The Future of Sustainable Cities: urban energy transition to 2030

Executive Summary

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Contents

Context and objectives

Since 2016 Monitor Deloitte Spain has been carrying out an in-depth analysis of the Energy Transition and its implications. This work has led to the publication of a variety of studies assessing the impact of meeting established climate targets as well as the transformations in the economy and the energy model that are required to meet these targets. This study will expand on these themes.

The focus of the analysis in this study is to understand the future of sustainable cities and their role in the energy transition in Spain. Cities are vital to the world's economies and will have an especially important role to play in driving energy sustainability and meeting climate targets. Indeed, the UN's Sustainable Development Goals include a specific goal for cities: Make cities inclusive, safe, resilient and sustainable.

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Executive summary

Cities will play a critical role in the energy transition

Cities account for 40% of final energy consumption and up to 70% of greenhouse gas (GHG) emissions

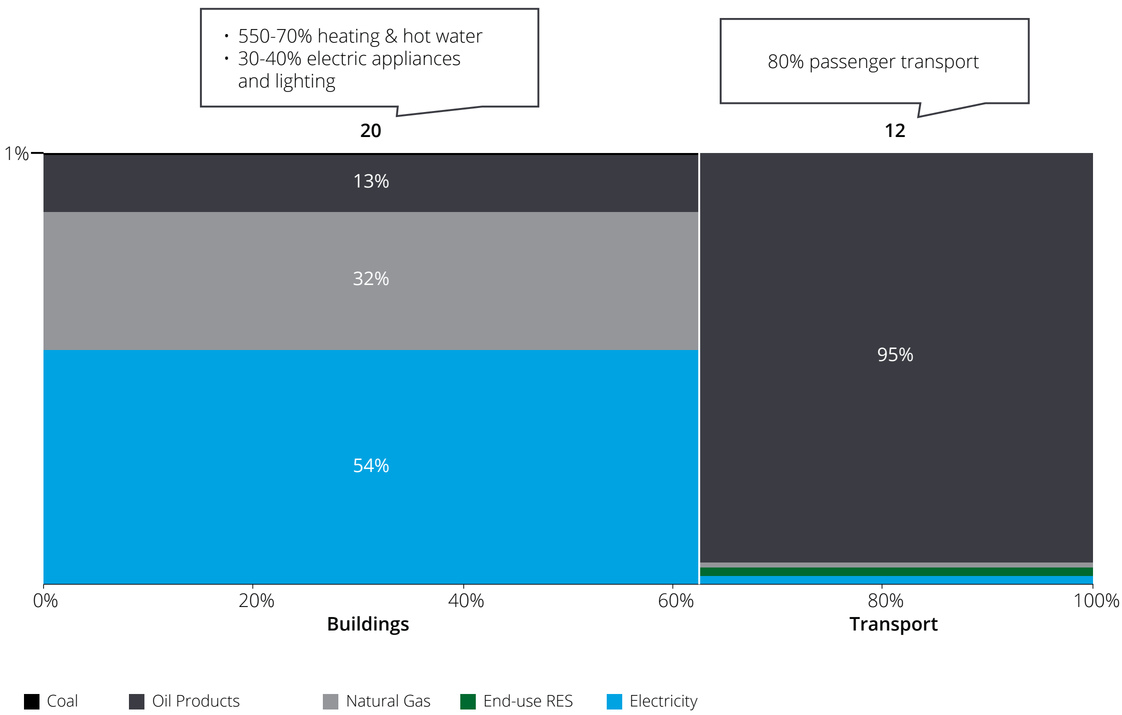
In Spain, cities[1] house 70% of the population and account for **40% of final energy consumption (in buildings and wheeled land transport[2])** and **70% of total GHG emissions** (229 $MtCO_2eq$ of a national total of 324 $MtCO_2eq$ in 2016).

Within energy consumption in buildings (both residential and services), electricity is the predominant energy carrier (54%) followed by natural gas (32%) and oil products (13%), whereas in transport, oil products account for 95% of the total energy consumption (see Exhibit 1)

Of the total GHG associated with cities, **69 $MtCO_2eq$ (~20%** of total GHG emissions in Spain) are **direct emissions** generated in the cities themselves by the major sectors (buildings, land transport and waste management), **30 $MtCO_2eq$ (~10%)** are **indirect emissions** from the electricity generation and refining necessary for consumption in the cities, and **130 $MtCO_2eq$ (~40%)** are **other indirect emissions[3]**, produced outside the cities but necessary to obtain and transport the products consumed there.

Transport and buildings are the sectors with highest contribution towards direct GHG emissions in cities. Emissions from the transport sector amounted to 38 $MtCO_2eq$ in 2016, almost all of them derived from oil products from combustion engines. Buildings directly emitted 21 $MtCO_2eq$, 65% of given emissions

Exhibit 1: Final energy consumption in cities by sector and energy carrier
(Mtep/year; 2016)



Source: MAPAMA; IDAE; Monitor Deloitte analysis

1 Taken to be towns with more than 50,000 inhabitants, including any suburbs they have with more than 1,000 inhabitants.

2 Other sectors that consume energy and emit GHGs in cities, such as waste management, manufacturing and civil aviation, were not included in this study due to their relatively low emissions and/or the fact that municipal authorities are less able to have an influence on them. For example, in 2016 manufacturing and air transport were responsible for 6% and 8% of GHG emissions in Madrid, respectively.

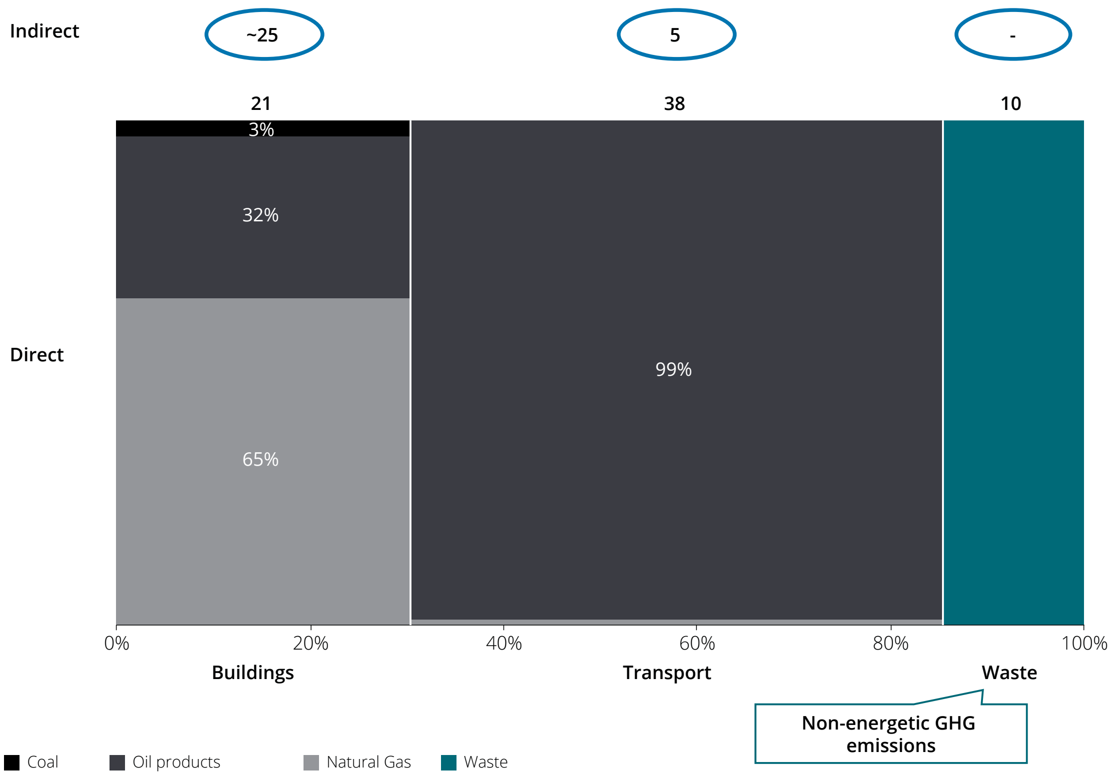
3 Not included in this study.

were derived from natural gas usage and 32% of oil products. Regarding indirect emissions, buildings contributed to 25 $MtCO_2eq$ and transport to 5 $MtCO_2eq$ in 2016 (see Exhibit 2).

Emissions of air pollutants like Particulates Matter (PM) and NO_x are also related to activity in cities. Some **30% of NO_x emissions and 55% of particulates** are produced in less than 10% of Spain's land surface. The concentration of these pollutants **has exceeded legal levels** on various occasions and in various Spanish cities (e.g. NO_x in Madrid and Barcelona) in recent years, with the consequent health risk for the inhabitants of those cities.

The economic growth and rising population in cities will only compound the situation, **making it increasingly important to accelerate the transition to energy sustainability in cities**.

Exhibit 2: GHG emissions in cities by sector and energy carrier
($MtCO_2eq$; 2016)

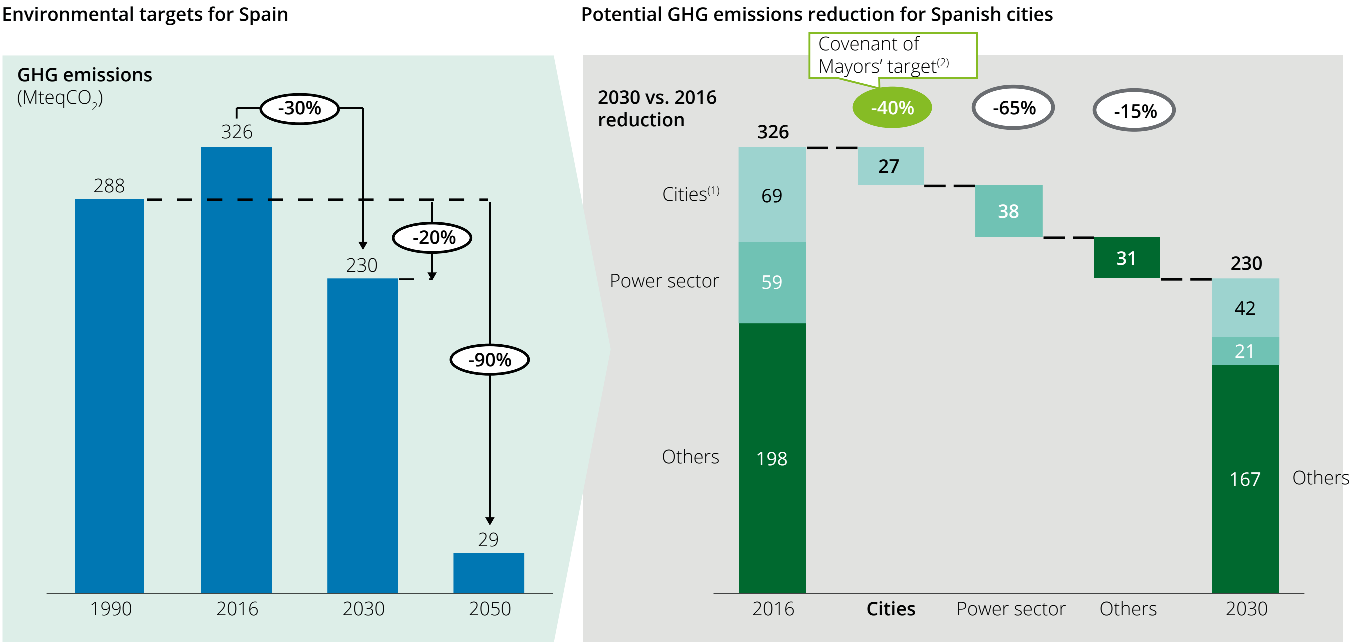


Source: MAPAMA; IDAE; Monitor Deloitte analysis

Cities have committed to ambitious energy sustainability targets

The municipalities that have signed the Covenant of Mayors[4] pledge to reduce **CO_2 emissions by at least 40% by 2030[5]**. The signatories also share the vision that **cities should be emission-free by 2050** (see Exhibit 3). In Spain, the drafts of Climate Change and Energy Transition bill and the Comprehensive National Energy and Climate Plan (PNIEC, introduced in February 2019) aim to reduce GHG emissions in Spain to below 230 $MtCO_2eq$ by 2030 (reduction of GHG emissions by at least 20% compared to 1990, or about 30% compared to 2016). Cities are **better able to achieve this reduction** because their principal emitting sectors already have sufficiently mature technologies for mass deployment (e.g. modal shift to public transport or less polluting vehicles in transport; heating controls or heat pumps in buildings), making the more ambitious targets feasible (40% emissions reduction in cities from 2016 to 2030 vs 30% at national level). This will offset the difficulties faced by other sectors such as manufacturing, heavy freight transportation and non-energy sectors. This study therefore takes the Covenant of Mayors target as the benchmark for reducing emissions[6]. This target means that, **in Spain, the current ~100 $MtCO_2eq$ of direct and indirect emissions in cities will have to hit 60 $MtCO_2eq$ by 2030 and zero by 2050**.

