in the fields of environmental economics[45], which can play leading roles in many of the actions planned. As long as they assume such roles, the spill-over effects will be minor.

It is important to remember, however, that not all projects have been financially assessed, especially those which, however part of PECQ, originated in other entities or are part of other plans. This implies that the effects of all measures included in PECQ will be higher than recorded in this section, mainly with high-impact projects that may have no economic value such as the Urban Mobility Plan of Barcelona (PMU) and the projects of the Port and Barcelona Airport arising from the Generalitat[46] action Plan.

44. Equivalent annual jobs, i.e. one year long full-time jobs. Therefore it does not reflect the number of contracts.

45. *El potencial econòmic del sector mediambiental* (The economic potential of the environmental sector), Department of Environment and Housing. Generalitat de Catalunya 2006.

46. Action Plan for Air Quality Improvements in Municipalities Declared as Areas of Special Atmospheric Environment Protection by Decree 226/2006, 23 May.

FIGURE 251 | GDP GENERATED FROM INVESTMENTS DERIVED FROM PECQ PROPOSALS (IN 2010 CONSTANT M€)

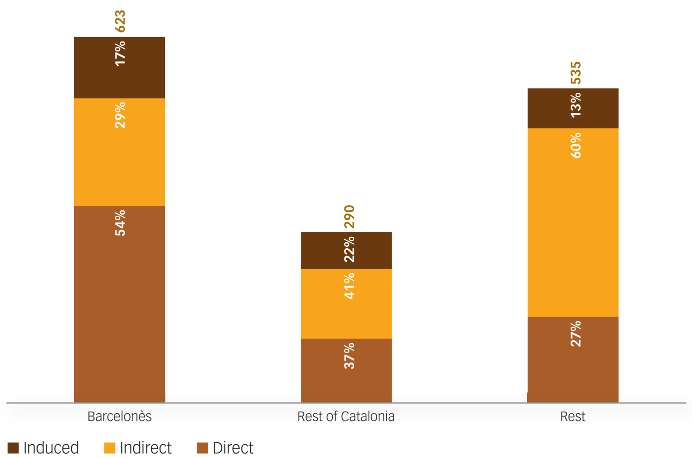
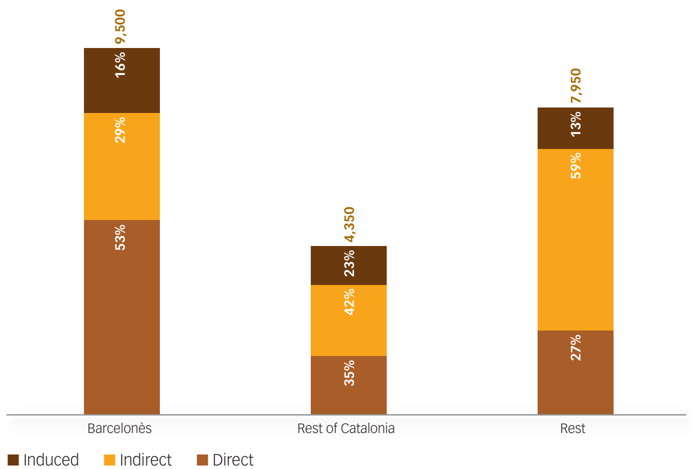


FIGURE 252 | JOBS GENERATED BY PECQ INVESTMENTS



▲ Includes vehicles which will comply with the European regulations Euro V (2011) and Euro VI (2015).

The effects of supply

The application of PECQ means savings of 1,678.85 GWh from different sources of end energy, as well as the generation of 139.5 GWh of electricity that can be injected into the grid. The result in a savings/income balance is estimated at 34.85 million €/year (considering energy prices from 2008 onwards), distributed among companies, public administration and consumers.

The assumption made was that the reduction of energy costs does not alter the final value of production[47] and that as a result, cost reduction becomes an increase in gross value added (GVA)[48], and therefore, in the real incomes of the people.

This assumption simplifies the calculation and yet has little impact on the outcome. To quantify how this cost reduction affects the area's overall economy, input-output tables have been used. This can be done by using different mechanisms.

According to the analysis applied (inverse Leontief matrix), improved efficiency would lead to an annual increase in Barcelona GDP of practically 53.6 million €, representing a 0.08% annual increase. As for jobs, a total of 1,070 jobs would be created yearly, which represents 0.09% of jobs located in Barcelona. These figures are due to a permanent efficiency improvement and, therefore, are not the result of an ending investment, but will rather continue beyond the scope of the Plan.

47. To the extent that energy efficiency represents a reduction in business costs, retail prices of products could also be reduced and competitiveness could thus improve. An analysis in this direction is uncertain since it depends on the performance and decisions of each company and on the analysis of their competitive position.

48. The concept of Gross Value Added (GVA) is calculated as the difference between the value of goods and services produced (this does not take into account the indirect taxes on final products (e.g. VAT) or net operating subsidies) and the costs of producing it. It includes therefore the real contribution of the sector in terms of value created, namely the contribution to the wealth that is embodied in wages, corporate profits and depreciation.

To compare the figures, other assessment methods with very similar results have also been used, such as the GVA method and the inversion[49] method. This calculation is based on an annual energy savings valued at current prices. If energy prices are growing faster than other prices in the economy, which is realistic, the effects of energy efficiency on GDP growth will be higher. Therefore, the figures obtained in this supply analysis are minimal.

It is important to note that, unlike in the demand analysis, where the impact is temporary for the duration of the PECQ, the effects coming from the supply side are consolidated in the local economy, since this energy efficiency is permanent, and its effects on GDP and jobs do not disappear. Around 70% of new business generated in Barcelona will take place within the service sector, reflecting the tertiary nature of the city. However, in the rest of Catalonia, over 40% of new business will be generated in the industrial field.

49. The GVA method considers that the change in the GVA becomes revenue benefiting the actors in every sector (workers and business owners) and turning into consumption and savings. The inversion method considers that any change in the GVA is transformed into investment and returns into the production activity through this route.

QUANTITATIVE ANALYSIS: METHODOLOGY

To analyse the effects of PECQ on the Barcelona economy, input-output analysis* based methodologies have been used. The input-output table (IOT), also called Leontief model, is a schematic representation of a particular economic system. It provides a global overview, while it is also detached from any specific economic model, and it provides an understanding of the sectoral interactions that occur both within the domestic economy and in relation to the external economic system. This method was chosen because it helps calculate the economic effects of a new production activity or a new investment, on a new territory. In this case, the actions arising from PECQ were applied.

The economic variables that are quantified in an input-output analysis are usually the following: production value, which measures the increase in production of goods and services produced in the whole economy; GDP, which assesses the added value that occurs in the economy due to investment; and jobs generated: full-time jobs per year, regardless of the number of contracts or of affected people.

To make the analysis there are two types of effects: the effects of demand and the effects of supply.

The hypothesis behind this method is that investments and the improvements in efficiency that a business or system can achieve, end up leading to an economic impact superior to that directly perceived within the affected company or system. To quantify this impact, there are three different types of effects, the sum of which is called the multiplier effect and shows the relationship between the investment and GDP obtained. These three types are: direct effects, as in derived from the investment in the project or received directly by the company or system; indirect effects, as in increased economic activity that occurs due to the effects that the investment has over complementary or directly related activities; and induced effects, caused by increased economic activity generated by the spending of those directly or indirectly related to the project.

* Thought out by and created by Leontief, W. Input-Output Analysis, Scientific American, 1965

The Economic and Social Profitability

There are two indicators in the profitability analysis: the economic and financial profitability indicator, and the social profitability indicator. The first shows the relationship between investments and costs necessary to carry out the proposals in the PECQ rated projects, as well as the value of financial savings achieved. It is, therefore, a return that is reflected in monetary benefits, i.e., in economic and financial terms.

The second one, the social or environmental performance indicator, in addition to incorporating the economic and financial profitability, also takes into account the benefits generated for citizens by the pollutant emissions reduction resulting from the decline in energy consumption. To quantify these benefits, valuation techniques have been applied to intangible assets; as explained later, these techniques allow intangible assets to be included in the calculation of profitability. The same indicators are obtained, NPV and IRR, but in this case it is about social NPV and social profitability IRR as the benefits achieved by the company are not monetary but in terms of welfare.

However, before calculating these profitability indicators, one must bear in mind that within PECQ there is a whole series of actions related to issues of public support, counselling, Plan monitoring, issues awareness, etc., to which no kind of return has been assigned, as they do not involve any energy savings themselves (although they are important because they help social agents take steps towards savings and rationalisation). These actions are estimated at about 12 M €, 2.5% of the total investment. It must be said, once again, that the Plan's profitability has been based on the projects whose evaluation and assessment were possible, leaving the rest out of the analysis.

Economic and financial profitability

Given the investment figures, energy costs reduction and duration of projects, the IRR[50] for each one of the proposals as well as the overall profitability of PECQ can be calculated. The fact that the actions of the Plan run during the PECQ validity period has been taken into account, even though the benefits of issues such as energy savings, will be extended throughout the lifetime of the effects of the measure.

The fact that the overall return is positive does not mean that all measures are. In fact, there are areas where it is negative, as the residential, the transport and waste sectors. This, however, helps manage PECQ so that less profitable actions can be financed in the short-term, and criteria for compensation be established if necessary.

When considering only the city Programme - the part of the Plan that needs the greatest private contribution -, and the 480.8 million € investment on money saving projects, the resulting average return is 3.60%. It is a low profitability, but a positive one, giving medium and long term yields. These results correspond to the economic profitability of the project, regardless of funding.

If only those proposals that do not generate direct cost savings are included, profitability slightly decreases to 3.38% yearly on average. The Council would provide 4% of the City Programme resources in the form of city subsidies, grants or tax exemptions. If this amount is deducted, profitability, measured as IRR, as obtained by the different agents participating in the Plan, increases slightly as it moves from 3.60% to 3.91% annually.

50. IRR (Internal Rate of Return) is defined as the interest rate that helps NPV (Net Present Value) equal zero. In fact, IRR helps compare expected future revenues from different investments, including as an investment the fact of investing in a bank or mutual fund with an agreed upon interest rate. The most economically profitable investment will be the one with the highest interest rate.

TABLE 79 | CITY PROGRAMME ECONOMIC PROFITABILITY, BY SECTOR

Economic profitability of the City Programme by sectors	
Technology	IRR (Internal rate of return)
Residential	-8.4%
Industrial	15.0%
Energy grids	15.1%
Commerce and services	6.7%
Renewable energies	7.2%
Transport	-6.7%
Waste	-3.2%
Other	5.1%

Social Profitability

The measures proposed in the PECQ also have another effect: the reduction of polluting gas emissions. These emissions, taken to economic terms, constitute an *"externality."*

In its most classical definition, an externality describes an action carried out by an economic agent or actor (individual or company) that has a direct impact on the welfare of others or on the production processes of other companies. This definition has been expanded gradually, incorporating into the externalities social and environmental effects that are related to the impact on the environment and the wellbeing of people. The latter is measured not only in terms of income, but also in the ability to enjoy a number of goods that affect the quality of life of the population.

To introduce these environmental effects on the profitability analysis, various methods of assessing intangibles that are widely accepted when making these types of calculation are used. Over the last few decades a range of methodologies have been developed to assess economic externalities; they are based on various approaches and their goal is to attach an economic value[51] to these externalities. This does not mean that they are intended as an exchange value, but rather as tools to evaluate the effectiveness of certain investments and activities. In recent years, the European Union has funded and promoted a number of research projects on issues of calculation of externalities, so that they may be used throughout Europe[52].

Introducing externalities in the economic and financial accounts is important in terms of efficiency and is a necessary element to make decisions, both in private and in public contexts. To do this, the monetary value of these externalities has to be calculated. This calculation is not immediate, especially in the case of social and environmental impacts which are the subject of this PECQ, since they don't have a market price and it is necessary to find a reference value that is able to capture its economic importance, consistently.

Overall, if externality prices are applied to quantities of pollution reduced by the Plan, a yearly value is obtained in terms of the reduction of polluting gases, measured in monetary terms. This value was entered in the model for calculating economic and financial profitability that also uses the costs and investments in the City Programme that have energy benefits and savings. All this creates the City Programme's social profitability, resulting in a NPV of 72.3 M €[53] and an IRR of 6.76%.

This increase in profitability is especially significant in the case of transportation. Indeed, if one considers only the reduction of energy costs, the measures designed for the transport sector are not profitable because they do not offset the large investments required. However, the inclusion of environmental issues turn the situation around.

51. This system has been used by the Ministry of the Environment and Housing of the Generalitat Administration in the Analysis of externalities, in the Strategy to develop a sustainable Catalunya, approved in 2010.

52. For example, in this study, methods and data from projects such as Needs (2007), ExternE (2005), Tremove (2005), Grace (2002), Greensense (2003), Cases (2008), Methodex (2007) were used.

53. NPV calculated with a 5% discount rate.

TABLE 80 | ASSESSMENT OF THE PRICE OF POLLUTANT EMISSIONS IN CATALONIA (EXTERNALITIES)

Assessment of the price of pollutant emissions	
	€* / tonne
CO_2	35,6
NO_X	3,312
PM_{10} (metropolitan urban areas)	152,753
$PM_{2,5}$ (metropolitan urban areas)	381,610

(3) Prices correspond to present values, measured in constant 2010 euros. A growing evolution was forecasted in some of the emissions such as CO_2.

TABLE 81 | CITY PROGRAMME PROPOSALS: SOCIAL PROFITABILITY BY SECTOR

Social profitability of the City Programme by sectors	
Technology	IRR (Internal rate of return)
Residential	-7.5%
Industrial	17.6%
Energy grids	11.5%
Commerce and services	4.3%
Renewable energies	7.4%
Transport	12.2%
Waste	2.4%
Other	9.3%

The negative returns in the residential sector have to do with the fact that the overall investment was taken into account.

* Social profitability is the sum of economic and financial profitability and the environmental profitability.

The Qualitative Assessment

The analysis has also foreseen a qualitative assessment of some PECQ projects as well as the potential impact they have on the production structure of the city and its surrounding areas of influence. The proposals related to housing reform and rehabilitation of buildings in particular, would have an economic impact focused on the construction industry, an important sector in strategic terms. The large decrease in the construction of new homes has led to a dramatic drop in building activity. Rehabilitation, therefore, becomes a factor to dampen the decline in this sector, with very positive social and environmental effects.

Taking 2008 data, the construction sector contributed 3.6% of the city productive activity and 5% of jobs. If we add the rest of the municipalities that make up Barcelona, the percentage rises to 9% of GDP and employment, indicating that many of the works within the city were carried out by professionals who live in surrounding municipalities. It is important to note that the construction sector is a labour-intensive activity, an important factor at a time like the present, which could create the possibility of recovering some of the jobs lost in the construction sector. Although it is a traditional activity that does not generate large increases in productivity, it is nonetheless an established activity.

Additionally, in economic terms, it is an activity with a significant multiplier effect. A recent study[54] on the rehabilitation of homes in Catalonia shows that for every euro spent on rehabilitation, production activity worth 1.8 euros is created, which in the case of actions related to sustainability it is an even slightly higher number.

Rehabilitation, and especially that related to energy efficiency improvement and environmental impact reduction, also affects a large number of diverse and specialised professions. It is therefore an opportunity to train personnel to carry out these activities and to create businesses to work in the sector. Besides the impact on the construction sector, evaluated at 44%, it is estimated that rehabilitation also impacts investment in other sectors such as construction materials (16%), manufacturing of metal products (10%), commerce (7%), real estate (3%), restaurants (3%), and business services (5%) among others; all these sectors have a significant number of companies located in Barcelona and nearby towns.

Moreover, the proposal on energy saving advice to households and commercial premises, as well as other related proposals, will require trained staff that can detect efficiency improvements to be adopted in each case. This would mainly affect the activities of professional advice, and the training activities related to addressing the needs arising from the new service.

The fact of also including a regulatory framework to regulate the incorporation of photovoltaic systems in the city will influence the business sector differently depending on the position in the value chain. The sector linked to the photovoltaic industry is often composed of young companies with high growth potential, although much will depend on the country's energy policy and the Administration. In addition, the technology used helps undertake decentralised initiatives at a local level. In fact, in recent years, a Catalan photovoltaic industry with examples throughout the entire territory has been developing, though mostly with a very important concentration around the Barcelona industrial belt.

So far, the Catalan industry has developed from domestic demand, just as Spain has as a whole. Catalan companies are small in size. In this sense, this project will generate a demand that would help encourage the production and distribution capacity and competitiveness, which will help consolidate the emerging photovoltaic cluster. Catalan companies, just like German, Japanese and Chinese companies, have the competitive advantage of experience gained in recent years and are eligible to enter countries that opt for the growth of these technologies. As a first step, Catalan companies would enter Mediterranean countries and in the future, they would enter other areas and developing countries with favourable climatic conditions and lack of technology.

54. The contribution of the rehabilitation policy of the Generalitat de Catalunya in the current economic framework, Environment and Housing Department. 2010.

In the Catalan photovoltaic industry, services dominate since the big business is in the distribution of imported products and the promotion of photovoltaic equipment. Catalonia does not have the most strategic industry in the value chain, namely the solar cell creation. But it does have positioned companies in the assembly of modules and the promotion and installation of photovoltaic systems with a significant number of companies that offer the "turnkey " service, technology centres with related research lines, distributors and representative associations, etc. At the same time, a strong auxiliary industry has developed with components not unique or of low value added such as photovoltaic equipment wiring or structures. In addition, a number of markets are being created to support photovoltaic activities in the areas of finance, legal, consulting, technical consulting, measurement, security, insurance and management.

In short, all constitute a sector with a very complete agent map. The largest group with the highest business volume are the *"turnkey-promoters"*, with nearly one hundred companies, of which the top five generated half of the segment's total turnover amounting of about 270 M €[55]. The second largest group is the *"dealers."* Around fifty companies engaged in importing and selling photovoltaic material with a turnover of over € 150 in 2008. Finally, there are twenty manufacturers of products in Catalonia that billed approximately 120 M € in 2008. It is the smallest segment in the Catalan photovoltaic business. All areas of production beyond the production of the PV cell are covered: assembly of modules, inverters, cam followers and other supporters such as batteries, structures and monitoring.

Regarding the analysis of some road projects related to mobility, the first corresponds to the project for controlling emissions issued by the most polluting vehicles, and to the analysis of action on traffic alternatives that seek consensus to be implemented. This is a measure directed to raising the awareness of those who drive the most polluting vehicles. The direct effects on the local productive sector are limited and specific because the implementation of the measure involves purchasing or renting technology to control emissions in the street as well as qualified personnel.

However, as the emission control of vehicles will generate an increase in the car repair shop business or acceleration in car replacement, about 28,000 vehicles will be affected either way, which will in turn stimulate the demand side of the car industry. In 2009, 39,900 new vehicles were registered in Barcelona, which is equivalent to 70% of the impact of the measure, -but bear in mind the vehicles not registered in Barcelona yet accessing the city daily. 18% of vehicles registered in Barcelona were manufactured in Spain and the rest came from other countries. According to INE data, however, 20.5% of the production value of the Spanish automotive sector is produced in Catalonia. All these figures give an idea of what this measure may represent in the extent of the productive structure of the country.

As for the project that proposes to redesign the distribution of goods, it should be noted that the importance of logistics and transportation has increased steadily in the Catalan economy in recent years. Additionally, it is a dynamic sector of the economy as evidenced by the ability to attract businesses. In the case of Barcelona, the existence of two strong logistics infrastructures such as the port and the Airport, and the logistics areas around them, make the transport and logistics activities represent over 10% of the GDP of the city.

The measure that incorporates PECQ refers to the restructuring of the logistics and distribution activities internal to the city and, therefore, plays an important role on the quality of life of people, since its goal is to streamline vehicle fleet mobility and reduce emissions. However, as far as the production structure, the effects on production in the city are less relevant. The construction of platforms and machinery and equipment required to carry out these activities generate a certain demand for sectors like construction or industry, important in the catchment area of the city, which will be extended throughout the implementation period of the Plan.

55. Source: study by Martín, Damià and Lòpez, Cèsar, La indústria catalana en el negoci fotovoltaic, Observatori de prospectiva industrial (The Catalan Industry in the photovoltaic business, Industrial Prospective Observatory), Catalan Ministry of Innovation, Universities and Companies, November 2009.

Regarding the project sought to reduce the movement of empty cabs, there is a measure that has almost no effect on the production structure of the city. The decrease in fuel consumption affects taxi drivers directly, and has positive effects on the environment but, on the other hand, raises no new requirements that may materialise in changes in the productive sector of the city. However, depending on how the measure is carried out, a more active and technological management of taxi stands, or a promotion of radio stations to access the service, will generate a certain demand in terms of research and technology.

FIGURE 253 | ECONOMIC AND SOCIAL PROFITABILITY OF PECQ PROPOSALS, BY ACTING SECTOR (IRR, INTERNAL RETURN RATE)

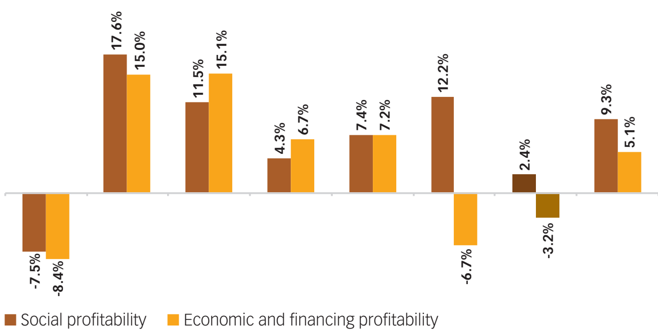


TABLE 82 | SUMMARY ECONOMIC, ENERGY AND ENVIRONMENT EVALUATION OF PECQ PROJECTS

Number of projects	Sector	Total cost [M€]	COST [M€]	Council cost [%]	Council cost [€]	Council cost €/inhabitant	Savings (en+) on final energy: Net savings (en+) of final energy [MWh/year]: Electricity	Natural gas	LPG	Petrol	Diesel	Hydrog.	Total final energy savings [MWh/year]	Electricity generation (en +) [MWh/year]	Primary energy: Total primary energy savings [MWh/year]	Total reduction (en+) of pollutant emissions [kg/year]: CO_{2eq}	NO_x **	PM_{10} **	$PM_{2.5}$ **
City Programme																			
4	Residential	87.30	22.27	2%	2.08	1.29	745.62	9,956.60	427.62	0.00	0.00	0.00	11,129.84	0.00	14,364.99	2,222,160.75	2,528.01	31.80	31.80
9	Industrial	22.40	22.40	0%	0.02	0.01	2,222.30	17,226.20	0.00	0.00	484.20	0.00	19,932.69	32,345.23	113,740.37	15,578,757.04	-29,197.83	-67.26	-67.26
7	Networks	86.65	53.95	12%	10.05	6.22	28,027.12	25,611.96	0.00	0.00	0.00	0.00	53,639.08	15,919.92	148,420.21	15,021,661.02	-10,613.01	-6,516.16	-6,516.16
6	Commerce and services	9.76	9.18	1%	0.13	0.08	2,134.51	-30,833.31	0.00	0.00	0.00	0.00	-28,698.80	14,141.70	6,798.07	-828,371.20	-8,737.42	-62.42	-62.42
14	Renewable energy generation	33.51	33.50	2%	0.77	0.48	633.36	2,891,47	0.00	0.00	0.00	0.00	3,524.82	8,545.55	28,062.89	3,753.831.23	697.33	4.68	4.68
18	Transport	158.29	120.86	3%	5.53	3.42	-1.696.20	-27,789.50	0.00	354,964.54	1,268,276.55	0.00	1,593,755.46	0.00	1,588,745.34	415,553,552.16	2,191,880.13	260,090.22	222,607.23
3	Waste	90.48	90.48	0%	0.00	0.00	-29,304.42	0.00	0.00	0.00	32.01	0.00	-29,272.41	56,042.55	71,716.07	241,440,917.89	-156,650.00	-22,150.00	-11,020.00
14	General	3.66	3.66	54%	1.98	1.22	7,255.95	1,768.38	56.09	0.00	0.00	0.00	9,080.42	0.00	21,627.41	1,435,481.84	459.76	3.79	3.79
10	Port/Airport																698,540.02	50,060.00	50,060.00
85	**City Programme total:**	**492.05**	**356.31**	**4%**	**20.56**	**12.72**	**10,018.24**	**-1,168.20**	**483.71**	**354,964.54**	**1,268,792.76**	**0.00**	**1,633,091.11**	**126,994.94**	**1,993,475.35**	**694,177,990.73**	**2,688,907.00**	**281,394.64**	**255,041.65**
Municipal Programme																			
13	Public buildings	135.98	44.46	100%	135.95	84.13	19,917.62	18,565.68	0.00	0.00	786.03	0.00	39,269.32	2,506.90	83,088.17	7,783,388.19	1,839.85	1.90	0.00
3	Public services	38.54	0.14	100%	38.54	23.85	7,321.28	0.00	0.00	0.00	0.00	0.00	7,321.28	10,000.00	46,437.75	4,674,478.56	0.00	0.00	0.00
2	Public lighting	1.65		100%	1.65	1.02	20,260.24	0.00	0.00	0.00	0.00	0.00	20,260.24	0.00	54,317.01	2,973,413.61	0.00	0.00	0.00
5	Public vehicle fleets	1,763.52	1,746.79	100%	1,763.52	1,091.35	-3,696.93	-67,905.84	0.00	-496.38	51,008.79	0.00	-21,090.35	0.00	-40,427.73	-604,099.32	51,759.76	6,687.21	0.00
23	**Municipal Programme total:**	**1,939.69**	**1,791.40**	**100%**	**1,939.66**	**1,200.36**	**43,802.21**	**-49,340.16**	**0.00**	**-496.38**	**51,794.82**	**0.00**	**45,760.49**	**12,506.90**	**143,415.19**	**14,827,181.04**	**53,599.61**	**6,689.11**	**0.00**
108	**PECQ total:**	**2,431.74**	**2,147.70**	**81%**	**1,960.23**	**1,213.08**	**53,820.45**	**-50,508.36**	**483.71**	**354,468.16**	**1,320,587.58**	**0.00**	**1,678,851.60**	**139,501.84**	**2,136,890.54**	**709.005.171,77**	**2.742.506,61**	**288.083,75**	**255,041.65**

TOTAL COST AND COST INCREASE: estimated total cost of projects, from the global point of view of the city. Total project costs are taken into account,-those assumed by all actors, from public administration to businesses and people-, and the cost increase- applicable mainly to projects of replacement or improvement of any item or installation. The overhead takes into account the increase that may represent a more efficient or fewer polluting emissions compared to conventional solutions. Please note that the costs are excluding VAT and excluding GDP increases (based on 2008).

COST OF THE CITY COUNCIL: estimation of the investment that the City Council will have to make to implement and encourage PECQ projects. This investment is part of the total cost of PECQ, as defined by the percentage that accompanies the figure. In the same way, and regarding the investment of the City, a cost per capita estimate is shown.

FINAL ENERGY SAVINGS: savings for each one of the energy resources consumed in Barcelona.

POWER GENERATION: production derived from new special regime equipment projects.

PRIMARY ENERGY SAVINGS: estimation of the savings derived from the reduction of final energy consumption.

(**) TOTAL REDUCTION OF POLLUTANT EMISSIONS: reduction of CO2eq emissions according to the Catalan electric mix, and reduction of NO_x, PM_{10} and PM2,5 in kg/year. In the case of CO2eq emissions, the original reduction has been taken into account, since CO2eq is a pollutant with global effects. On the other hand, in the case of NO_x and PM_{10} emissions, only the reduction of emissions in the city have been taken into account, in addition to the specific equipment and installations that affect the quality of the air in the city.

4.4 - Achievement of the Covenant of Mayors

In March 2007 the European Union adopted the package *"Energy for a changing world"*, which pledged unilaterally to reduce CO_2 emissions by 20% by 2020, increasing energy efficiency by 20% and ensuring that 20% of the energy supply comes from renewable sources.

Because of this commitment, the European Commission promotes the Covenant of Mayors, an initiative that aims to bring this challenge locally with the active participation of all the people. The Covenant was born of a series of non-formal consultations with many European cities, and is open to any municipality regardless of their size. By adhering to this Agreement, the municipalities, through their councils, commit to developing a sustainable energy action Plan within a maximum of one year from the date of signature.

