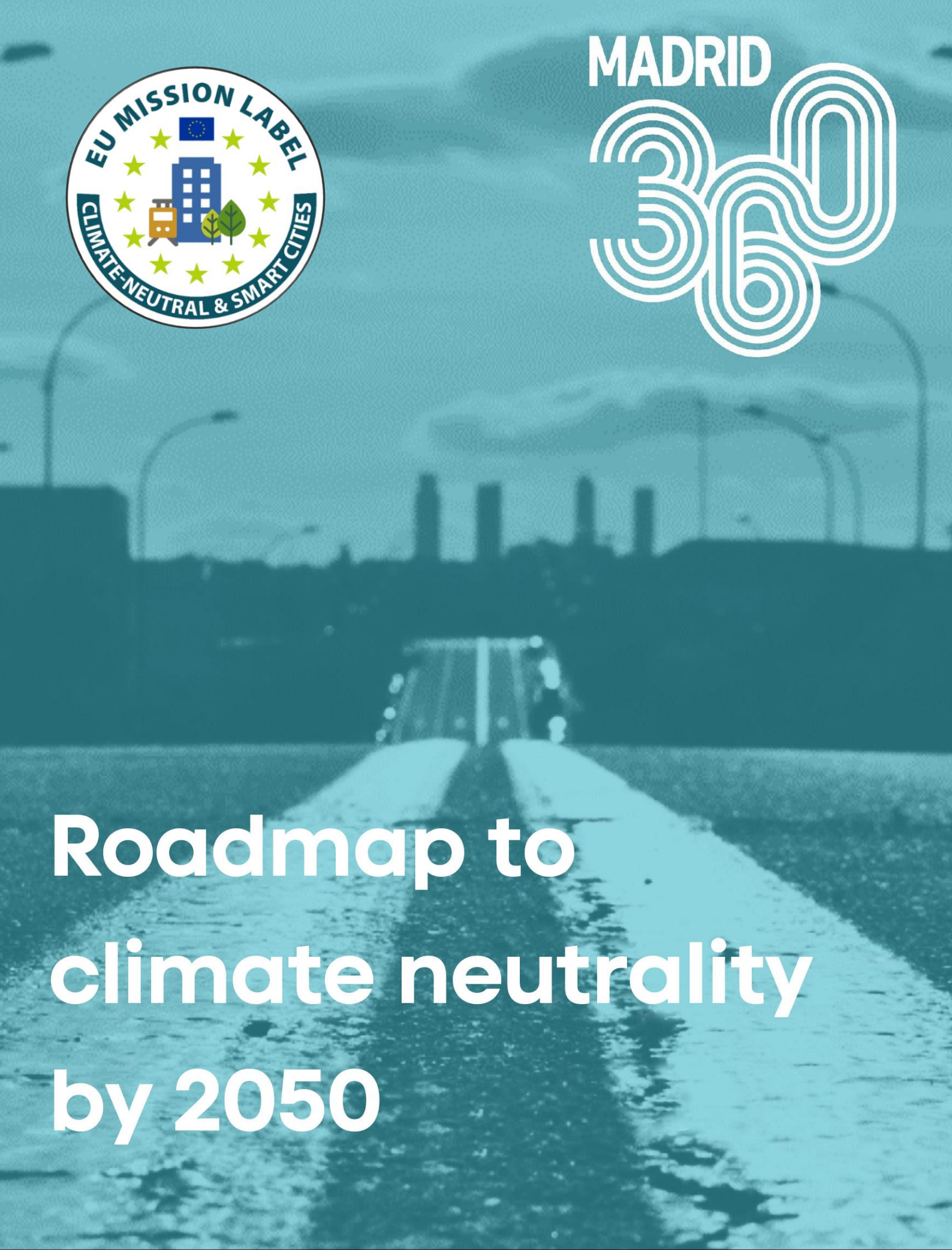



MADRID 360

# Roadmap to climate neutrality by 2050

2024 update

MADRID

# MADRID
# Roadmap to climate neutrality by 2050

## Contents

# 1 | Vision and commitment

The objective of this Roadmap is to define the city of Madrid's top-priority lines of action against Climate Change, an environmental challenge with increasingly visible effects that have a direct and profound impact on the society and economy of Madrid.

Climate change impacts are becoming ever more complex due to interactions and cascading effects at a global level, but cities have gradually taken on a key role.

Urban environments cover less than 2% of the Earth's surface but contain over half of the global population (over 80% of the population in Spain). They are centres of high energy intensity, accounting for over 75% of global energy consumption, and are responsible for 60% of the greenhouse gas emissions that cause global warming, making cities the most significant contributors to climate change.

However, cities are also very vulnerable to impacts resulting from changes in climate that jeopardise urban systems, from impacts related to the supply of essential resources such as water, energy or food, to those related to health, migratory flows or economic activity.