Exhibit 3: Environmental targets for Spain and for Spanish cities



(1) Residential, services and waste sectors direct emissions
(2) Over 1,800 Spanish municipalities have signed the covenant, including 92 cities with population of 50,000+, including the main Spanish cities (Madrid, Barcelona, Sevilla, Valencia, Málaga, Zaragoza…). There is no consensus over the base year for the 40% reduction target

Source: MITECO; Monitor Deloitte analysis

The business-as-usual emissions evolution will not allow Spanish cities to meet the 40% reduction target by 2030

4 European Commission initiative that aims to expedite the urban energy transition process and provide cities' inhabitants with access to safe, sustainable and affordable energy. More than 7,000 local governments from 57 countries have already joined the covenant, including Spain's major cities.

5 Cities do not all use the same base year against which to measure the 40% reduction in emissions undertaken in the Covenant of Mayors, but rather take the first year for which they have available emissions data or inventories. This study takes 2016 as the base year for measuring the 40% reduction in emissions by 2030.

6 The target for cities applies to both their direct and their indirect emissions.

Another way that cities are attempting to become more sustainable is by driving measures to **improve air quality**. Spain's 2030 emissions reduction targets (for the whole country), using 2005 as the base year, are 88% for SO_2, 62% for NO_x and 50% for PM2.5. Cities are most affected by these emissions so therefore are trying to limit them more actively.

Reducing the emissions of GHG and pollutants **should be a government priority**. Cities **have the commitment, the technical capabilities and the need to contribute** to this reduction.

Business as usual is not enough to hit the emissions and air quality targets

We established four types of Spanish cities

We analysed seven Spanish cities (A Coruña, Barcelona, Madrid, Malaga, Seville, Vitoria and Zaragoza) that are representative of conditions in the country's cities in terms of climate (cold / mild) and size (large[7] / midsize). Based on energy consumption and emissions by sector, we can group cities into four types:

- **Large city, cold climate**: comparable emissions in buildings (50%) and transport (50%) due to high heating consumption and commuting levels.
- **Large city, mild climate**: higher emissions in transport (~60%) than buildings (~40%) due to high commuting levels and less need for heating than in colder cities.
- **Midsize city, cold climate**: far higher emissions in buildings (60–70%) than in transport due to greater heating needs and less need for motorised transport within the city itself.
- **Midsize city, mild climate**: higher emissions in transport (60-65%) than in buildings due mainly to reduced heating needs.

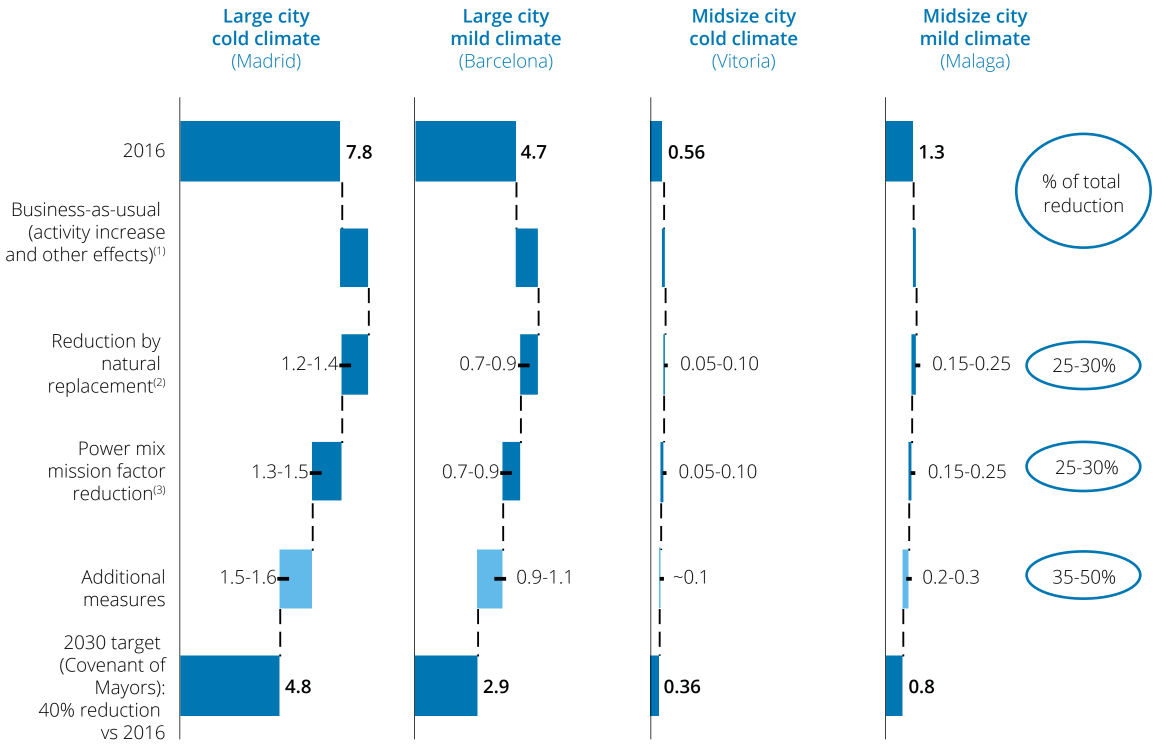
Spanish cities are already working on measures to improve energy sustainability

The cities under analysis are already working to improve energy sustainability, and best practices can be observed:

- In terms of municipal support for sustainability, for example, **Madrid publishes a regular energy consumption and emissions inventory**, which is put together according to European Environment Agency guidelines. The **Barcelona municipal bus depot is one of the most sustainable in Europe**, and the city is working to develop electric bus lines.
- In terms of **buildings, Zaragoza** has made noteworthy strides. For example, it has earmarked funds to refurbish more than 3,500 buildings that are over 40 years old with a focus on energy sustainability. It has also constructed 10,000 new bioclimatic homes in the Valdespartera ecocity, with energy savings of up to 90%.
- In transport terms, **Vitoria is notable for promoting non-motorised transport**, which went from making up 52% of journeys in 2006 to 65% in 2016, boosted by the city council's Sustainable Mobility Plan. **Seville stands out for its promotion of cycling**, with the highest modal share of cyclists among the cities analysed, and **Malaga made noteworthy strides in sustainable mobility** with the Zem2All project (pilot project with 200 electric cars and 243 charging points).

7 More than one million inhabitants.

Exhibit 4: Direct and indirect GHG emissions in Spanish cities
($MtCO_2eq$/year)



(1) Other effects include a 15% reduction of emissions from waste, in line with other non-energy sectors
(2) Includes replacement of boilers every 15-20 years, home appliances every 10-15 years and cars every 13-18 years
(3) Considers a 60-70% pwoer mix emission factor reduction

Source: Monitor Deloitte analysis

Despite these efforts, additional measures must be taken or targets will not be met

The rising economic activity and population in cities (especially large cities) will drive up GHG emissions and pollution by 15–20% by 2030. **This upward trend will be offset by two key effects of emissions reduction policies**: 1) natural replacement of equipment at the end of its useful life (technological developments and environmental regulations mean that current options are more efficient and less polluting than the older models that they replace); and 2) reduction of the electricity mix emissions factor thanks to the increased use of renewables.

However, these developments alone **will not allow cities to hit the target** set by the Covenant of Mayors (40% reduction in GHG emissions by 2030). **Additional efforts** will be have to be made (see Exhibit 4).

Moreover, with respect to air quality, the overshoot of legal pollutant limits (especially of NO_x) in certain cities will require **urban energy sustainability initiatives to be implemented in the very near future, especially for wheeled land transport**, which is the main cause of NO_x concentration in cities[8]. The severity of the issue demands measures with an immediate impact, because we cannot rely on the natural replacement of vehicles to improve air quality.

To help achieve the necessary additional reduction in emissions, we have identified a **series of initiatives** for each sector: **transport** (modal shift to public transport or walking, development of smart mobility, promotion of electric vehicles, replacement of pollutant, old vehicles); **buildings** (optimisation of energy use, replacement of heating and electrical systems with more efficient models, refurbishing, promotion of self-consumption) and **municipal services** (improved street lighting, electric municipal vehicles).

8 Some 60–80% of the average annual concentration of NO_x from local sources is generated by vehicular traffic. Source: Spanish national emissions inventory

Exhibit 5: Energy sustainability measures analised

Transport	Modal shift Smart mobility Less pollutant vehicles Mobility demand reduction	• Public transport (metro, bus, tram) • Non motorised modes (walking, bicycle, scooters, etc.) • New moblity models (carsharing and carpooling) • Transport under demand • Electric vehicle introduction • Discourage the use of oldest and most pollutant vehicles • Electric/low emissions light duty vehicle • Electric/low emissions bus • Urbanism optimisation • Flexible working hours/ home-working
Residential buildings	Usage improvement Heating device replacement Retrofitting Appliance replacement Distributed generation	• Heating control systems • Heating device replacement by heat pump • Heating device replacement by condensing gas boiler • Window/closing replacement • Façade insulation improvement • Roof insulation improvement • Appliance/lighting replacement • Distributed generation
Services	Usage improvement Heating device replacement Retrofitting Appliance replacement Distributed generation	• Heating control systems • Lighting control systems • Additional measures • Heating device replacement by heat pump • Heating device replacement by condensing gas boiler • Additional heating devices • Window/closing replacement • Façade insulation improvement • Roof insulation improvement • Appliance/lighting replacement • Self consumption
Municipal consumptions	Lighting Public fleets and buildings	• Smart lighting control systems & LED lighting • Emission-free public fleet • Sustainable public buildings

Transport: reducing the use of private vehicles and accelerating the adoption of less-pollutant/greener vehicles