In this regard, Covenant of Mayors Scenario is the name for the emissions reduction that would represent the sum of reductions associated with the proposed projects in the Municipal Programme with respect to the reference year, without taking growth trends into consideration. This method of presenting results is optimal for monitoring the incidence of each of the measures proposed, and it is the method proposed by the European Commission to evaluate the action plans of sustainable energy required when signing the Covenant of Mayors.

Thus, based on consumption and on emissions per capita associated with 2008, it is expected that the successive proposed action plans will lead emissions per capita to drop by 23%.

Total reductions (not per capita) from the City Programme are 16% in the case of greenhouse gas emissions and 9% in the case of energy consumption, both lower than per capita results. That is, the expected population increase in the coming years will provide an improvement in overall efficiency of the city. Efficiency is one of the great added values achieved by compact cities since population growth does not imply a linear growth of energy consumption.

The final scenario will always be conditioned by external variables foreign to the projects. Thus, the evolution of the electric mix configuration (Catalan or Spanish) will largely determine the improvement or worsening of the final results.

Either way, the commitment for Barcelona is to ensure a greater than 20% reduction in emissions associated with the Municipal Programme, a drop resulting from the implementation of the projects that depend exclusively on the local Administration (see Figure 290). Also, PECQ offers the necessary elements so that the city goals are also maintained in line with those proposed by the European Commission.

FIGURE 254 | EVOLUTION OF ENERGY CONSUMPTION WITH THE ACHIEVEMENT OF THE COVENANT OF MAYORS

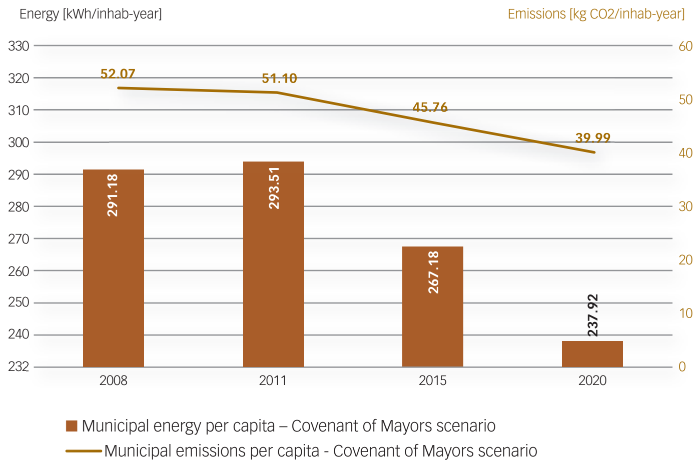
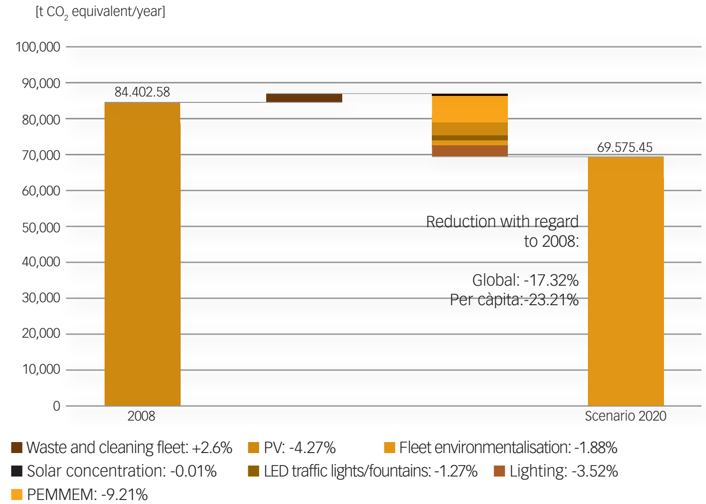


FIGURE 255 | EVOLUTION OF EMISSIONS WITH THE ACHIEVEMENT OF THE COVENANT OF MAYORS



STRATEGIES FOR ACTION

5.1 - The structure of the plan

To bring about the scenario set out in the previous chapter, the following strategy for action includes a set of projects aligned with the PECQ's objectives. To make it easier to manage the projects and carry out subsequent analysis, they are classified according to different criteria. These projects need to help the city reach both the objectives put forward in the PECQ and the commitments to cut greenhouse gas emissions associated with municipal activity by 20% by 2008[56]). The Plan is structured in two blocks:

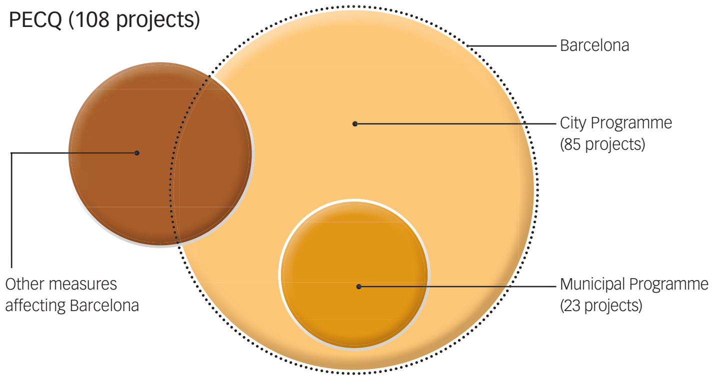
- **THE CITY PROGRAMME**: this includes those projects associated with the dynamics and functioning of the city as a whole, with the exception of projects that are the direct responsibility of Barcelona City Council. It, therefore, includes the following sectors: domestic, commercial, industrial, road mobility (excluding, here, municipal vehicles), etc.
  It also includes other projects or action plans that have already been approved - some of which are run by the City – that have been incorporated into the programme because they affect the future direction of the city from an energy or environmental perspective.
  - Barcelona Urban Mobility Plan (PMU).
  - Port and airport projects derived from the Generalitat's action plan.
  - Projects to be implemented by TMB to improve energy efficiency and reduce atmospheric emissions.
  - Projects to improve the treatment of solid urban waste.

56. Reduction compared with the 2008 figure, excluding the associated baselines. For an analysis of the effect of the projects in a baseline scenario, please see the City Programme.

- **THE MUNICIPAL PROGRAMME**: this includes projects related to matters that are the exclusive competence of the Council: municipal buildings, public lighting, traffic lights, water fountains and municipal vehicles.

In total, the PECQ includes 108 projects, of which 85 belong to **the City Programme** and 23 to **the Municipal Programme**.

FIGURE 256 | PECQ PROJECTS BY PLAN



The PECQ projects have also been classified into two different categories: sector and programme.

- **SECTOR** defines which sector is directly affected by the project or measure. The sectors listed below were identified. They are in descending order of importance within the relevant programme (City or Municipal):

The City Programme

- RESIDENTIAL: projects that affect both residential buildings and homes themselves; the programme also includes measures that have a direct impact on the public and on energy demand in the home.
- INDUSTRIAL: projects aimed at the industrial sector, whether the industry is large or small.
- NETWORKS: projects associated with district heating and cooling (DHC) networks, along with measures related to the quality of electricity and natural gas services.
- COMMERCE AND SERVICES: projects aimed at energy improvements or environmental improvements in the tertiary sector, including offices and commercial premises.
- RENEWABLE ENERGY: projects aimed at generating energy in the city, either using renewable sources or through the efficient use of energy. Although some of the projects could be included in other sectors – e.g. industrial or services – the decision has been made to separate them so as to prioritise the decentralised generation of energy.
- TRANSPORT: projects that affect both road mobility in its widest sense, and the type of vehicles that are used.
- WASTE: future projects related to the treatment of waste residues at supra-municipal level, although considered from an energy and environmental perspective relating to the city of Barcelona.
- GENERAL: general or cross-cutting projects that affect or involve more than one sector or society at large.
- PORT/AIRPORT: projects related to the infrastructures at Barcelona's port or airport.

The Municipal Programme

- PUBLIC BUILDINGS AND FACILITIES: projects involving public buildings managed by the City (PEMEEM).
- PUBLIC SERVICES: measures that directly affect the public services managed by the City.
- PUBLIC LIGHTING: projects that involve public lighting installations managed by the Council.
- PUBLIC VEHICLE FLEETS: measures that affect fleets of municipal vehicles.

TABLE 83 | **CLASSIFICATION OF PECQ PROJECTS BY SECTOR**

Classification of PECQ projects – number of projects by sector		
Sector	PROGRAMME	PECQ
Residential	City Programme (85)	4
Industrial		9
Networks		7
Commerce & services		6
Renewable energy generation		14
Transport		18
Waste		3
General		14
Port and Airport		10
Public buildings	Municipal Programme (23)	13
Public services		3
Public lighting		2
Public vehicle fleets		5
Projects total		**108**

- **PROGRAMME**: defines technical and policy issues.
  - RENEWABLE ENERGIES: projects aimed at increasing energy output by means of renewable energy sources.
  - ENERGY EFFICIENCY: projects that have a direct impact on improvements in energy efficiency. It should be noted that, although a number of projects included elsewhere also improve energy efficiency, it is not considered appropriate to include them in this programme.
  - LOCAL EMISSIONS: projects that help to improve air quality, ranging from prevention to measures directed at the sources of greenhouse gas emissions.
  - MANAGEMENT, COMMUNICATION AND BEHAVIOUR: projects that have a direct impact on social behaviour regarding the use of energy and energy consumption without affecting comfort; projects that have a positive impact on energy efficiency and/or reducing pollutant emissions by means of management improvements; projects that propose new laws or by-laws, or the review and monitoring of those currently in force; projects that contribute knowledge and information to the public about the City's energy/environmental performance along with the best options for making savings and cutting emissions; projects or measures to provide public and municipal workers not only with information about the relationship between energy and the environment but also with the tools to reduce consumption and emissions whilst not affecting comfort or productivity

FIGURE 257 | CLASSIFICATION OF PECQ PROJECTS BY PROGRAMME

Programme	Projects
Renewable energies	20
Energy efficiency	25
Local emissions	32
Management, communication, behaviour	31
Projects total	**108**

5.2 - Challenges and strategic lines

5.2.1. - THE CHALLENGES

The learning process that resulted from carrying out an exhaustive and cross-cutting diagnosis of a large city like Barcelona, along with the introduction of new visions brought into the consultancy process, led to a re-think of the challenges considered during the conceptualisation of the PECQ. When tackling the problems related to air quality in a more specific way, the situation in which the City finds itself calls for this area to be considered a priority for reasons of public health. For this reason, besides considering the importance that the public's actions have on energy consumption, it is essential to understand and determine the direct relationship between local pollution and health, which is directly related to the quality of the air that is breathed on a daily basis.

In this context, **the supra-environmental benefits of saving energy and of renewable energy must be demonstrated**. Besides having an important role to play in decentralising energy production, facilities that take advantage of indigenous resources also have an educational value in reminding the public that energy is something that must be generated. Similarly, there is also an associated economic and social benefit in the form of job creation and atomisation of the energy sector. For this reason, procedures need to be made easier so that bureaucracy does not become the main hurdle to overcome.

With regard to communication, the PECQ includes the dissemination of energy and environmental knowledge in a structured manner - i.e. avoiding messages that are mere slogans associated with major campaigns, and providing more relevant periodic information and data so the data is well understood and so that the local administration's credibility is reinforced. This way, the public is made co-participants in reaching savings and reduction targets because, beyond the political sphere, without their active support and involvement, it is literally impossible to reach the objectives put forward. It is not a question of placing excessive responsibility on the general public but, rather, of emphasising the importance of their share of the responsibility whilst highlighting the responsibility taken on by other sectors that have, in the past, shown low levels of commitment. On the other hand, diverse channels must be used including more mainstream communication mechanisms to reinforce particular aspects related to energy efficiency and renewable energy. Thus, it could be useful to make use of mass media channels to communicate these ideas.

Historically, lack of knowledge amongst the public about the energy sector has been attributed to its complexity. On the other hand, the facts prove that the public deals with energy information of varying degrees of complexity on a daily basis, ranging from the fuel consumption of a car to a refrigerator label. This is why information needs to be standardised, making it possible to include energy as another variable when making decisions. This energy knowledge will undoubtedly become more important when the price of energy increases.

Another tool for raising awareness amongst the public are public-sector installations and the policies adopted by the tertiary sector, which have considerable influence (by way of the examples they set) when conveying the values of a sustainability culture applied to energy use.

5.2.2 - STRATEGIC LINES

The City Programme

- **L1 - Influence the relationship between how people behave, how society behaves and how organisations behave in terms of energy consumption.**

  By way of information action and awareness measures, make the public aware of the need to use energy wisely and of the environmental impact of using energy inefficiently.

- **L2 - Introduce the need to apply energy efficiency principles when rehabilitating buildings and refurbishing housing.**

  Care must be taken to ensure that new buildings incorporate energy efficiency criteria and that rehabilitation projects and small-scale refurbishments also take energy efficiency into consideration, both in the construction plan and also in the installations themselves.

- **L3 - Continue prioritising the use of the main renewable resources available to the city and incorporate high-efficiency technology.**

  The main renewable source available to Barcelona is solar energy. The number of installations needs to continue to increase and existing ones need to work and be managed properly. In addition, in order to decentralise energy generation, the barriers to introducing little-used renewable energy sources need to be overcome.

  Where technically viable, commitment needs to be made to district networks.

  The use of fossil fuels should require promoting the best available technology.

- **L4 - Reduce the presence of private vehicles in Barcelona - the cause of one of the main public health problems in Barcelona: air pollution.**

  This objective involves carrying out projects within the Barcelona Urban Mobility Plan and taking on all the objectives of the Mobility Pact, especially those relating to improving public transport and to cycling.

  However, a key aspect is technological change to reduce the use of diesel and move towards using less-polluting fuels that have a lower environmental impact and affect individual health to a lesser degree.

  The visualisation of the problem also involves information and awareness initiatives.

- **L5 - Reduce the environmental impact of large infrastructures and economic actors such as industry, the port and airport.**

  Promote collaboration on energy with the industrial sector and with other economic actors in the city in order to strengthen those strategic lines of action regarding the environment that are already planned by the managers concerned.

The Municipal Programme

- **L1 - Reduce the impact of transport in the city**

  This objective is two-fold: firstly, to rationalise the use of vehicles in municipal fleets whilst evaluating the viability of alternative transport systems (public transport, cycling, car-sharing), and, secondly, introduce technological changes to vehicles so they are perfectly adapted to the urban environment and to the purpose they serve, whilst making it a priority to minimise the impact on air quality.

- **L2 - Rationalise the use of energy in both new and existing facilities.**

  This process of rationalisation has two different aspects to it: one technological, the other behavioural. With regard to the former, the need for municipal services is set to increase over the next ten years, as new facilities are being built and existing ones improved. For this reason, clear and detailed objectives are called for that introduce the best available technology and apply it to new projects.

  With regard to the behavioural aspects, facility users (municipal workers and members of the public) need to be aware of the impact of using them – even the most efficient systems become less effective if they are misused or badly managed.

- **L3 - Lower the proportion of primary energy used by municipal services that comes from fossil fuels.**

  In light of the success of the Solar Thermal Ordinance, Barcelona needs to continue to lead the introduction of renewable energy in the city. Besides being dependent on external resources, the high level of dependency on fossil-based resources has both an environmental and a security impact. It is, thus, necessary to make the most of the current energy context, which lends itself more to these kinds of initiatives, to extend decentralised energy generation and take advantage of local resources to generate not only heat and cold but also electricity and transportation fuels.

FIGURE 258 | THE PECQ'S STRATEGIC LINES

THE CITY PROGRAMME

- Influence the relationship between how people behave, how society behaves and how organisations behave in terms of energy consumption.
- Introduce the need to apply energy efficiency principles when rehabilitating buildings and refurbishing housing.
- Continue prioritising the use of the main renewable resources available to the city and incorporate high-efficiency technology.
- Reduce the presence of private vehicles in Barcelona - the cause of one of the main public health problems in Barcelona: air pollution.
- Reduce the environmental impact of large infrastructures and economic actors such as industry, the port and airport.

THE MUNICIPAL PROGRAMME

- Reduce the impact of transport in the city.
- Rationalise the use of energy in both new and existing facilities.
- Lower the proportion of primary energy used by municipal services that comes from fossil fuels.

5.3 - The projects

5.3.1 - THE CITY PROGRAMME PROJECTS

The City Programme includes 85 projects (78.7%) of the 108 foreseen in total by the PECQ. They are grouped according to the following sectors and areas: residential (4), industrial (9), networks (7), commercial and services (6), renewable generation and special regime (14), transportation (3), waste (18), general (14), and Port/Airport (10).

EL SECTOR RESIDENCIAL

- **RES1 - Consumption display units inside homes.**
  Objective: education on energy consumption and extending best practices that help reduce the electric consumption in the home.
  From the social study carried out within the PECQ framework, it turns out most families do not know whether they consume much or little energy compared to the average family, nor do they have a notion of their own energy consumption.
  Description: various devices which display energy usage statistics are currently entering the market at very competitive prices, as are other similar models such as those used for monitoring low energy consumption, which are offered at a very low monthly price. All these approaches have Google PowerMeter connection capabilities to databases and other data management systems.
  This project proposes the promotion of energy (initially electric) consumption visualisation devices in the home. This promotion could be offered in the following ways and the options can be:
  The Barcelona City Council installs an *"electricity consumption visualisation device"* in the home for a specific period of time (i.e. from 2 to 4 weeks). The customer may order the device by phone, online, or at any public library. The device is installed in the home, allowing for dynamic measuring and visualisation of the energy consumption. The device also digitalises the data which is then made accessible by computer. This way the customer can see their energy consumption hour by hour, even including consumption when some appliances are switched on.
  After the stipulated period, an expert in energy efficiency (i.e. it could be linked to the Advisor's project) could visit the home to analyse the measurements and give energy saving advice to the customer.
  Alternatively, the device may also be purchased (sales commission model to support the initial service costs).
  There is also the possibility of offering computer game/video console styled features to visualise the savings potential (i.e. fee games). This approach could be linked to the project *"Compared Consumption: energy consumption and environmental impact comparative platform"*.

- **RES2 - Thorough monitoring system for the energy efficiency measuring application in the residential sector.**
  Objective: to integrate in one single municipal protocol, the monitoring for the correct implementation of the measures related to renewable energies, or energy efficiency in the residential sector.
  Description: it is proposed to create a municipal monitoring and supervision procedure which integrates all the energy efficiency and energy generation components present at a building of mostly residential use. Regardless of whether it is a new or an existing building, this proposal enables the centralisation of a single protocol for the administrative/technical verification of the performance of specific measurements related to the energy efficiency in the homes.
  In the beginning, this monitoring system should monitor the following installations:
  - Monitoring for the correct performance of the Solar Thermal Ordinance.
  - Monitoring for the correct performance of the solar thermal installations derived from OST (linked to other PECQ projects).

- Monitoring for the correct performance of the Photovoltaic Ordinance.
- Supervision of the correct replacement/installation of energy efficiency measures in the homes where fiscal and other advantages are received (i.e. replacement of windows, appliances, etc.).
- Supervision of the correct execution of energy efficiency improvements performed in residential buildings in the context of major and minor works refurbishment projects (i.e. insulation, etc.).

- **RES 3 - Proposal for a regulatory framework for energy improvements in building rehabilitation.**

  Objective: it is proposed to develop and adapt a regulatory framework which facilitates the incorporation of criteria from the CTE and the Eco-efficiency Decree in minor works that foresee work on the facade in residential sector buildings, in order to reduce the energy demand of the building.

  Description: to develop a regulatory frame that affects the actions involving the building envelope and that incorporates the aspects of the CTE and the Eco-efficiency Decree that are applicable to construction and that foresee an energy demand reduction, such as work on the facades.

  Currently, the CTE incorporates its application in refurbishment and alterations or refurbishment of existing buildings with a useable surface area greater than 1,000 m^2 and where more than 25% of the enclosures are renovated.

  This project will enforce the incorporation of the CTE and the Eco-efficiency Decree energy efficiency criteria that are related to the building envelope and therefore related to the energy demand reduction of said envelope, in the refurbishment of mainly residential buildings that foresee acts on the building envelope.

  The application of this project covers all the buildings with less than 1,000 m^2 of useable surface area incorporating major as well as minor works that affect the building envelope, especially the ones affecting the facade.

  Because of the possible technical, physical or building cataloguing complications, it is necessary to keep the pertinent exceptions in mind.

- **RES4 - Improvements in energy efficiency in housing refurbishments.**

  Objective: to take advantage of the home improvements to encourage the energy improvement.

  Description: a project which will encourage taking advantage of home improvement works in order to incorporate energy efficiency concepts. Considering that home improvement projects can be an opportunity to improve the insulation of windows, and of certain walls, or to replace electric appliances in favour of natural gas to generate heat (more efficient in primary energy); and considering, additionally, that one very important housing industry sector where it would be well worthwhile improving energy efficiency are rentals, it is proposed to develop a project that encourages the incorporation of energy efficiency concepts when undertaking home improvement work, by encouraging the owners, especially in the rental sector.

  The idea is to decrease the Real Estate Tax or other taxes if, when undertaking home improvement projects, it is proven that the following upgrades related to energy efficiency have been made:

  - improvement of window frames, glass and shutters,
  - improvement of certain wall insulation (home interior insulation),
  - substitution of electric heat generation systems (except the oven) in favour of natural gas systems.

THE INDUSTRIAL SECTOR

- **IND1 - Energy service companies in the industrial sector.**
  Objective: to improve the energy efficiency in the industrial sector and stimulate a new market based on energy efficiency.
  Description: to favour energy services outsourcing in the industrial sector.
  Many industries need energy assistance to take optimal advantage of their savings potential, along with helping them define future strategic lines of energy generation or of service outsourcing. In conjunction with the Zona Franca Consortium Services Platform, it is proposed to support companies with technical assistance, stimulating, at once, the entrepreneurial communication between energy supply companies and energy consumption companies.

- **IND2 - Energy efficiency agreement with other entities in the industrial sector.**
  Objective: to reach an agreement to integrate efforts in measures and incentives which will lead to energy efficiency in the industrial sector.
  Description: establish an agreement with other entities on energy efficiency in the industrial sector to solve the following issues:
  - Disseminating real energy saving experiences by means of energy efficiency or local generation in the sector.
  - Promoting, from the Administration, the creation of an industrial energy efficiency promotional programme, with an *"award"* system, with real energy measure and specific reduction objectives. A wide variety of consultations to industries on *"how they would do it"* is proposed for two reasons: to design something that *"fulfils"* needs, and to get commitment and motivation.
  - Reinforcing and consolidating already existing industrial advising programmes (for example, the ICAEN PAGE programme) to optimise communication with the industry and to capture the needs of each one of them, while adapting the Administration programmes and acts to the industries' reality.
  - Focusing efforts (promotion, incentives, information, subsidies…) on the installation of energy measuring devices and on the connection to the control panel that industries normally have, and on recording the data regularly. What is measured can be reduced. This way, the energy efficiency measures evaluation would be evident to industries.
  - Consolidating the Administration's *"energy manager"* figure, offering management tools and tools for *"normalising"* procedures to those responsible for the energy part of industry, as well as trying to *"convince"* top management on the importance of this figure and the need to have resources available as well as decision making power.
  - Promoting the coordination between the different agents and improve the Administration's role as a contact with the industries, to have one single spokesperson. This would prevent the risk of *"tiring"* the industry from happening, and would maintain its availability to cooperate.

- **IND3 – Industrial sector energy efficiency management systems.**
  Objective: promoting energy efficiency to the industrial sector.
  Description: the implementation of energy management systems in the industrial sector generates energy savings and process improvements. It is proposed to develop a project that promotes these management systems as long as they are associated with specific energy reduction objectives and linked to the company's strategy plan. Additionally, the management system should include the necessary measuring elements to be able to energetically characterise the processes by different zones.
  It is proposed to increase the energy efficiency in the industrial sector in conjunction with the ICAEN and the Zona Franca Consortium Services Platform, by designing strategies to support these industries in becoming more energy efficient and therefore more competitive.
  The implementation of EN 16001 can be encouraged as a support tool.

- **IND4 - Increasing energy efficiency in production processes.**
  Objective: to improve the industrial sector production processes to reach lower levels of energy consumption and emissions with the same production.
  Description: the overall analysed industries in the PECQ have an energy saving capability when improving the quality of the raw material that enters the production process and when applying process improvements. It is proposed, in conjunction with the ICAEN and the Zona Franca Consortium Services Platform, to design support strategies for the industries to become more energy efficient and therefore more competitive.
  Some methods or methodologies to work on according to process type:
  - Heat recovery from combustion fumes generated by certain equipment in some plants.
  - PINCH Analysis: industrial plants have multiple needs concerning heat and cold. The use of process integration strategies can generate important improvements in the energy efficiency of these processes. The Pinch Analysis, also known as process design Pinch method or Pinch technology, is a methodology to optimise energy recuperation in industrial processes by minimising the local investment. This methodology includes optimising the thermodynamic linkage between the cold and heat flows in industrial processes.

  The use of Pinch Analysis allows for greater energy savings than those obtained from conventional methods such as the heat recovery from gases escaping from furnaces, insulation and the steam trap management system.

- **IND5 - Promoting cogeneration in the industrial sector.**
  Objective: to improve the energy efficiency in the industrial sector and to increase the distributed energy generation.
  Description: to promote the installation of cogeneration plants that give out useful heat, mainly to the different processes in the industry. This type of project is technically and economically viable and is presented as company investment.
  Eventually, other modalities to develop the project, such as the Energy Service Company (ESC) model, could be evaluated.

- **IND6 – Sludge drying for energy rationalisation**
  Objective: to make the most of a sub-product such as sludge to generate energy.
  Description: certain industries with small wastewater treatment plants generate tonnes of sludge which could be used energetically as biomass or municipal solid waste if we had a drying system available. The analysis for real possibilities to implement drying systems in certain industries is brought up.
  The proper management of such waste has the following advantages:
  - Reduction of waste and savings when managing them.
  - Production from a non-fossil fuel source.

  Additionally, there are various options to make use of this biomass:
  1. Biomass for self-consumption.
  2. Biomass for sale.

- **IND7 - Photovoltaic (PV) solar energy in industrial roofing.**
  Objective: to take advantage of available space with great solar absorption capability such as industrial roofing to produce energy.
  Description: It is proposed to revitalise the potential of some solar roofs by using the administrative advice and support to facilitate the installation of photovoltaic energy in certain industrial roofs, whether the roof is owned or rented, hence bringing about solutions to possible barriers such as the industrial land rental temporality and the PV system amortisation period.
  Not only does this project offer energy generation and CO_2 emissions reduction, but it also carries an important corporate image aspect to it. In addition, it can be integrated at the electric car recharging sites, quite a current issue. Some companies have already evaluated the available roofs, estimating a very high average installable total power.
  This project is also related to other PECQ projects in which it is proposed to reduce photovoltaic solar installation implementation formalities.

- **IND8 - Separation of coloured and clear bottles to improve septic performance**
  Objective: to improve the performance of companies which melt bottles to make glass.
  Description: it is proposed to install, in the bottle recycling process, a machine that separates clear from coloured bottles and, this way, reach an energy efficiency increase in the process of melting glass for recycling purposes.
  In glass manufacturing, raw material is melted and said material reacts to form glass. The introduction of recycled material in the raw material lowers the specific glass production energy.

- **IND9 - The energy savings in painting booths in small/medium size auto body shops.**
  Objective: to encourage energy efficiency in auto body shops and car paint shops by using a new technological system adaptable to conventional booths.
  Description: Energy efficiency in auto body shops and car paint shops can be improved by using a new technology applicable to the car paint booths. This new system is adaptable to any conventional or newly built paint booth and consists of equipment that brings additional air in perpendicular direction to the cabin's main circulation, in such a way that it modifies the conditions of the vertical flow, accelerating noticeably the evaporation of the applied paint water, and therefore considerably reducing energy consumption and CO_2 emissions.
  According to a study commissioned by the ICAEN, there is a new technology (created in the UK and with ample experience in the leading EU countries on the promotion of energy savings) applicable to the car paint booths and which can be adapted to any conventional or new construction paint booth. This technology consists of equipment that brings additional air perpendicular to the main booth circulation, such that it modifies the conditions of the vertical flow, noticeably accelerating the evaporation of the applied paint water, and considerably reducing energy consumption and CO_2 emissions. For example, with said ICAEN's study system, hot air drying time is reduced from 96 minutes in a conventional booth to only 60 minutes. Also, during the drying process that calls for auxiliary lateral air circulation, a greater quantity of caloric energy available in the air is taken advantage of, leading to time savings in the hardening process and substantially improving the energy performance.