What is clear is that cities have a vital role to play in the solution to this challenge by developing their potential in terms of resources and action. Cities already lead climate initiatives as centres of knowledge and innovation that shape patterns of social behaviour, making the shift to a new low- or zero-emission urban model a necessary part of any global-scale sustainability strategy.

The Madrid 360 Environmental Sustainability Strategy, presented in September 2019, already noted that "*the compelling need to curb climate change led the European Union to establish clearer and more ambitious limits on gas emissions in cities*" in its introduction and, in 2020, the European Council endorsed the new binding target for the EU to reduce its net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels (European Green Deal). The Madrid 360 Strategy has developed this Roadmap not only to respond to this challenge, but also to establish more ambitious objectives, as befits those cities aiming to spearhead the fight against climate change.

The climate action described in this Roadmap has its roots in the general objective established by the Madrid 360 Environmental Strategy: to transform Madrid into a more environmentally sustainable city, having a direct impact on improving quality of life, developing a low-carbon economy, and increasing security and resilience in the face of climate risks. It identifies and develops the most relevant Madrid 360 actions on reducing greenhouse gas emissions in order to stop, revert and mitigate the effects of climate change, as well as climate adaptation measures that increase the city's capacity to respond to climate impacts. Further, the city wants its progress in the transition to climate neutrality to follow the principles of 'leave no one behind' and 'do no harm'. Accordingly, this Roadmap aims to help develop the local economy, through social innovation and the creation of job opportunities.

The **City of Madrid's Roadmap to Climate Neutrality by 2050** aligns municipal policies with EU and national policies, while taking ownership of the most ambitious challenges for reducing greenhouse gas emissions. The targets of this Roadmap are to **reduce the city of Madrid's emissions by 65% by 2030, compared to 1990, and to achieve climate neutrality by 2050** (sustainable scenario).

But this journey does not start here: Madrid has already travelled some distance along this path. This Roadmap adds to a set of commitments, plans and instruments that feed into the city of Madrid's climate-planning process, resulting in a living plan that is in constant evolution and expansion through the addition of new initiatives.

The Roadmap is therefore a technical analysis whose purpose is to support the city of Madrid's political commitment to taking action on climate change. This commitment is primarily a response to international movements and tools, some of the most significant of which are detailed below.

- The European Green Deal. On 11 September 2019, the Commission presented its Communication on the **European Green Deal**. This is a new growth strategy for the EU aiming to transform it into a climate-neutral, equitable and prosperous society with a modern, resource-efficient and competitive economy. At the European Council meeting in 2019, EU leaders restated their commitment to taking a leadership role in the global fight against climate change, confirming the target of climate neutrality by 2050. In December 2020, the European Council endorsed a new binding target for the EU to reduce its net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels, which is 15 pp above the 2030 target agreed in 2014. These targets were included in the European Climate Law passed in June 2021, which established and defined the objective of climate neutrality by 2050.

- **Recover, Transformation and Resilience Funds** (Next Generation EU). An ambitious financing plan, with a programme for Spain that includes 'A country committed to decarbonisation, investing in green infrastructure and moving from fossil fuels to a clean energy system' as one of its main objectives and has the green transition as one of its four core elements. The climate variable is therefore one of the primary factors determining allocation of the funds associated with the Plan.

The **Paris Agreement**, reached within the framework of the Conference of the Parties (COP21, December 2015) to the Convention on Climate Change. In line with the conclusions of the scientific community (IPCC), this agreement sets the target of keeping the rise in global temperature below 2°C, recommending that the increase be kept below 1.5°C to avoid irreversible consequences, and establishes that emissions reductions must be translated into the specification of nationally determined contributions. It is also worth highlighting Madrid's significant role in the celebration of **COP 25** (December 2019), in which the climate vision and ambition of our city was restated.

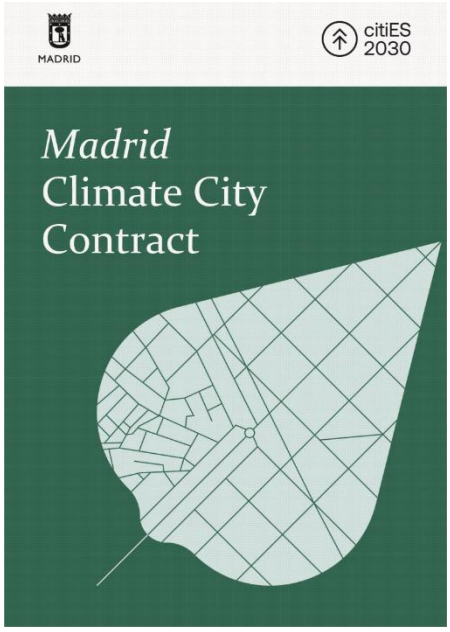
- The challenge taken on by Madrid City Council as a member of the **C40** Cities Climate Change Leadership Network, which set a 2020 deadline (Deadline 2020 Initiative) for producing a Roadmap to achieve zero greenhouse gas emissions by 2050, with an interim target for 2030.