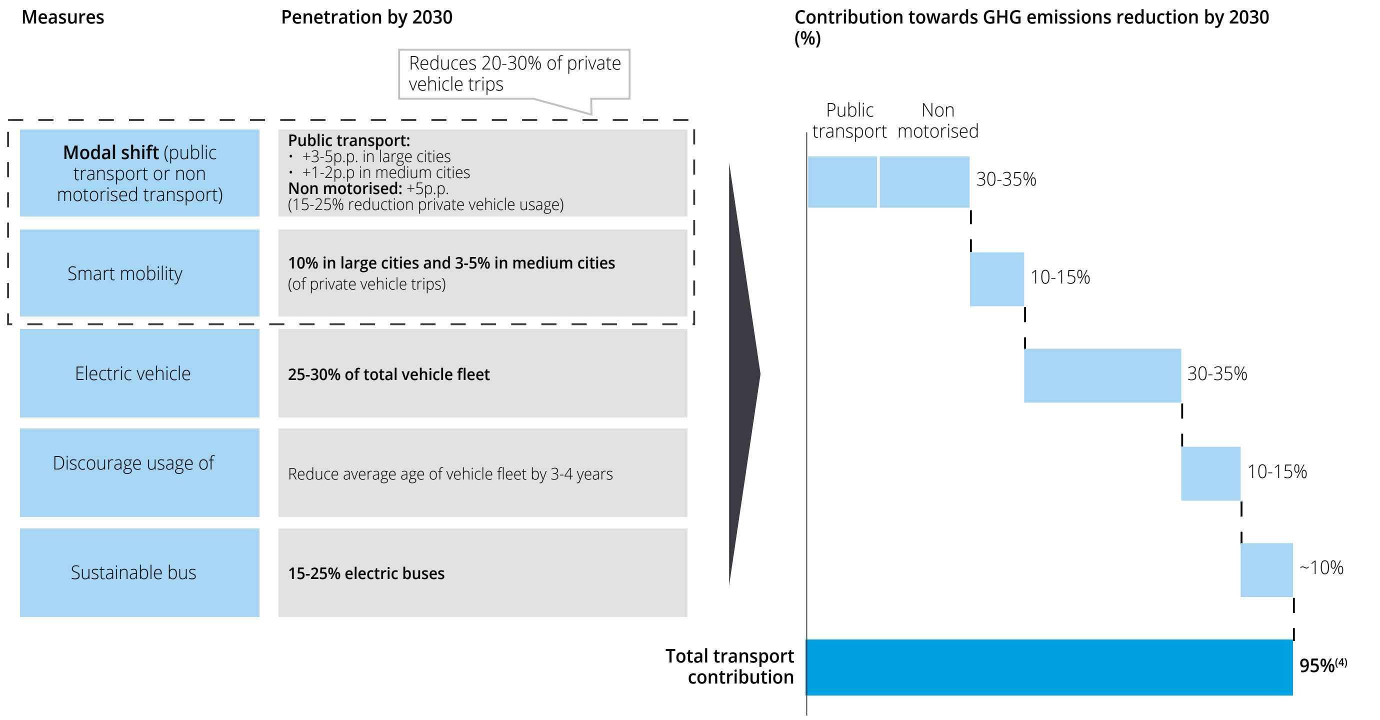
In cities, passenger transport accounts for 70–80% of transport-related energy consumption and emissions, which necessarily makes it the focus of initiatives to be carried out in cities. The type of measures to take depends largely on the size of the city, the relative weight of the suburbs (vs downtown) and topography.

In order to prioritise the initiatives with the largest impact in this sector, we looked at each one's capacity to reduce GHG emissions and congestions, free up public space and improve air quality. Based on this, the priority initiatives are (see Exhibit 6): modal shift to public transport; smart mobility; increasing electric vehicles penetration; and discouraging the use of older and more polluting vehicles.

- **Modal shift to public transport**: This would reduce GHG direct and indirect emissions per passenger-km by 70% in the case of conventional buses, and more than 90% in the case of rail or metro[9]. Public transport accounts for 30–35% of passenger transport in large cities and 10–15% in midsize cities[10]. The factor that **best explains the use of public transport**, where there is adequate connectivity and frequency, is the **difficulty of using a private vehicle** (congestion, parking, traffic restrictions, etc.). **The availability and quality of service of the public transport in Spain's analised cities are comparable**, and even exceed, **those of major international cities[11]**, although restrictions on the use of private vehicles are still limited. Cities must increase the use of public transport (by 3–5 p.p. of modal share by 2030 to catch up with the leading cities) by placing greater restrictions on the use of private vehicles.

- **Modal shift to non-motorised transport**: In midsize cities, non-motorised transport accounts for 45–50% of total transport, while in large cities it accounts for

Exhibit 6: Sustainability measures in the transport sector



(1) Large cities
(2) Medium cities
(3) Includes carsharing, carpooling and transport under demand
(4) Other 5% includes urbanism, home-working, and natural gas cars
(5) Direct and indirect emissions. Compared to a current average vehicle.

Source: Monitor Deloitte analysis

9 Vs private vehicles.

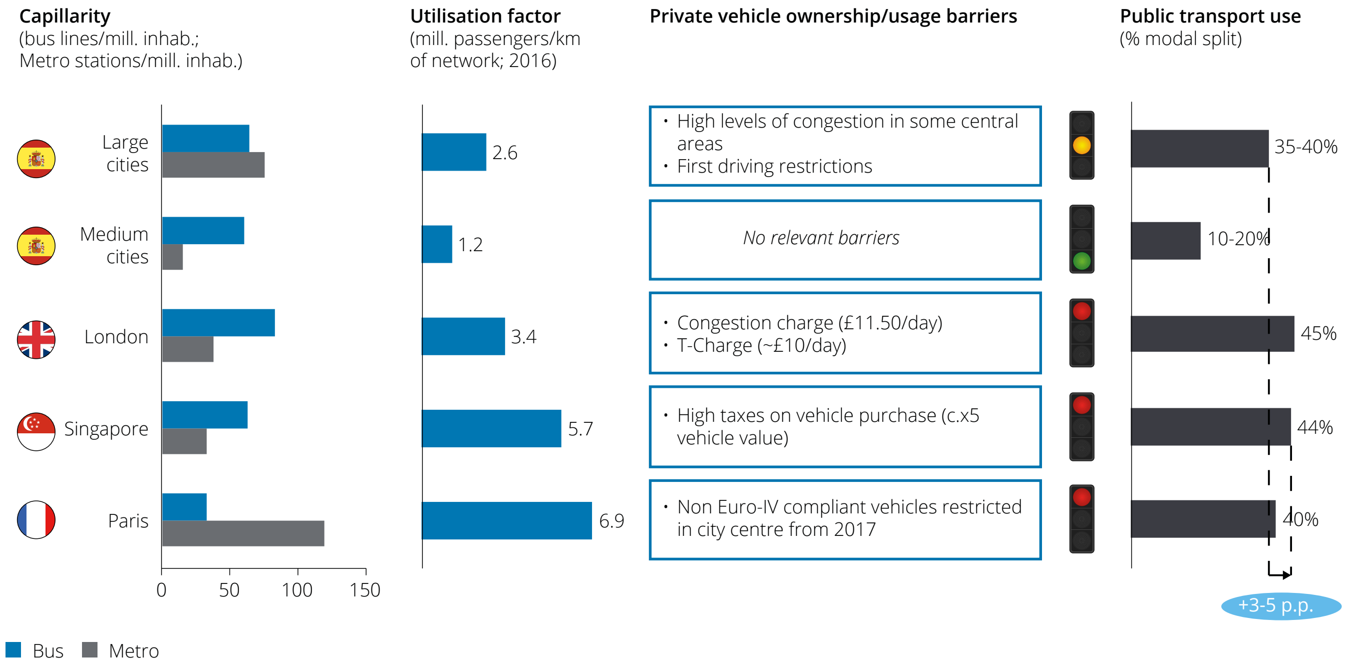
10 Measured using total journeys per passenger in the city.

11 All the international cities that have achieved a greater preponderance of public transport (e.g. London and Singapore) have in place measures to disincentivise or restrict the use of private vehicles.

only ~30%. Walking has greater potential in midsize cities than in large cities, where average journeys are longer (see Exhibit 7). Shifting to cycling[12] would require initiatives like the installation of bicycle lanes and parking infrastructure. The share of non-motorised modes must be increased by ~5 p.p. in both midsize and large cities.

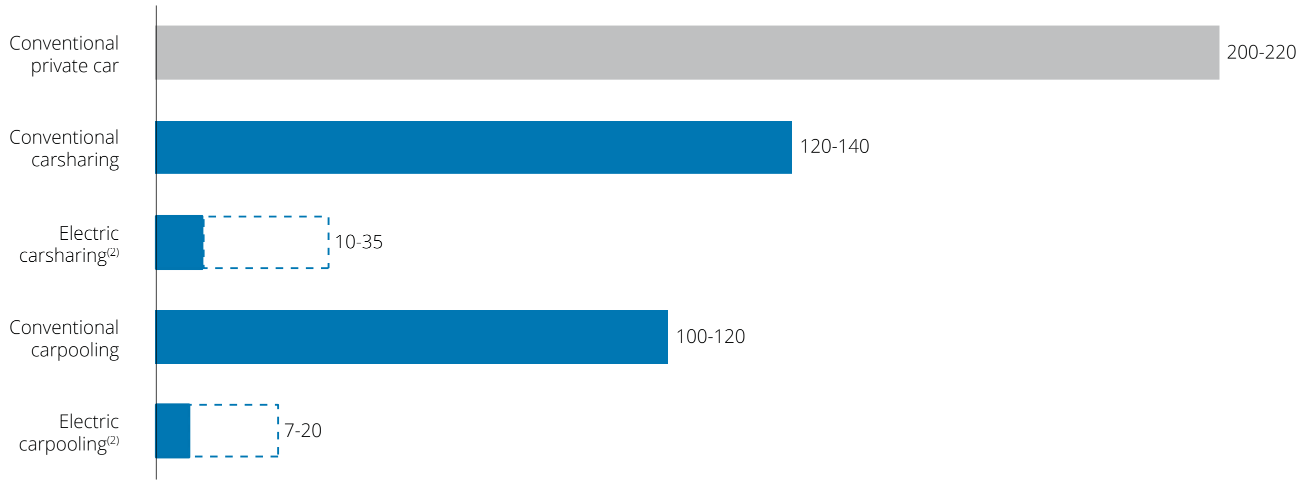
- **Smart mobility**: New mobility models like carsharing and carpooling have grown in recent years thanks to digitisation and greater supply. **This initiative has greater potential in large cities** given the higher demand, which provides the necessary scale for its economic viability. By 2030 these models should account for up to 10% of journeys in private vehicles in large cities. In midsize cities, they will probably have less penetration (3–5% by 2030).