THE NETWORK SECTOR

- **XAR1 - Zona Franca Power Plant- Gran Via L'Hospitalet.**
  Objective: to take advantage of available residual energies in Barcelona such as heating from biomass and cooling from the re-gasification plant to generate less CO_2 and to reduce the dependency on fossil fuels.
  Description: the project consists in installing an energy plant in the Zona Franca named *"Zona Franca Power Plant- Gran Via L'Hospitalet"*, to generate electricity, cooling and heating, with a system of residual cold recuperation from the Port de Barcelona re-gasification plant, completely supported with conventional equipment to generate heat and cold, and a biomass plant to generate electricity from the use of heat.
  The Barcelona City Council has initiated this project by inviting tenders and awarding the project execution and management.
  The project has various execution phases:
  - PHASE I: heat and cold generation plant at La Marina and biomass energy valorisation Plant.
  - PHASE II: heat and cold generation plant in Zona Franca, ENAGAS cooling recuperation Plant, and transportation network up to the Zona Franca Plant.
  - PHASE III: expansion up to the new Hospitalet de Llobregat territories and up to the new Zona Franca service building territories.

  Operations are to begin in March 2011 (PHASE I) and the connection to the heating network is forecasted for the year 2015 (which corresponds to the development of PHASE II of the project).

- **XAR2 –**
  Objective: extension of the Fòrum-22@ centralised DHC system to the St. Andreu-Sagrera transformation area, to improve the energy efficiency and the reduction of primary energy consumption.
  Maximise the use of residual energy from the energy revalorization plant in Besòs (TERSA).
  Description: the area of Sant Andreu - Sagrera has started an urban transformation process which will entail building more than 1,100,000 m^2 of new roofing for diverse uses, as well as an urbanisation process which will incorporate new streets and parks along the entire stretch that is currently taken by the outdoor train line structure.
  Part of this project includes the installation of a centralised DHC system and its connection to the current Fòrum and 22 @ network and, therefore, the supply of heating and cooling through high efficiency systems.
  In a first phase, the installation of this system and its connection to the current network would support the DHC energy demand of about 321,500 m^2 of tertiary sector roofing (about 10,130 MWh/a of heating and 47,050 MWh/a of cooling).
  To carry out this network extension it is necessary to install a local network of 4 tubes (2 km), which would connect to the local network (2 km) and to a substation with an installed power of about 23 MW of heating and 32 MW of cooling.

- **XAR3 – Information system about the network and the quality of the energy systems (electricity and gas).**
  Objective: to evaluate and follow up on the quality indexes to create specific reports for those government agencies and departments or municipal companies that must make decisions about the planning or management of electric and gas infrastructure projects.
  Description: information system that collects data periodically about the status of the network, its use, and the quality of the services it provides, and which enables the incorporation of such data into the Energy Observatory.
  The information system should have:
  - Data stored in electronic format.
  - An open database which allows:
    - A document manager that allows search criteria and/or document filters in pdf, dwg and other formats.
    - A visualisation interface (graphical user interface) that allows users to access the database.

- **XAR4 – Software programme supporting the electric infrastructure tracking.**
  Objective: to make information processing more agile and safe, to evaluate the network reliability and to establish medium and long term objectives, based on the available data on the configuration and characteristics of the electric installations.
  Description: decision making support *"mechanism"* that allows the Administration to simulate proposals submitted by the Utilities (transportation and distribution), also enabling the Administration to submit new proposals or suggest consensus solutions to differences in proposals between one Utility and another.
  The *"mechanism"* has to be able to evaluate the load distribution in the Barcelona electricity grid, in high voltage transmission and medium voltage distribution networks. It must be a decision making support element, not a computation or planning tool.

- **XAR5 – Modernisation of electricity and gas supply incident communication protocol.**
  Objective: to adapt the protocol activation criteria and the notification formats to the new Law of electric supply quality warranty, and to establish activation criteria for gas supply incidents within the protocol.
  Description: writing a new protocol of communication between distribution companies, trading companies, and the Administration, to formalise the exchange of data about incidents and the quality of electricity and gas supply.

- **XAR6 – To encourage the connection of the household sector to the DHC network.**
  Objective: to promote the connection of multi-household buildings to the DHC networks.
  Description: the large majority of DHC network clients belong to the tertiary sector. It is proven that the DHC network is one of the most efficient solutions to cover the thermal demand for buildings. To promote communication between the network's developer and its manager, by using intermediaries who manage the energy retail billing with the network's wholesale manager.

- **XAR7 – Communication programme to promote the installation of microCHP systems to replace old thermal-based equipment.**
  Objective: to promote the installation of small cogeneration units in certain buildings.
  Description: without forgetting solar thermal energy, identifying where the uses of a microCHP system would make more sense (superior optimal emission balance or greater primary energy savings), and ease facilitate the penetration. For example, this system can be introduced in equipment changes, since they are not affected by the OST mandate.

THE COMMERCIAL AND SERVICES SECTOR

- **COM1 - To create a regulatory framework for DHC in the commercial and services sector.**
  Objective: to avoid energy waste due to CO_2 emissions and to lack of public awareness.
  Description: to create a regulatory framework that affects the closing and automation of street doors of stores that permanently leave their doors open when these systems are used (very common in some cafés), as well as the use of outdoor space heaters.
  Therefore, at first, an inventory will have to be made of businesses or services (such as hotels) that use heating or AC and keep their street doors open while using these systems.
  Along with the development of a favourable regulatory framework, it will be necessary to elaborate an awareness programme for the commercial and services sector to evaluate the initiative as a common good.

- **COM2 - Installing tri-generation systems (CCHP) in large hotels in lieu of renovating ordinary installations with obsolete equipment.**
  Objective: to promote the installation of trigeneration systems (CCHP) in large hotels to improve energy efficiency, and reduce primary energy consumption and CO_2 emissions.
  Introduction and consolidation of a model of generation distributed to the city.
  Description: this project intends to promote the implantation of trigeneration systems (CCHP) in the large city hotels, both those currently being built and those currently operating which have the necessary space and whose thermal generation equipment requires revamping.
  The development of these systems can be managed either as the equipment owner's or manager's own investment, or by outsourcing to energy service companies (ESC).
  Tri-cogeneration would satisfy partial demand for heat (sanitary hot water, heating, laundry, etc.) and for cold while generating electricity and achieving an overall performance close to 70%.

- **COM3 – To encourage the installation of solar thermal systems in existing athletic clubs.**
  Objective: to reduce fossil fuel energy consumption and to promote the installation of solar thermal systems to large heat consumers.
  Description: to promote the implantation of solar thermal systems in existing athletic clubs (since the new buildings are already regulated by the Solar Thermal Ordinance and the CTE) so they have a good orientation and absorption area potential, by informing them of the advantages and possible urban landscape subsidies.
  There are currently in Barcelona 534 m^2 of solar thermal collectors in inventory at the following five public athletic centres:
  - *Estadi Joan Serrahima 43 m^2*
  - *Piscines Bernat Picornell 334 m^2*
  - *Centre Municipal de Vela 76 m^2*
  - *Poliesportiu Municipal de la Creueta del Coll 36 m^2*
  - *Vestidors Guàrdia Urbana Zona Franca 45 m^2*

  The proposal is to increase the number of installations, both in public and in private buildings by using various strategies such as information and diffusion of solar thermal system advantages, whether it is with one's own investment or with a third party's investment (energy service companies) or by means of Urban Landscape subsidies, among others.

- **COM4 – Installation of micro cogeneration systems (micro-CHP) at athletic centres.**
  Objective: to promote the installation of micro cogeneration systems in the sports equipment to improve the energy efficiency, to reduce primary energy consumption and CO_2 emissions.
  Introduction and consolidation of a model of generation distributed to the city.
  Description: this project intends to promote the implantation of micro cogeneration systems in the city's sport equipment, both within upcoming buildings and within existing ones which have the necessary space and which require thermal generation equipment revamping.
  The development of these systems can be managed either as the equipment owner's or manager's own investment, or by outsourcing to energy service companies (ESC).

Micro cogeneration would satisfy partial demand for heat (sanitary hot water, heating, swimming pool heating, etc.) and for cold (AC) while generating electricity and achieving an overall performance close to 65%. Whenever possible, consideration will be given to the use of fuels from renewable sources (biomass or biogas) to increase the renewable contribution to the city, otherwise natural gas would be used as a low emission fuel.

This proposal has been designed and evaluated on the assumption that the cogeneration implantation would be exempt from compliance with the Solar Thermal Ordinance but, in many cases, these two actions could be compatible and would lead to improvements in the environment (a detailed analysis will be necessary in each case).

- **COM5 – Implantation of infrastructure sustainability criteria and sustainable product purchase criteria, among other measures, in TMB (Transports Metropolitans de Barcelona).**

  Objective: set of projects that have the following different objectives:
  - **To sustainably design and manage the infrastructures, as well as to reduce air and noise pollution, improve air quality and combat climate change.**
  - **To internally promote the culture of sustainability.**
  - **To design and implement an Integrated Environmental Management System.**
  - **To promote a sustainable mobility culture among the people and increase market share and the reputation of TMB.**
  - **To promote public transportation through dialogue with stakeholders and synergies with the Administration and other operators.**

  Description: set of projects led by TMB that entail a whole series of measures outlined below:

  Design, construction and maintenance of infrastructures with environmental sustainability criteria.

  Implementation of environmental criteria when buying TMB products and services.
  - Bus network emissions map: creation and implementation of a tool (emissions simulator) to produce emissions maps based on vehicle features and network characteristics.
  - To promote a communication plan, training and internal environmental participation to achieve the highest degree of awareness and participation of staff in the process of TMB towards sustainability.
  - Scoreboard of the environmental performance of TMB according to ISO 14001/EMAS: implementation of an online tool for tracking the environmental performance of TMB through the presentation of indicators of water consumption, energy consumption, material consumption, waste generation and emissions.
  - Plan for external communication on environmental sustainability.
  - System for obtaining information on the people's habit evolution and their environmental values.

- **COM6 - Optimisation of power and water management at TMB facilities.**

  Objective: to increase energy efficiency and to optimise water management at metro and bus premises.

  Description: a project which will be executed by TMB to better manage energy with the revamping of systems and achieving better efficiencies and reducing water consumption at TMB premises.

  TMB annually consumes 11.4 million KWh of electricity and 38,405 m^3 of water in their facilities.

  In addition, the metro consumes 196.2 million kWh annually by the fleet, 71.6 million kWh at the facilities and 78,892 m^3 of water (Source: annual TMB 2009).

  TMB offers a series of actions for the future (2010-2014) set out below:
  - Water and energy audits to other centres.
  - Implementing measures to reduce water and energy consumption:
    - Replacement of conventional lighting systems in favour of lighting systems with low power consumption.
    - Flow limiters, reducers or aerators, flow reducers for sink taps and showers.
    - Renovation of conventional toilets with double push button or interruption button.
  - Pilot test to improve efficiency in water and energy consumption at a shop and at a station, such as: consumption audits, definition and implementation of savings criteria and monitoring mechanisms.

RENEWABLE GENERATION AND SPECIAL REGIME

- **ER01 - Regulatory framework to regulate the incorporation of PV systems in the city.**
  Objective: that new buildings for commercial use and public services have a lower dependence on external energy and emit less CO_2 to operate.
  To encourage the use of renewable energy in the urban environment.
  Description: The purpose of this project will be to regulate the mandatory incorporation of solar photovoltaic energy systems in buildings and constructions of public and private property located in the municipality of Barcelona, both for the direct use of electricity produced and for injecting it into the mains, with the intent to promote the use of renewable energy in the urban environment.
  The determinations of this Ordinance affect and shall apply to:
  - the completion of new buildings or constructions, or
  - the rehabilitation or complete refurbishment of the building or construction.
  - the relevant change of use of the building or existing constructions.

  The major affected uses are:
  - Commercial, housing or other public service > 3,000 m^2
  - Civic centres, houses and other buildings for social use> 1,500 m^2
  - Offices> 1,500 m^2
  - Industrial and / or stores> 1,500 m^2
  - Public Administration buildings> 1,500 m^2
  - Schools/ Education Centres> 1,500 m^2
  - Sports Halls> 3,000 m^2
  - Health Centres> 3,000 m^2
  - Car parks (depending on certain considerations)> 3,000 m^2

  The goal is to install an electrical power equal or superior to, at least, 7 Wp of PV per square metre of roof constructed for uses affected.

- **ER02 - Checking the correct maintenance/functioning of solar installations arising from the Solar Thermal Ordinance (OST).**
  Objective: to make sure that all the installations arising from the OST have optimal performance throughout its useful life (tolerance 0 to malfunction).
  Description: throughout the history of the Solar Thermal Ordinance, the City Council in its protocol for surveillance of solar installations resulting from the application of the Ordinance, has seen how some have no proper maintenance and/or are not exploited to their capacity.
  Many of these disorders are due to the actual users' ignorance of how the installation works and of how it can contribute to their economy.
  A two-stage project should therefore be initiated:
  - STAGE1: to educate users on the global importance of using solar thermal energy, on the need to hire a proper preventive and corrective maintenance service, and on how to leverage the potential that is installed in their home as well as its economic and environmental benefits.
  - STAGE 2: supervision of solar systems in which there may be fines if there is proof that the facility continues to operate incorrectly due to the users' misuse.

- **ER03 - Proposal to simplify the process of connecting small facilities ER.**
  Objective: To facilitate the connection of PV installations to the network throughout the area of Barcelona and Catalonia.
  Description: to simplify procedures for the connection of low power PV installations undertaken within low power installations equal or inferior to that contracted for housing such as, for example, installations of less than 5 kWp.
  Reduce the costs of time and paperwork required by the local and regional authorities, and of the network manager for the installation of PV power. Set up a one top procedure in these two legislation areas.
  In the first phase, person receiving and managing the documentation provided (with utilities, Business Management Office, etc.) would be made available to the public.

- **ER04 - Promote the installation of small PV power on community roofs.**
  Objective: To encourage the installation of small PV systems in roofs of multifamily housing.
  Description: to establish a procedure to convey the many parties involved and save the resulting complications (owner of the installation, its manager, promoter…).
  In recent years, the majority of installed PV power has been supplied by a small number of developers and local authorities.
  The ultimate goal is to atomize PV installations on as many rooftops as possible by diversifying the types of promoter of such facilities.
  To encourage this, a website can be created where, in addition to information, it can offer a public consultation service with a pre-computation of the potential PV generation for all buildings in Barcelona with simple economic calculation (cost, payback, etc.). This site can be an internal web page that compares consumption and can also lead to PV project with participation schemes in case that the rooftop does not have space or sunlight.
  As a result of this procedure, a test would be carried out with five volunteer buildings.

- **ER05 – Diagnostic and Analytic Study on solar thermal power systems.**
  Objective: To update records on solar thermal power systems executed in Barcelona with real data on their characteristics and status to date. Assess the degree of compliance with the OST and correspondence with the license granted by the City Council.
  Description: to assess the percentage of solar thermal power systems that are operating and contributing with energy savings, whatever the source of production of conventional SHW.
  To do this, we propose:
  - To determine the casuistry of technical anomalies that cause the solar thermal power system to not work or not perform as expected, allocating the reasons and causes.
  - To estimate the impact on energy saving and its correction cost according to a classification of incidents based on criteria such as the origin or severity.
  - To equip technicians authorised by the Industrial Engineers of Catalonia with the minimum theoretic and practical knowhow necessary to complete the validation tasks on solar thermal power systems.

  These first 80 current installation audits have a double purpose, since they are performed by authorised technicians along with engineers specialised in the sector. This way, on one hand the authorised technicians acquire the knowhow that will enable them to improve the first occupation inspections and, on the other, the engineers in charge of the installation audits give to the AEB knowledge on the current state of the installation park.

- **ER06 - Promoting PV installations of medium and large power with participation schemes.**
  Objective: To approach the possibility of investing in renewable energy to a greater number of people.
  Description: both in Barcelona and abroad similar initiatives have already been successfully undertaken with different technologies (wind, photovoltaic). The ultimate goal of this proposal is to make PV installation investment look attractive by fractioning the initial cost in relatively reduced payments. This way, the reduced cost encourages the participation of people who would normally not invest in this sector, and it fragments the ownership of power plants.
  It is proposed to promote the scheme through the logistical and administrative support for these initiatives, whether promoted from the association or private sector, or from local government itself, providing public roofs for this purpose.

- **ER07 - Study of the solar thermal energy potential in Barcelona.**
  Objective: based on a study of the potential of renewable energy resources and of efficient power generation technologies in the city, focused on ten Specific Studies (SS): solar thermal, photovoltaic, mini-wind power, biomass, exploitation of groundwater, geothermal heat pumps, micro-cogeneration, natural gas expanders, use of residual heat and district networks (DHC), which is underway for the city, new strategies and policies need to be defined to promote solar energy within the urban fabric, including new developing areas.

Description: The project aims to define the full potential of solar thermal energy, and should serve as a tool to help decisions about new policies for the implementation of solar thermal energy in the city. The project is proposed in two phases:

- Phase 1: individual and specialized studies (SS) on the technological potential and possible scenarios for each of the technologies described (10), in which the technological potential of the ST will be obtained.-
- Phase 2: tool and methodology for analyzing the SS's: development of a tool (such as a spreadsheet) that allows a comparison of technologies, allowing to determine the technological solution which, from the efficiency standpoint, provides better coverage for a specific demand.

- **ER08 - Guide rehabilitation of Thermal solar power systems rehabilitation guide.**
  Objective: To have a tool to set the guidelines regarding the rehabilitation of solar facilities, that includes the main plots and casuistry concerning technical anomalies that make solar thermal power systems not work or not give the expected contribution, allocating the reasons or causes, and proposing solutions in each case for their rehabilitation and to insure its proper future functioning. This guide will also address the facilities which, given their age, would need to be rehabilitated.
  Description: The rehabilitation guide should allow:
  - Establish the most common problems, causes and solutions (rehabilitation packages).
  - Assess the solutions' technical and economic impact.
  - Establish a series of technical requirements that must guarantee the rehabilitation projects, whether made by designers or installers (technical reports type).
  - Define an administrative procedure that ensures the monitoring and control of such actions which will usually be processed as minor works licenses.
  - Suggest ways of financing and investment recovery for the facilities' owners (advance of initial investment).
  - Define mechanisms that ensure sustainability of facilities performance (conditioning subsidy payments to audits' results).
  - Installation and maintenance companies, CCVV and agencies such as IMPUQV, ICAEN and IDAE would be needed to create this guide.

- **ER09 - Adaptation of the Solar Thermal Ordinance text.**
  Objective: To streamline administrative processes; to ensure functional requirements of solar thermal installations (STI), and incorporate new technologies and/or new STI systems designs, adapting to the best technology and industry evolutionary improvements.
  Description:
  - Minimum coverage and conditions for justification on the working STI.
  - Exemptions for partial or complete substitution for alternative systems.
  - Exemptions for lack of surface.
  - Documentation of STI legalization and complementarity of the Final Certificates and RITE Certificates.
  - Monitoring systems.
  - Operating STI audit procedures in operation.
  - Adaptation of the handling process to the new electronic licensing process.

- **ER10 - Solar thermal installations monitoring open platform.**
  Objective:
  - **Get online aggregated data about solar energy heat generation for hot water production, real solar panels and energy savings, for the audits of operating STI's.**
  - **Have a complementary tool for field audits.**
  - **Monitor the balance of the STI park growth not only in installed square metres but also in kWh of energy savings, and thus assess the adequacy of energy policies.**
  - **Have data to improve the designs of the facilities.**
  - **Allow users to be familiar with their STI operation and savings.**
  Description:
  - Install an STI monitoring system that allows downloading the aggregated data of the selected STI.
  - Allow different user profiles (EIC, AEB, owner) access information with greater or lesser detail.

- Comply with the Data Protection Act (LOPD).
- Be scalable and open to use by maintainers.

- **ER11 - Feasibility study of the scenario of STI's operated by third parties.**
  Objective: To analyze the viability of companies assuming STI's, and hence ensuring their best performance.
  Description: To assess whether there is a profile of small and medium enterprises capable of working under ESCO or alike for centralized STI facilities, assuming the management of a pool of facilities. If so, encourage it.
  Likewise, study the feasibility of facilitating initial contact between these companies and the owners / users of the facilities by creating a platform managed by the Administration (Energy Agency, for example.)

- **ER12 - Solar Ordinance Integrated Manager (SOIM).**
  Objective:
  - **On the one hand it helps to expedite obtaining the solar report needed to obtain first occupation building permits, activities, and the like.**
  - **Have a reliable record of STI's installed in Barcelona.**

  Description:
  - An STI scale simulation engine with larger number typologies than presently available.
  - An STI audit record.
  - An STI analysis report system, based on installation and audit data.

- **ER13 - Implementation pilot project of mini-wind power on roofs.**
  Objective: To encourage the installation of small installations of mini-wind power on multifamily building roofs so that their electricity production covers a fraction of the consumption derived from the building's maintenance.
  Description: Establishing a procedure to convey the many actors involved and solve the potential complications (facilities' owner, the manager of this facility, the developer…).
  The ultimate goal is to break down the barriers of mini-wind power (mainly due to the tariff framework) and to normalise the presence of this technology in the city.
  Resulting from the procedure, a test would be developed with 5 volunteered buildings.

- **ER14 - Pilot project for implementing mini-wind power in industrial areas.**
  Objective: To encourage the installation of small mini-wind power facilities in industrial areas.
  Description: the social study made under the PECQ shows that most families do not know whether they consume much or little compared to the average nor do they have a notion of energy consumption.
  Various electrical consumption visualisation devices are currently entering the market very competitively, as are other models such as those for monitoring small consumers, which are offered at a very low monthly cost. All these models have Google PowerMeter connection possibilities for database and other data management systems.
  This project proposes the promotion of energy (initially electric) consumption visualisation devices in the homes and the options can be:
  The Barcelona City Council installs an *"electricity consumption visualisation device"* in the home for a specific period of time (i.e. from 2 to 4 weeks). People may order it by phone or online or at any public library. The device is installed in the home, allows for measuring and visualising the consumption at any given moment, and also digitalises the data which becomes accessible by computer. This way the user can check the consumption hour by hour and even some appliances when switched on.
  After the stipulated period, an expert in energy efficiency (i.e. it could be linked to the Advisor's project) could visit the home to analyse the measurements and give energy saving advice to the user.
  As an option, the device may also be purchased (sales commission model to support the initial service costs).
  There is also the possibility to promote computer games/video console features to visualise the savings potential (i.e. fee games), and this could be linked to the project *"Compared Consumption: energy consumption and environmental impact comparative platform"*.

THE TRANSPORT SECTOR

- **TR01 - Emission controls on the most polluting vehicles and traffic intervention alternative analysis, seeking consensus to implement them.**
  Objective: According to the study of characterization of the fleet in terms of emissions made in Barcelona as part of PECQ, 10% of most polluting vehicles are responsible for 40% of emissions of PM_{10} and 38% of the NO_x, and this 10% is composed of 52.7% of commercial vehicles and 36.8% of passenger cars.
  The project objective is to detect the most polluting vehicles, and their emissions reduced to an average value in its class. It is estimated that, with this measure, reductions in NO_x emissions by 13% and 20% in particulates can be achieved. To directly raise the awareness of the more polluting vehicles drivers. To work with national and regional government to incorporate the assessment of NO_x and PM_{10} in the Vehicle Technical Inspection protocol.
  Description: The project is proposed in two phases:
  1st phase: creating awareness of the effect road traffic has on city air quality, by carrying out emission controls measured in vehicles' exhaust, and attaching them to the registration plate number to take action. In this way, we want to detect vehicles exceeding the average values of emissions set as maximum by the European legislation for each category of vehicles, and to inform drivers that their vehicles are polluting above these thresholds, informing them about the effect that emissions of gaseous pollutants have on the environment, and spurring them to take the necessary corrective measures. Therefore, it is a deterrent phase where various checkpoints in the city would be set and users would be informed.
  In parallel to the first phase, state and regional government would work together to incorporate to the current protocol of the Technical Vehicle Inspection additional values and more restrictive measures than the current opacity of smoke and CO measures, which are considered inadequate to the problem of environmental pollution, especially NO_x and, therefore, making it impossible for vehicles that do not meet these parameters to circulate around the city.
  The duration of this first phase is projected to be two years.
  2nd phase: after the first phase of stimulation, a procedure shall be established so that the most polluting vehicles cannot drive through the city without taking the necessary corrective actions, having to go through the Technical Vehicle Inspection for the confirmation that the vehicle complies with relevant environmental parameters. In the case of fleets, the necessary mechanisms will be established so that the most polluting vehicles have limited access to loading and unloading areas of the city. Alternatives of intervention on the traffic will be analyzed and consensus to implement them will be sought.

- **TR02 - Sectoral agreements to reduce the use of diesel in vehicle fleets.**
  Objective: To reduce the use of diesel for the benefit of other cleaner fuels through agreements with agents of private fleets and other users.
  Description: This project aims to promote fuel vehicles with lower emissions of NO_x and particulates than diesel such as natural gas, LPG or petrol, since diesel is the fuel that has more emissions of these pollutants, although it may be more efficient and have less CO_2 emissions than others. In fact, diesel vehicles, according to real measurements made in Barcelona with the RSD-which remotely detects pollutants coming out of car exhausts- emit 3 times more NO_x and up to 8 times more particulates than the same passenger gasoline fuelled vehicles. Even the Euro IV emission standards allow diesel cars to emit 3.13 times more than gasoline cars.
  In this regard it is proposed by possible agreements with the business sector, to act on older vehicles and when people replace their vehicle, have them do so in favour of those running on other cleaner fuels like natural gas, LPG or gasoline hybrids, or electric, or even gasoline.
  Therefore, we consider the following resolutions:
  A> Agreement with taxi drivers to reduce the use of diesel in taxis circulating in the city.
  B> Agreement with the business sector to reduce the use of diesel delivery vans in the city.
  C> Agreement with businesses so that their diesel Euro III passenger vehicles within their fleets are replaced in favour of gasoline (or gasoline hybrid), natural gas, LPG or electric cars.

- **TR03 - Environmental labels awarded to less polluting cars.**
  Objective: To make companies and individuals prioritize the acquisition and use of cleaner vehicles to the expense of the more polluting ones.
  Description: this aims to encourage businesses (and even people) to buy and use (when they have to) cleaner vehicles from the standpoint of local emissions (NO_x and particulates) at the expense of the more polluting ones.
  The environmental label (more focused on company fleets) may be a sign that gives a good corporate responsibility image as well as allowing to obtain various benefits such as loading and unloading area reservations for cleaner delivery vehicles or for company cars awarded with the environmental label, plus discounts at B: SM car parks for vehicles with the environmental label (including private vehicles, etc.). In addition, there may be tax breaks for companies that have their entire fleet tagged *"green."* In parallel, it could be proposed that their drivers take efficient driving courses, savings on fuel could be shared between the company and the driver, and only then will the measure be doubly efficient. The tag issuer will have to be seen.
  Alternatively to the previous measure, instead of tax advantages and to promote the primary measures, one idea is to sanction and/or restrict access. The idea would be to paint some loading and unloading areas in a particular way to indicate they can only be used by certain clean vehicles or vehicles with environmental accreditation. It is a measure that can make the vehicle space availability more efficient and competitive to companies that initially join the environmental accreditation protocol for their vehicles.
  It will be necessary to talk with unions and employers' associations within the transport sector and consumer goods sector.
  For policies beyond the business sector, such as private vehicles, information policies must be made about the environmental benefits of alternative fuels like natural gas, LPG or electricity as well as new technologies.