- The Covenant of Mayors for Climate and Energy, which Madrid has participated in since its foundation in 2008, whose purpose is to bring together the local governments that have voluntarily committed to meeting and surpassing the EU's climate and energy targets.

- Since April 2022, Madrid has participated in the **EU Mission for climate-neutral and smart cities**, one of the components of the new 'Horizon Europe' EU Framework Programme for Research and Innovation for 2021–2027, whose objective is to support, promote and showcase 100 European cities' shift to climate neutrality by 2030, turning them into experimentation and innovation hubs as an example for other cities.

As part of its commitments within the EU Mission, Madrid's Climate City Contract was signed at the end of March 2023. This contract engages with the Mission by providing a systematic vision of the entire city and three key strategic interventions: new climate-neutral urban developments, a new culture for citizens of the future through initiatives in university campuses and schools that will be transformed into zero-emissions environments, and the transformation and regeneration of a consolidated city in which public space and facilities act as climate-neutral nodes.

In October 2023, the European Commission awarded Madrid the 'Mission Label', recognising the city's ambition and work on developing its Climate City Contract. The CitiES2030 initiative, which brings together the Spanish cities in the Mission, has become the national leader within the EU Mission, putting Madrid at the forefront of the cities working to develop a tool for collaborating with the Spanish state and other institutions to move forwards in urban decarbonisation.


The Roadmap develops the climate action already outlined in a general sense by the Madrid **360 Environmental Strategy** and the **Air Quality and Climate Change Plan**, and also specified in such institutional declarations as:

**The 'La Villa' 2020 Agreements (*Acuerdos de la Villa 2020*)** in which the MEC.GT1.067/274 Agreement highlights the need for specific municipal actions to fight climate change in order to meet, as a minimum, the national and European targets for 2030 and 2050 on decarbonisation and climate neutrality.

**The Declaration of Climate Emergency** (25/09/2019), through which the Plenary of Madrid City Council approved the need to establish the political commitments, regulations and resources necessary to ensure the progressive reduction of greenhouse gases.

This Roadmap is the product of an analysis coordinated by the Urban Planning, Environment and Mobility Area which, from the start, received contributions from a range of sources:

- The participation of several municipal departments, which has served to align policies and goals, and to pursue the synergy necessary for climate action.
- The technical guidelines of the cities networks, including the C40 network.
- Universities and research centres, through European projects and specific studies.
- Consultants specialising in decarbonisation and private entities focused on energy and climate strategy.
- Collaboration with a range of organisations, social bodies and private entities to better integrate social factors such as access to public resources, job creation and public engagement, which are crucial for progressing towards decarbonisation commitments.

# 2 | The starting situation

Achieving the Roadmap's objectives depends largely on how the socioeconomic context accompanying the process develops. Putting many of the measures into practice will require economic investment from the public and private sectors, and an explicit goal of securing social cohesion and inclusive development. The Roadmap therefore needs to pay close attention to environmental, economic, social and technological trends, which include the following variables:

### Social trends

- Population ageing
- Environmental awareness of the population
- Capacity to manage energy consumption and production
- Energy poverty (energy crisis)
- Demographic process of urbanisation
- Active and shared mobility, modal shift

### Technological trends

- Development of more efficient technologies (e.g. heat pumps, hybrid or electric vehicles) and energy sources (e.g. hydrogen)
- Increased proportion of renewables in the energy mix
- Reduced cost of renewable energy generation and batteries
- New models of energy production and distribution (self-consumption)

### Economic trends

- Economic growth
- Development of collaborative business models
- Development of environmental taxes
- GHG emissions cost
- Green employment opportunities
- Remote working

### Environmental trends

- Development of more precise GHG calculation and tracking tools
- Increase in adverse weather events
- More stringent EU energy, climate and air quality regulations
- Mitigation and adaptation policies (EU Missions)
- Rewilding cities and promoting biodiversity
- Urban proximity planning

Madrid City Council has a large number of tools at its disposal to help it produce a diagnosis of the urban situation, including the socioeconomic analysis, monthly economic situation report, diagnostic reports by district, vulnerability rates by district, and the city diagnostic report carried out as part of the Review of the General Urban Development Plan of Madrid.

## Environmental trends

In recent years, the city of Madrid has launched policies, plans and actions to reduce Greenhouse Gas Emissions (GHG). These actions have generally been linked to other municipal plans such as those addressing air quality and urban mobility or regeneration, with the aim of using resources efficiently, developing synergies and aligning different municipal policies.

To understand the current status of these emissions and how they have changed over time, Madrid City Council produces the city's annual GHG Inventory. The inventory provides information on direct emissions (scope 1) and indirect emissions caused by electricity consumption and distribution losses (scopes 2 and 3), broken down by economic sector.