Exhibit 7: Public transport in Spain and across leading international cities



Source: Observatorio de Movilidad Metropolitana; Transport for London; Singapore Land Transport Authority; Greenpeace; RATP Paris; Monitor Deloitte analysis

Exhibit 8: Direct and indirect GHG emissions of different smart mobility alternatives
(grCO_2eq/passenger-km)[(1)]

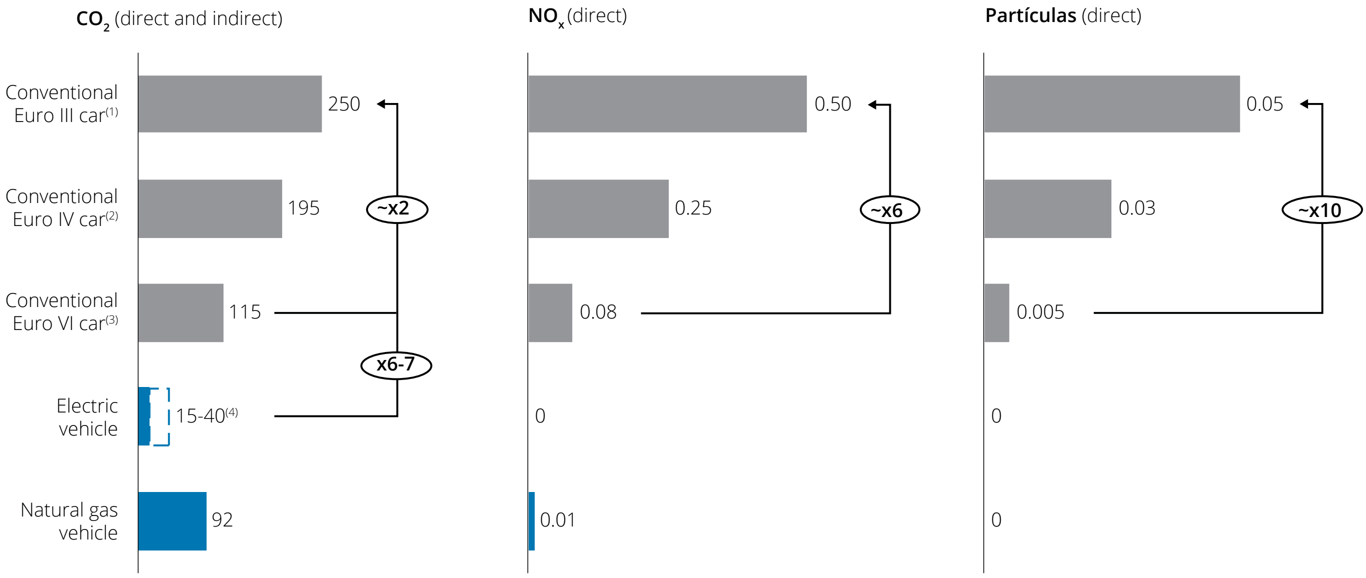


(1) Assumed fuel consumption: ICE private car: 10l/100km in cities; ICE carsharing: 6l/100km in cities; electric carsharing: 15kWh/100km in cities; ICE carpooling: 10l/100km in cities; electric carpooling: 20kWh/100km in cities.
(2) Lower range: 2030 power sector emission factor in 2030 (0.08 kgCO_2eq/kWh); upper range: 2016 power sector emission factor (0.22 kgCO_2eq/kWh

Source: Monitor Deloitte analysis

12 For the purposes of this study, non-motorised transport is considered to include bicycles, electric scooters and other powered personal mobility devices.

Exhibit 9: CO_2 and particulates emissions by type of vehicle
(g/km)



(1) Vehicles registred between 2000 and 2005
(2) Vehicles registred between 2005 and 2008
(3) Vehicles registred from 2009 onwards
(4) 2016 power mix emission factor: 40 gCO_2/km; 2030 power mix emission factor: 15 gCO_2/km

Source: Monitor Deloitte analysis

- **Increasing electric vehicles penetration**: Electric vehicles do not directly emit particulates or NO_x and emit six to seven times less GHG[13] than Euro III vehicles and three times less than new conventional vehicles. The future growth of electric vehicles will depend on the availability of new models, access to charging points and the degree of restrictions on conventional vehicle traffic. Local governments must push measures to promote the development of electric vehicles, such as cutting red tape, freeing up public land, establishing a model to put in place charging infrastructure, and providing municipal tax exemptions (tax on motor vehicles). To hit the targets of the Covenant of Mayors, electric vehicles must account for 25–30% of the vehicle population by 2030.

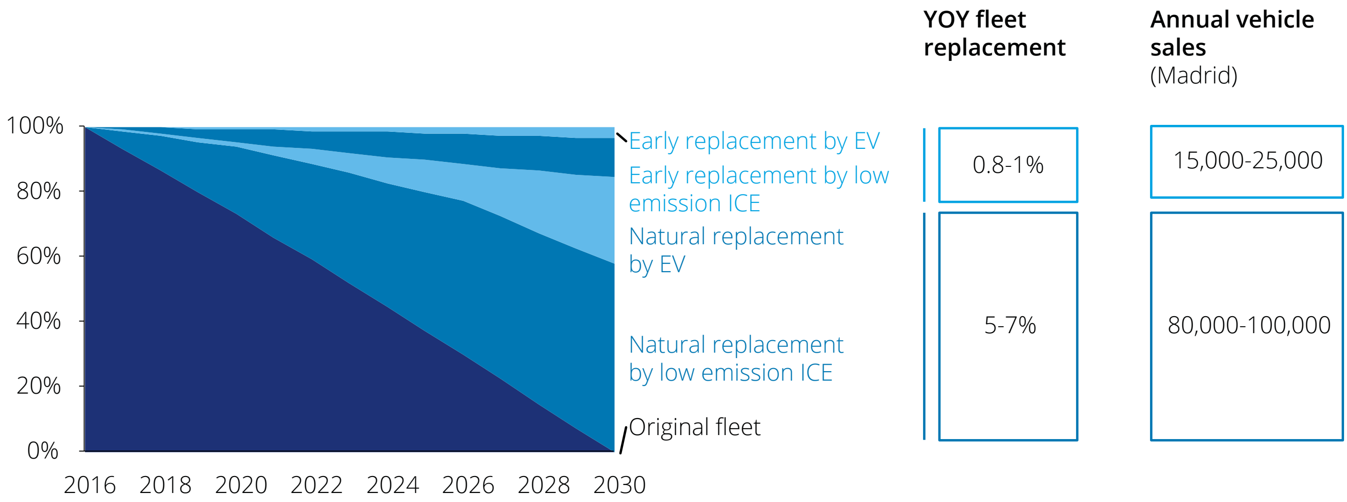
- **Discouraging the use of older and more polluting vehicles**: The current average age of the Spanish passenger vehicle fleet is over 14 years[14], and ~40% do not meet the minimum specifications for an environmental badge from Spain's Directorate-General for Traffic[15]. An older diesel Euro III[16] vehicle emits ten times more particulates, six times more NO_x and almost twice as many GHG emissions as a new conventional Euro VI vehicle over its useful life (see Exhibit 9). Municipal governments must establish traffic restrictions on older vehicles, expand the areas covered by these restrictions and increase taxes on more polluting vehicles.

  In cities, the vehicle fleet should comprise 70–75% conventional vehicles and 25–30% electric vehicles, with an average age of 6–7 years (4–5 years less than that of the current vehicle population in cities). This renewal process will require a 10–30% increase in annual vehicle sales and a significant expansion of charging infrastructure for electric vehicles (see Exhibit 10).

- **Shift to less polluting vehicles (public transport)**: The compressed natural gas (CNG) bus is a competitive alternative (with almost the same final cost as a diesel bus) that would improve air quality

13 En las ciudades analizadas este valor se situa en 10 - 11 años
14 Turismo con clasificación inferior a Euro III (gasolina) o Euro IV (diesel)
15 Vehículo matriculado antes del año 2005 y que no alcanza las especificaciones mínimas para tener distintivo medioambiental de la DGT
16 Rendimientos: bomba de calor (entre 200 y 400%, en función del clima), caldera de condensación (~110%)

Exhibit 10: Vehicle fleet in Madrid
(%)



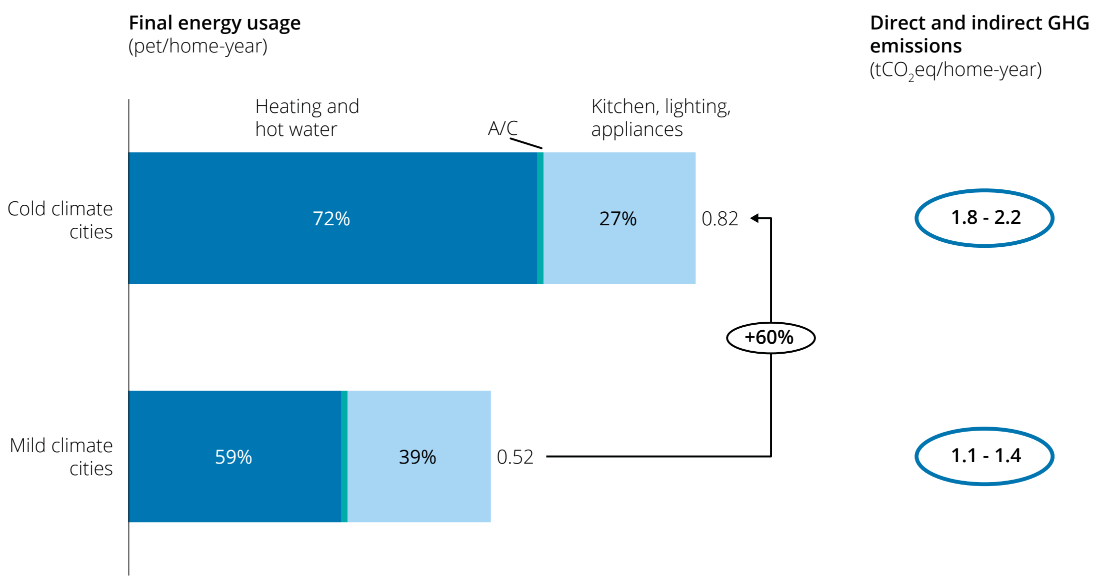
Source: Monitor Deloitte analysis

in cities (80–100% less emissions of pollutants than older diesel buses). Moreover, new conventional buses, equipped with exhaust gas scrubbers, have almost the same level of pollutant emissions as CNG buses. Electric buses still bear higher acquisition costs than conventional buses, but their operating costs are lower. They should therefore be adopted progressively starting in large cities, which have greater resources and capabilities.

Residential: promoting more energy-efficient heating equipment, heating control systems and refurbishments

Heating and domestic hot water consume the most energy in homes (60-70% of energy consumption). In cities with cold climates, a home can consume 50-80% more energy than a home in a mild climate, which means that climate is the most significant factor when it comes to analysing consumption and urban sustainability initiatives in this sector.

Exhibit 11: Final energy consumption by usage and emissions in buildings



Source: IDAE; Monitor Deloitte analysis

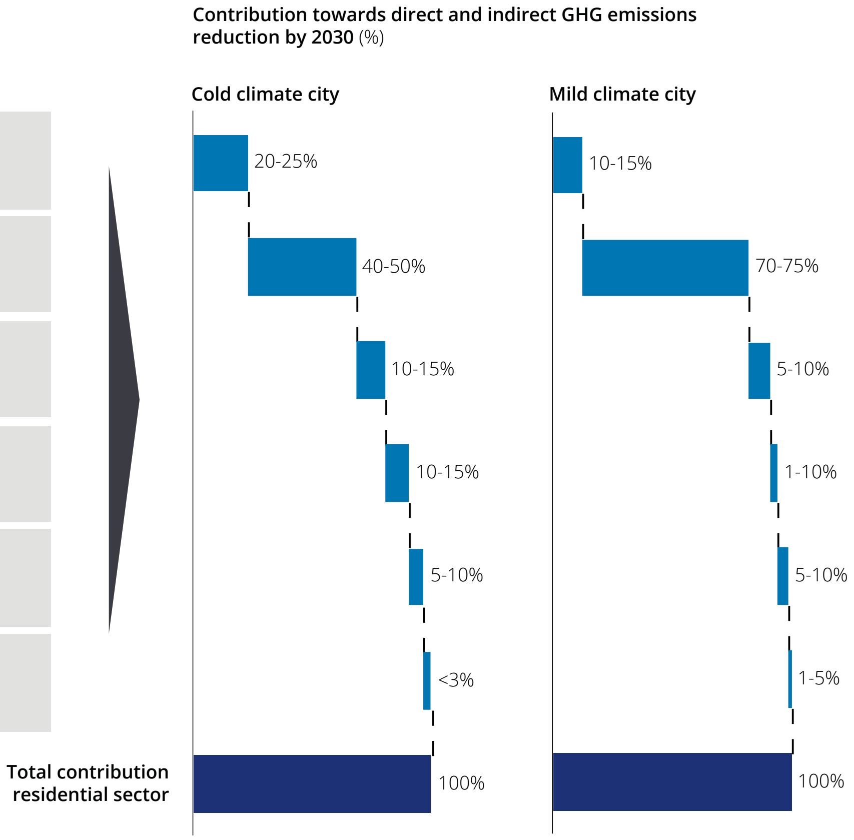
Based on the potential for abating GHG emissions, the return on the initiatives, the investment and other aspects such as the original domestic equipment, the priority actions would be as follows: implementing heating consumption control systems; changing to more energy-efficient heating equipment; refurbishments; the renewal of domestic appliances; and, to a lesser extent, the installation of self-consumption facilities (see Exhibit 12).