- **TR04 - Rethinking the distribution of goods.**
  Objective: To reduce the number of freight vehicles in cities by consolidating goods terminal end. To use lower energy consumption vehicles (including electric vehicles) for capillary distribution, as well as to improve the traffic flow in the city Ring roads (reducing congestion) and at rush hour in general.
  Description: this project entails an analysis of the distribution of goods, to later take a series of actions involving a better efficiency in the allocation and lowering traffic congestion during rush hour. It is thought that, among others, the following actions might be interesting: distribution micro-platforms; analyze the heavy vehicle daytime restriction schedule in the Ring roads; increase the heavy vehicle (25 tons) distribution at night time.
  Distribution micro-platforms --> It is proposed to establish certain package consolidation platforms inside the city, where larger capacity vehicles unload their goods regardless of the adjacent shops store hours. Thus, shipping inside the city can be performed with greater capacity vehicles outside heavier traffic hours, and even at night. This measure represents driving time savings, more productivity for distribution companies, so fewer vehicles have to access to the cities.
  Subsequently, the final delivery from the platform to the shops is made in lower capacity vehicles, which may be low power, or even electric vehicles.
  The use of the goods distribution micro-platform is only considered appropriate for small business and for some of the shops affiliated to the network HORECA (hotels, bars and restaurants).
  Analyzing heavy vehicle circulation restrictions in the Ring roads --> it is worth analyzing the potential environmental and energy efficiency effects of heavy vehicle Ring road time regulation. This would, in part, alleviate Ring road traffic congestion, allow a more fluid traffic, and therefore a more energy efficient and environmental traffic. Reaching agreements with the Port Authority and other stakeholders would be necessary in case of implementation.
  Increase night time deliveries with heavy vehicles (25 tonnes).--> distribution of goods during a night time slot means the operation of vehicles during periods when there is no traffic congestion and no problems related to interaction with other vehicles.

Additionally, higher tonnage vehicles can be used, which increases the capacity of vehicles with which distribution is performed. This leads to a lower number of vehicles to transport the same volume of goods. This operation is aimed at major retail outlets that may have reception/receiving night staff. Large stores that have a higher viability are supermarkets. Special care must be taken on choosing measuring areas because of the noise issue.

- **TR05 - Facilitating the introduction of new technologies that produce less pollution, such as electric motorcycles.**
  Objective: To promote policies to introduce new technologies such as electric motorcycles or hybrid bike, in parallel to promoting the replacement of older bikes.
  Description: this aims to promote the introduction of electric or hybrid bikes, less polluting than conventional ones, encouraging the revamping of the pool of motorcycles.
  To facilitate this change in the business sector, agreements with parcel and food delivery companies, etc. must be made. By adopting the electric bike as a main tool, tax incentives could be proposed.
  Moreover, this measure can be associated with the measure of *"environmental label that rewards less polluting cars"*, to encourage companies to make the technology change through a return on investment in form of socially responsible company image and marketing.
  For the private sector, electric bikes charging stations will be encouraged in areas of high influx of students and universities, etc.

- **TR06 - Reduction of empty taxi traffic.**
  Objective: To reduce the annual veh-km travelled by taxis without customers.
  Description: taxis circulate empty for a significant period of time through the streets of Barcelona until someone stops them for their transportation service. This causes taxis to travel many kilometres empty and at no charge, with the environmental and economic cost that this entails.
  For this reason it is considered necessary to amend the passenger pick up system such that it can only be done by previous appointment with companies within the industry or directly at a set of taxi ranks optimally located in singular points of the city.
  The number of taxi ranks must be expanded and mechanisms must be established to avoid having empty taxis driving around. Taxi rank location signs will be needed for people to find them. The network of taxi ranks will have to be expanded with little distance between them (closer to the people).

- **TR07 - Test Pilot on traffic management with traffic light control and environmental criteria.**
  Objective: To determine the effectiveness or otherwise of the traffic environmental management.
  Description: it is proposed to start a pilot test in a certain area of the city that is significant enough to check the effects of traffic management on emission and congestion reduction. The modelling of future projection indicates that the area that will require more monitoring and control in terms of air quality is the area where the Eixample XVPCA station is. Therefore, if such is the tendency, it is proposed to start the pilot test in this area.
  Its implementation will be based on data collected from more than 80 detectors that the City Council has on the road network, data monitoring the trajectories of some TMB buses and data coming from GPS equipped taxis operating in Barcelona. The time series analysis will be a whole week (5 working days, one Saturday and one Sunday) for 24 hours, to ensure the definition of the entire domain of flow-density relation (QK).
  Next, a traffic light management system will be developed to control the flow of access to each district of Barcelona. The latest implementation of new technological equipment for regulating traffic lights made in Barcelona during 2009-2010 will allow the correct development of the dynamic traffic light plan, with a direct and real-time communication between control centre and the regulator of each traffic light. The aim of this measure is to make temporary applied delays to vehicles in access roads significantly inferior to travel time savings in the area.

- **TR08 - More efficient TMB bus network model.**
  Purpose: To plan and manage the public transport network with sustainability criteria and a more energy and service efficient criteria.
  Description: creating a new bus network with more efficient lines and lines accompanied by right of way elements, which can achieve greater circulation speed. This benefits both the user because it reduces travel time and the operator, because it requires a lower number of vehicles to provide the same service.
  This project is, by itself, a strategic project initiated years ago, that is related to redefining a new TMB network and a new plan for city public transport that will contribute to improving sustainability.
  Precisely because of its contribution to sustainability, it is included in this Plan for information purposes. For implementing and monitoring purposes a strategic project should be considered, a reason why decisions will be made by the senior management of TMB.
  Hence, the proposal to evaluate, with TMB, the viability of having hybrid buses circulate (both hybrid diesel buses that are not amortised and new ones that are to be purchased, all hybrid-series, i.e. with electric traction and using the heat engine as an electricity generator) activating the minimal impact circulation mode within the most sensitive areas of the city with regard to air pollution, reducing their impact in these areas.

- **TR09 - Continue the TMB policies of replacing the bus fleet with cleaner technologies.**
  Objective: To make the fleet of Buses in Barcelona more efficient and less polluting.
  Description: TMB policy will continue to replace buses with less polluting vehicles. In this sense, TMB will commit in the coming years, also as a result of research and pilot tests, to a technical change to systems and/or sources that are less polluting and more efficient.
  Currently, 295 bus units are circulating with natural gas (27%), less NO_x and particulate emissions than diesel, and experiments are under way to adapt the concept of hybrid vehicles to diesel buses, with a substantial improvement in energy efficiency and emissions. In 2009, the fleet was composed of 498 with diesel (E1/2/3), 122 with biodiesel (E1/2/3), 76 with diesel Ad-blue, 89 with diesel AGR and 295 with CNG.
  In 2010 TMB forecasts, as a pilot test, 40 hybrid diesel buses circulating. Later, the policy of TMB is to continue increasing natural gas buses up to 40% and the rest are estimated to be diesel or the latest diesel generation.
  The project involves, in the period 2010-2014, the following revamping:
  2010 -> 4 standard hybrids.
  2010 -> 5 minibuses with Euro IV diesel technology.
  2010-2011 -> 522 installations of particulate matter and NO_x filters for Euro II and Euro III diesel vehicles (vehicles of Euro I and Euro II part will be eliminated).
  2010-2011 -> 100 vehicles transformed from diesel to hybrid.
  2011 -> 80 additions of CNG vehicles: 52 standard and 28 articulated.
  2012 -> 30 additions of standard hybrid vehicles.
  2012 -> 30 additions of CNG vehicles: 20 standard and 10 articulated.
  2012 -> 7 minibuses with advanced technology with hydrogen, diesel, hybrid or CNG.
  2014 -> 62 additions of standard and articulated hybrids.

- **TR10 - Improve road and TMB stops street furniture infrastructure.**
  Objective: To make city bus transport more efficient and comfortable.
  Description: this aims to improve road infrastructure in some parts of the city (i.e. extending the bus lane width, etc.), in addition to improving specific urban furniture such as TMB bus stops to make them more comfortable for the user (i.e. stop platforms, etc.).
  Moreover, it is proposed to upgrade the stops with UIB (User Information Boards), to keep the user informed about waiting times and other possible information.

- **TR11 - Company fleets of electric bicycles instead of motorcycles.**
  Objective: To reduce vehicle traffic in the city and therefore reduce pollutant emissions.
  Description: replace part of some company fleets of motorbikes with electric bikes, since this transport is competitive on short journeys if done with traditional vehicles; electric motor bikes with an electric motor to be operated in moments that require more effort such as in streets with considerable slope, or to counteract the effect of wind, or save longer distances.
  This measure not only produces an environmental benefit because it is a non-polluting medium, but it also allows economic cost savings to the employer because it does not need fuel to operate.

- **TR12 - Support the introduction of cleaner fuels at service stations.**
  Objective: To consider what the future gas station will be like and what fuels and services it will have to offer to modify the specifications or the conditions for granting land for street service stations.
  Description: because of the tendency to diversify the variety of fuels used in automotive, and motivated, among others, by policies for implementing cleaner vehicles such as electric or hybrid vehicles, the use of natural gas, etc., it is important to wonder what service will be required in future to service stations, and what modifications will be required to meet the demand of vehicles circulating in the city.
  It is therefore proposed to favour, by modifying the condition specifications of petrol concessions in public land, the introduction of cleaner fuel than diesel and gasoline. This way, the use of vehicles fuelled by other sources can revitalised.
  This measure is important so projects such as *"sectoral agreements to reduce the use of diesel vehicles in the fleets"* and *"environmental label that rewards less polluting cars"* can succeed.

- **TR13 - Street cleaning along busy streets using groundwater to reduce the re-suspension of particulates.**
  Objective: To reduce the re-suspension of asphalt particulates.
  Description: use the groundwater to clean the roads to reduce the effect of re-suspension of particulates with the circulation of vehicles. This cleaning will be done with a modular management that will also take into account the emission levels of particulates and the drought episodes, though pathways with more IMD should have higher intensity cleaning.
  As an alternative to the use of groundwater, there is also the thought of a pilot test with machines like Dustless Sweeping Technology.

- **TR14 - Network of public charging points for electric vehicles.**
  Objective: To provide the logistics and infrastructure necessary to enable the development and introduction of electric vehicles in the city.
  Description: The project aims to develop a network of charging points to prepare the city with the infrastructure necessary for the gradual introduction of electric vehicles in the city in coming years.
  The project includes the development of the Movele project which includes the implantation of 230 charging points (82 street level and 142 on public car parks) until 2011.
  This project also supports other projects such as *"sectoral agreements to reduce the use of diesel in vehicle fleets"*, *"environmental label that rewards less polluting cars"* and *"promote the introduction of new technologies such as cleaner or electric scooter pluggable hybrid"*, which can encourage the use of electric vehicles and, therefore, there must be an adequate charging infrastructure.

- **TR15 - Agreement to reach a variable fee at Barcelona incoming toll booths based on vehicle occupancy and vehicle type.**
  Objective: To increase the average occupancy of vehicles entering in Barcelona.
  Description: supporting the establishment of a price reduction exclusive to cleaner vehicles or to vehicles with high occupancy.
  With this action, people who travel by private vehicle will hardly see themselves forced or able to shift towards public transport, but nevertheless, they will be attracted to a more sustainable use of private vehicles.
  This will be necessary:
  - To stay open to negotiation with concession companies to support the action and to cooperate when setting necessary assessment, management and operation guidelines to carry out its implementation.
  - Install detectors at the entrance of the toll to identify the number of people travelling in a vehicle. Thus, high occupancy vehicles paying tolls with credit card or with a Via T card will benefit from lower fees. If vehicles drive through a manual toll booth, the number of passengers will be counted visually and the reduction of tariff will be made manually.
    - With Via T cards or with a license plate reading, the vehicle type will be identified, so that cleaner vehicles will be charged a lower toll to access the city.
    - If there are toll free alternative roads into the city, one part of the users will choose to avoid payment. For this reason, the monetary cost of the toll fees should be similar to the cost related to the time increase implied by the alternative pathway loop.

- **TR16 - Promote efficient and economical driving courses.**
  Objective: To educate and raise awareness among drivers about the benefits and potential savings from driving more efficiently.
  Description: campaign to encourage the people and employees of public administration to take efficient driving courses as well as informative courses on the available technologies and sources or alternative fuels to gasoline and diesel fuels and less polluting.
  It is shown that, with the help of specific techniques of driving, energy savings and, therefore, a reduction in polluting emissions can be achieved.
  In addition, there are other benefits such as a reduction in vehicle maintenance spending (brakes, clutch, gearbox and engine), an increase driver comfort while driving which is reflected in a reduction of stress and as a result of all this, a decrease in the risk of accidents between 10 and 25%.
  There is the possibility of uploading the results of the students' average consumption before and after the class on the Internet to compare consumption and to communicate and to promote the effectiveness of the class and the potential energy and economy saving.

- **TR17 - Review and implementation of the Barcelona Biking Strategic Plan.**
  Objective: To review the Barcelona Biking Strategic Plan and to adopt objectives that encourage the continued expansion of the bike.
  Description: While the Barcelona Biking Strategic Plan covers the period of 2006-2010, given its success, it is proposed to revise it and update it to continue improving and expanding the network in number of kilometres of bike lanes in the city in coming years, as well as to bring new and better services.
  So for the coming years, even with the increased number of kilometres of city bike lanes, it will be necessary to increase this figure based on a rational study of the mobility within the main city roads that do not have bike lanes. On the other hand, cyclists' safety from motor vehicles must be improved, as well as the distribution of the bicycle lane network by further widening the cycle lanes from sea-to-mountain areas so they match those that already exist between the Llobregat and Besòs rivers.
  The specific objectives of the Barcelona Biking Strategic Plan, in addition to the improvement and/or unification of existing infrastructures, are:
  - Increase the number of kilometres covered by bicycle.
  - Change the modal distribution in general or according to the purpose of the trip.
  - Reduce the speed of motorised vehicles / coexistence.
  - Reduce the accident rate.
  - Improving the image residents and public space users have towards cyclists.
  - Improving the health of residents.
  - Offering mobility alternatives to visitors and tourists.
  - Inform / advice the people on the possibilities of cycling in Barcelona.
  - Move the young (secondary education and university students) to have more interest in cycling.

- **TR18 - Barcelona Urban Mobility Plan (PMU) projects.**
  Objective: This project incorporates all projects established within the Barcelona Urban Mobility Plan until 2018.
  The Barcelona PMU has, as a starting point, the consideration of four main objectives. Mobility arising from the PMU should be: safe, sustainable, equitable, efficient
  Description: This project contains all Barcelona PMU approved projects, as well as the effects of energy consumption reduction and pollutant emission reduction that it is expected to have once fully implemented. Although Barcelona's urban mobility plan is valid for the period of 2006-2012, due to its mainly strategic nature, it was developed with a vision through 2018.
  Among the projects envisaged in the PMU and which will mainly displace a significant portion of mobility from private to public transport, the following are to be highlighted:
  - Investing in improvements on public transport frequency in the less serviced areas at night, expanding schedules and services, and improving the speed of commercial buses.
  - Extending the metro and tram network to areas of high demand currently not serviced by rail.
  - Encouraging the creation and management of intercity bus terminals and connecting stations.
  - Promoting projects, construction and management of BUS-HOV lanes.
  - Promoting measures to give greater priority to street level collective public transport versus the private sector.
  - Etc.

  According to the Barcelona PMU 2018 *"Mobility Pact"* scenario, it is expected (after all projects are executed) to experience a reduction in road circulation (in veh·km) of 1.1% across the city compared to 2006 circulation levels, and a reduction of 20.7% over the 2018 trend scenario.
  In short, the PMU indicates the following:
  - In 2006: 16,686,628 veh-km/day.
  - Est. 2018 trend: 20.8 Mveh-km/day.
  - Est. 2018 Mobility Pact: 16.5 Mveh-km/day.

THE WASTE SECTOR

- **RSU1 - PROGREMIC 2007-2012 (Programme of Municipal Waste Management in Catalonia).**

  Objective: PROGREMIC objectives:
  - **To prevent waste production by weight, but also in volume, diversity and danger, decoupling waste production from economic growth.**
  - **To develop a good selective collection at the source, as a strategy to get quality materials that are useful in the recycling market.**
  - **To particularly promote the management and sorting at the source of the organic fraction of municipal waste.**
  - **To encourage commercial collection at the source.**
  - **To promote a true recycling market, under the sufficiency and proximity criteria.**
  - **To ensure the complementarity of models.**
  - **To accommodate the system of waste management to the system of urban management.**
  - **To reduce the final landfill, especially from biodegradable and recoverable materials.**
  - **To incorporate the people in waste management activities, to maximize the involvement, as well as the people's and the managers' knowledge.**
  - **To ensure the quality and transparency of information.**
  - **To prevent contamination of soil and to regenerate degraded soil.**

  Description: The new Municipal Waste Management Programme in Catalonia for the period 2007-2012 (PROGREMIC) is a programme to better manage municipal waste. Although the programme includes a new logic in the planning of waste management in the Catalan region, Barcelona is clearly one of the most important municipalities due to its size. Therefore, despite being a programme for another area, it seems advisable to consider it within the PECQ for its relevance in Barcelona's waste management energy and environmental future. It should be noted that the data included in this portfolio (energy and environmental) is data weighed in Barcelona based on the PROGREMIC calculation for the overall programme.

  The PROGREMIC is an instrument of legal nature to help plan the coordination of the Government of Catalonia with the activity of the local administration. Its purpose therefore is to ensure consistency between all the authorities that manage the set of actions needed to promote prevention, reuse, selective collection, recycling and other forms of material recovery, energy recovery, disposal of waste and regeneration of degraded soils and spaces. The PROGREMIC contains a series of general objectives, as defined by the regulations, which are mandatory for local authorities concerned, according to their competence.

  Some of the measures incorporated in the PROGREMIC are:

  specific actions for dissemination, communication and training in prevention and waste management, drafting of regulations, promoting the establishment of rates that include all the costs of management and promotion of waste generation payment systems, raising the proposal to implement a collection and return system (SDDR) for certain products and packaging at the state level, strengthening of research and innovation, implementation of measures to regulate single use plastic bags, promotion of disposable asset and responsible consumption, promotion the greening of events, promotion of segregated commercial collection, regulation and efficiency improvement at the treatment plants, particularly with organic waste, etc.

- **RSU2 - PMGRM 2009-2016 (Metropolitan Municipal Waste Programme). Weighted in Barcelona.**

  Objective: The programme has four main objectives, based on priorities established by the Waste Framework Directive, adopted on 28 December 2008, as follows:
  - **Maintain or reduce waste generation in the metropolitan area through prevention initiatives.**
  - **Complement and optimize the facilities for waste treatment in the framework of EMSHTR to reach a recycling of over 50% of general waste, between the sorting done by the people and that recovered from treatment plants.**
  - **Follow the path already started, of ensuring the treatment of 100% of all municipal waste fractions (MWF) or those that can be assimilated, including the fraction. The treatment of the fraction is essential to recover usable material and produce biogas and compost.**

- **Ensuring a stable waste management, which will prioritize energy recovery over disposal, as indicated by the Waste Framework Directive 2008.**

Description: the Metropolitan Programme for Municipal Waste Management 2009-2016 (PMGRM) is the planning tool for the metropolitan waste management and is related to state and regional waste management plans. Also important is the scope of temporal, material and territorial application. The PMGRM writes it and the Metropolitan Water Services and Waste Treatment Entity (EMSHTR) approves it based on the relevant regulations at European, national and regional level. There must also be planning for waste management in the metropolitan area which, on the other hand, is now integrated into the provisions of Law 6 / 1993 PROGREMIC. PROGREMIC does not specify actions nor funding required to achieve their specific objectives on prevention and RS. It is PMGRM that is required to collect the PROGREMIC goals and lay the foundations for achieving them. Therefore, all investments, savings and emissions reduction resulting from the PROGREMIC objectives are evaluated on the PMGRM reports.

The PMGRM incorporates measures for municipal waste management with improvements in existing treatment plants and adding new ones:

- Some measures incorporated by PMGRM to improve waste management are:
- Treat all organic fraction from municipal waste which is collected separately by anaerobic digestion or composting plants, treat all the fractions collected selectively as follows: ERE, RV and RVOL; produce a compound of organic fraction from municipal waste and a stable one of other features that meet requirements defined by RD 824/2005 of 8 July on fertilisers, treating the entire fraction as a parent flow before a final treatment of waste, minimizing the waste generated at installations, ensure stable management of waste generated at the facilities, improvements to adapt the energy recovery plant in Sant Adrià de Besòs in order to enhance eco-parks rejects, various actions on Ecopark 1 and Ecopark 2 to maximize the treatment capacity of the organic fraction from municipal waste.
- - New facilities planned for the PMGRM expanding the capacity of waste management:
- Centre for object exchange between individuals, new sorting plant of ERE, new bulky waste treatment plant, new treatment plant for remains, two mobile recycling centres and a push for permanent recycling centres, and modernization of energy recovery and other facilities, restoration of quarries filled with waste.

- **RSU3 - Possible expansion of the capacity of certain facilities in the period from 2017/2019. Weighted in Barcelona.**

Objective: To ensure the ability of municipal waste treatment at end of PECQ period.

Description: A study had been made for the period 2009-2020 on the saturation of the PMGRM facilities capacities; the result is that if given the High scenario of PMGRM waste generation extended until 2020, treatment plants capacity shortage for the years 2017 and 2020 has been detected for bulky waste.

Consequently, if the estimates made are confirmed, it is proposed that the following facility expansion projects should be are carried out:

- Enhancing the capacity of voluminous waste treatment facilities: if the detected deficit is confirmed, the treatment capacity of bulky waste should be expanded starting from the year 2017. 50.000 t/y for the year 2020 is the estimated treatment need.
- Enhancing the capacity of waste treatment in 2020: If the detected deficit is confirmed, the waste treatment capacity should be expanded starting from the year 2019. 20.000 t/y for the year 2020 is the estimated treatment need, but the cumulative capacity for the period 2019-2020 is 30,000 tonnes.

THE GENERAL SECTOR

- **GE01 - Monitoring the PECQ and the energy monitoring programme in the city.**
  Objective: To track the future evolution of energy consumption and emissions in the city, as well as the execution of projects derived from PECQ.
  Description: track annually the evolution of the degree of execution of PECQ projects, as well as to maintain the work already undertaken in the last years of *"Energy Observatory"* and so, continue to monitor the energy consumption of the city, of power generation facilities within the city, and all the energy generated, according to energy source type. However, calculate the emissions of pollutants resulting from energy consumption, as well as from other emission sources such as waste treatment.

- **GE02 - Programme to monitor the local emissions inventory in Barcelona and their dispersion**
  Objective: Keep updated the modelling tool of the dispersion of pollutants in the city of Barcelona so that it is a useful monitoring and verification PECQ tool.
  Description: although the air quality is already monitored hourly, in addition to annual reports, this project has another line of action that can support the first one. It is proposed to track the NO_x and PM_{10} emissions (or other contaminants that exceed the legal limits) and link emissions to actual emission measurements of the stations located in Barcelona. This can be done if the model of pollutant dispersion in Barcelona already developed under the PECQ is well maintained and updated.
  Therefore, it is proposed to update every two years the Barcelona city emissions inventory and hence keep track of the evolution of the local pollutant emissions inventory affecting the Barcelona air quality (i.e. NO_x and PM_{10}). Subsequently, it is proposed to modernize the pollutant emission and thus enable its comparison to actual emission measurements of the stations located in Barcelona.
  This will involve using the modelling tool of the dispersion of pollutants that Barcelona has used at PECQ as a tool for analyzing the origin of NO_2 and PM_{10} emissions, as a tool for controlling, managing and verifying the evolution of the city and of the PECQ measures affecting local pollutant emissions.
  An agreement with Public Health, within the City Council, will be necessary to coordinate the project.

- **GE03 - Real time information on current air quality and forecasts.**
  Objective: Platform with alert subscriptions to predict the days and hours as well as that parts of the city where there will be high concentrations of pollutants, to warn high risk groups such as asthmatic patients or people with breathing difficulties.
  Description: Currently, various cities (London, Liverpool, Copenhagen, Aalborg, Vienna, Beijing, etc.) already have air quality forecast models based on a model of pollutant dispersion, a weather forecast model, a forecast model for other pollutants such as O3, and other inputs such as emissions inventory. In fact, local pollution depends not only on emissions, but also on the weather (wind, temperature, etc.) and on other items such as ozone which, in part, comes from outside the area and, with greater or lesser concentration, create chemical reactions causing a higher or lower number of certain pollutants.
  These forecast models allow -by means of different channels like the Web, email or SMS subscriptions, screens in the city, etc. - to give notice to different high risk groups of the population (asthmatic patients, people with respiratory difficulties, etc.) on higher risk areas of the city and on the times when the risk is higher.
  It is proposed to implement a website as a communication centre, but with alert subscription services that, based on updated emissions inventory and other exogenous data such as background pollution, meteorology, etc. can forecast the emission of different pollutants three days in advance.
  An agreement with Public Health, within the City Council, will be necessary to coordinate the project.

- **GE04 - PECQ website.**
  Purpose: To inform and sensitize the people and businesses of government initiatives and objectives into a single portal.
  Description: add PECQ contents onto the Barcelona Energy Agency website, with its goals and other factors of interest such as educational information, recommendations, news, grants, computer tools, etc. In addition, this website should be a showcase of PECQ projects and its execution progress.
  The information must be understandable to the people and easy to access, include information about public aid, and keep a list of RE facilities in Barcelona. The website should also have links suitable for compared consumption projects, etc.
  Among other content, the PECQ website should also be a gateway for other PECQ projects such as:
  - Energy savings advisory for homes and businesses.
  - Home consumption viewer and web platform for compared consumption in the residential and business sectors.
  - Ensure proper maintenance/operation of solar installations resulting from the OST.
  - Appliance Refurbishment Plan in the home.
  - Watch the PV and mini-wind power potential that each building has.
  - Forecast of air quality in Barcelona.
  - Where can I subscribe to the PV cooperative.
  - Information on single stop procedures.
  - Tour of the PECQ objectives.
  - Etc.

- **GE05 - Programme of awareness and communication about energy, consumption, and their environmental effects.**
  Objective: To sensitize the population and the business sector about energy and its environmental effects, and communicate the goals of PECQ.
  Description: it is proposed to start a continuous media campaign with a defined storyline to give continuity to the campaign and to the message to be transmitted.
  Campaign orchestrated with a series of initiatives:
  - Awareness raising programme to help understand the effects energy consumption has on the environment, and that it is everyone's responsibility to take care not to waste energy and to use renewable energy whenever possible.
  - Communication programme to publicize the objectives of the PECQ.
  - Communicate and raise awareness regarding the analysis of the lifecycle of products we consume.
  - Also adding to the awareness and reporting on the environmental costs of excess consumption (in reference to consumerism) and the issue of packaging.

  It should be noted that, according to the sociological study prepared under the PECQ, 29% of the Barcelona population belongs to the so-called conscious segment and therefore, according to the ethnographic study, the people in this segment *"…show interest and are environmentally conscious and aware of their impact and they would like to know more, as they would easily change their lifestyle to be more "sustainable"*; they would like to consume less energy if they are shown how to go about it and what the beneficial impact would be". Regarding the comfortable segment (27%), they lack a clear perception of what the environmental impact of the household sector is, since they have the perception that most of the contamination is derived from industry/business. It must be explained to them that part of the pollution problem is in the hands of the people themselves.
  It is proposed that the storyline of the campaign should be attractive and catchy to get the public anxious and eager to see the campaign's *"next chapter"*.

- **GE06 - viability to look at defining a regulatory framework to ensure the utmost energy efficiency in buildings in accordance with their use.**
  Objective: To study the viability at defining a favourable regulatory framework that integrates other existing and future regulations related to power generation systems in buildings and energy efficiency measures.
  Description: due to the fact that there are more and more regulations and ordinances applicable to buildings in the area of power generation and energy efficiency, and as often in the projects, some systems can overlap with others, there needs to be a new single regulatory

framework for energy efficiency of buildings that includes all other municipal ordinances (solar thermal Ordinance, photovoltaic Ordinance, etc.) and providing for other alternatives (i.e. micro-generation, DHC), with an analysis of the whole and to assess the natural resources of the environment and energy alternatives that are commercially available.
This legislation would contribute, for each project, to the study from a global point of view of minimizing the consumption of primary energy and/or emissions of greenhouse gases, without favouring any single technology, requesting an analysis of alternatives from the designer with their respective justification for the selected alternative.