The inventory follows the methodology used by the European CORINAIR project, coordinated by the European Environment Agency (EEA), and complies with the requirements established by the Intergovernmental Panel on Climate Change (IPCC) and the Task Force on Emission Inventories and Projections of the United Nations Economic Commission for Europe (TFEIP–UNECE). The data collection, analysis and consolidation process results in a time lag in the publication of the inventory, meaning that the latest report is for 2021. The data in the 2021 GHG Inventory show a total emissions volume of **8,224 ktCO$_2$eq**, of which **6,356.4 ktCO2eq** (77.3%) were direct emissions and **1,867.6 ktCO$_2$eq** (22.7%) were indirect emissions.

*Breakdown by sector of total GHG emissions (2021)*

| Sector | Emissions kt $CO_2$ eq | Contribution (%) |
|---|---|---|
| **Residential, commercial and institutional** | 3,648.4 | 44.4 |
| **Industry*** | 503.7 | 6.1 |
| **Road transport** | 2,253.4 | 27.4 |
| **Other modes of transport** | 653.8 | 8.0 |
| **Waste treatment and disposal**** | 808.6 | 9.8 |
| **Others***** | 356.2 | 4.3 |
| **TOTAL** | **8,224.0** | **100** |

*(*) Includes industrial emissions from combustion and non-combustion processes (SNAP groups 03 and 04)*
*(**) Includes waste treatment and wastewater treatment*
*(***) Includes extraction and distribution of fossil fuels, use of solvents and other products, agriculture and nature (excluding $CO_2$ absorption by sinks)*

*Direct and indirect GHG emissions (2021)*

| 2021 | Emissions kt $CO_2$ eq | Contribution (%) |
|---|---|---|
| **Direct** | 6,356.4 | 77.3 |
| **Indirect** | 1,867.6 | 22.7 |
| **TOTAL** | **8,224.0** | **100** |

By economic sector, the residential, commercial and institutional (RCI) sector produces the most emissions at **3,648 ktCO$_2$eq** (44.4%), followed by road transport at **2,253 ktCO$_2$eq** (27.4%) and waste treatment and disposal at **808.6 ktCO$_2$eq** (9.8%).

Between 1990 and 2021, the city of Madrid's direct GHG emissions decreased by 24% and indirect emissions decreased by 60%, translating into a total emissions reduction of 37%. In the 2000–2021 period, direct emissions decreased by 20% in the RCI sector (despite the increase seen in the last year) and by 44% in the road transport sector. It is worth noting that the COVID-19 pandemic continued to have a significant impact on emissions in 2021, with a decisive impact on activity in some sectors, such as those related to passenger or goods transport.

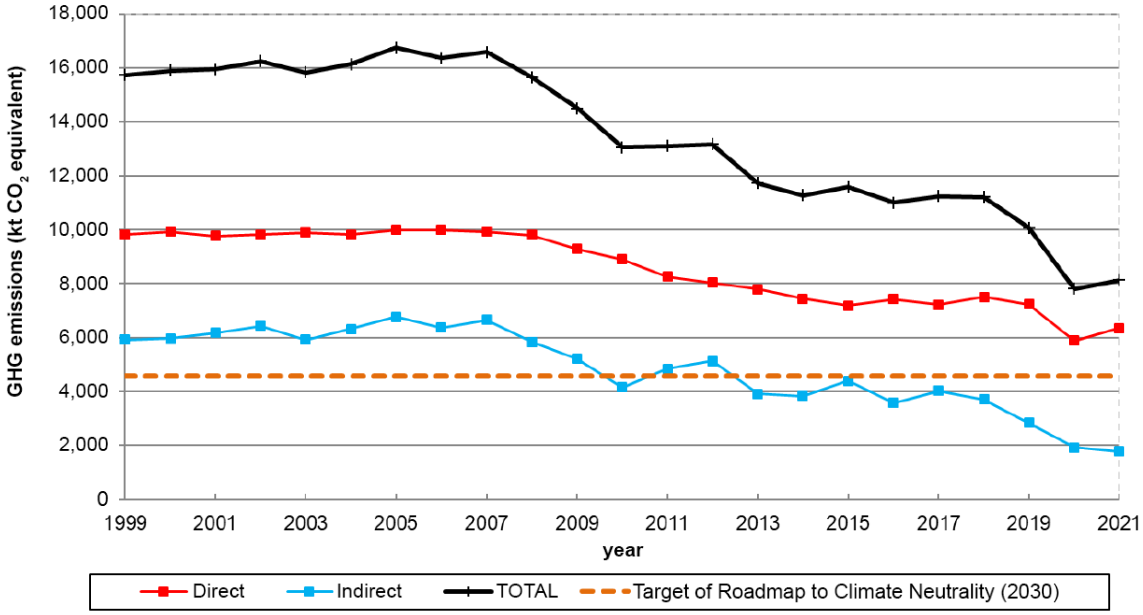
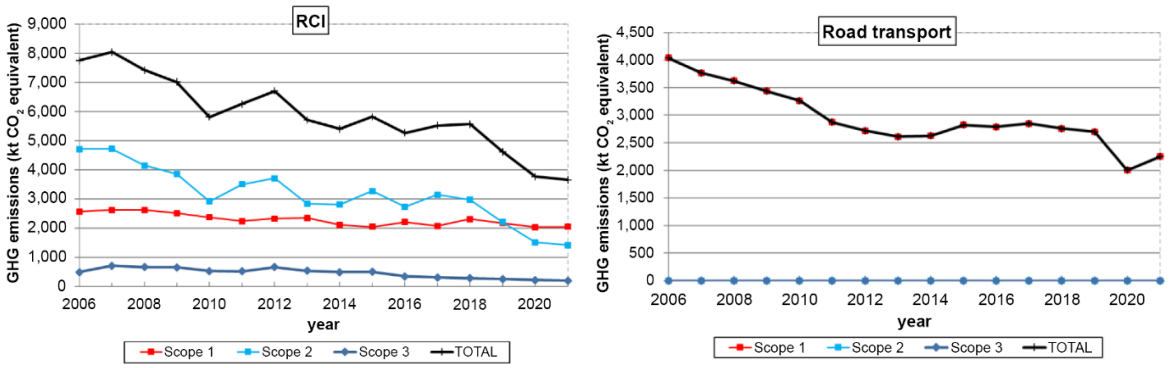