- **Heating consumption control systems** (thermostats that enable heating consumption to be adapted to ad-hoc domestic needs) can reduce heating energy consumption by 15 to 30%. In cities with cold climates, where the heating consumption is greater and central heating systems are used, a penetration of 30-50% of homes equipped with these heating consumption control systems would be required by 2030. This should be a priority action, since it renders the investments in the other subsequent initiatives more efficient.

Exhibit 12: Sustainability measures in the residential sector

Introduction priority order

Measures	Penetration by 2030 (% total homes)
Heating control systems	Cold climate: 30-50% Mild climate: 15-30%
Heating device replacement by heat pump	Cold climate: 10% Mild climate: 20-30%
Heating device replacement by condensing gas boiler	Cold climate: 30-40% Mild climate: 15-20%
Retrofitting	Cold climate: 10-20% Mild climate: 5-10%
Appliances replacement (A+++ vs A++)	Cold climate: 30-40% Mild climate: 20-13%
Distributed generation	Cold climate : <5% Mild climate: <10%



(1) Compared to a house with a conventional gas boiler

Source: Monitor Deloitte analysis

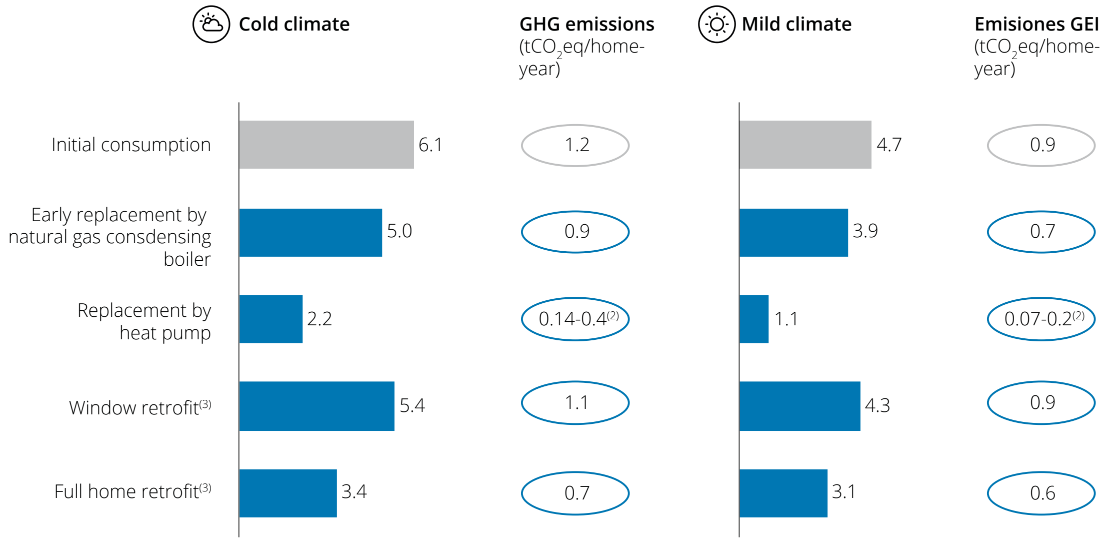
Heating control systems and heating device replacement by heat pumps contribute to over 60% of the total emissions reductions in the residential sector

- The next action in terms of priority depends on factors such as the original equipment (whether or not homes have fixed radiators), the climate zone, the investment in the refurbishment to be undertaken or the extent of such refurbishment, etc. These factors should determine whether the action consists of an **upgrade to more energy-efficient heating equipment** (heat pump or natural gas condensing boiler), a **refurbishment** or a **combination of both**.

- **Heat pumps[17] have the greatest capacity for reducing energy consumption and emissions at homes** due to their superior performance (see Exhibit 13). **In cold climates**, the prior existence of heating systems using radiators and boilers makes it difficult to change to this type of equipment, since doing so requires the installation of an air-to-water heat pump, which entails costlier and more complex[18] work to achieve a similar degree of thermal comfort. This means that the full cost of this initiative for users in cold climates is greater than the cost of a natural gas condensing boiler-based system. This increased cost is basically due to the current electricity tariff, together with the aforementioned barriers. An improvement in these factors (for instance, a tariff that adequately reflected the supply costs, or technology developments) would mean that in cold climates heat pumps would have a full cost similar to that of a natural gas condensing boiler.

In cities with a **mild climate**, air-to-air heat pumps, which have a lower installation cost, are the most suitable option (due to their better performance and user profitability), and 30% of homes should have replaced their system with one based on this technology by 2030. Meanwhile, in **cities with cold**

Exhibit 13: Heating and hot water energy consumption(1)
(MWh/home-year)



(1) Example home used: 90m2, built between 1960 and 1980, natural gas conventional boiler used for heating and hot wáter, 90% efficient. Heat pump efficiency in cold cliamtes; 250%. Heat pump efficiency in mild climates: 400%. Natural gas condensing boiler efficiency: 110%.
(2) The upper range represents power mix of 2017: 0.22kgCO_2/kWh and lower range represents the power mix of 2030: 0.07kgCO_2/kWh
(3) Considers the retrofitted home keeps the original natural gas conventional boilers

Source: Monitor Deloitte analysis

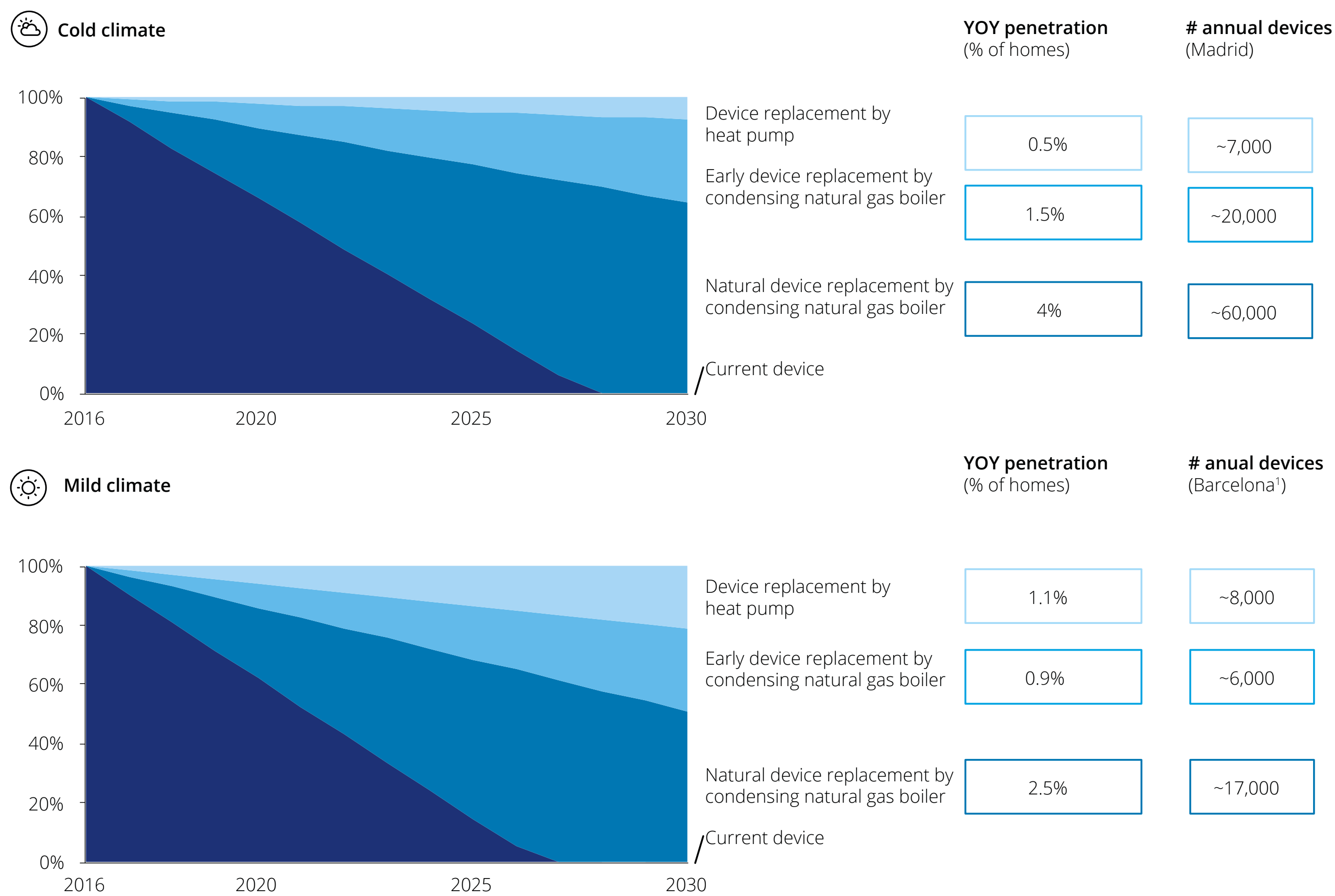
17 Performance: heat pump (between 200% and 400%, depending on the climate), condensing boiler (~110%).

18 Requires building work to install air conditioning ducts with fan coils or underfloor heating systems.

climates[19] **the early replacement of heating equipment** (conventional natural gas or oil-fired boilers) with natural gas condensing boilers (30-40% of thermal boilers) and changing to heat pumps (~10% of homes by 2030) should be encouraged in cases where the barriers can be reduced, such as in a comprehensive refurbishment or in newly constructed buildings (see Exhibit 14).