- **GE07 - Agreement between administrations to monitor all the energy certification of buildings.**
  Objective: agreement between governments to monitor the overall energy certification of buildings and the CTE and other energy regulations applicable to buildings.
  Description: the RD47/2007 application of building energy certification is regulated by the Government of Catalonia. The City Council should have the information and procedures relating to the CTE and RD47/07 energy certification of buildings located in the municipality of Barcelona.
  It is proposed to initiate a flow of information agreement between the Barcelona City Council and the Generalitat de Catalunya, as agile enough for the Council to monitor the level of implementation of the CTE and RD47/07 energy certification in new construction and rehabilitation of residential buildings and in the future, the regulations concerning the certification of existing buildings, before they are approved by the competent body.
  Other energy standards for buildings such as the Eco Decree must also be incorporated.
  Ultimately, it may be that the City Council requires a minimum energy rating of new buildings being built in the municipality. In this case, it is essential to have mechanisms and monitoring tools that are necessary to monitor this properly.

- **GE08 - Environmental works to reduce emissions of pollutants.**
  Objective: To reduce emissions of particulates and other pollutants resulting from the execution of works and the movement of trucks.
  Description: project already initiated by the City Council and which involves, for large civil works (H-9, HST, beaches, ATLL, etc.) requesting that the construction companies bidding for the job have to use low emission trucks and to take action to reduce emissions and re-suspension of particulates.
  A mechanism for environmental monitoring of the work must be in place to verify proper work progress.

- **GE09 - Setting energy and environmental efficiency criteria in new urban projects.**
  Objective: To establish rules to ensure that new urban projects harness the full potential of energy efficiency and use of natural resources that each area can offer.
  Description: building, just as other sectors are changing their rules in favour of improving energy efficiency and reducing emissions of pollutants into the atmosphere. In reference to urban planning, although there are *"manual"* or guidelines to improve these aspects in reference to the current regulations, there has not yet been a transformation of the urban regulations to common and optimal criteria or thresholds from the various points of view needed in planning assessment, including energy efficiency.
  Following regulatory changes in the building sector, the next natural step would be a transformation in the way of thinking and regulating urban planning. Please note that the difficulty posed by this change implies that it must be done in a transitional manner while assessing many aspects, since there is a conjunction of urban, social, economic, environmental and energy factors; aspects that require joint analysis in order to set minimum and maximum values, ranges or thresholds.
  Therefore, PECQ proposes to promote and accelerate this transition towards a more conscious planning from the point of view of energy and therefore a project is added to PECQ to incorporate to the current process, key chapters of analysis of different alternatives that each

project can present with the respective justification of the adopted solutions, all from the standpoint of energy efficiency and use of available resources, but without forgetting other key aspects of planning.

- **GE10 - Strategic study on adaptation to climate change in the city of Barcelona.**

  Objective: To have a clear view of the risks and costs of adaptation to climate change, and of a set of measures and projects to anticipate their effects on the people of Barcelona, on its infrastructure and on its economy.

  Description: Project that proposes to develop a strategic study to predict the effects of climate change on the Mediterranean, its shore along Catalonia and, specifically, the possible impact on the city of Barcelona, its people and its economy and to also incorporate the concepts of resilience and adaptation to the effects of climate change. As other cities like New York, Liverpool, or areas like the Australian coast, Japan, UK, etc. are already doing, the idea is to analyze the effects of climate change on the people of Barcelona before, for example, extreme heat/cold waves, intensification of storms, increased drought stress, decrease in precipitation, sea level rise and intensification of the effects of the sea on the sandy beaches or infrastructure near the coast, on the wildlife, food availability, etc. The study should be complete enough to allow risk assessment and the costs of possible solutions and to make decisions to adapt to climate change and, above all, anticipating the effects.

  In short, proposals should be given to reduce or mitigate the effects of climate change in the city of Barcelona, taking the necessary actions to:

  - Ensure the supply of water.
  - Reduce the impact of floods, identifying first the potential risks of the infrastructures of the city and adapt them according to the risk of damage.
  - Take into account the future rise of sea level.
  - Promote active animal and plant species management and conservation programmes and improve the quality of habitats.
  - Rethink the tourism model.
  - Invest more resources in preventing and combating forest fires.
  - Prepare for heat waves.
  - Improve energy efficiency and reduce the use of fossil fuels.
  - Prevent the city from high-impact weather events such as heavy snowfall, major storms, etc.
  - Prioritizing strategies and regulations necessary to adjust to climate change.
  - Draw a map of coastal climate change vulnerability of the coast.

- **GE11 - Energy saving advisor for homes and commercial premises.**

  Objective: that people, employers and store owners have access to an expert or benchmark for consultations and to act on energy saving, economic and energy efficiency.

  Description: from the social study with environmental and energy components carried out by the PECQ, it seems that there is a significant percentage of the population that does not have a clear understanding of how they can save energy and whether they are spending a lot or little.

  This project proposes to create or provide a customized energy advice service for households, small shops, local services and offices.

  This personal adviser goes to the homes or places of business, makes a simple preliminary diagnosis in which potential savings are easily detected, and delivers a report saying, "you are spending X and you may end up spending X - Y in a year if you do Z ".

  The project also provides real information on inadequate uses to support the campaigns.

  The cost of advice may be included in the equipment maintenance contracts of households/business premises if agreements with the guild are reached. Alternatively it can be arranged to charge the customer and if consumption goes down the cost is credited; or it could be free in the beginning and the customer is charged if in a year consumption is not reduced. So there must be a companion during the process to facilitate the implementation of proposed actions and to eliminate doubts. However, it may well be a very small cost and easily recoverable with economic savings proposed by the consultant.

  An agreement should however be reached with the Barcelona Chamber of Commerce or other groups to ensure that the measure is comprehensive and more effective.

- **GE12 - Consumption comparisons, platform for comparing energy consumption and environmental impact.**
  Objective: that individuals, businesspeople and traders raise their awareness of their own energy consumption and take appropriate action to reduce it, helped by a system that allows comparisons of unitary consumption and energy and financial savings achieved by other individuals or businesses.
  To inform individuals whether they consume much or little energy compared to other people and/or neighbours or friends.
  Description: a web platform for managing people's energy consumption data that allows individuals to make comparisons. As an alternative to creating the platform, an existing one can be used, like Google PowerMeter.
  The project will:
  - Monitor past energy consumption as well as consumption indicators (kWh/m^2, kWh/person, etc.) of people or businesses that have an installed device for measuring and monitoring energy consumption.
  - For citizens or businesses that do not have installed a device as mentioned above, the system will allow for consumption data entry based on consumer monthly bills or notes, for example.
  - Open the possibility to compare indicators of private consumption or families with similar characteristics or local shops.
  - Portal for dissemination of good practices and rankings of the best *"savers"* and most effective measures for industries.
  - Comparisons with the average consumption in BCN and/or District and/or other cities if the project expands.
  - The platform provides advice to reduce consumption and CO_2 emissions.
  - Design incentive programmes and *"competitions"* where children can be encouraged to *"educate"* the adults doing educational projects in schools linked to the consumption of each household and; the case of the commercial sector, you can create a label *"more efficient business or less CO_2 emissions."*

- **GE13 – Pilot test on photocatalytic building materials to reduce the presence of NO_x in the air.**
  Objective: To see the effectiveness of new photocatalytic materials to reduce the concentration of NO_x in the air.
  Description: a pilot demonstration of the effect of some materials with photocatalytic capability on certain pollutants like NO_x and the organic particulates in suspension.
  Certain materials such as ceramics, mortar, painting, and paving stones that are currently entering the market have the ability to reduce pollutants present in the atmosphere such as NO_x, PM_{10}, benzenes, carbon oxides or aromatic polycondensates. Depending on the type of pollutant, photocatalytic cement with photocatalytic capability, with the help of sunlight, transforms the pollutants into nitrates, carbonates or sulphates, all nontoxic compounds.
  It is proposed therefore to apply a material with these characteristics in one large area or inside a tunnel (it can also work in the presence of artificial light with wavelengths below 400 nm) to measure the effect of absorption of NO_x and particulates on air quality.

- **GE14 - Educational programme for exchanging experiences and ratios of consumption and emissions in schools.**
  Objective: To make school students encourage parents to save energy through an educational programme that can be treated as a school game.
  Description: based on the project *"Compared consumption, platform for comparison of energy consumption and environmental impact"*, adapt the web platform to incorporate a network of schools and school students to the system, and thus be able to incorporate new and imaginative educational programmes in schools.
  This project is related to the project: *"Dissemination of educational content towards the rational use of energy and the environment in schools."*
  The possibilities are many, for example, that students can incorporate the energy consumption of their families to the platform, and comparatives and rankings can be easily made among classmates between classes of the same school or even between different schools.

PORT / AIRPORT

- **AE01 - Aircraft electric supply at the Barcelona airport.**
  Objective: To reduce the number of minutes of APU use in order to reduce emissions of nitrogen oxides.
  Description: to promote and optimize the use of auxiliary power supply units of the aircraft (APU) to minimize emissions of air pollutants generated by the equipment.
  The APU are used during the time that the aircraft is parked and needs power for electricity, pneumatics and air conditioning.
  The APU connection time will be measured and will not exceed 5 minutes.
  There will be periodic checks on the total allocation of fixed or remote locations, to learn how the management of aircraft parking places is improving, as the use of fixed sites increases.
  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **AE02 - gradual replacement of vehicles that operate within the Barcelona Airport.**
  Objective: To renew the Airport fleet with newer vehicles to reduce emissions of nitrogen dioxide.
  Description: The purpose of this project is the gradual replacement of ground support vehicles (GSE) that operate at the airport of El Prat de Llobregat. This measure is expected to obtain a reduction of emissions of nitrogen dioxide.
  To evaluate the effectiveness of the measure to be adopted it is considered useful to adopt the use of the following indicators which, in turn, constitute a form of monitoring:
  - Airlines that are starting to develop the proposed vehicle replacement plan.
  - Number of vehicles that have been replaced by new ones.
  - Evaluation of the possible inclusion of new sources of propulsion for GSE vehicles, and their progress assessment within a set period of time.

  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **AE03 - Optimization of land operations improvement at Barcelona Airport.**
  Objective: To optimize the ground routes of aircraft and vehicles to reduce fuel consumption while on the ground.
  Description: With the new terminal, ground operations have been optimized, which translates into better energy consumption efficiency of aircrafts when circulating on the ground. The project is kept alive to continue to reduce emissions of NO_x and PM_{10}, hence further improving ground operations.
  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO01 - Introduction of environmental requirements to the fleet of trucks operating in the Port of Barcelona.**
  Objective: to reduce emissions associated with the fleet of trucks operating in the Port of Barcelona.
  Description: 19,760 truck trips are performed daily in the port area, of which 25% corresponds to container traffic. The Port of Barcelona has a P + authorization to transport containers, which allows for faster flow in and out of the Barcelona port area. In order to control emissions of these vehicles (containers), the Barcelona Port Authority will establish environmental criteria in the requirements and incentives needed to obtain this authorization.
  The environmental requirements regarding emissions of NO_x and PM are:
  - Vehicles that are not approved under the Euro II or a later standard, will not be able to obtain such license from 2007 onwards.
  - Vehicles that are not approved under the Euro III or a later standard, will not be able to obtain such license from 2010 onwards.
  - For vehicles manufactured under the above mentioned standards, there will be the possibility of obtaining a P + license only if emissions corrective measures are instituted.

Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO02 - Promotion of rail freight in the Port of Barcelona.**
  Objective: To promote the use of rail freight as a more efficient and less polluting transport.
  Description: the plan is to increase rail transport as one of the priority lines of action. The actions carried out in this project are:
  - Creation of an internal network of public nature with new access points, used with objective criteria and compatible with the Port Community Logistics, and with the commitment of terminals and operators.
  - Direct rail access to port without delay. Creation of a mixed gauge track (Iberian/European) to remove existing bottlenecks.
  - Improving European gauge railway access for other countries through the use of new high-speed line AVE under construction for the goods. In order for this goal to be achieved, it is necessary to ensure the French railway network capability.
  - Combination of mainland and European long corridors with direct, regular and frequent services.
  - Attracting rail and intermodal operators.
  - A pressure strategy in the form of joint lobbying with other organizations and institutions before the European Union and the Ministry of Public Works to resolve the current capacity problems in the Mediterranean corridor, which also affect other mainland and southern European ports.

  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO03 - Early Renewal of the fleet of domestic vessels within the Port of Barcelona.**
  Objective: To replace, in the short term, 40% of the boats and set up the year 2015 as an end of the adjustment period to the standard-Stage IIIa.
  Description: replace the oldest domestic boats and incorporate vessels approved in accordance with the strictest recognized standards of emission of pollutants into the air.
  The Port Authority of Barcelona will include in all bid selection processes for different services, specific clauses that require the use of vehicles with as low emissions as possible under the currently planned rules.
  In terms of both domestic tug boats and the rest of domestic boats, the adaptation to the Stage-IIIa standard rules can be done either by replacing the engine or by modifying it substantially.
  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO04 - Electrification of the Port of Barcelona.**
  Objective: To supply power from shore to vessels docked at the pier to reduce emissions from auxiliary engines used by these boats.
  Description: Power is supplied from the pier, during the period that the vessels are berthed there. This will serve the energy needs for Hotelling tasks, loading and unloading - currently supplied with auxiliary engines. It is an efficient measure to reduce emissions in port communities, often exposed to high levels of air and noise pollution. It is estimated that the environmental benefit is around 90%.
  The application of this measure requires equipping the Port of Barcelona with power connection points for boats and also make modifications to boats. The level of complexity and cost of this activity varies greatly depending on the type of ship and its way of operating.
  For the Barcelona port two electrification actions are considered:
  - Installing a mobile type power supply point at the new Prat quay (container ships), and a power supply point at the port terminal area by the adjacent pier or by the Barcelona Pier (cruise ships) both with the possibility of extension to more points, in the future.

  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO05 - Modification of port fee schedule at the Port of Barcelona.**
  Objective: To reduce emissions by promoting the use of technologies that control them, through a credit to ships that prove their emission reduction compliance.
  Description: The measure is about the Barcelona Port Authority establishing a port tax schedule providing for exemptions from port dues for less polluting vessels.
  The Port of Barcelona is part of the Public Transportation of the State, which has a schedule of fees regulated by Law 48/2003 of 26 November, based on economics and general interest port services. Article 27.5 of the Act provides that ships demonstrating compliance with certain environmental requirements will receive a discount of 3% in the accruals to be paid.
  The Barcelona Port Authority will expand the scope of this allowance to vessels that demonstrate the use of the following technologies:
  - Engines that were not manufactured in accordance with IMO NO_x standards and that have been amended subsequently to conform to these standards.
  - Vessels equipped with emissions control systems with proven efficacy, such as DWI, HAM, EGR or SCR.
  - Ships that have opted for the use of alternative fuels such as natural gas or other options that lead to significant reductions in emissions of nitrogen oxides or particulate matter. This category includes the ships using MDO, having previously operated with RO.

  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO06 - Improvement in the handling of dusty materials in abundance at the Port of Barcelona.**
  Objective: To achieve some adjustments in the procedures for handling solid powders in abundance on the dock to limit diffused particulates emissions associated with this traffic.
  Description: The idea is to incorporate a series of requirements into the port ordinance that will regulate the procedures for port handling of solid powders in abundance on the pier.
  The expected measures to be adapted are:
  - Best practices in the use of machinery.
  - Measures in the transport of goods.
  - Limit or suspend the operations when wind speed exceeds certain thresholds.

  Besides, additional measures will be taken:
  - With regard to access, traffic roads and surfaces with vehicle, trucks and machinery traffic.
  - With regard to the stacks of dusty materials.
  - With regard to the loading, unloading and/or powdery material handling with trucks or machinery, with stacks, hoppers and the like.
  - Ground operations and treatment operations.
  - Reference values (300 mg/m^2*day of * sedimentable particle concentration).

  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

- **PO07-Renovation of the auxiliary machinery for loading and unloading at the Port of Barcelona.**

  Objective: gradual replacement of the auxiliary machinery for loading and unloading to reduce

  NO_x i de PM_{10} emissions, among operators of the terminals at the Port of Barcelona.

  Description: the aim is the gradual renewal of the auxiliary machinery for loading and unloading at the Port of Barcelona, to reduce NO_x and PM_{10} emissions.

  Following are the expected lines of action:

  - Operating the units pre Stage I will not be allowed in the year 2010.
  - Operating the units pre Stage II will not be allowed in the year 2015.
  - Acquisition of second hand equipment will not be allowed.
  - The use of Stage IIIa will be required in the year 2010 for major operators.
  - Use of alternative fuels.

  Note: This project is associated with the Government of Catalonia Action Plan linked to the declaration of the Atmospheric Environment Special Protection Areas.

5.3.2 - MUNICIPAL PROGRAMME PROJECTS

The municipal Programme's set of projects will be implemented through the PECQ's ten year scope, and divided into three successive action plans: 2010-2011, 2012-2015 and 2016-2020. Projects can be deployed in one or more action plans, given some application particularities that the different projects can offer.

THE MUNICIPAL PROGRAMME 2010-2011

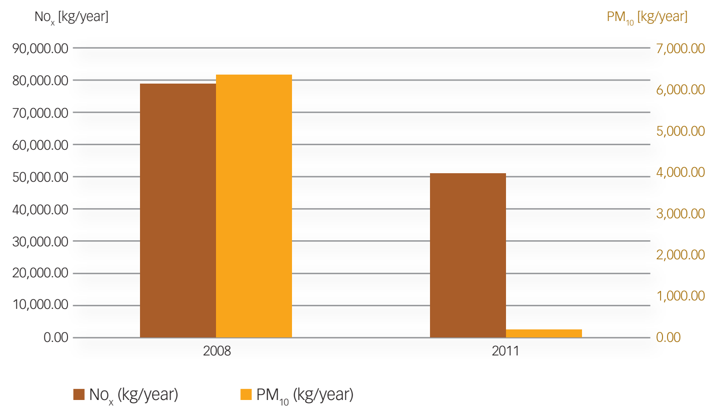
The first action plan includes projects that were promoted during the preparation of PECQ, and which will take place throughout 2011. It should be noted that possible conflict can result from reading off the expected results, such as is the increase in energy consumption and GHG emissions.

This is due to the deployment of the new cleaning and waste collection fleet which, as explained throughout this document, is more energy intensive due to greater mobility of vehicles since the collection of the different fractions has increased, while drastically reducing emissions of local pollutants. This action plan should make a powerful impact on the objectives of improving the air.

TABLE 84 | GOAL FOR THE MUNICIPAL PROGRAMME ON AIR QUALITY IMPROVEMENT

Local pollutants				
		2008	2011	Difference
NO_x	[kg/year]	78,809.78	50,954.03	-35.35%
PM_{10}	[kg/year]	6,292.71	209.95	-96.66%

FIGURE 259 | GOAL FOR THE MUNICIPAL PROGRAMME ON AIR QUALITY IMPROVEMENT



MUNICIPAL PROGRAMME 2012-2015

The 2012-2015 Action Plan includes the main part of the projects associated with PECQ. Almost half of the emissions reduction is due to happen during this period. Highlighted in this period is the start of the implementation of projects relating to solar concentration systems for their added value in innovation.

MUNICIPAL PROGRAMME 2016-2020

The final action plan culminates with a 23% emissions reduction from 2008 levels, deploying all the projects planned, without counting the communication and behaviour actions.

PEMEEM PROJECTS

The buildings and public equipment sector has great potential for action, which is the reason why a Plan for improving energy saving in municipal buildings (PEMEEM), - which is a main municipal PECQ Programme-, has been drafted.

The goal of PEMEEM for 2020 is to achieve an approximate reduction of GHG emissions arising from energy consumption in municipal buildings of 20% compared to the situation in 2008.

The PEMEEM projects, included in the various action plans, involve a reduction of 3,198,852 MWh in energy consumption and a reduction of (GHG) 8,221 t in greenhouse gas emissions.

TABLE 85 | RESULTS FROM THE IMPLEMENTATION OF PECQ MUNICIPAL PROJECTS PROGRAMME

Municipal Programme's Action Plan 1			
2010-2011		Active projects 17	New projects PA1 17
		Covenant of Mayors scenario	
Energy consumption	Action plan's total potential [MWh/year]	11,892.11	
	% with regard to 2008 (accumulated. [kWh/inhab·year])	0.80%	
GHG's	Total [t CO_2/year]	-110.05	
	% with regard to 2008 (accumulated. [CO2/person·year])	-1.87%	

Symbol criterion: negative means reduction

Municipal Programme's Action Plan 2			
2012-2015		Active projects 17	New projects PA2 5
		Covenant of Mayors scenario	
Energy consumption	Action plan's total potentia [MWh/year]	-29,590.16	
	% with regard to 2008 (accumulated. [kWh/inhab·year])	-8.24%	
GHG's	Total [t CO_2/year]	-6, 424.98	
	% with regard to 2008 (accumulated. [CO2/person·year])	-12.11%	

Symbol criterion: negative means reduction

Municipal Programme's Action Plan 3			
2016-2020		Active projects 12	New projects PA3 1
		Covenant of Mayors scenario	
Energy consumption	Action plan's total potentia [MWh/year]	-40,569.34	
	% with regard to 2008 (accumulated. [kWh/inhab·year])	-18.29%	
GHG's	Total [t CO_2/year]	-8,292.10	
	% with regard to 2008 (accumulated. [CO2/person·year])	-23.21%	

Symbol criterion: negative means reduction

PUBLIC BUILDINGS

- **PU01 - Implementing Government measures for savings and efficiency in municipal buildings.**
  Objective: Implementing Government measures for energy savings and efficiency in municipal facilities.
  Description: Implementing the Government measures that establish strategies for saving, efficiency and renewable energy in municipal facilities. The Government Measure is a transversal tool used to implement PEMEEM, an action that involves all departments and areas of the City Council. The scope of action on the buildings is large, since it will cover the areas of savings, energy efficiency, renewable energy and the greening of the various offices and municipal facilities.

- **PU02 - Carrying out the energy saving work table and the role of energy manager of the municipal facilities**
  Objective: To carry out the energy saving work table and the figure of energy managers of municipal facilities.
  Description: The energy saving work table operation will be developed with the aim of carrying out the strategies established by PEMEEM.
  The Board is composed of the AEB as a technology consultant and expert on energy issues, and the Department of Maintenance and Planning for the General Services Sector facilities, which will become the benchmark for the region.
  To coordinate the knowledge on the buildings' energy, the position of building energy manager will be created: a person who will be knowledgeable about the state and condition of the facilities, the energy consumption, etc., whether they are the responsible administrator, responsible for the equipment maintenance, knowledgeable on the condition of the equipment and the energy consumption levels, etc.

- **PU03 - Write the protocol for municipal building and building reception.**

  Objective: Write the protocol for municipal building and building reception.

  Description: The Building Protocol is a collection of actions and recommendations that will have to be undertaken by the various entities of the City Council related to the promotion and management of buildings, both new construction and rehabilitated buildings.

  Initially it will include criteria recommendations for savings, efficiency and, in general, energy management, and subsequently it will expand into environmental criteria.

- **PU04 - Writing a protocol for communication, awareness and good practice.**

  Objective: To write the protocol for communication, awareness and dissemination of good practice.

  Description: drafting a protocol for communication, awareness and dissemination of good practices that will be entered in the transversal (horizontal) strategic objectives of the + Sustainable City Programme, which includes the following requirements:

  1. Develop an organised culture socially responsible and environmentally correct:

     It involves, firstly, changes within workers' habits. The success of this change is directly related to:

     - Creating a sense of shared purpose throughout the organization.
     - Motivating professionals and work teams.
     - Share knowledge (training and information).

     It requires developing internal management elements necessary to achieve environmental and social objectives:

     - Analysis and improvement of work processes.
     - Regulated Actions.
     - Introduction of clauses in the specifications.
     - Commissions and specific work groups.

  2. Establish a communication strategy for the programme:

     To encourage professionals and to generate a sense of mission among employees and also to provide the programme with municipal strategic centralization and give it local visibility.

- **PU05 - Introducing monitoring systems for municipal installations - Energy Management Systems (EMS).**

  Objective: To introduce efficiency and energy saving measures in lighting equipment of municipal buildings.

  Description: implementing energy monitoring systems for the buildings in the Barcelona City Council. This measure will reveal the energy consumption of buildings in real time, detect deviations and act to correct them.

  The counting and control of energy consumption is essential for the proper management of energy. It is the first step in any investment, it is the control system which allows to design savings indicators. Likewise, a centralized energy consumption monitoring system makes past and current consumption values instantly available and makes it easy to detect energy leaks.

  The monitoring allows consumption readings available to the energy manager of the building but also to other institutions such as the Energy Agency of Barcelona, which will be able to accurately track the savings obtained by the investments in improvements. Moreover, the display of consumption values is also a useful tool for raising awareness among people, a reason to consider the proposition to install some tracking devices in the busiest buildings, or to make the information available via the Internet.

  A large scale control and tracking system for the current building stock would be, to a large extent, an absolutely essential tool to know precisely the energy consumption of each building. In any case, the control and monitoring system could also apply to new constructions, forcing, for example, through the new construction bidding process, to assess the incorporation of management and control systems as well as comprehensive home automation systems, in buildings.

- **PU06 - Implement energy saving and efficiency measures in municipal facilities.**
  Objective: To implement efficiency and energy saving in municipal buildings.
  Description: investment in energy saving measures with the aim of reducing energy consumption.
  The energy saving measures have to solve each of the energy problems, such as minimizing the effects of climate through appropriate design and bioclimatic parameters, reducing demand through good thermal insulation, etc.
  The measures to be implemented are:
  - Rehabilitating thermal power of the interior envelope of existing buildings.
  - Improving energy efficiency of lighting inside existing buildings.
  - Improving energy efficiency of thermal equipment in buildings: demand optimization.
  - Improving the energy efficiency of existing lift equipment in buildings.

- **PU07 - Implementing systems to generate high thermal efficiency.**
  Objective: To implement systems to generate high thermal efficiency.
  Description: There is municipal equipment with a high heat consumption level. At the same time, the systems that generate heat and cold that are currently installed in various municipal offices will be reaching the end of their useful life. So when these systems need to be replaced will be the perfect time to evaluate the most efficient possible cooling alternatives.
  The systems to implement are:
  - Improving the energy efficiency of thermal equipment in buildings: generation optimization.
  - New fuel generation systems.
  - Cogeneration at facilities with high heat consumption.
  - Connect municipal equipment to district heating networks.

  Regarding the mechanism of action, the strategy should be, for existing buildings, to establish inventories of equipment that currently exist to meet the needs of air conditioning and act directly, enhancing their revamping or opting to outsource where it has access to networks or urban district heating. Instead, the new buildings, as obliged by law to meet certain energy efficiency requirements in their heating installations, intervention is needed through improved compulsory legislation or marking a minimum energy grade point based on the energy certification regulations of new buildings.

- **PU08 - Implement measures of renewable energy.**
  Objective: To implement renewable energy measures.
  Description: Investment in renewable energies equipment that allows the use of renewable and free energy resources. When talking about integrating renewable energy in buildings, priority is often given to solar energy applications, both thermal and photovoltaic, and to biomass applications, usually by using biomass boilers. Investment will also take place in power generation systems using photovoltaic systems.
  Specifically, the actions to carry out are:
  - Installation of solar thermal systems at municipal facilities.
  - Installation of solar photovoltaic at municipal facilities.
  - Feasibility of biomass facilities.

  Feasibility mini-wind power systems.

- **PU09 - Spread the establishment of energy service companies at municipal facilities.**
  Objective: To promote the implementation of Energy Services Companies (ESC) at municipal facilities.
  Description: Energy Services Companies (ESC) are private companies whose main line of business is selling end-user comfort and to do so, they are responsible for the purchase of energy supply, for the management of energy generation and consumption equipment and maintenance, with the intention of generating comfort in the most efficient way from an energy perspective.
  In an energy services contract, the ESC are responsible for the planning, implementation and financing of a variety of energy efficiency measures in the customer's facilities. These measures aim to optimize the provision and use of energy, which is consumption and cost savings for the customer.