**Figure 6: Direct and indirect GHG emissions in the municipality of Madrid over time**




The indicators show much lower per capita emissions in the municipality of Madrid than the national average, as well as higher energy intensity.

Municipal emissions per capita decreased by 55% in the 2000–2021 period as a result of population growth (15%) and the reduction in total GHG emissions (48%). Additionally, Madrid's 'emission intensity per unit of GDP' decreased by 65%, resulting from the combination of this GHG emissions reduction and an increase in GDP (47%).

In 2021, the municipality of Madrid contained 7% of Spain's national population and generated 3% of its total GHG emissions. The municipal per capita emissions were therefore 59% lower than the national average (2.5 vs 6.1 t/inhabitant). Madrid generated 13% of national GDP, meaning that its 'emission intensity per unit of GDP' was also 78% lower than the national level (59 vs 268 t/M€2010). These important differences are largely due to the economic structure of the municipality, with most economic activity concentrated in the third sector (services) rather than industry, whose higher energy consumption generates more emissions.

*Municipal and national emissions indicators (2021)*

| 2021 | Emissions per capita (t $CO_2$ eq/inhab.) | Emissions per unit of GDP (t $CO_2$eq / M€$_{2010}$) |
|---|---|---|
| **Madrid** | 2.5 | 59 |
| **Spain** | 6.1 | 268 |
| **Madrid/Spain ratio** | 0.41 | 0.22 |

During the period analysed (2000–2021), per capita emissions decreased more in Madrid than in Spain as a whole (55% in Madrid compared to 36% nationally) despite the fact that the population grew proportionally more at a national level (17% in Spain compared to just under 15% in the municipality of Madrid). This means that the larger decrease in per capita emissions was due to a greater reduction in municipal emissions (48% compared to 25% nationally). Looking at emissions per unit of GDP, this indicator decreased by 65% in Madrid in the 2000–2021 period, while the decrease in Spain as a whole was 45%. This distinct change reflects a larger decrease in total GHG emissions at a municipal level and a greater increase in GDP.

Mitigation efforts have focused on the highest-emitting sectors of transport and building, involving the development of convergent policies such as those addressing air quality, building renovation and energy efficiency.

Thanks to the combination of actions taken at a municipal level and by other institutions and sectors, the city of Madrid is generally on the right path when it comes to emissions reductions, although the trends show the need to move faster and increase GHG reduction rates.

To meet the objectives set in this Roadmap, it is necessary to continue and escalate emission mitigation policies, addressing challenges such as **decoupling economic growth from increasing energy consumption and emissions**, and promoting an inclusive form of development that engages citizens and fosters social cohesion, supporting the move towards sustainable models of urban transformation.

## Economic trends

The City Council publishes Madrid Economy report each year, providing a socioeconomic analysis of the city and a general overview of the current situation and trends. The 2023 edition shows a situation of sustained economic growth over the past few years, part of a clear path of recovery from the crisis at the end of the 2000s, as well as a reduction in employment and economic activity in some strategic sectors resulting from the pandemic. The city has managed to recover and exceed pre-pandemic economic performance, with record numbers of people in registered employment at the end of 2022 and beginning of 2023.