- There are different kinds of **refurbishment to reduce energy consumption** in a residential building (façades, roofing, windows or comprehensive). However, due to the **barriers to undertaking such action** (high investments, the long timeframes for recouping investments, lack of a refurbishment culture, the need for the community association to reach an agreement regarding certain

Exhibit 14: Heating devices population by climate zone



(1) Natural device replacement differs due to the different number of homes with boilers

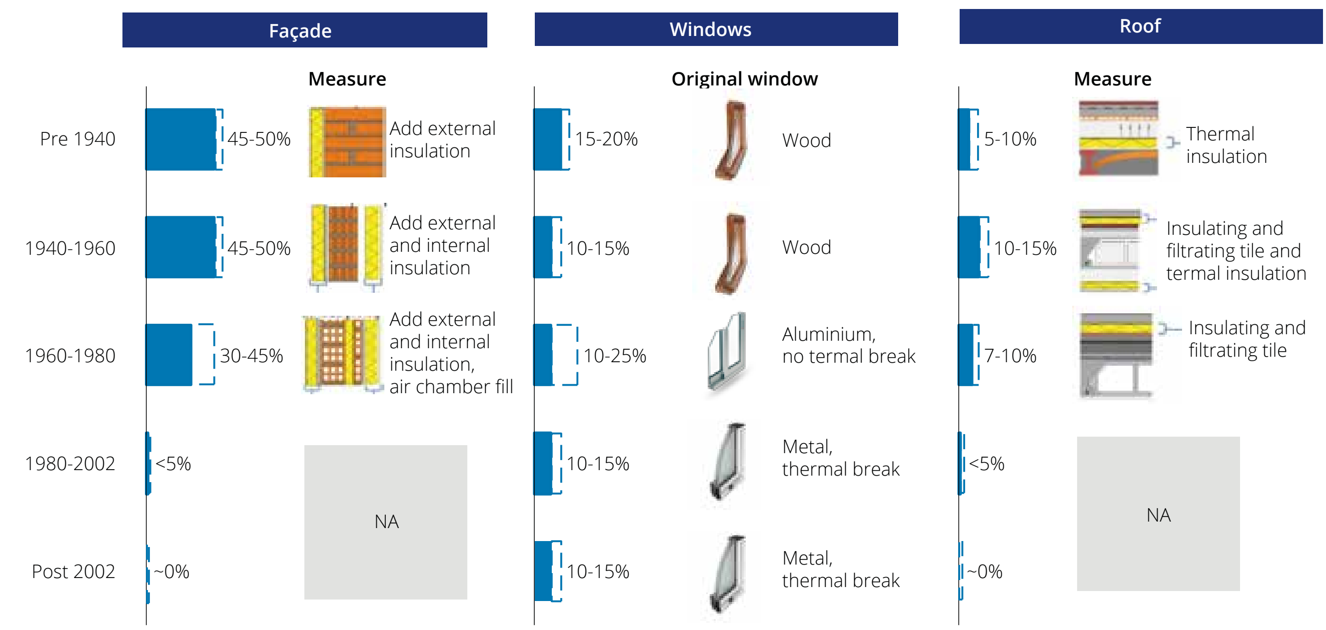
Source: Monitor Deloitte analysis

19 La sobreinversión se define como la diferencia de inversiones entre la opción considerada en el estudio como actuación energéticamente sostenible y la opción convencional (por ejemplo, diferencia de inversión entre un vehículo eléctrico y un vehículo convencional)

initiatives, etc.), **lower degrees of penetration** were considered in respect of these initiatives. Window refurbishment involves the fewest barriers (lower investment, fewer implementation difficulties). In cities with cold climates, it would be necessary to refurbish 10 to 20% of homes by 2030. ~75% of those refurbishments would be window refurbishments.

Despite the significant reduction in consumption due to refurbishments (>60% of heating consumption in the case of a comprehensive refurbishment), heat pumps give rise to greater reductions in consumption, and fewer barriers must be overcome in order to implement such systems, particularly in cities with mild climates. In cities of this kind, this solution also has a lower final cost for users.

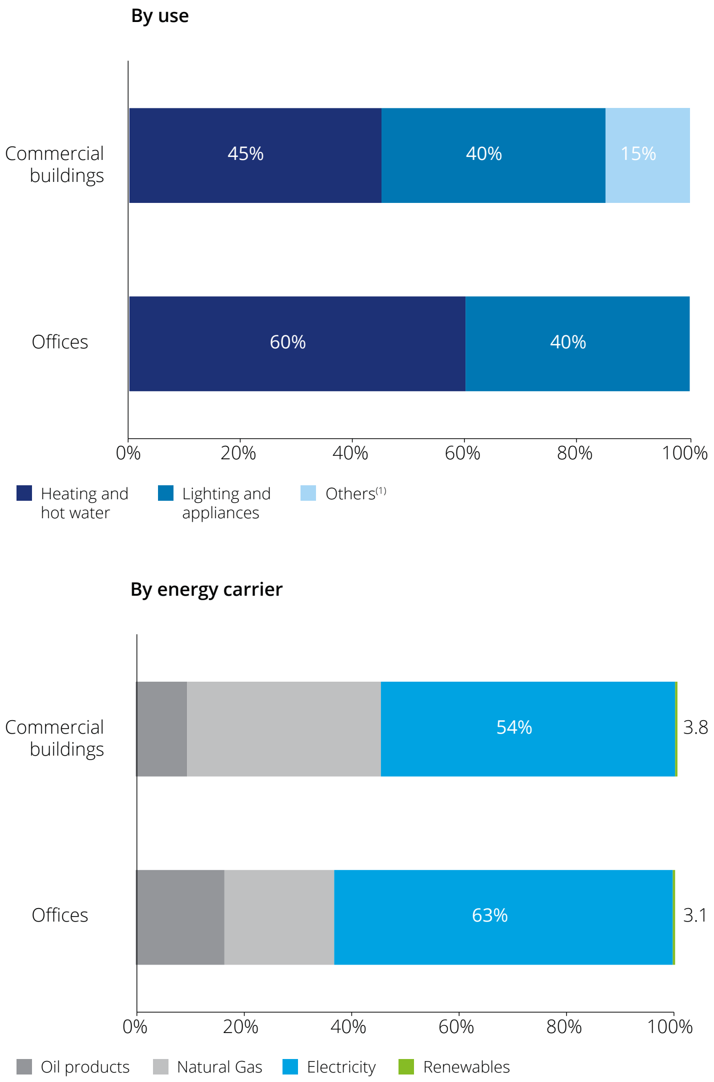
Exhibit 15: Energy retrofitting in residential buildings according to building age and energy consumption reduction (%)



Source: Instituto Valenciano de la Vivienda; CSIC; Monitor Deloitte analysis

Despite the considerable energy consumption reduction retrofitting allows for, heating device replacements by heat pumps have to overcome less barries and should therefore have a higher penetration rate

Exhibit 16: Final energy consumption by type of building, use and energy carrier
(Mtep/year)



(1) Other usages such as kitchen or other non electric devices

Source: IDAE; Informe GTR; Catastro; Monitor Deloitte analysis

- Residential **distributed generation** in cities should be implemented primarily on roofs that have a sufficiently large available surface area, are easily accessed and have suitable orientation, or on surfaces close to the buildings (courtyards, gardens, car park roofs, etc.). In this way, it will be possible to develop facilities that are large enough to harness economies of scale (which may imply a difference of up to 30% in the total cost compared to a single photovoltaic panel installation).

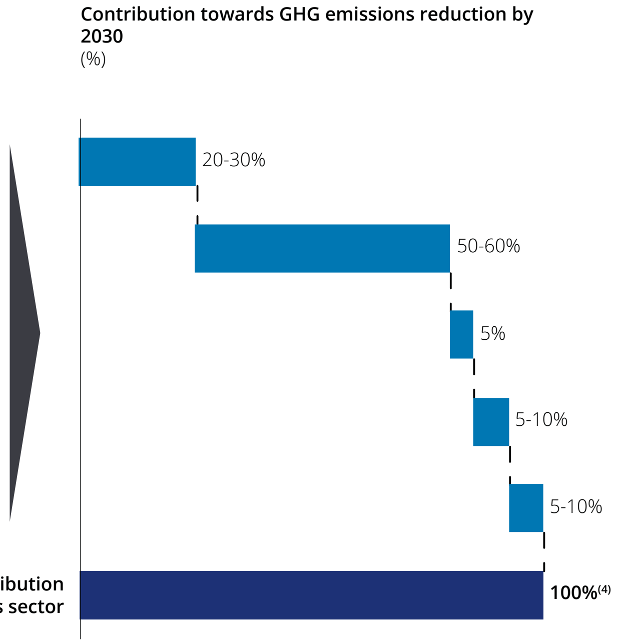
Services (offices and stores): promoting the implementation of heat pumps and improved lighting systems

The services sector encompasses a very diverse range of buildings such as offices, large shopping centres, small stores, hospitals, leisure centres, hotels, cafés, educational centres, etc. However, offices and stores consume 65% of energy and are at the core of analyses and recommendations. Air conditioning (40-60%) and lighting (20-45%) are what consume the most energy in these sectors, and the main initiatives that have been analysed to improve sustainability in this sector would be the following (see Exhibit 16):

- **Heat pumps are a much more competitive option in large buildings (shopping centres, large office buildings)** than in the residential sector, due to the higher relative demand for cooling (heat pumps are more competitive than having one heating system and another cooling system), the greater consumption that offsets the higher upfront cost and the absence of other barriers (lower instance of prior radiator heating systems or greater rationality). On the basis of this greater appeal, an additional **penetration of 30-40% of office and commercial surface** would be required by 2030.

Exhibit 17: Sustainability measures in the services sector

Measures	Penetration by 2030
Energy usage improvement (heating and lighting control systems)	**20-40% additional m²** equipped with smart heating and smart A/C
Heating device replacement (heat pump)	**20-40% additional m²** equipped with heat pump
Retrofitting	**10% m²** retrofitted
Appliances replacement	**10-15% of m²** with replaced appliances
Distributed generation	**5% of m²** equipped with distributed generation panels



Source: Monitor Deloitte analysis

- **Lighting** is another area of consumption with major potential for reduction. Changing lighting equipment to LED systems **allows a 70-80% reduction in consumption**, whilst intelligent lighting control systems give rise to a reduction of 15-30%. The high profitability of these initiatives means that installing LED lighting in **90-100% of services sector space by 2030** is a realistic objective.

- There are fewer barriers against **distributed generation** in the services sector due to the fact that it is easier to find appropriate locations since certain premises (large retail buildings, offices, car parks, leisure centres, etc.) have roofs that are sufficiently large and accessible. In such cases, distributed generation gives rise to savings on current electricity tariffs for owners across a large part of Spain. A large services building (for instance, a shopping centre or a large office building) can produce up to 15-25% of its electricity consumption by means of a distributed generation facility.

Public services consumption: ensuring efficient lighting, electrifying the municipality fleet and improving municipality buildings sustainability
Public services energy consumption constitutes a very small proportion of the total consumption (in Madrid, public lighting consumption is ~1% of the city's total electricity consumption). Despite this, **the public sector must promote the implementation of energy sustainability measures to set an example for other players**.

The **improvement of public lighting** (by changing to LED lighting and through the penetration of intelligent consumption management systems) and **zero-emission public vehicle** fleets must be the action focal point (barring action in municipal buildings, for which the proposed initiatives are similar to those included in the services sector analysis).

Also, **self-consumption in municipal buildings**, just like in the services sector, **gives rise to potential savings in premises with roofing that is suitable** for the installation of such equipment (municipal car parks, leisure centres, appropriate office premises, etc.). However, some municipalities are promoting renewable energy generation facilities in the outskirts of towns or cities, where the resource can be availed of more efficiently than in the buildings themselves. This enables the same emissions to be abated at a 5-20% lower cost.