In general, the ESE contract guarantees a fixed minimum savings. The difference in annual energy cost before and after implementing the measures provides some funds in the annual budget with which the client pays the company during the service contract.

- **PU10 - To encourage the purchase of green energy.**
  Objective: The project aims to encourage the purchase of green energy for local consumption and, in general, to the public.
  Description: Barcelona participates, via + Sustainable City Programme, in the Procura + Campaign coordinated by the ICLEI-Local Governments for Sustainability city network.
  This network is dedicated to the promotion of green purchasing among European local authorities.
  As for buying green energy, the contracts for electricity and municipal services are coordinated and implemented by the Barcelona City Council General Services sector, incorporating Procura + criteria.

- **PU11 - Collection, centralization and data processing of municipal energy consumption in the Energy Observatory.**
  Objective: to centralize all data on local consumption and be the leading reference for the City Council regarding energy and environmental indicators.
  Description: The analysis of consumption data of the 2,015 municipal establishments has involved a high volume of data. That includes the location of the building, the surface, and the available consumption data on the different energy sources used. The results have helped to define the current situation of energy consumption in municipal facilities, as well as to predict the possible future growth of energy consumption and GHG associated emissions.
  The centralization of information on the energy consumption of municipal facilities by the Energy Observatory, helps to centralize and manage actions to improve the energy efficiency of facilities and track to assess energy policies, carrying out corrective actions for possible deviations from the predictions made. That is, the centralization of energy information concerning the municipal installations in the City Council, helps the Energy Observatory to establish itself as the only energy manager of these establishments and to carry out joint policies on energy consumption improvement according to the needs of each installation.

- **PU12 - Pilot project for a generation system for cooling from solar concentration.**
  Objective: a pilot installation of solar concentration technology for the production of cooling by an absorption machine. Pushing for the entry of this technology in Barcelona.
  Description: the shape of the demand curves for cooling and for solar thermal energy production seek a perfect combination between the needs and the availability of solar resource when associated with a thermally activated cooling machine. To study the performance of such facilities to ensure its replicability.

- **PU13 - Pilot project to install solar concentration for the production of electricity.**
  Objective: a pilot installation of solar concentration technology for electricity production in order to study the feasibility of replication of these technologies in an urban environment. Pushing for the introduction of solar thermal energy for electricity production in Barcelona.
  Description: concentration technologies have allowed significant improvement on the behaviour of a series of solar technologies that currently exist due to the reduction of the required capturing area and to the increase of the attainable temperature. These facts ensure a higher energy density and can predict an interesting future that is already being used in large thermo solar installations in the south of the peninsula.
  Therefore, it is highly recommended to implement a pilot test that would start the expansion of this technology in an urban context such as Barcelona. At first, it could work with a small concentration of low power facilities (such as disk stirling), without ruling out other emerging low territory occupation thermo solar technologies.

PUBLIC SERVICES

- **SE01 - Improved energy efficiency of ornamental fountains.**
  Objective: To reduce energy consumption of fountains and other ornamental sites.
  Description: implement energy efficiency measures in ornamental fountains equipment to reduce consumption. After the field inspection, the following is proposed:
  - Identify opportunities and areas of action.
  - Estimate potential savings and investments from measurements with hydraulic pumping systems and reactive compensation.
  - Apply cost saving measures that offer better results.

- **SE02 - Ongoing replacement of traffic lights that use incandescent bulbs with ones that use LED lighting.**
  Objective: To reduce the traffic signal light power consumption by replacing traffic lights that use incandescent bulbs with ones that use LED lighting.
  Description: This project plans to continue the work of gradual replacement of all the lights of traffic lights that currently have incandescent light bulbs for new traffic lights with LED technology. The project also includes the need to improve connections and the proper equipment maintenance to help improve the overall system efficiency.

- **SE03 - Installation of 8 MW of PV on equipment and other municipal areas.**
  Objective: investment in renewable energy installation that allows the use of renewable energy resources that exist in the city.
  Description: The project proposes the addition of 8 MW of PV on municipal equipment and space, using different methods of promoting such systems such as the transfer or lease of spaces, facilities, gazebos in parks and public spaces, etc., to third parties.

PUBLIC LIGHTING

- **EN01 - Modernization and improvement of public lighting equipment.**
  Objective: To modernize the lighting equipment in the city.
  Description: The plan to improve the lighting in a first phase until 2011 plans to replace 6,600 lights in the city.
  The measures to be implemented as envisaged in the modernization and improvement of lighting are:
  - Replacement of mercury lamps for high pressure sodium vapour.
  - Implementation of flux regulators.
  - Adjustment of operative light levels.
  - Implementation of the half off wherever feasible.
  - Lighting with LED.

- **EN02 - Light pollution reduction measures.**
  Objective: public lighting equipment upgrade to reduce light pollution.
  Description: The goal is to reduce the presence of light where it is not necessary or where it is not convenient to have it and, therefore, avoid dispersion into the sky (by direct emission or reflection on walls and streets), light intrusion and glare. Action is necessary on nearly 23,000 points of light with the change of 19,300 lamps and the installation of approximately 3,700 new media (with its corresponding new light and lamp).

PUBLIC VEHICLE FLEET

- **FL01 - Environmentalisation of municipal vehicles.**
  Objective: The objective of the project is to environmentalise municipal fleets to make them more efficient and consume less energy.
  Description: in the owned and external fleet there is a need to leverage the renovation or improvement of the existing park and replacement of diesel or gasoline vehicles that there are now, for other vehicles that use alternative fuels, provided the market offers vehicles with these features intended for the purpose for which they are acquired.
  Set a municipal fleet standard to establish the characteristics of consumption and vehicle emissions from the municipal fleet, which may include:
  - Replacing conventional energies with bio fuels in the vehicles that make up the current municipal fleets, reducing the presence of diesel.
  - Incorporation of new technologies in the acquisition of vehicles for municipal fleets (LNG, CNG, hybrids and electric vehicle).
  - Installation of systems for reducing particulate emissions and NO_x in diesel vehicles not amortised from the municipal fleet.

  The fleet of waste collection, given its complexity, is considered in a separate project.

- **FL02 - Diffusion of current technologies (renewable fuels, hybrid vehicles, etc.) and providing better professional resources and knowledge in the energy technology sectors to people responsible for acquiring municipal vehicles.**
  Objective: To provide information regarding the best available technologies in transportation to the individuals responsible for the acquisition of new vehicles for municipal fleets or external fleet management contracts, so that such choices will take efficiency criteria into consideration.
  Description: preparation of clear and updatable course material regarding the best available technologies in transport and its diffusion to all stakeholders.

- **FL03 - Feasibility study of the use of biogas generated at Barcelona eco-parks and at the closed Garraf landfill to propel the municipal fleet.**
  Objective: To use the biogas generated in urban waste management facilities to propel the municipal vehicle fleet equipped to use CNG.
  Description: In 2008 there were 32 million Nm^3 of biogas produced from the Vall d'en Joan closed landfill and from ECOPARKS 2 (Montcada i Reixac) and 3 (Sant Adrià). That same year, municipal fleets consumed 1.5 million Nm^3 of CNG. It is proposed to assess the technical and economic viability of using this local renewable resource in municipal fleets.

- **FL04 - Rationalisation programme of the local internal mobility.**
  Objective: To study the use of municipal fleet vehicles and to optimise the resources allocated to each service.
  Description: detect whether certain services may be subject to a process of rationalisation in terms of kilometres travelled and type of vehicle used. In this case, promote the use of public transport, bicycle and electric scooter for most trips when possible.
  Proposing the use of car sharing systems in fleets of cars that only drive a few kilometres per year.

- **FL05 - Entering a new cleaning contract based on the use of environmentalised vehicles.**
  Objective: To minimize the impact associated with the increased mobility of the waste collection fleet derived from the widespread collection of organic waste and improve the selective collection, and cleaning & collection environmental efficiency.
  Description: This project is already initiated by the City Council. The city of Barcelona has hired the cleaning service and waste collection with different specialised companies for an extended period of time, according to the equipment amortisation time. The year 2009 is a year of change, the contract from 2000 to 2009 ends, and from 1st November 2009 the implementation of new 2009-2017 contract began.
  The actions that were derived from the new contract were:
  1. Waste Minimization: Promote the prevention of waste generation.
  2. Increased selective collection: Increase from 34% selective collection in 2009 to 50% in 2012.

3. Increasing the selective collection of organic waste to 55%: extending the collection of the organic fraction to 100% of the population of Barcelona. Changing the model of collection, increasing from 4 containers (bi-compartmented as per the organic fraction of municipal waste and other) to 5 individual containers.
4. Reduce the inappropriate content in the organic collection at home to 15%: reduction to 15% inappropriate content in the organic fraction, PROGREMIC's goal. Change from bi-compartmented containers to exclusive organic collection containers.
5. Improved environmental efficiency of vehicles: use of vehicles with a more sustainable energy source, such as compressed natural gas (35%), biodiesel (35%) and electric (30%).
6. Impact of sustainability variables in the remuneration of the service: incorporation of an annual control of sustainability variables and a formula for impact on the remuneration of the service according to these variables.

It is expected that the new system of selective collection (which extends from four to five fractions collected, as well as their frequency) will lead to a 20% increase of veh-km.

The aim of the new cleaning contract is to green the fleet in order to produce the minimum increase in emissions despite the associated increase in kilometres travelled.

Also, there will be a minimization of emissions of local pollutants (NO_x, particulates) by the fleet using mainly cleaner fuels in most thermal vehicles (qualifying with EURO V) and electric.

5.4 - Monitoring

The PECQ also plans to monitor future changes in energy consumption and emissions in the city as well as the degree of implementation of each of the projects it contains. This monitoring will, essentially, be based on annual energy balances prepared by the Energy Observatory, managed by the Barcelona Energy Agency, and also by means of a battery of indicators. With regard to the indicators, two review methods have been defined based on two kinds of indicators:

- ACTION INDICATORS: those that are directly linked to the actions carried out by the body responsible for executing the Plan. They make it possible, therefore, to assess the degree of compliance with the actions set out in the Strategic Action Plan, irrespective of whether the responsibility for carrying them out is the Council's or that of the public and private bodies involved. The action indicators are objective in that their assessment is based on measurable data. For example, an action indicator could be to increase installed photovoltaic power in the City by means of the PECQ's projects in terms of the total power that the PECQ sets as a target.
- REACTION INDICATORS: those that aim to show trends in macro data about Barcelona from an energy and environmental perspective. Reaction indicators are more complex than action indicators in that they are influenced by other factors that are exogenous to the execution of the PECQ (the energy situation and economic climate in the city, climatic effects that may cause changes in energy consumption or generation, any changes in the electricity mix, and, even, how close to reality the baseline scenario defined in the PECQ is, amongst other factors). For example, a reaction indicator related to a previous action could be the percentage of renewable energy generated in the city compared with total energy consumed in the city.

The aim of these two kinds of monitoring indicators is, on the one hand to follow up accurately the implementation of the PECQ's projects, and, on the other hand, to monitor their impact on the city and on the city's macro data in order to assess the real impact and overall reach of the Plan on an ongoing and comprehensive basis.

Each of the projects defines an implementation timetable for the next few years along with the units of measurement that will make it possible to evaluate the degree to which each project has been implemented - and for the projects as a whole - and to follow up the implementation of the PECQ in accordance with the action indicators. These units of measurement are: *"kW of installed power"*, *"m² of panels"*, *"vehicles"*, *"housing"*, *"survey"*, *"lighting fittings"*, *"buses"*, and *"project"*, amongst others.

FIGURE 260 | PECQ MONITORING INDICATORS

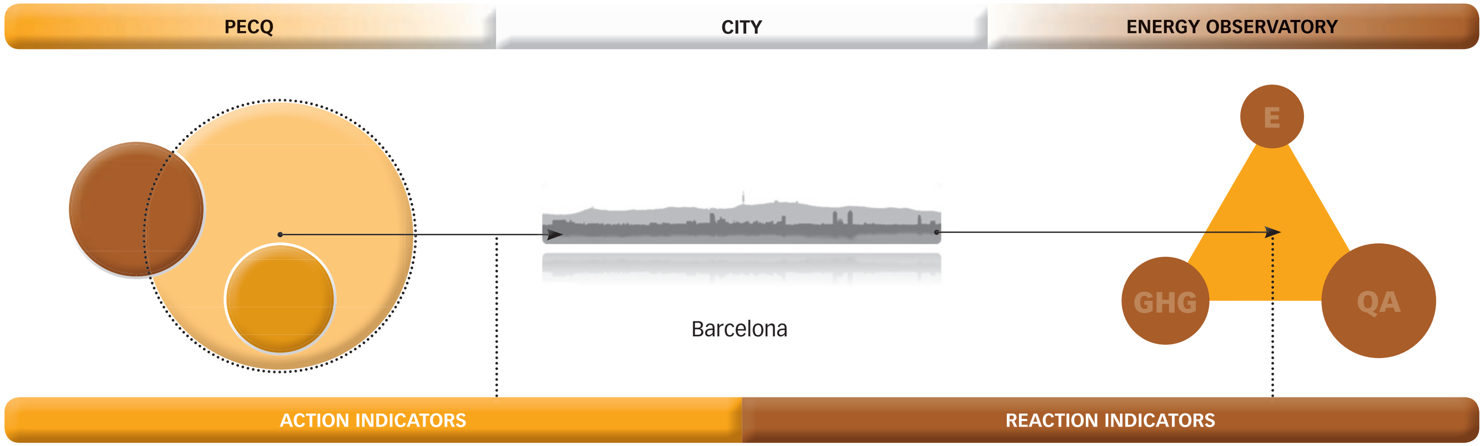
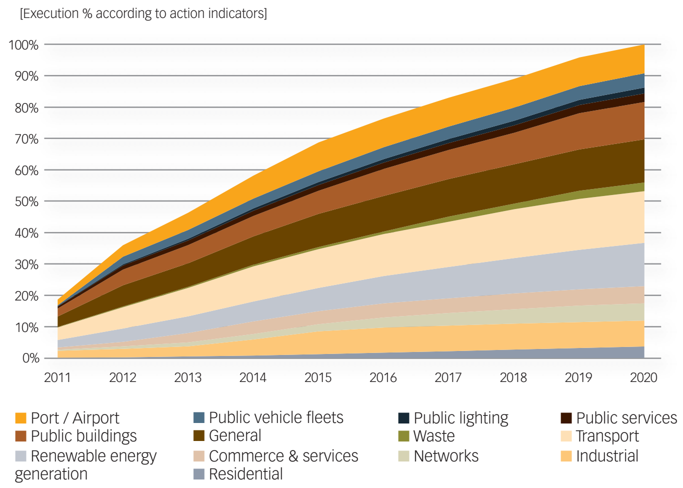


FIGURE 261 | FORECAST OF THE DEGREE OF IMPLEMENTATION OF PECQ PROJECTS



Scenarios and strategies for action - BLOCK 6

ENVIRONMENTAL ASSESSMENT

6.1 - Prior considerations

6.1.1 - OBJECTIVES AND ENVIRONMENTAL VALUES

The PECQ, a direct product of a drive towards sustainability, faces a number of strategic challenges that are clearly of an environmental nature, such as:

- Reducing the increase in the city's energy consumption.
- Reducing the increase of greenhouse gas emissions associated with energy consumption.
- Improving the quality of the city's air.

Arising from these challenges are a number of more specific objectives:

- Increasing the consumption of self-generated energy and the amount of energy produced from renewable sources (biogas, photovoltaic and solar thermal).
- Reducing immission levels of NO_2, PM_{10} and $PM_{2.5}$.
- Improving air quality levels in terms of other pollutants.
- Improving efficiency and the environmentalisation of transport in Barcelona.
- Involving all agents and groups in reaching the PECQ's objectives.

Another of the environmental objectives in the PECQ is to meet the Covenant of Mayors' commitment to reducing GHGs by 20% by 2020, whilst increasing energy efficiency and the use of renewable energies.

Without doubt, the most important contribution of the PECQ is the fact that one of cornerstones is to improve air quality, besides preventing pollution by greenhouse gas emissions. This new approach of the Plan, compared with previous documents, is of fundamental importance in confronting current quality levels in the city and the towns in the metropolitan area. Over recent years, immission levels for NO_2 and PM_{10} have been exceeded and, in line with current legislation, Special Protection Areas of the Atmospheric Environment have been created and an action plan to reduce air pollution has been prepared.

In this context, the PECQ brings together all the projects it is possible to carry out in the city so as, on the one hand, to reduce the increase in energy consumption in Barcelona and to cut the rise in greenhouse gas emissions associated with the city, and, on the other hand, to improve air quality, most importantly in terms of NO_x and airborne particles. This implies that, although this is a city plan, Barcelona City Council is not the only agent that can work towards reaching these objectives. Thus, the PECQ includes other projects that involve external agents. These projects are also quantified and included in the strategic action plan.

FIGURE 262 | OUTLINE OF THE PECQ AND ITS ENVIRONMENTAL ASSESSMENT

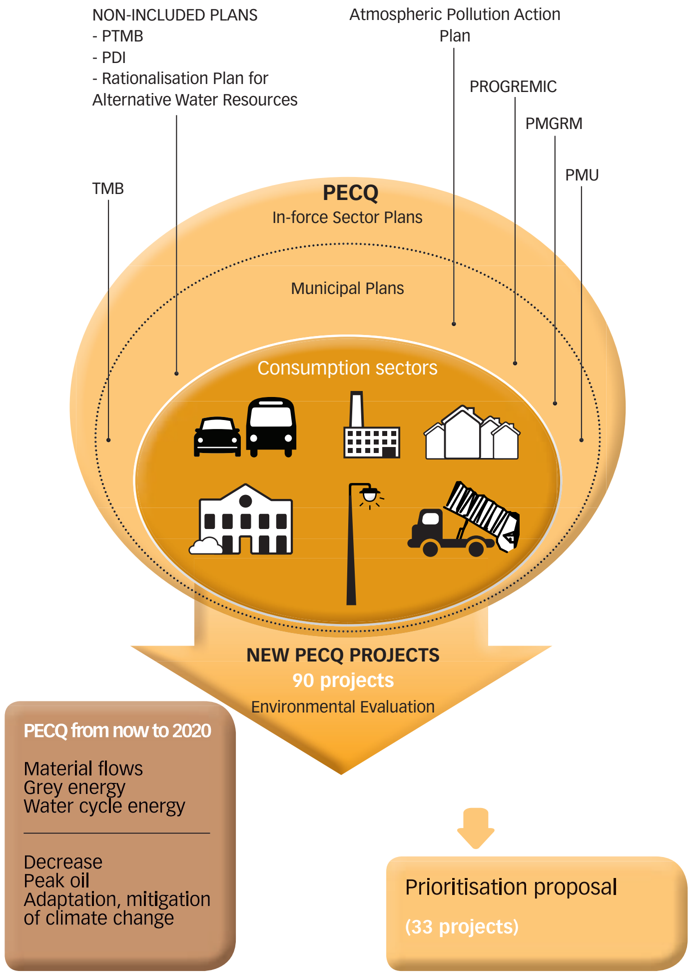
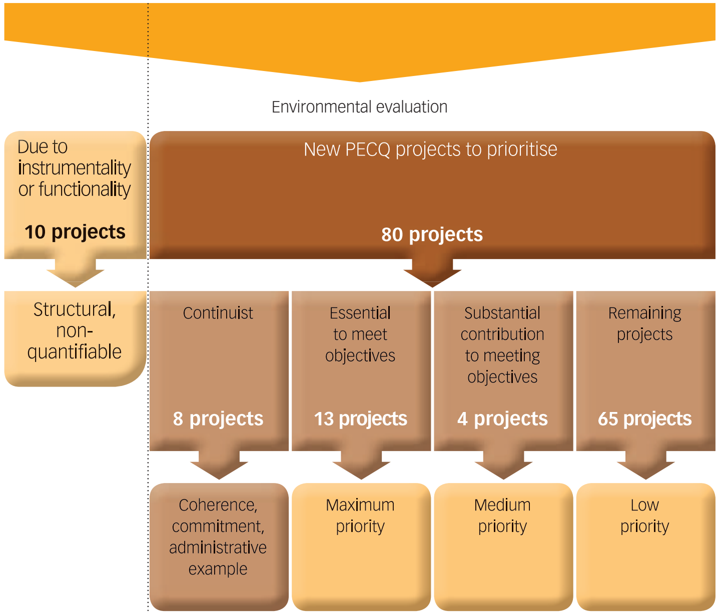


FIGURE 263 | OUTLINE OF THE ENVIRONMENTAL ASSESSMENT AND PRIORITISATION OF PECQ PROJECTS



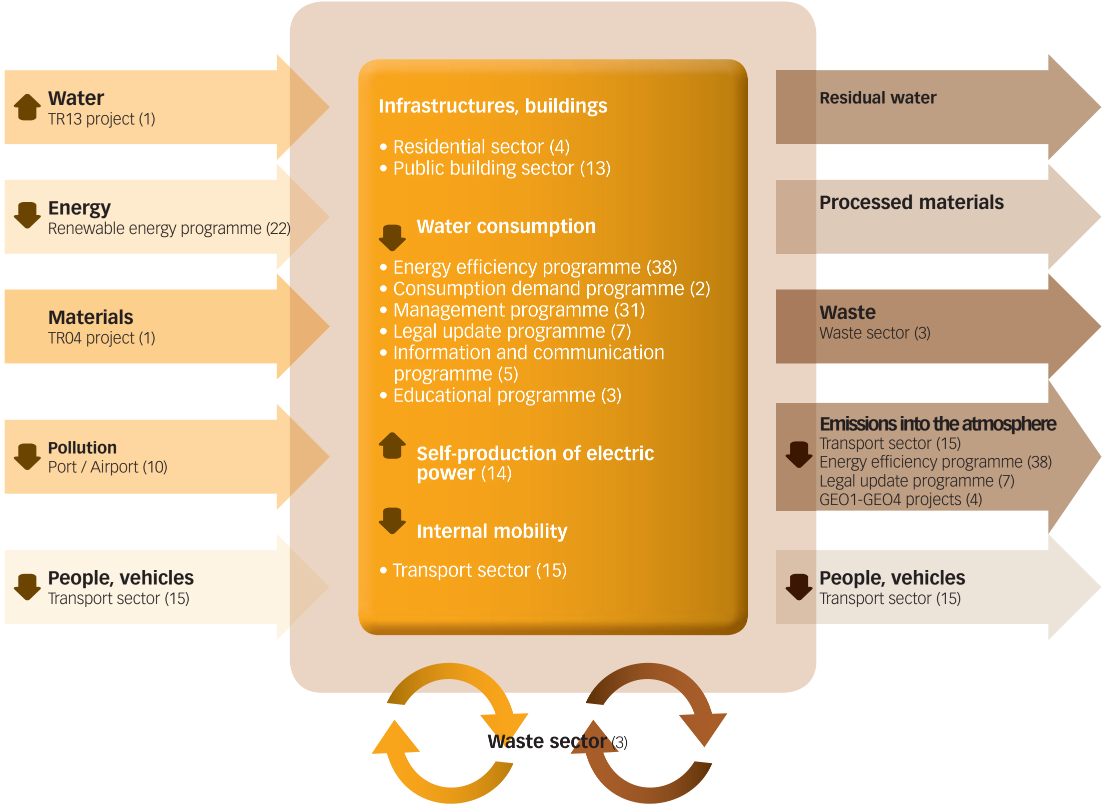
6.1.2 - RELATIONSHIP WITH THE URBAN SYSTEM

The energy vector accounts for the highest number of projects associated with the PECQ's action strategy, as do local and global atmospheric emissions. However, there are also projects and specific sectors that are related to other vectors and urban metabolism flows such as those associated with waste management.

The PECQ also affects other areas of activity and dynamics in the city:

- **URBAN STRUCTURE AND BUILDING**: the PECQ proposes applying an energy efficiency programme in a number of sectors: residential (housing rehabilitation), grids (DHC), and general (energy certification of buildings and energy and environmental efficiency in new urban projects). It also proposes promoting a viability project to look at defining a regulatory framework to ensure the utmost energy efficiency in buildings in accordance with their use (GE06).
- **SOCIOCULTURAL VARIABLES:** the PECQ also aims to influence the behaviour and attitudes of the general public towards energy and also to tackle the widespread lack of knowledge regarding energy consumption and the measures that can be taken to improve energy efficiency.
- **TECHNOLOGY:** in the transport sector, the PECQ proposes the introduction of new technologies that are less polluting, such as electric vehicles. Also included in the energy efficiency programme is a proposal to incentivise District Heating and Cooling, cogeneration and trigeneration.
- **URBAN MANAGEMENT:** there is a specific management programme in the classification of PECQ projects that comprises projects in different sectors and that could include the review programme, since it is the responsibility of the administration governing the city to establish the legal framework. There is also a link between a number of measures in the general sector and management, such as setting energy and environmental efficiency criteria in new urban projects (GE09).

FIGURE 264 | RELATIONSHIP OF PECQ PROJECTS WITH URBAN METABOLISM FLOWS



▲ The number of projects is indicated in brackets. The black arrows show the trend the PECQ favours with regard to each of the flows.
TR13 – Street cleaning along busy streets using groundwater to reduce the re-suspension of particulates / TR04 – Rethinking the distribution of goods / GE01- Monitoring the PECQ and the energy monitoring programme in the city / GE02- Programme to monitor the local emissions inventory in Barcelona and their dispersion.

6.2 - Assessment

6.2.1 - NEW PROJECTS IN THE PECQ

Procedural analysis

The environmental assessment only takes into account the 90 new projects in the PECQ - it does not make sense to assess projects from other plans that have undergone a process of assessment at the appropriate time.

This way, individual evaluations of each project are not carried out and neither is consideration given to the appropriateness of their implementation - inasmuch as all projects have clear environmental objectives – although they are evaluated on a joint basis to determine whether the totality of the projects meet the qualitative and quantitative objectives set down.

The first exercise is to analyse the relationship between each project and the three main environmental vectors – energy, climate change and air quality – or with the one that applies, if they only relate to one of the three. To do this, the indicator that is considered most representative is used in each case:

- Energy: primary energy saving.
- Climate change: savings of CO_2 emissions.
- Air quality: savings of NO_x emissions.

This analysis only looks at projects that the PECQ has evaluated from an energy and environmental perspective. Of the 90 projects that are the subject of assessment - only the new ones, leaving aside current sectoral planning – 12 have not been quantified. Only those projects that have a direct effect on energy consumption or pollutant emissions were evaluated. So, more socially orientated projects, although they have an indirect effect on energy savings and cutting emissions, have been considered to have a zero saving.

Later, the degree of contribution of the various sectors to reaching the three PECQ objectives was determined and projects were evaluated with regard to quantitative objectives, taking into account the 2020 objectives for the PECQ overall.

Achievements

Overall, implementing all the projects is forecast to reduce primary energy (25.9% of the PECQ total) by 553,000 MWh/year, final energy (11.6% of the PECQ total) by 194,000 MWh/year, the generation of 83,500 MWh/year (59.8% of the PECQ total), a saving of 72,973,000 t of GHGs (10.3% of the PECQ total), 719,500 t of NO_x (26.24% of the PECQ total), 139.000 t of PM_{10} (48.4% of the PECQ total) and 132,000 t of $PM_{2.5}$ (51.9% of the PECQ total).

With respect to meeting the Covenant of Mayors commitments, greenhouse gas reductions are expected to have fallen by 17.5% by 2020 compared with 2008, or 23.5% if only the municipal sector is taken into consideration.

When it comes to quantifying renewable energy, the situation is more complex in that both the Spanish/Catalan generation mix and self-consumption of electricity need to be considered, as does the 100% increase resulting from applying PECQ projects compared with 2008. Specifically, there are 14 PECQ projects (renewable energy generation and special scheme) that imply a primary energy saving of 280,000 MWh/year and a final energy saving of 3,525 MWh/year. Evaluated solely in terms of the municipal sector, it should be taken into consideration that, compared with 2008, PECQ projects in the municipal programme related to renewable energy have increased by 500%.

Finally, an evaluation of energy efficiency arising from the Covenant of Mayors objectives can be carried out using an intensity indicator measured in Wh/€, producing a result of 11.4% compared with 2008. In terms of this parameter, however, there is insufficient data to carry out a parallel estimate on the municipal sector. The results of this assessment are shown in the diagrams, tables and graphs below.