The city's economic structure is dominated by services (88.3%), followed by industry (7.4%) and construction (4.3%). Within the services sector, the most significant subsectors are information and communications; professional, scientific and technical activities; real estate, and financial activities. These four groups account for 40% of the total added value generated by Madrid's economy.

Madrid's economy has stood out in recent years for its relative strength, along with a growing entrepreneurial drive. According to the economic situation report for November 2023, GDP grew by 5.8 % in 2022: half a percentage point less than the previous year, and equal to national growth. The pandemic caused Madrid's economy to contract by 10.5% in 2021, a slightly smaller recession than in Spain as a whole, although there was growth in all sectors in 2022, except for financial activities and insurance in the services sector. The analysis underlines the importance for the city of strategic sectors such as tourism, transport infrastructure, research and education, finance and exports.

According to the Economically Active Population Survey 2022, Madrid's average annual employment rate was 71.61% for people aged between 16 and 64, and the unemployment rate was 10.97%. However, the figures provided by the Madrid City Council Stable Household Panel were higher, with a higher risk of unemployment for women (17.5% compared to 14.7% for men) and people born outside the EU (19%). The energy transition is an opportunity to create jobs and develop the local economy. The green employment report produced by the Ministry for the Green Transition and Demographic Challenge notes the lack of trained professionals to meet the increasing demand for specialised employment that will arise during the green transition.

It is also worth highlighting the changing trends in remote working seen since the start of the pandemic. Despite the decrease recorded after that period, remote-working rates in the Community of Madrid remain above the national average. National Statistics Institute (INE) data for the second quarter of 2022 showed that 22% of workers in the region work from home occasionally or for more than half their working days. Nevertheless, 46% of jobs in the Community of Madrid could currently be performed through remote working, representing a 24% gap with respect to the current proportion of remote workers. This indicator points to significant potential for expanding remote working in the region, with around 785,000 additional people who could work remotely with relative frequency compared to the current situation, potentially resulting in decreased daily travel and, therefore, increased emissions reductions.

## Social trends

In demographic terms, the city's population reached 3,339,931 inhabitants in January 2023, representing an increase of 1.6% compared to 2022. This increase was a significant change after the loss of almost 50,000 inhabitants caused by the pandemic in the two preceding years, and a return to the positive trend observed in the 2015–2019 period. The city is also part of a metropolitan area that contains almost 7 million inhabitants.

Data from the Municipal Population Register show a society undergoing a process of ageing, evidenced by the fact that 17% of the population is aged under 19, while 20% is over 65. The arrival of people from other countries has facilitated the incorporation of new workers into the productive economy, creating an expansion in the base of the age pyramid that represents the most economically active segments of the population, and generally helping to counteract the demographic ageing process.

According to the data on household types in Madrid's social diagnosis report for 2021–2022, one-person households account for 31.1% of the total in the city of Madrid, and 12.3% of households consist of one person aged over 65. Figures on living arrangements show that around one in three households comprises an adult couple with dependent children, while one in four consists of couples without children. The report also shows that 8.2% of households have other types of living arrangements, with a significant proportion of migrants in this category.

While single-parent households make up only 2.5% of the total, their impact on the city's social services is considerably greater, due to the vulnerability associated with this family structure. Additionally, in 38.6% of households, the person with the role of primary earner is a woman. It is worth noting that the average age of these primary earners is 62 years, again reflecting a society facing the challenge of an ageing population, while also demonstrating the difficulties young people are facing when it comes to setting up their own households.

In terms of economic vulnerability, 28.14% of households have trouble making ends meet each month. Particularly deserving of attention are the households that struggle to cover their housing costs (7.93%), keep their home at an adequate temperature in summer or winter (7.06%), or pay basic utility bills (5.91%). It is important to note that these last two situations are indicative of what is commonly termed energy poverty. It is also worth underlining that single-parent households and those containing only one elderly person tend to accumulate disadvantages and experience more significant harm to their wellbeing.

With regards to perceptions of the climate transition, 57% of the population in the Community of Madrid has a positive vision of the impact of the green transition on their local context, according to a Report by the Fair Transition Observatory. The inhabitants of Madrid also expressed a greater willingness than the national average to adopt measures to help fight climate change, such as installing solar panels on their homes (92% vs 89%) or purchasing a hybrid or electric car (78% vs 69%). When considering mobility trends, it is important to note that the pandemic created significant changes in mobility patterns in Madrid. While the Mobility Report 2020 provided relatively stable figures on the use of motorised vehicles (approximately 425 vehicles per 1000 inhabitants), vehicle registrations decreased by 51.7% in 2023 compared to the previous year, according to data from the General Secretariat of Statistics.