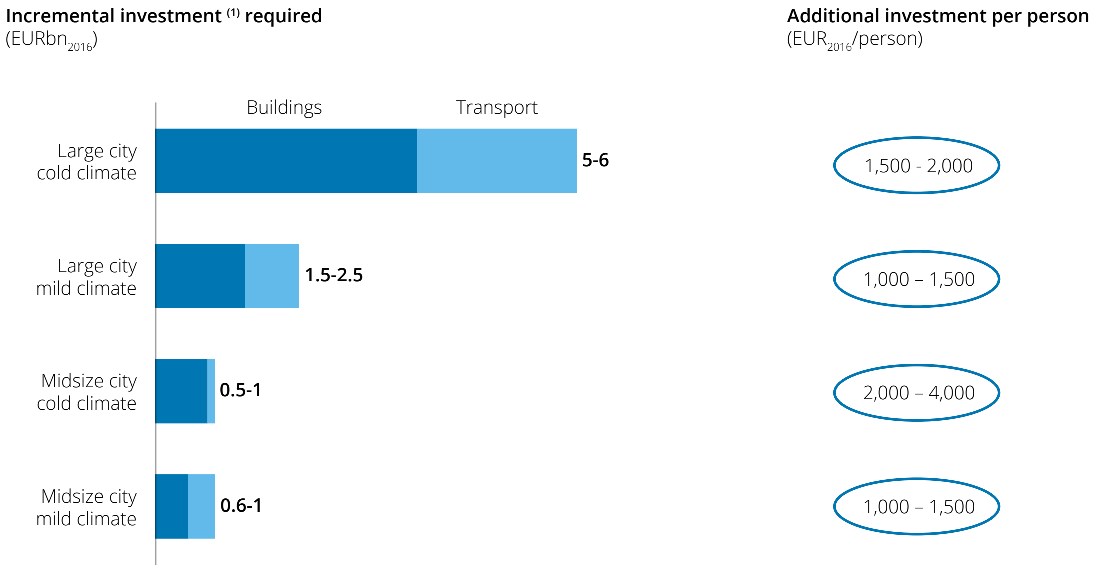
Meeting the emissions reduction targets will require an overinvestment of between EUR 1,000 and 4,000 per inhabitant until 2030

Changing the energy model requires the support of the public authorities

The additional steps to be taken in order to achieve the target reduction of 40% will require an **overinvestment[20] of between EUR 1,000 and 4,000 per inhabitant until 2030**, depending on the type of city. In a large city with a cold climate, such as the city of Madrid, between EUR 1,500 and 2,000 per inhabitant (EUR 5,000 to 6,000 million in total) will be required, whilst in a medium-sized city with a cold climate, such as Vitoria, this investment would be in the region of EUR 2,000 to 4,000 per inhabitant (EUR 500 to 1,000 million in total, see Exhibit 18).

Most sustainability initiatives have negative abatement costs, i.e. **the economic value of the energy saved is greater than the overinvestment required**. This result reflects the fact that most of the equipment and technology necessary in order to make the urban energy transition are already available and are more competitive than other, less sustainable options. On the other hand, **another series of initiatives have a positive[21] abatement cost** which, under normal circumstances, would not be implemented by citizens or companies, since **they cost more than the business-as-usual option**. These initiatives **require regulatory and legislative support** from the public authorities in order to encourage their adoption at the necessary level.

Exhibit 18: Incremental investment required to meet emissions reduction targets



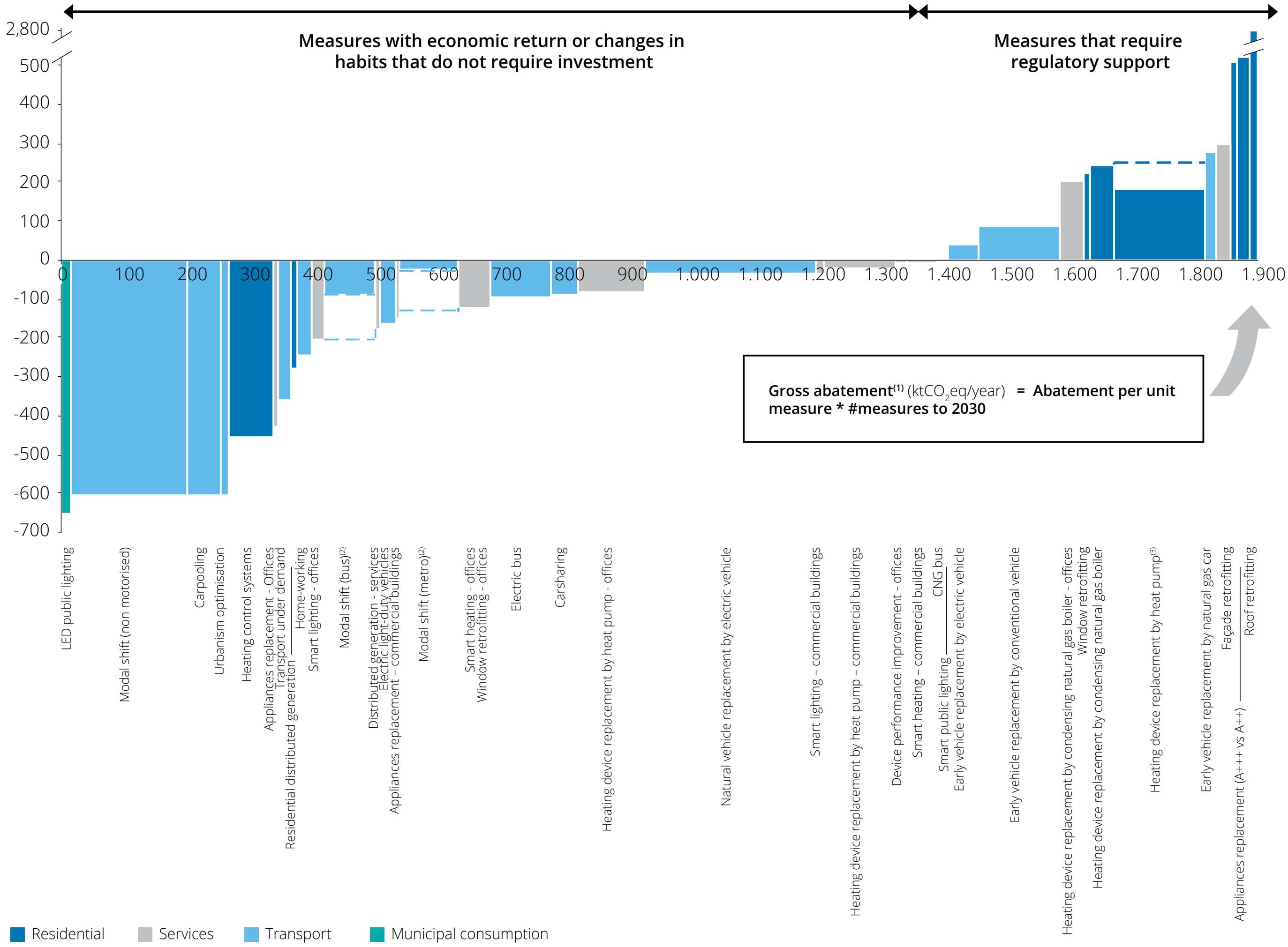
(1) Additional investment required from the non sustainable option to the most sustainable measure

Source: Monitor Deloitte analysis

20 Actuaciones donde el ahorro de consumo de energía no permite recuperar el mayor coste de inversión necesario

21 Initiatives where the savings in energy consumption does not enable the necessary greater investment cost to be recouped.

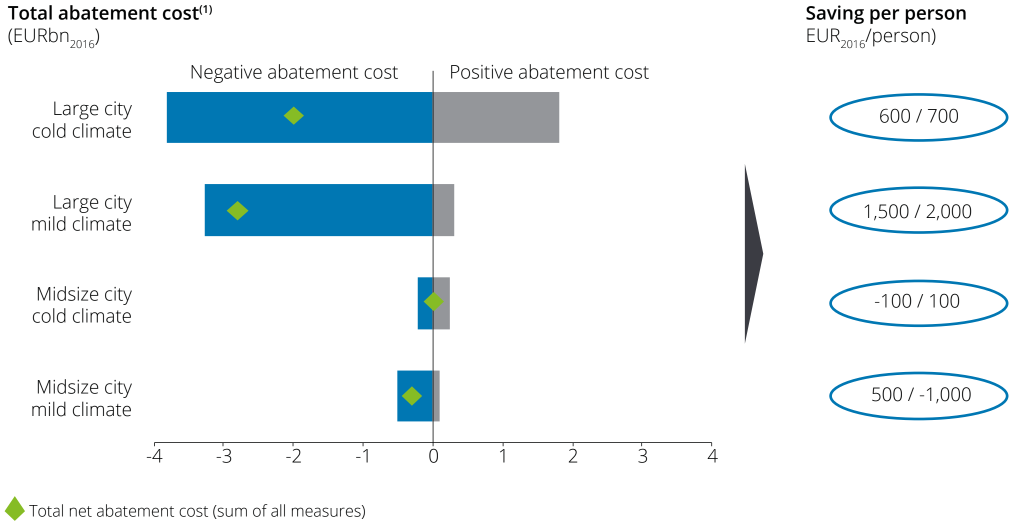
Exhibit 19: Abatement cost example for a cold climate city
(€/tnCO_2eq)



(1) Abatement without taking overlap from different measures into account
(2) The dotted area represents the abatement cost should the investment required in additional buses be passed onto final users
(3) The dotted area represents the abatement cost should the electricity tariff be revisited

Source: Monitor Deloitte analysis

Exhibit 20: Total abatement cost per city and savings per person



(1) Calculated considering that the required investment in public transport infrastructure is not passed on to the consumers directly

Source: Monitor Deloitte analysis

The **profit from the initiatives with a negative abatement cost offsets the cost of the other initiatives that have a positive abatement cost in most cities. The average citizen would obtain a net saving of up to EUR 2,000**[22] **as a result of the investments required** in order to reduce emissions in Spanish cities and achieve the objective set out in the Covenant of Mayors (see Exhibit 20).

Recommendations for urban energy sustainability

The transition calls for measures that work in four dimensions with regard to the energy model in cities

The energy transition in Spanish cities requires measures based on four core ideas, namely: i) defining targets and a municipal governance model; ii) promoting new sustainability mobility models; iii) implementing initiatives that increase energy efficiency and the use of zero-emission energies in buildings; and iv) turning municipalities into an example of energy sustainability.

The measures that have been presented are primarily aimed at city councils. However, other measures have been established which, due to their nature or particular significance, must be promoted or activated by other public authorities.

Establishing objectives and an energy sustainability governance model in each municipality

- Implementing **measurement, inventory and reporting processes in relation to energy consumption and emissions**. Creating **organisational units** responsible for these processes within the local authorities and providing them with specialised resources.

- Defining (or confirming) the **energy sustainability targets** of each city from 2030 to 2050 in line with the objectives assumed at national level.

- Designing and approving **municipal strategic plans on energy sustainability** that enable the objectives of reducing GHG emissions and improving air quality to be met.

- Establishing **municipal governance models** that enable **roles and responsibilities** to be allocated and defined and inter-municipal **coordination** bodies and mechanisms to be promoted.

22 Depending on the type of city, this saving may vary between EUR 0 and 2,000.

- Introducing an **index that measures the progress made by cities towards energy sustainability** and enables **best practices to be identified**.

Favouring passenger transport with a greater emphasis on public transport, non-motorised transport and non-polluting energy sources

- Establishing obligations whereby city councils must perform regular **mobility surveys** to ascertain their citizens' mobility patterns.

- Defining **mobility plans** to reduce emissions and improve air quality, as pledged for 2030, and establishing use targets per mode of transport.