Overall, it can be seen that there is a significant concentration of projects with a reasonably strong focus on energy and climate change, and few that focus on air quality, on account of the fact that they are near the axis for NO_x 0% savings.

On this axis, we can find a set of measures related to energy saving in the public sector (50-80% saving of primary energy) along with a number of measures relating to renewable energy (50-70% primary energy saving, 35-50% GHG savings, and a 0% NO_x saving) and industry (approximately 50% primary energy saving, 50% GHG saving, and a 0-10% NO_x saving).

The measures that are more focused on the air quality vector are related to transport. Thus, we can find transport management measures on the 10-30% NO_x emissions saving axis and on the 80% energy saving axis (as is the case in the reductions from empty journeys, the redistribution of goods transport and the variable tariff depending on occupation), and measures of transport environmentalisation that are more related to the implementation of cleaner fuels (less use of diesel, promotion of electric vehicles, environmentalisation of municipal vehicles, the monitoring of emissions from higher polluting vehicles and an analysis of alternative transport policies that have a consensus of support).

Also noteworthy are the projects that are outside the triangle and that, rather than representing a saving, represent a contribution. This applies to the XAR1 (Zona Franca – Gran Via l'Hospitalet Power Station) and IND1 (Energy Service Companies in the Industrial Sector) projects, which produce NO_x. However, it should be noted that the exercise does not compare the effectiveness of the measures but, rather, the objectives that were taken into account.

It can be observed, therefore, on a general basis, that many projects that contributed to primary energy savings also led to savings in GHGs, even though this is not associated with lower NO_x emissions. Air quality is a vector that requires specific measures (in particular, in transport) and, often, these measures do not involve objectives related to energy or climate change.

The sector that has the greatest impact on air quality is transport, which also has a significant impact on energy and climate change objectives, although to a lesser degree. Whilst public buildings, lighting and residential have a greater impact in terms of energy compared with GHGs, other sectors, such as industry, public services and the generation of renewable energies, have a more significant GHG component than energy component.

As for energy objectives, the main contributors are, besides transport, network sectors and public buildings. Two sectors that clearly contribute to energy consumption, rather than savings, are commerce and services and public vehicle fleets.

With regard to the objective of cutting GHGs, the transport and network sectors contribute, in a similar way to energy, to a significant GHG saving, followed by industry and public buildings.

FIGURE 265 | DIAGRAM SHOWING THE MEASURES IN THE CONTEXT OF THE THREE BASIC PECQ VECTORS

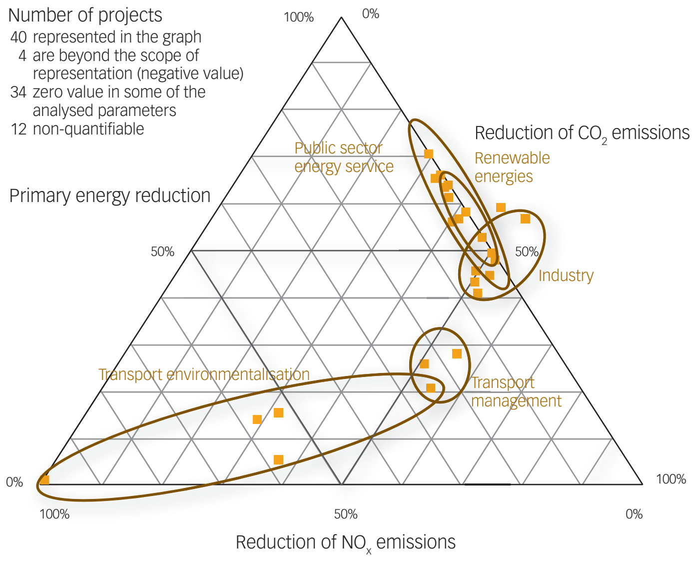


FIGURE 266 | REDUCTIONS AND INCREASES IN FINAL ENERGY, GHGS AND EMISSIONS OF NOX, BY SECTOR

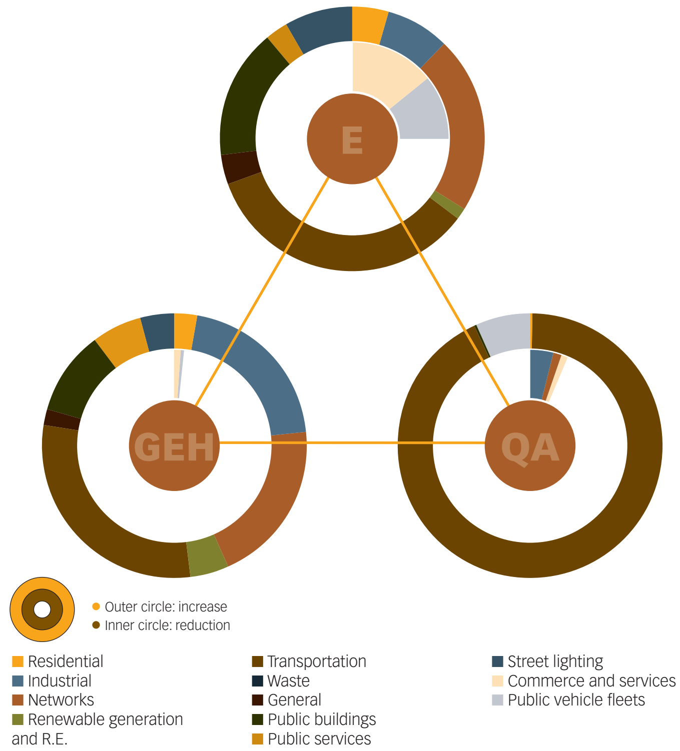


TABLE 86 | QUANTITATIVE OBJECTIVES SET FOR THE NEW PECQ PROJECTS FOR 2020

Objectives set up to 2020 – Energy		
	PECQ Objective – 2020 (% with regard to 2008)	
To reduce the whole city's final energy consumption	-9.90	%
To reduce final energy consumption per inhabitant within the municipal sector	-18.50	%
To increase local energy generation in RE	38.00	%
To increase the local generation of power with renewable energies	2.00	x times
Biogas + Biomass	1.60	x times
PV + mini-wind power	4.40	x times
Objectives set up to 2020 – Greenhouse gases (GHG)		
	PECQ Objective – 2020 (% with regard to 2008)	
To reduce GHG emissions per inhabitant while maintaining emissions per inhabitant similar to those in 2008 (Catalan electricity mix)	-17.50 -	%
To reduce GHG emissions per inhabitant (Catalan electricity mix)	-12.60 -	%
To reduce GHG emissions per inhabitant within the public sector (Catalan electricity mix)	-23.50	%
Objectives set up to 2020 – Air quality		
	PECQ Objective – 2020 (% with regard to 2008)	
To reduce NO_x emissions	-26.00	%
To reduce PM_{10} emissions	-39.00	%

FIGURE 267 | RELATIONSHIP BETWEEN 2008 VALUES, PECQ OBJECTIVES AND OBJECTIVES FOR NEW PECQ PROJECTS IN TERMS OF ENERGY

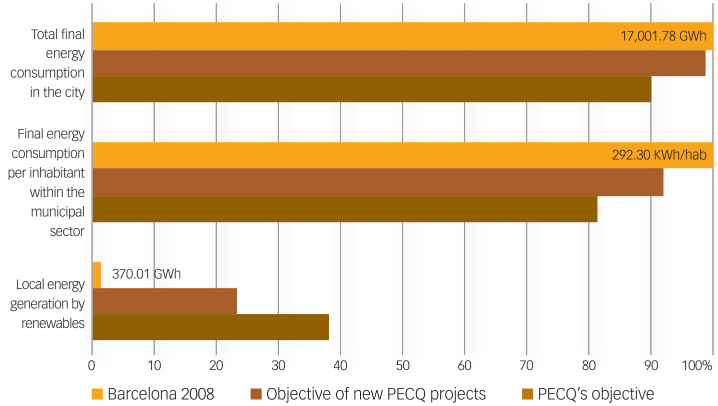


FIGURE 268 | RELATIONSHIP BETWEEN 2008 VALUES, PECQ OBJECTIVES AND OBJECTIVES FOR NEW PECQ PROJECTS IN TERMS OF RENEWABLE ENERGY

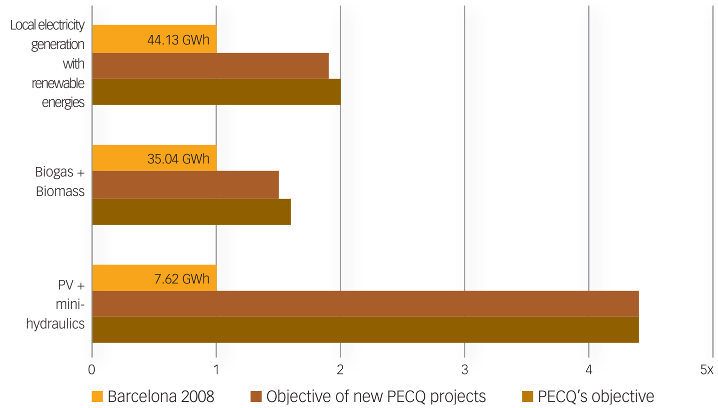


FIGURE 269 | RELATIONSHIP BETWEEN 2008 VALUES, PECQ OBJECTIVES AND OBJECTIVES FOR NEW PECQ PROJECTS IN TERMS OF GREENHOUSE GASES

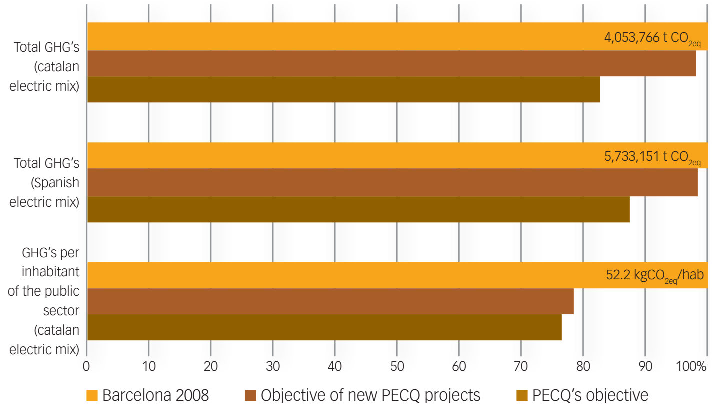


FIGURE 270 | RELATIONSHIP BETWEEN 2008 VALUES, PECQ OBJECTIVES AND OBJECTIVES FOR NEW PECQ PROJECTS IN TERMS OF AIR QUALITY

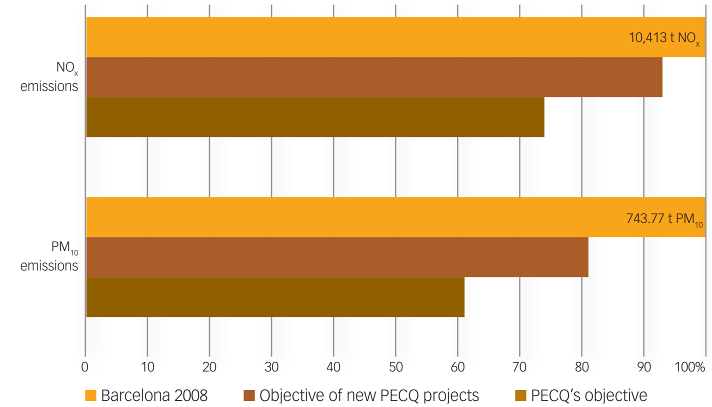


TABLE 87 | LIST OF PECQ PROJECTS

THE RESIDENTIAL SECTOR	
RES1	Consumption display units inside homes.
RES2	Thorough monitoring system for the energy efficiency measuring application in the residential sector.
RES 3	Proposal for a regulatory framework for energy improvements in building rehabilitation.
RES4	Improvements in energy efficiency in housing refurbishments.
THE INDUSTRIAL SECTOR	
IND1	Energy service companies in the industrial sector.
IND2	Energy efficiency agreement with other entities in the industrial sector.
IND3	Industrial sector energy efficiency management systems.
IND4	Increasing energy efficiency in production processes.
IND5	Promoting cogeneration in the industrial sector.
IND6	Sludge drying for energy rationalisation.
IND7	Photovoltaic (PV) solar energy in industrial roofing.
IND8	Separation of coloured and clear bottles to improve septic performance.
IND9	The energy savings in painting booths in small/medium size auto body shops.
THE NETWORK SECTOR	
XAR1	Zona Franca Power Plant- Gran Via L'Hospitalet.
XAR2	Extension of the DHC system to the La Sagrera.
XAR3	Information system about the network and the quality of the energy systems (electricity and gas).
XAR4	Software programme supporting the electric infrastructure tracking.
XAR5	Modernisation of electricity and gas supply incident communication protocol.
XAR6	To encourage the connection of the household sector to the DHC network.
XAR7	Communication programme to promote the installation of microCHP systems to replace old thermal-based equipment.
THE COMMERCIAL AND SERVICES SECTOR	
COM1	To create a regulatory framework for DHC in the commercial and services sector.
COM2	Installing tri-generation systems (CCHP) in large hotels in lieu of renovating ordinary installations with obsolete equipment.
COM3	To encourage the installation of solar thermal systems in existing athletic clubs.
COM4	Installation of micro cogeneration systems (micro-CHP) at athletic centres.
COM5	Implantation of infrastructure sustainability criteria and sustainable product purchase criteria, among other measures, in TMB (Transports Metropolitans de Barcelona).
COM6	Optimisation of power and water management at TMB facilities.

RENEWABLE GENERATION AND SPECIAL REGIME	
ER01	Regulatory framework to regulate the incorporation of PV systems in the city.
ER02	Checking the correct maintenance/functioning of solar installations arising from the Solar Thermal Ordinance (OST).
ER03	Proposal to simplify the process of connecting small facilities ER.
ER04	Promote the installation of small PV power on community roofs.
ER05	Diagnostic and Analytic Study on solar thermal power systems.
ER06	Promoting PV installations of medium and large power with participation schemes.
ER07	Study of the solar thermal energy potential in Barcelona.
ER08	Guide rehabilitation of Thermal solar power systems rehabilitation guide.
ER09	Adaptation of the Solar Thermal Ordinance text.
ER10	Solar thermal installations monitoring open platform.
ER11	Feasibility study of the scenario of STI's operated by third parties.
ER12	Solar Ordinance Integrated Manager (SOIM).
ER13	Implementation pilot project of mini-wind power on roofs.
ER14	Pilot project for implementing mini-wind power in industrial areas.
THE TRANSPORT SECTOR	
TR01	Emission controls on the most polluting vehicles and traffic intervention alternative analysis, seeking consensus to implement them.
TR02	Sectoral agreements to reduce the use of diesel in vehicle fleets.
TR03	Environmental labels awarded to less polluting cars.
TR04	Rethinking the distribution of goods.
TR05	Facilitating the introduction of new technologies that produce less pollution, such as electric motorcycles.
TR06	Reduction of empty taxi traffic.
TR07	Test Pilot on traffic management with traffic light control and environmental criteria.
TR08	More efficient TMB bus network model.
TR09	Continue the TMB policies of replacing the bus fleet with cleaner technologies.
TR10	Improve road and TMB stops street furniture infrastructure.
TR11	Company fleets of electric bicycles instead of motorcycles.
TR12	Support the introduction of cleaner fuels at service stations.
TR13	Street cleaning along busy streets using groundwater to reduce the re-suspension of particulates.
TR14	Network of public charging points for electric vehicles.

TR15	Agreement to reach a variable fee at Barcelona incoming toll booths based on vehicle occupancy and vehicle type.
TR16	Promote efficient and economical driving courses.
TR17	Review and implementation of the Barcelona Biking Strategic Plan.
TR18	Barcelona Urban Mobility Plan (PMU) projects.
THE WASTE SECTOR	
RSU1	PROGREMIC 2007-2012 (Programme of Municipal Waste Management in Catalonia).
RSU2	PMGRM 2009-2016 (Metropolitan Municipal Waste Programme). Weighted in Barcelona.
RSU3	Possible expansion of the capacity of certain facilities in the period from 2017/2019. Weighted in Barcelona.
THE GENERAL SECTOR	
GE01	Monitoring the PECQ and the energy monitoring programme in the city.
GE02	Programme to monitor the local emissions inventory in Barcelona and their dispersion.
GE03	Real time information on current air quality and forecasts.
GE04	PECQ website.
GE05	Programme of awareness and communication about energy, consumption, and their environmental effects.
GE06	viability to look at defining a regulatory framework to ensure the utmost energy efficiency in buildings in accordance with their use.
GE07	Agreement between administrations to monitor all the energy certification of buildings.
GE08	Environmental works to reduce emissions of pollutants.
GE09	Setting energy and environmental efficiency criteria in new urban projects.
GE10	Strategic study on adaptation to climate change in the city of Barcelona.
GE11	Energy saving advisor for homes and commercial premises.
GE12	Consumption comparisons, platform for comparing energy consumption and environmental impact.
GE13	Pilot test on photocatalytic building materials to reduce the presence of NO_x in the air.
GE14	Educational programme for exchanging experiences and ratios of consumption and emissions in schools.
PUBLIC BUILDINGS	
PU01	Implementing Government measures for savings and efficiency in municipal buildings.
PU02	Carrying out the energy saving work table and the role of energy manager of the municipal facilities.
PU03	Write the protocol for municipal building and building reception.
PU04	Writing a protocol for communication, awareness and good practice.
PU05	Introducing monitoring systems for municipal installations - Energy Management Systems (EMS).
PU06	Implement energy saving and efficiency measures in municipal facilities.
PU07	Implementing systems to generate high thermal efficiency.
PU08	Implement measures of renewable energy.
PU09	Spread the establishment of energy service companies at municipal facilities.
PU10	To encourage the purchase of green energy.
PU11	Collection, centralization and data processing of municipal energy consumption in the Energy Observatory.
PU12	Pilot project for a generation system for cooling from solar concentration.
PU13	Pilot project to install solar concentration for the production of electricity.
PUBLIC SERVICES	
SE01	Improved energy efficiency of ornamental fountains.
SE02	Ongoing replacement of traffic lights that use incandescent bulbs with ones that use LED lighting.
SE03	Installation of 8 MW of PV on equipment and other municipal areas.
PUBLIC LIGHTING	
EN01	Modernization and improvement of public lighting equipment.
EN02	Light pollution reduction measures.
PUBLIC VEHICLE FLEET	
FL01	Environmentalisation of municipal vehicles.
FL02	Diffusion of current technologies (renewable fuels, hybrid vehicles, etc.) and providing better professional resources and knowledge in the energy technology sectors to people responsible for acquiring municipal vehicles.
FL03	Feasibility study of the use of biogas generated at Barcelona eco-parks and at the closed Garraf landfill to propel the municipal fleet.
FL04	Rationalisation programme of the local internal mobility.
FL05	Entering a new cleaning contract based on the use of environmentalised vehicles.

6.2.2 - ENVIRONMENTAL ACTION PRIORITISATION

Project groups

After having assessed PECQ projects in terms of their objectives, a hierarchy of priorities from an environmental perspective is needed. With regard to this, three levels of importance and priority have been identified: projects that are essential for their instrumentality or functionality, those that are essential for consistency and continuity with previous actions, and those that are essential for reaching each of the Plan's individual objectives (energy, air quality and climate change).

- **PROJECTS THAT ARE ESSENTIAL FOR THEIR INSTRUMENTALITY/ FUNCTIONALITY**

  In this section, reference is made, in particular, to the projects in the Plan that are included in programmes concerned with information and communication, education and demand in consumption. These projects are listed below:

- GE04. PECQ website.
- GE05. Programme of awareness and communication about energy, consumption, and their environmental effects.
- PU04. Writing a protocol for communication, awareness and good practice.
- FL02. Diffusion of current technologies (renewable fuels, hybrid vehicles, etc.) and providing better professional resources and knowledge in the energy technology sectors to people responsible for acquiring municipal vehicles.
- TR03. Environmental labels awarded to less polluting cars.
- GE12. Consumption comparisons, platform for comparing energy consumption and environmental impact.
- GE15. Educational programme to exchange experiences and energy and emissions ratios in schools.
- TR06. Promoting the running of courses about efficient and economic driving.
- RES1. Consumption display units inside homes.
- GE12. Energy saving advisor for homes and commercial premises.

- **KEY PROJECTS TO ENSURE CONSISTENCY AND CONTINUITY OF ACTIONS**

  This area includes projects that are given priority - even though most of them are not key projects in terms of energy consumption, climate change or air quality, neither do they form part of structural projects – on account of their functionality in education or awareness. These projects represent a total final energy saving of 8,580 MWh/year, a reduction of 5,531,150 kg/year of GHGs, and a reduction of 97,470 kg/year of NO_x.

- ENO_2. Light pollution reduction measures.
- ERO2. Checking the correct maintenance/functioning of solar installations arising from the Solar Thermal Ordinance (OST).
- FL01. Environmentalisation of municipal vehicles.
- FL05. Entering a new cleaning contract based on the use of environmentalised vehicles.
- RES3. Proposal for a regulatory framework for energy improvements in building rehabilitation.
- RES4. Improvements in energy efficiency in housing refurbishments.
- SEO2. Ongoing replacement of traffic lights that use incandescent bulbs with ones that use LED lighting.
- TRO2. Sectoral agreements to reduce the use of diesel in vehicle fleets.

- **PROJECTS THAT ARE ESSENTIAL IN ORDER TO REACH INDIVIDUAL PECQ OBJECTIVES**

  Following an analysis of those projects that stand out in each of the financial[57], energy and environmental parameters, a list comprising the following projects has been drawn up. The values represent the percentage contribution of each of the projects in relation to the overall value for each parameter.

57. The parameters "Δ cost € total/kg CO_{2eq} reduction" and "Δ cost € Council/kg CO_{2eq} reduction" are used to refer to the extra cost of applying the measure compared with not applying it. The terms used are not economic but, rather, refer to the cost of reducing a tonne of CO_{2eq} by means of the measure.

TABLE 88 | LIST OF PROJECTS THAT ARE ESSENTIAL IN ORDER TO REACH THE MAIN INDIVIDUAL OBJECTIVES OF THE PECQ

	Energy			CO_2 and reduction cost			Air quality		
	Electricity generation	Final energy savings	Primary energy savings	CO_{2eq} emission reduction	Δ cost € total/reduced kg CO_{2eq}	Δ cost € City Council/reduced kg CO_{2eq}	NO_x emission reduction	PM_{10} emission reduction	$PM_{2.5}$ emission reduction
COM4 - Installation of micro cogeneration systems (micro-CHP) at athletic centres.	12	-11	1	-1	- 3	-	-1		
EN01 - Modernization and improvement of public lighting equipment.		10	9	4					
ER01 - Regulatory framework to regulate the incorporation of PV systems in the city.	10		4	4	5				
IND5 - Promoting cogeneration in the industrial sector.	31	-22	3	1	4		-6		
IND8 - Separation of coloured and clear bottles to improve septic performance.		22	9	12			1		
PU06 - Implement energy saving and efficiency measures in municipal facilities.		10	7	5	2	3			
SE03 - Installation of 8 MW of PV on equipment and other municipal areas.	12		5	5					
TR01 - Emission controls on the most polluting vehicles.							79	70	74
TR02 - Sectoral agreements to reduce the use of diesel in vehicle fleets.		7	2	5	2		9	4	4
TR06 - Reduction of empty taxi traffic.		26	9	18			8	5	5
TR13 - Street cleaning along busy streets using groundwater to reduce the re-suspension of particulates.								16	17
XAR1 - Zona Franca Power Plant- Gran Via L'Hospitalet.	19	15	18	14	2	1	-2	-5	-5
XAR2 - Extension of the DHC system to the La Sagrera.		12	8	6	1				
Total	**84**	**69**	**75**	**73**	**13**	**4**	**88**	**90**	**95**

- **OTHER PROJECTS CONSIDERED IMPORTANT ON ACCOUNT OF THEIR ENVIRONMENTAL CONTRIBUTION**

  This point contrasts the contribution of various projects with respect to the following parameters:

- Energy:
  - Electricity generation (MWh/year)
  - Total final energy saving (MWh/year)
  - Total primary energy saving (MWh/year)
- Climate change:
  - Savings of GHGs.
- Air quality:
  - Savings of NO_x emissions
  - Savings of PM_{10} emissions
  - Savings of $PM_{2.5}$ emissions
- Relationship between economic cost and efficiency:
  - Total extra cost of saving 1MWh by means of a specific measure (Δ€ totals / MWh saved over lifespan).
  - Total extra cost to the Council of saving 1MWh by means of a specific measure (Δ€ Council / MWh saved over lifespan).
  - Total extra cost of saving 1 t of GHG by means of a specific measure (Δ€ totals / kg GHG reduction over lifespan).
  - Total extra cost for the Council of saving 1t of GHG by means of a specific measure (Δ€ Council / kg GHG reduction over lifespan).

TABLE 89 | CHARACTERISATION OF NEW PROJECTS IN RELATION TO ENERGY, ENVIRONMENTAL AND ECONOMIC PARAMETERS.

The blue bars represent a positive contribution to the parameter, whilst the red bars show a negative contribution.

		Electricity generation (Mwh/y)	Final energy savings (Mwh/y)	Total primary energy savings (Mwh/y)	CO_2 savings and emissions	NO_x savings and emissions	PM_{10} savings and emissions	$PM_{2,5}$ savings and emissions	Δ eur total/MWh saved along service life	Δ eur City Council/MWh saved along service life	Δ eur total/kg CO_{2eq} reduced along service life	Δ eur City Council/kg CO_{2eq} reduced along service life
COM1	To create a regulatory framework for DHC in the commercial and services sector.											
COM2	Installing tri-generation systems (CCHP) in large hotels in lieu of renovating ordinary installations with obsolete equipment.	blue	red	blue	red	red	red	red				
COM3	To encourage the installation of solar thermal systems in existing athletic clubs.		blue	blue	blue	blue	blue	blue	red	red	red	red
EN02	Light pollution reduction measures.		blue	blue	blue							
ER02	Checking the correct maintenance/functioning of solar installations arising from the Solar Thermal Ordinance (OST).		blue	blue	blue	blue	blue	blue	red	red	red	red
ER03	Proposal to simplify the process of connecting small facilities ER.											
ER04	Promote the installation of small PV power on community roofs.	blue		blue	blue				red		red	
ER05	Diagnostic and Analytic Study on solar thermal power systems.											
ER06	Promoting PV installations of medium and large power with participation schemes.											
ER07	Study of the solar thermal energy potential in Barcelona.											
ER08	Guide rehabilitation of Thermal solar power systems rehabilitation guide.											
ER09	Adaptation of the Solar Thermal Ordinance text.											
ER10	Solar thermal installations monitoring open platform.		blue	blue	blue	blue			red	red	red	red
ER11	Feasibility study of the scenario of STI's operated by third parties.											
ER12	Solar Ordinance Integrated Manager (SOIM).											