# 3 | Emissions-reduction targets

The urgent need to accelerate emissions reduction processes requires an increased level of ambition in decarbonisation targets and shorter timescales for achieving carbon neutrality. The Paris Agreement and the targets set by the European Union in the Framework on Climate and Energy for 2030 are the benchmarks at the European level. At the local level, Madrid City Council initially adopted the targets set out in Plan A, the Air Quality and Climate Change Plan for the city of Madrid. However, in order to meet the most advanced European targets, and considering the context of the European Green Deal, the city of Madrid has not only taken up the European Commission's challenge to increase climate ambition in Europe for 2030, but has made a more ambitious commitment in its Madrid 360 Environmental Strategy:

**A 65% reduction in greenhouse gas emissions by 2030 (compared to 1990), exceeding the European target by 10 percentage points and putting Madrid on the path to climate neutrality by 2050.**

Considering that emissions in 1990 were **12,954 kt$CO_2$eq (13 Mt$CO_2$eq)** and that, if the trend in emissions seen to date and the expected trajectory (current trend scenario) are followed, it will not be possible to meet the targets set, the following GHG emissions-reduction scenarios are proposed for the city of Madrid:

Under the **sustainable scenario**, which involves focusing on the emissions reduction measures with the greatest abatement capacity and making use of innovative implementation tools, as described below, the projected emissions for **2030** would be **4.5 Mt$CO_2$eq**, representing a **65.3% Mt$CO_2$eq** reduction compared to 1990, reaching **1.4 Mt$CO_2$eq** in **2050**, with carbon neutrality achieved through offsetting mechanisms.

Under the **enhanced scenario,** which requires unlikely but technically feasible socioeconomic changes, the projected emissions for **2030** would be **3.4 Mt$CO_2$eq,** representing a **73.8% Mt$CO_2$eq** reduction compared to 1990, reaching **0.6 Mt$CO_2$eq** in **2050**, with carbon neutrality achieved through offsetting mechanisms. Madrid's Climate City Contract has started a process of exploring how the city could follow this 'enhanced scenario' and thereby set more ambitious targets for the decarbonisation of its systems.

Other municipal and regional documents have established commitments that are consistent with the sustainable scenario outlined in this Roadmap. Within the framework of the Madrid 360 Sustainable Mobility Plan, emissions-reduction projections have been made using an urban traffic simulation model, assuming a reduced use of private vehicles and replacement of the fleet of vehicles in circulation. According to these estimates, the approximate reduction in GHG emissions by urban traffic is expected to exceed 65% by 2030, compared to the levels recorded in 1999. In parallel, the Community of Madrid has set specific GHG reduction targets in its Air, Climate and Energy Strategy 2023–2030, and underlined their cons with this Roadmap, its proposals and targets.

## Emissions-reduction scenarios

Meeting the proposed targets requires all sectors of society, and particularly the various governmental agencies, to develop policies, plans and actions that promote transformation of the sectors and primary mechanisms responsible for emissions.

Reaching carbon neutrality by 2050 necessitates a progressive year-on-year reduction that should meet successive interim targets until that date. The pace of emissions reduction will be determined by the set of measures implemented, at the local and supra-municipal levels.

The following three trajectories towards decarbonisation have been defined, which differ according to the measures implemented and contextual conditions:

**CURRENT-TREND SCENARIO**

This scenario assumes the continuation of projected economic growth, emissions reductions in line with current trends in energy demand along with current levels of uptake of technology and activity and consumption patterns.

- Changes in line with current trends in emissions-reduction levers (e.g. replacement of equipment at the end of its useful life with devices that are more efficient but use the same technology).
- Reduction of the emission factor associated with the electricity mix by approx. 60% (2030 vs 2015) and by 100%, in line with the projections contained in the Integrated National Energy and Climate Plan (INECP).
- Expected trend in economic growth.