- Defining **action plans for each municipality** that include: i) **restricting vehicle access to, and motor traffic in**, city centres based on their GHG and pollutant emissions (due to their age or their Spanish Directorate-General for Traffic badge); ii) improving the public transport service or extending it to areas/neighbourhoods with less coverage; iii) **facilitating the use of non-motorised transport** by providing exclusive lanes and parking facilities located at key points; and iv) **boosting intermodality** in large cities by developing the necessary infrastructure (deterrent car parks, bus lines, etc.).

- Carrying out **information and awareness campaigns** on the objectives and on the benefits for air quality and improved mobility in cities.

- Developing legislation that facilities the rollout of **intelligent mobility business models (carsharing, carpooling, etc.)**, particularly in large cities. Making it mandatory for these models to be implemented on an electric mobility basis and to be integrated with other modes of city transport.

- Fostering the **penetration of electric vehicles and the recall of old vehicles** (both for passenger cars and light-duty commercial vehicles): i) **annual electric vehicle penetration and old vehicle recall targets**; ii) **plans to restrict access and movement of vehicles that produce emissions, particularly older vehicles**; iii) **tax measures to discourage use of old (more polluting) vehicles**; and iv) **economic, tax exemption-based incentives** for acquiring **electric vehicles** (where their cost is higher than that of their conventional counterparts, supplementing any benefits that have been or may be established at state or autonomous community level).

- Promoting the development of **infrastructure for private and publicly accessible electric vehicle charging**, including: i) establishing **public charging infrastructure targets** and rollout plans; ii) **facilitating the development** of **publicly accessible charging infrastructure in cities** by municipal bodies and other public authorities; and iii) promoting mechanisms to **reduce barriers to increasing the number of private charging points** at residential blocks.

- Establishing obligations whereby workplaces with more than 50 employees must implement **corporate sustainable mobility plans**.

- Carrying out specific plans for the **introduction of less polluting public transport vehicles**, establishing the objective whereby all new urban buses in the main Spanish cities will be electric as of 2030 and a schedule for **replacing old buses** with new, less polluting buses.

- Encouraging adaptation of the current **electricity tariffs** so that they constitute an efficient price signal and the **electric charging takes place during low grid usage periods**, thus upholding the principles of tariff sufficiency.

Implementing initiatives that increase energy efficiency and clean building sources

- Defining **action plans with respect to buildings at municipal level**, which include: i) preparing an **inventory of the stock of buildings** to identify the building solutions used and existing equipment; ii) identifying the **priority actions for each building segment**; iii) setting development targets to be met for each action by 2025 and 2030; iv) developing **investment plans** that include the necessary public and private resources; and v) establishing **specific measures to promote the actions**.

- Establishing an **objective whereby all buildings should possess energy certificates by 2030**. These energy certificates should be amended to identify the actions to be carried out on the building (state-level action).

- Launching **information campaigns directed at tenants and property owners** on the measures considered in the building action plans.

- Establishing a **timeframe for restricting the sale of equipment** that is not energy efficient, based, for example, on its energy class.

- Encouraging the **inclusion of sustainability criteria in building refurbishments** (i.e. taking advantage of the natural refurbishment to incorporate energy efficiency actions).

- Supplementing the **Technical Building Code for new buildings** so that it establishes restrictive limits on energy consumption, depending on the climate zone, which make it necessary to implement highly efficient solutions and zero direct emissions (state-level action).

- Promoting adaptation of the current **electricity tariffs so that they constitute an efficient price signal** that does not penalise the adoption of electric equipment over other, less sustainable carriers.

Turning the municipal authorities into an example of sustainability in terms of their energy use

- Renewing the **municipal lighting systems so that all municipal lighting uses LED technology by 2030**.

- Establishing an **electric vehicle penetration** timeframe for passenger cars and heavy vehicles belonging to the municipal fleet. From 2025, all new passenger cars belonging to the municipal fleet should be zero emission. For heavy vehicles, this obligation should be established from 2030.

- Establishing a specific timeframe in each city for rendering the fleet of taxis and private hire vehicles electric from 2022-2025.

An Energy Sustainable Cities Index (ESCI) would enable progress towards urban energy sustainability to be monitored

The need for an index to measure the energy sustainability of cities

An index would be a useful tool for determining the degree of energy sustainability of cities and the effectiveness of the measures that are implemented to meet the objectives taken on with a view to 2030. No index that pursues this objective has been established to date. An **Energy Sustainable Cities Index (ESCI)** is therefore proposed, the adoption and use of which by public decision-makers will enable **urban energy sustainability to be measured** in order to **understand the efforts that are required** and **focus them on the areas in which the impact on improvement would be greatest**.

Definition of urban energy sustainability
Urban energy sustainability rests on four pillars, namely: i) the **support of the public authorities**, which involves realising the commitment of public decision-makers in the form of targets, plans and exemplariness; ii) **efficiency with respect to the final energy consumption**, which implies increased use of public transport and non-motorised transport, or the renewal of equipment and an increase in energy-efficient building refurbishments, among other initiatives; iii) the **reduction of the impact of energy consumption on cities**, which includes the **improvement of air quality** and the **reduction of direct GHG emissions**; and iv) the use of energy from **renewable** sources and with an **appropriate level of affordability and quality**.

The Energy Sustainable Cities Index (ESCI)
An index has been established to assess how energy sustainable a city is in a simple and effective manner. The **index is established on the basis of the energy sustainability pillars** described above and is calculated using an indicator structure (with the proposed weight of each pillar appearing in brackets):

- **Support of the public authorities (25%):**
  - The existence of energy consumption and emission measurement schemes.
  - The existence of municipal urban energy sustainability targets.
  - The availability of information on the economic investment earmarked for energy sustainability and the amount of that investment.
  - Public exemplariness: i) energy classification of the municipal stock of buildings; ii) percentage of municipal buses that run on electricity and gas; iii) percentage of zero-emission municipal service vehicles; and iv) penetration of LED lighting.
- **Efficiency with respect to the final energy consumption (25%):**
  - For the building sector: unitary energy consumption in the residential and services sector (adjusted on the basis of the city's climate); and ii) average energy classification of buildings in the city.
  - For the transport sector: energy consumption in the transport sector per inhabitant; ii) modal split between public transport, non-motorised transport and private vehicles; and iii) average age of the stock of vehicles.
- **Reduction of the impact of energy consumption (GHG emissions and pollutants) (25%):**
  - For direct GHG emissions, including the building sector, with the percentages of energy consumption in buildings by energy carrier, and the transport sector, with the percentage of electric vehicles with respect to the total number of vehicles in the city.
  - For air quality: measurements of NO_x and particle concentrations.
- **Consumption of renewable, affordable and quality energy (25%):**
  - The percentage of electricity consumption -from renewable sources- in the city, generated at facilities located in the city (or at facilities located beyond the limits of the municipality itself but promoted by the municipal authorities).
  - The affordability of the energy, measured as a percentage of income earmarked for energy consumption.

The index seeks to measure the energy sustainability of cities with a view to 2030. Based on the aforementioned aspects, an energy sustainable city in 2030 would have an index equivalent to 100.

The Energy Sustainable Cities Index (ESCI) allows to assess how energy sustainable a city is in a simple and effective manner

Exhibit 21: Sustainable Energy Cites Index detailed indicators

	Indicator	2016 (Score: 50)	2030 (Score: 100)	
Public Administration support	Energy consumption and emissions measurement	Annualy updated measurement	Annualy updated measurement; segmented by sectors and carriers; prepared with official guides	D
	Energy sustainability targets	Targets to 2030; ambition over 40% reduction; segmented by sector; follow-up mechanisms available		D
	Investment allocated towards energy sustainability	Investment per person required (estimated for each city archetype)		C
	Public exemplarity: public buildings energy qualification	50% of public buildings with B-qualification or above	>80% of public buildings with B-qualification or above	C
	Public exemplarity: electric and natural gas municipal buses	Natural gas buses represents 20% of bus fleet; electric buses represents 5%	Natural gas buses represents 50% of bus fleet; electric buses represents 30%	C
	Public exemplarity: zero-emission municipal vehicles	10% of municipal vehicles	80% of municipal vehicles	C
	Public exemplarity: LED lighting	50% of lights are LED	All public lighting is LED	C
Efficiency in energy consumption	Buildings: unit energy consumption (corrected with temperatura)	Analised cities' average	Required value to achieve 40% reduction	C
	Buildings: average buildings' energy qualification (residential and services)	5% of buildings with C-qualification or above	20% of buildings with C-qualification or above	C
	Transport: energy consumption per person	Analised cities' average	Required value to achieve 40% reduction	C
	Transport: modal share	Current share in each city	+5 pps of modal shift to public transport; +5 pps. Of modal shift towards non motorised transport	C
	Transport: average car fleet age	Average fleet age: 10 years	Average fleet age: 6 years	C
Impact of energy consumption reduction	Buildings: % fossil fuel/electricity based energy consumption	60% electricity; 40% fossil fuels	80% electricity; 20% fossil fuels	C
	Transport: % of electric vehicles in total fleet	5% of vehicle fleet	30% of vehicle fleet	C
	Air quality: NO_x /particulates concentration	0: over current legal limit	50% reduction with respect to current concentration levels	C
Renewable, affordable and available energy	% distributed generation	1% of energy consumed produced through distributed generation	5% of energy consumed produced through distributed generation	C
	Energy affordability (% of income spent on energy)	15% of total home income	10% of total home income	C

D Scores with discrete values
C Scores with continuous values

Illustrative estimate of the Energy Sustainable Cities Index

The effective implementation of the index calls for the cooperation of the various city councils in compiling the most up-to-date information on each of the aspects analysed. For illustration purposes, an initial calculation of the index was performed, and the arithmetic mean for the cities analysed is 39 (the lowest value being 28 and the highest, 43). The ranges for the various components of the index are as follows:

- The "support of the public authorities" pillar, between 11 and 35. Under this heading, the highest-scoring cities are distinguished by the fact that they perform and publish a measurement of the final energy consumption and emissions, updated on a yearly basis, broken down by sector and energy carrier and prepared on the basis of official guidelines, and also by the fact that they have a rollout of less polluting public transport vehicles that exceeds 30%.

- The "efficiency with respect to the final energy consumption" pillar, between 34 and 50. The cities that stand out with respect to this pillar boast an energy consumption in the transport sector per inhabitant that is lower than 0.15 toe/inhabitant-year (equivalent to a distance of 2,000 km travelled by car per year, when the average of the cities analysed is 3,000 km), thanks to the promotion of non-motorised transport and the fact that this amounts to more than 60% of the modal split.

- The "reduction of the impact of energy consumption" pillar, between 28 and 44. Under this heading, the highest-scoring cities have a degree of electrification of consumption in the residential sector that exceeds 60%, whilst the average for the cities analysed is below 50%.

- The "consumption of renewable, affordable and quality energy" pillar, between 8 and 65. With regard to this aspect, the highest-scoring cities are characterised by the fact that the domestic energy cost is approximately 10% of family income, whilst in other cities this value can go up to 18%.

Although Spanish cities are now aware of the challenge of improving energy sustainability, they still have a long way to go before they reach the finishing line in 2030. This index also enables best practices in the various cities to be identified and potentially extrapolated to other cities in order to improve sustainability.

For centuries, cities have led commercial development, economic growth, technological advances and innovation. One of the greatest challenges that society will face in the coming decades is the fight against climate change and the energy transition, and cities must demonstrate their leadership ability in order to make the imperative change to the energy model possible and be themselves the driving force for change. The public authorities must foster energy sustainable cities that use energy efficiently and increase renewable energy consumption. If the energy transition does not happen in cities, it will not happen at all.

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