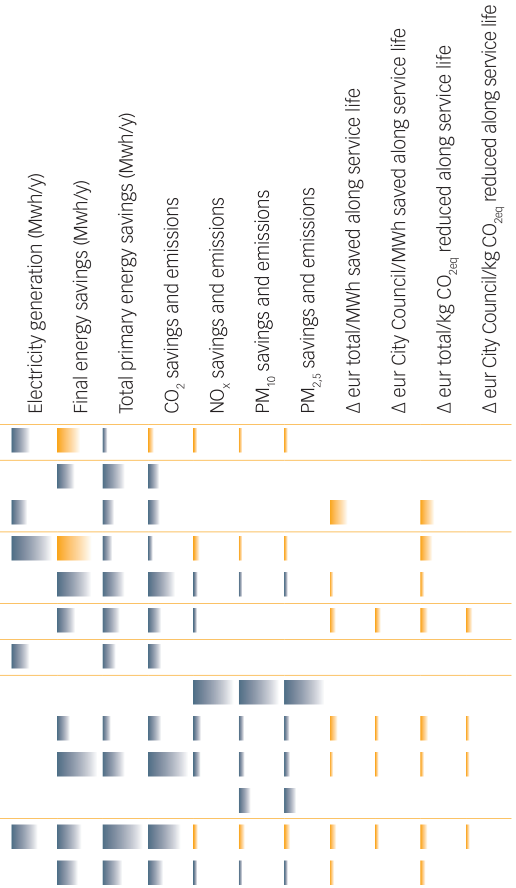
ER13	Implementation pilot project of mini-wind power on roofs.
ER14	Pilot project for implementing mini-wind power in industrial areas.
FL01	Environmentalisation of municipal vehicles.
FL02	Diffusion of current technologies and providing better professional resources and knowledge in the energy technology sectors to people responsible for acquiring municipal vehicles.
FL03	Feasibility study of the use of biogas generated at Barcelona eco-parks and at the closed Garraf landfill to propel the municipal fleet.
FL04	Rationalisation programme of the local internal mobility.
FL05	Entering a new cleaning contract based on the use of environmentalised vehicles.
GE01	Monitoring the PECQ and the energy monitoring programme in the city.
GE02	Programme to monitor the local emissions inventory in Barcelona and their dispersion.
GE03	Real time information on current air quality and forecasts.
GE04	PECQ website.
GE05	Programme of awareness and communication about energy, consumption, and their environmental effects.
GE06	Viability to look at defining a regulatory framework to ensure the utmost energy efficiency in buildings in accordance with their use.
GE07	Agreement between administrations to monitor all the energy certification of buildings.
GE08	Environmental works to reduce emissions of pollutants.
GE09	Setting energy and environmental efficiency criteria in new urban projects.
GE10	Strategic study on adaptation to climate change in the city of Barcelona.
GE11	Energy saving advisor for homes and commercial premises.
GE12	Consumption comparisons, platform for comparing energy consumption and environmental impact.
GE13	Pilot test on photocatalytic building materials to reduce the presence of NOx in the air.
GE14	Educational programme for exchanging experiences and ratios of consumption and emissions in schools.
IND1	Energy service companies in the industrial sector.
IND2	Energy efficiency agreement with other entities in the industrial sector.
IND3	Industrial sector energy efficiency management systems.
IND4	Increasing energy efficiency in production processes.
IND6	Sludge drying for energy rationalisation.
IND7	Photovoltaic (PV) solar energy in industrial roofing.
IND9	The energy savings in painting booths in small/medium size auto body shops.
PU01	Implementing Government measures for savings and efficiency in municipal buildings.
PU02	Carrying out the energy saving work table and the role of energy manager of the municipal facilities.
PU03	Write the protocol for municipal building and building reception.

PU04	Writing a protocol for communication, awareness and good practice.
PU05	Introducing monitoring systems for municipal installations - Energy Management Systems (EMS).
PU07	Implementing systems to generate high thermal efficiency.
PU08	Implement measures of renewable energy.
PU09	Spread the establishment of energy service companies at municipal facilities.
PU10	To encourage the purchase of green energy.
PU11	Collection, centralization and data processing of municipal energy consumption in the Energy Observatory.
PU12	Pilot project for a generation system for cooling from solar concentration.
PU13	Pilot project to install solar concentration for the production of electricity.
RES1	Consumption display units inside homes.
RES2	Thorough monitoring system for the energy efficiency measuring application in the residential sector.
RES3	Proposal for a regulatory framework for energy improvements in building rehabilitation.
RES4	Improvements in energy efficiency in housing refurbishments.
RSU3	Possible expansion of the capacity of certain facilities in the period from 2017/2019.
SE01	Improved energy efficiency of ornamental fountains.
SE02	Ongoing replacement of traffic lights that use incandescent bulbs with ones that use LED lighting.
TR03	Environmental labels awarded to less polluting cars.
TR04	Rethinking the distribution of goods.
TR05	Facilitating the introduction of new technologies that produce less pollution, such as electric motorcycles.
TR07	Test Pilot on traffic management with traffic light control and environmental criteria.
TR10	Improve road and TMB stops street furniture infrastructure.
TR11	Company fleets of electric bicycles instead of motorcycles.
TR12	Support the introduction of cleaner fuels at service stations.
TR14	Network of public charging points for electric vehicles.
TR16	Promote efficient and economical driving courses.
TR17	Review and implementation of the Barcelona Biking Strategic Plan.
XAR3	Information system about the network and the quality of the energy systems (electricity and gas).
XAR4	Software programme supporting the electric infrastructure tracking.
XAR5	Modernisation of electricity and gas supply incident communication protocol.
XAR6	To encourage the connection of the household sector to the DHC network.
XAR7	Communication programme to promote the installation of microCHP systems to replace old thermal-based equipment.

TABLE 90 | CHARACTERISING OF KEY PROJECTS TO MEET THE THREE MAIN PECQ OBJECTIVES IN RELATION TO ENERGY, ENVIRONMENTAL AND ECONOMIC PARAMETERS

The blue bars represent a positive contribution to the parameter, whilst the orange bards show a negative contribution.

COM4	Installation of micro cogeneration systems (micro-CHP) at athletic centres.
EN01	Modernization and improvement of public lighting equipment.
ER01	Regulatory framework to regulate the incorporation of PV systems in the city.
IND5	Promoting cogeneration in the industrial sector.
IND8	Separation of coloured and clear bottles to improve septic performance.
PU06	Implement energy saving and efficiency measures in municipal facilities.
SE03	Installation of 8 MW of PV on equipment and other municipal areas.
TR01	Emission controls on the most polluting vehicles.
TR02	Sectoral agreements to reduce the use of diesel in vehicle fleets.
TR06	Reduction of empty taxi traffic.
TR13	Street cleaning along busy streets using groundwater to reduce the re-suspension of particulates.
XAR1	Zona Franca Power Plant- Gran Via L'Hospitalet.
XAR2	Extension of the DHC system to the La Sagrera.



Special mention is made of the following four projects:

- GE11. Energy saving advisor for homes and commercial premises.
- PU05. Introducing monitoring systems for municipal installations.
- TR05. Facilitating the introduction of new technologies that produce less pollution, such as electric motorcycles.
- IND4. Increasing energy efficiency in production processes.

Carrying out these projects will make it possible to increase the final energy saving by 22%, the primary energy saving by 12% and CO_2 emissions savings by 11%. Implementing the key projects and these four other projects will account for more than 85% of the energy saving and, for the PECQ's new projects, a saving of 84% in CO_2 emissions.

Synthesising the priority projects

The 33 priority projects are summarised below along with the reasons why each project is important. It should be noted that this list comprises a set of important projects with respect to the set of new PECQ projects that have been drawn up from an environmental perspective in accordance with earlier analyses. It is not in any particular order of environmental importance or degree of commitment. The projects are in sector order.

Some of them have a double function. There are seven projects (EN01, GE12, IND4, PU05, PU06, TR02, TR05) that, on the one hand, have been given a significant quantitative evaluation in terms of energy, climate change or air quality, and, on the other, have a functional structure on account of their pedagogical or awareness value, or that provide continuity with the environmental actions and policies carried out to date.

TABLE 91 | SUMMARY OF PROJECT PRIORITISATION FROM AN ENVIRONMENTAL PERSPECTIVE

	Energy objective	Climate change objective	Air quality objective	Instrumentality or functionality	Administration consistence
COM4. Installation of micro cogeneration systems (micro-CHP) at athletic centres.	■				
EN01. Modernization and improvement of public lighting equipment.	■				■
EN02. Light pollution reduction measures.					■
ER01. Regulatory framework to regulate the incorporation of PV systems in the city.	■				
ER02. Checking the correct maintenance/functioning of solar installations arising from the Solar Thermal Ordinance (OST).					□
FL01. Environmentalisation of municipal vehicles.					■
FL02. Diffusion of current technologies (renewable fuels, hybrid vehicles, etc.) and providing better professional resources and knowledge in the energy technology sectors to people responsible for acquiring municipal vehicles.				■	
FL05. Entering a new cleaning contract based on the use of environmentalised vehicles.					■
GE04. PECQ website.				■	
GE05. Programme of awareness and communication about energy, consumption, and their environmental effects.				■	
GE12. Consumption comparisons, platform for comparing energy consumption and environmental impact.	□	□		■	
GE13. Pilot test on photocatalytic building materials to reduce the presence of NO_x in the air.				■	
GE14. Educational programme for exchanging experiences and ratios of consumption and emissions in schools.				■	
IND4. Increasing energy efficiency in production processes.	□	□			
IND5. Promoting cogeneration in the industrial sector.	■				
IND8. Separation of coloured and clear bottles to improve septic performance.	■	■			
PU04. Writing a protocol for communication, awareness and good practice.				■	
PU05. Introducing monitoring systems for municipal installations. Energy Management Systems (EMS).	□	□		■	
PU06. Implement energy saving and efficiency measures in municipal facilities.	■			■	
RES1. Consumption display units inside homes.				■	
RES3. Proposal for a regulatory framework for energy improvements in building rehabilitation.					■
RES4. Improvements in energy efficiency in housing refurbishments.					■
SE02. Ongoing replacement of traffic lights that use incandescent bulbs with ones that use LED lighting.					■

	Energy objective	Climate change objective	Air quality objective	Instrumentality or functionality	Administration consistence
SE03. Installation of 8 MW of PV on equipment and other municipal areas.					
TR01. Emission controls on the most polluting vehicles.					
TR02. Sectoral agreements to reduce the use of diesel in vehicle fleets.					
TR03. Environmental labels awarded to less polluting cars.					
TR05. Facilitating the introduction of new technologies that produce less pollution, such as electric motorcycles.					
TR06. Reduction of empty taxi traffic.					
TR13. Street cleaning along busy streets using groundwater to reduce the re-suspension of particulates.					
TR16. Promote efficient and economical driving courses.					
XAR1. Zona Franca Power Plant- Gran Via L'Hospitalet.					
XAR2. Extension of the DHC system to the La Sagrera.					

Those projects that stand out because they make an important contribution to meeting the individual objectives for energy, air quality and climate change are highlighted in green/orange/purple, respectively. The same colours, but in a lighter shade, are used to indicate those projects that complement those highlighted in meeting the objectives. The projects in blue in the fourth column have a functionality or instrumentality that is essential and intrinsic to the Plan, to its development or to the question of communicating it to the public. Projects shown in a reddish colour indicate those projects that stand out on account of the Council's consistency in terms of environmental policy and actions carried out to date.

6.2.3 - DIRECTIVES AND RECOMMENDATIONS

Although all the projects in the action strategy are carried out based on specific environmental objectives that are expected to be met when the project is implemented in full, the PECQ covers a ten-year period, during which time the context can change in all areas.

Below is a set of directives and recommendations that may be of use if the monitoring reports reveal trends that are different from those that are expected with regard to meeting the objectives for 2020, either because the projects have not had the desired effect or because the environmental or energy context has undergone extreme changes (extreme pollution, peaks in energy consumption, peak oil, etc.) and new measures are called for.

- **Initiatives proposed throughout the process of drawing up the PECQ but that were not included in the projects**
  - Efficiency stamp from the Barcelona Energy Agency. Stamp that catalogues energy efficiency (financial saving) in homes.
  - AEB *Showroom*. Space for experimenting with best practices in energy consumption.
  - Following up fuel cell technology.
  - Bicycle fleets for companies.
  - Incentivising videoconferencing systems in companies or shared public spaces.
  - Municipal renewal plan for domestic appliances.
  - Introduction of energy efficiency criteria and renewable energy in the rehabilitation of city markets.
  - Introduction of solar thermal systems in parks and gardens work centres.
- **Possibility of making PECQ projects more environmentally ambitious**
  - RES2 – Subsidising energy audits, and the work of an energy advisor in particular, in older buildings or those where energy demand is higher. Regional distribution of subsidies depending on the energy restructuring of each neighbourhood.
  - RES4 – Municipal bylaw that incentivises energy efficiency in rental accommodation. Considering measures such as: carrying out compulsory energy audits that must be attached to rental contracts; demanding a minimum level of energy efficiency for rental accommodation, etc.
  - IND7 – Photovoltaic panels on the roofs of surface car parks (e.g. Llobregat desalination plant).
  - IND8 – Return of deposit/refund systems (DDR) to save energy and promote bottle re-use. This would not only bring about the separation of clear and coloured bottles, it would also minimise the need to melt down bottles and make new ones.
  - COM – Regulation of air conditioning in public buildings and on public transport. Limiting the difference between exterior and interior temperatures (e.g. in the underground: street-platform-train). With regard to offices, carrying out a multi-criteria study to look at the need to turn off all lights at night without creating a security risk.
  - TR01 – Working with Technical Vehicle Inspection (ITV) centres in order to bring pressure to bear on owners of vehicles that do not pass the ITV owing to problems associated with pollution, as recorded on the ITV. Turn the ITV into the ITAV (Technical and Environmental Vehicle Inspection) in order to ensure that vehicles on the road are as unpolluting as possible, bearing in mind the age and type of the vehicle. Use of environmental radars that also incorporate an acoustic element. Incentivising the replacement of lorries.
  - TR06 – Studying the viability of introducing collective taxis. Routes would be based on demand at rush hour and on complex combinations with Collective Public Transport (e.g. journeys around the ring roads). This would make it possible to try out new routes, assess the demand and then establish routes based on demand.
  - TR06 – Setting up financial incentives to promote the use of taxi ranks to stop taxis driving around and consuming fuel unnecessarily (lower fixed fare at taxi ranks). Introducing more taxi ranks to accommodate higher demand.

- TR08. More efficient bus network model.
  - Laying out information about all the public transport networks (integrated plan for bus, metro, tram, train and even Bicing [community bicycle programme], as well as taxi ranks and all collective public transport vehicles).
  - Introducing genuine park & ride schemes at city access points that connect with BRT systems.
  - Concluding the introduction of the iBus system at all public transport stops.
  - Segregation of traffic to favour collective public transport. Studying the possibility of setting aside complete lanes for collective public transport, taxis and services. Looking at the option of introducing HOV (High Occupancy Vehicle) lanes with traffic light priority systems to promote higher occupancy of private vehicles in the city.
  - Semi-direct buses (e.g. the bus follows the same route every hour but stops at only half the stops).
  - Improving the Bicing scheme to turn it into an efficient and reliable service that complements other collective public transport systems.
- TR16 – Extending driving efficiency courses for commercial vehicles and taxis, etc. Incentivising research and technology that monitors driving efficiency. Monitoring average fuel consumption of taxis.
- EN – Education and awareness with regard to energy consumption over Christmas. Restriction of timetables and lighting to reflect the Council's energy saving policy.

- **New lines of action**
  - Studying the best way of introducing environmental and energy aspects into the tax system to promote the saving and responsible consumption of resources.
  - Incentivising teleworking as a measure to combine work and family life, reducing compulsory mobility and making working hours more flexible. Starting part-time teleworking pilot studies (1-2 days a week).
  - Promoting the introduction of green roofs where viable (and where they do not prevent the installation of solar energy systems) to promote lower energy demand and counteract the heat island effect. This will also increase the amount of green space in Barcelona and improve air quality.
  - In the event that the monitoring reports show that meeting the 2020 quality targets is unviable, the possibility of introducing tolls at city access points will be looked at, together with a park & ride system that connects efficiently with the public transport network and with BRT buses that run non-stop to key locations in the city. Incentivising these locations as intermodal stations and providing incentives so that interurban transport companies stop there, allowing passengers to connect with the public transport system.

This list shows options that lend flexibility to the policies proposed in the PECQ via the projects outlined. They help make it possible to meet the 2020 objectives, as well as the objectives for energy and environmental quality set down in international commitments and in current legislation

Conclusions in reflections for the future

Cities in a changing global energy environment

Idea 1 – THE ENERGY SCENARIO IS CHANGING: AND CITIES ARE ADAPTING

Energy drives the city's systems. All human activity by those who live there depends on it. After all, without energy, there is no city. The energy requirements of these systems have been increasing continuously over recent decades in line with their increasing complexity. All the forecasts suggest this trend will continue as the city's population continues to increase progressively and European cities undergo a process of metropolitanisation.

Nevertheless, the international energy and socio-environmental scenario is changing. The energy resources that, over recent decades, have met a demand that has grown exponentially are running out or are insufficient to satisfy global expectations that are far removed from a genuinely sustainable vision of energy use. At the same time, confirmation of the global impact on the climate of greenhouse gases associated with the intensive and widespread use of fossil-based resources, as well as the effects of local pollutants on the health of the population (something about which increasing amounts of information is emerging) is accelerating changes that will profoundly modify people's relationship with energy over the years to come.

In this context, if cities - increasingly the focus of future human development - want to maintain their dynamism and activity, they need to adapt quickly to these changes and tackle the question of energy (and, consequently, the environment) as one of their main policy areas.

Idea 2 – EFFICIENCY, SAVINGS AND LOCAL RESOURCES: CITIES TAKING ACTION

Using energy resources rationally – i.e. reducing intensity and increasing efficiency – makes it possible to face the challenges of the future better able to adapt to change. This is the main alternative that the cities have at their disposal to reducing the impact of their metabolism.

Technology and, in particular, a proactive attitude on the part of the public and social and economic players, have a key role to play to successfully internalise efficiency in everyday city activities, both individual and collective. Measuring the economic and social benefits of this strategy turns energy savings into a competitive element for organisations and for the city as a whole.

Besides creating efficient consumers, urban systems can also become energy generation centres by taking advantage of local resources and technologies that are highly efficient and available. Solar energy, cogeneration, turning waste into energy, district heating and cooling systems, or even small-scale wind energy, offer cities the opportunity to reduce their dependence on outside energy and the diversify their production centres.

Idea 3 – SUSTAINABLE MOBILITY AND MORE EFFICIENT BUILDINGS: CITIES MOVING FORWARD

Mobility of people and goods, and the use of buildings and urban amenities head the list of energy consumption in cities. The concentration of activities and people in a limited space and, at the same time, the configuration of large cities as centres of attraction for all manner of activities, generate a demand for energy that has not ceased to grow over recent years.

Correcting this trend requires changing consumption habits and introducing new technologies that make it possible to move towards a more efficient use of the available resources. On the one hand, this applies to the mobility of people and goods, as price forecasts and the availability of fossil fuels introduce factors of uncertainty that need to be managed appropriately. Promoting more sustainable means of transport and urban systems need to be one of the challenges tackled by local governments.

And on the other, it applies to the energy management of buildings and equipment, given that households, businesses and services have increased the amount of global energy they consume on account of their growing demand for air conditioning and the increase in electric and electronic equipment. Becoming aware of the costs of energy and of its local and global impact must, therefore, be a priority when making savings and efficiency the main local energy resource in cities.

Idea 4 – AIR QUALITY AND CLIMATE CHANGE: THE RESPONSIBLE CITY

Reducing energy consumption has a direct relationship on reducing polluting emissions and emissions of greenhouse gases. It also has an effect on the health of those who live in the city. This is an undisputed fact.

Decarbonising economic activity and production in the city - i.e. reducing the consumption of fossil fuels – is an essential step towards improving air quality and curbing greenhouse gas emissions. Besides the advantages arising from the efficient use of energy and from making the most of local energy resources – both from an economic perspective and also in terms of dependency on other countries – these two aspects require special emphasis given that they contribute to creating a more healthy urban environment and that they reduce the global impact of local activity.

The responsibility of cities when it comes to energy is not limited, therefore, to its geographical area; it goes further, as in the case of the demand for and consumption of material resources or water. Urban systems of the future need to be more conscious than ever of this clear fact and take action to reduce their carbon footprint

The PECQ: planning evidence and managing uncertainty

In a context of changes in how we look at energy and its use in urban systems, the PECQ 2011-2020 for Barcelona has been written in such a way as to be a flexible and adaptable tool. For this reason, ongoing checking and monitoring is required, in the implementation of projects and in terms of the objectives that are met. Only in this way can it adapt itself to a changing global context and correct, in a proactive way, undesired trends and situations. For this reason, the Plan includes a number of indicators designed to facilitate monitoring tasks.

It aims, therefore, to be a road map that, based on knowledge and global and sectoral analysis, defines the actions to take to reach the goals that all local administrations, if they are being socially and environmentally responsible, need to consider when planning and managing the city. This is in addition, naturally, to the objectives that are set by higher-level institutions.

By no means is this considered to be a simple task. A culture of sustainability leads to significant challenges to reverse a number of trends. For this reason, the effort to move towards a more efficient society - with lower greenhouse gas emissions and better air quality - needs to be a collective, shared challenge. In other words, build from a basis of co-responsibility. Fortunately, the seed has already been sown. A great number of individuals, organisations and groups of people have, for many years, been working in the socio-environmental and economic spheres to put forward the need to act proactively to establish a new relationship between human beings, natural resources and ecosystems.

However, when preparing a strategic document like the PECQ, it is of fundamental importance to decide how to treat issues that are incipient in the global panorama – and that cannot be left out of the process of reflection and analysis – but about which too little is yet known for them to be incorporated into the baseline scenario in the planning process. The resilience of urban systems and the future impact of a philosophy of economic decline, on the one hand, and, on the other, the appraisal of environmental services, the calculation of the city's grey energy and the energy flows associated with the material resources consumed by the city, or knowledge of the processes involved in adapting to climate change, are all questions that do not yet resonate strongly, although they will need to be taken into account in future versions of the Plan.

It is clear that uncertainty is inherent in any kind of plan. The planning process sets objectives and concrete action proposals in a specific time frame. It is this time aspect that needs to integrate a degree of uncertainty, in particular in the medium and long term inasmuch as it is always impossible to predict sudden changes and their impact on economic cycles. Global factors are difficult to control and can substantially modify forecasts included in plans. Whilst this could be considered a shortcoming, it can also be seen as positive for the planning process.

In the specific case of the PECQ, as a document that includes other city plans, it needs to incorporate logic and uncertainty. Planning establishes lines and trends for the future, although defining them depends on the opportunities presented at each moment. One means to help overcome this uncertainty is to establish priorities for projects so as to provide the Plan's managers with tools that enable them to put special emphasis on policies that are structural *"building blocks"* and that make a decisive contribution to achieving target trends and strategic lines of action.

The PECQ is still based on an economic model built on an energy system based on carbon - fossil fuels. However, there is a clear need to incorporate long-term strategies that face up to oil depletion and, consequently, more expensive oil. How are cities to adapt to this global situation of oil scarcity? What kind of urban fabric will resist the changes that are to come? Can the impact of this dependency be minimised?

Some of the projects in the PECQ take into account this realistic outlook; they do not, however, do so in depth, so as to avoid giving the Plan a catastrophic tone. The exercise is, however, complex to carry out because it requires coming up with plausible, seamless alternatives, whilst remaining immersed in a very important change at global level. The ITC revolution and social networks are, perhaps, the clearest examples of this change. However, there are other fundamental changes that are taking place that will put an end to a socioeconomic model based on permanent growth and on the externalisation of the consequences. The current economic crisis is the first important reaction to this trend, which is heading towards a new model that internalises, in economic balance sheets and traditional economic indicators (such as GDP) the environmental and social costs of urban systems.

Incipient initiatives such as time banks, fair trade cooperatives, market exchanges, creative commons, Cittaslow (slow city) and BookCrossing, and a great number of others, are the tip of the iceberg of deep social and economic change and transformation. To talk of slowing down would still appear to be utopian. However, any exercise in strategic planning also needs to plan for scenarios that are far removed from reality at any given moment but that are possible scenarios in the future.

In this context, one of the PECQ's main challenges is to ensure that, during the application of its action plan, new trends - or others that may arise – and knowledge acquired of the impact of the measures that are adopted, are incorporated. The transformation of the PMEB into the PECQ is already a clear example of the city's willingness to renew itself and to adapt to change. The PECQ has incorporated new aspects not covered in the PMEB. The methodology has been improved and the Plan has gone into depth into a number of areas that the previous plan only touched upon. One of the priorities has been to acquire in-depth knowledge of the impact of global warming and of the measures cities need to take in order to adapt.

In a globalised world, cities have limited room for manoeuvre. However, against a backdrop of continuous development of urban systems and their complexity, there is still a lot of ground to cover. The PECQ is a clear expression of the willingness and ability of Barcelona to adapt to change and to move towards an urban model that is efficient, healthy and competitive.

Acronyms

AEB: Barcelona Energy Agency

AMB: Metropolitan Area of Barcelona

ARC: Waste Agency of Catalonia

HV/MV/LV: High voltage / Medium voltage / Low voltage

ATM: Metropolitan Transport Authority

CTCC: CHP plant

CTE: Technical Building Code

DHC: District heating and cooling

EMSHTR: Metropolitan of Hydraulic Services and Waste Treatment

EMT: Metropolitan Transport Organization

FGC: Ferrocarrils de la Generalitat de Catalunya

FORM: Organic fraction of municipal waste

GHG: Greenhouse Gas

LPG: Liquefied Petroleum Gas

LNG/CNG: Liquefied Natural Gas / Compressed Natural Gas

ICAEN: Catalan Energy Institute

IPCC: United Nations' Intergovernmental Panel on Climate Change

LDV/HDV/MDV: Light Duty Vehicle / Heavy Duty Vehicle / Medium Duty Vehicle

NIEPI: Number of interruptions equivalent to the installed capacity

OMA: Environmental Ordinance (of Barcelona)

WHO: World Health Organization

OST: Solar Thermal Ordinance (of Barcelona)

PDI: Infrastructure Master Plan of Catalonia

PECQ: Energy, Climate Change and Air Quality Plan of Barcelona 2011-2020

PEMEEM: Barcelona Saving and Improvement Efficiency Plan in Municipal Buildings

GDP: Gross Domestic Product

PMEB: Barcelona Energy Improvement Plan

PMGRM: Metropolitan Municipal Waste Management Programme

PMU: Urban Mobility Plan (of Barcelona)

PROGREMIC: Municipal Waste Management Programme of Catalonia

PROGRIC: Industrial Waste Management Programme of Catalonia

PTSIRMC: Territorial Sectoral Municipal Waste Management Infrastructure Plan of Catalonia

PVE: Municipal waste and the energy recovery plant

RAEE: Waste from Electric and Electronic Devices

SR: Special Regime (of electricity generation)

RMB: Barcelona Metropolitan Area

OR: Ordinary Regime (of electricity generation)

RSD: Remote Sensing Device

MSW: Municipal Solid Waste

GIS: Geographic Information System

TIEPI: Interruption time equivalent to installed capacity

IRR: Internal Rate of Return

TMB: Transports Metropolitans de Barcelona

HOV: High Occupancy Vehicles

XVPCA: Air Pollution Surveillance and Control Network

Chemical nomenclature and units

CH_4: methane

CO_{2eq}: Equivalent carbon dioxide

VOC: Volatile organic compounds

kg: Kilograms

km : Kilometres

kW / MW / GW: Kilowatts / Megawatts (103 kW) / Gigawatts (106 kW) – power unit

kWh / MWh / GWh: Killowatts hour / Megawatts hour (103 kW) / Gigawatts hour (106 kW) – consumption or energy generation unit.

NO_x: nitrogen oxides

O_3: ozone

PM_{10}: solid particles (diameter smaller than 10 µ)

$PM_{2.5}$: solid particles (diameter smaller than 2,5 µ)

t: tonnes

TEU: twenty feet equivalent unit

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SECTORAL STUDIES

Topic	Organisation/s
DWELLINGS	AIGUASOL
	FIP ARQUITECTES
SOCIAL BEHAVIOUR VS. RATIONAL USE OF ENERGY	CREAFUTUR
CHARACTERISATION OF VEHICLE POPULATION	TECHNET
TRANSPORT	BARCELONA REGIONAL + CENIT
INDUSTRY	ISUNO
WASTE	RESA
ECONOMIC ANALYSIS	GABINET ESTUDIS ECONÒMICS
ENERGY SUPPLY SERVICE QUALITY	Electricitat: AGÈNCIA D'ENERGIA DE BARCELONA, INSTITUT QUÍMIC DE SARRIÀ, UNIVERSITAT POLITÈCNICA DE CATALUNYA
	Gas natural: AGÈNCIA D'ENERGIA DE BARCELONA + IDOM
URBAN PLANNING	BARCELONA REGIONAL
VALLBONA ECO-NEIGHBOURHOOD	BARCELONA REGIONAL + COL·LEGI ARQUITECTES DE CATALUNYA + UNIVERSITAT POLITÈCNICA DE CATALUNYA
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Ajuntament de Barcelona

Barcelona pel Medi Ambient

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