**SUSTAINABLE SCENARIO**

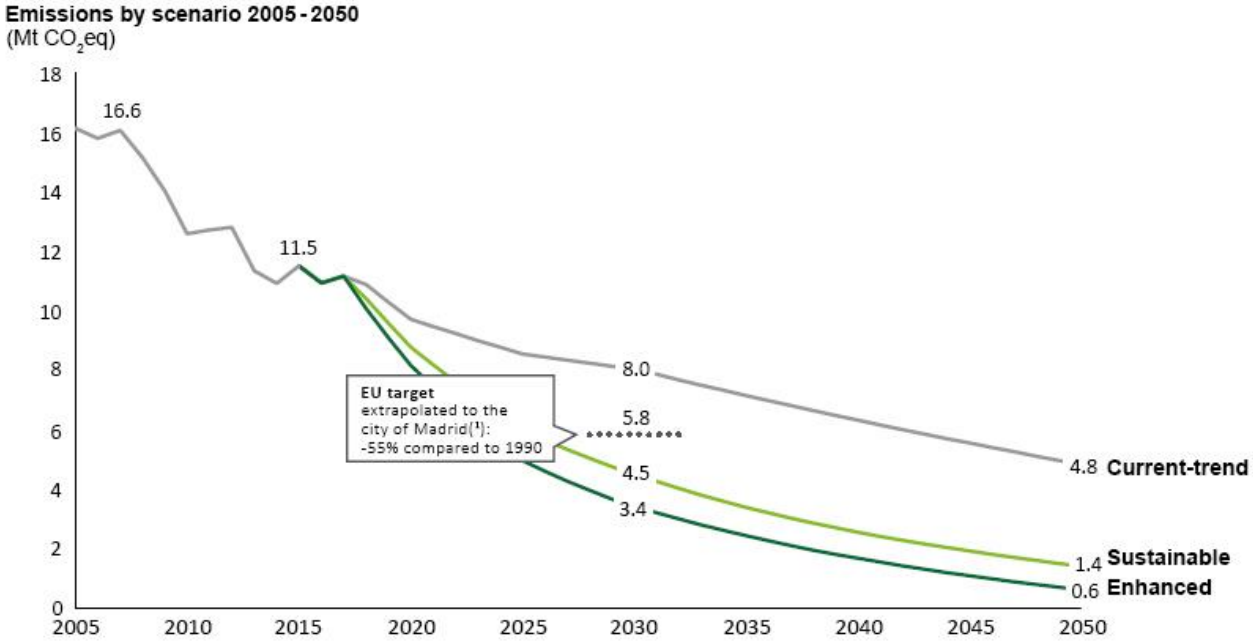
In addition to the expected economic growth and progression of current trends, resulting from the contextual conditions, more ambitious and faster-paced emissions-reduction measures are implemented.

- Expected trend in economic growth in addition to measures that address activity and consumption patterns, reducing energy demand (e.g. urban proximity schemes, remote working, etc.).
- Implementation of ambitious measures to increase the pace of GHG emissions reduction (e.g. replacing equipment before its useful life ends, measures to promote penetration of new technology, heat pumps, electric vehicles, building renovation).
- Increased ambition in reducing the emission factor associated with the electricity mix to reach approx. 85% (2030 vs 2015) and 100%, in line with the projections contained in the INECP.

**ENHANCED SCENARIO**

Additional and faster-paced measures on demand reduction and new-technology penetration are implemented, on top of the sustainable-scenario projections, but the degree of uncertainty is increased by the inclusion of less well-defined political, social and technical contexts in the projections.

- The economic projections in the current-trend scenario are maintained, but a more ambitious set of measures to reduce energy demand is included.
- The measures applied in the current-trend scenario are enhanced to achieve greater reductions, but based on less reliable political, social and technological assumptions.
- Reduction of the emission factor associated with the electricity mix to reach approx. 85% (2030 vs 2015) and 100%, in line with the projections contained in the INECP.




According to the emission trajectories for the sustainable and enhanced scenarios, the EU's ambitious targets for 2030 will be met in both scenarios. The projected emissions for that year in the sustainable scenario are **4.5 $MtCO_2eq$,** a decrease of 61% compared to 2015 and 65.3% compared to 1990 in tonnes of GHG emitted, improving on the targets proposed by the EU.

The enhanced scenario is even more ambitious, reaching **3.4 MtCO2eq** in 2030, which is 70.4% lower than 2015 and 73.8% lower than 1990 levels.

In 2050, there would be residual emissions of **1.4 $MtCO_2eq$** in the sustainable scenario and **0.6 $MtCO_2eq$** in the enhanced scenario, which would need to be compensated by supplementary offsetting measures such as GHG absorption by forest plantations.

As the graph shows, 2020–2030 is a particularly important period in the decarbonisation trajectories, when a strong push is needed in implementing measures and creating the conditions that will drive decarbonisation forwards by momentum in the second period of 2030–2050.

## Co-benefits of climate policies

The road to climate neutrality involves changing many current urban models along with social and economic transformation. Important co-benefits will be created during this process, connected to the decarbonisation actions. Raising awareness about these co-benefits and explaining them clearly could be vital to create incentives and secure effective public participation in the decarbonisation process.

Actions to improve the energy efficiency of the building stock will have the co-benefit of improved housing quality, especially in the buildings and areas of the city with the highest levels of vulnerability. These actions will also improve access to energy, reducing rates of energy poverty and generating positive impacts on health, education and children's performance at school. Energy efficiency improvements also provide opportunities to create new high-quality, skilled jobs, helping to strengthen the local economy.

Changes in mobility will have a direct effect on the city's air quality and noise pollution levels, due to reduced demand, the penetration of new technologies and a modal shift towards sustainable forms of transport. The assimilation of new behaviours such as remote working and the development of urban proximity planning will reduce the demand for travel and increase the prevalence of non-motorised forms of mobility such as walking and cycling. Mobility-related mitigation policies have co-benefits for the population's health, from improvements in the city's environmental conditions to the promotion of healthy lifestyle habits connected to active mobility.

The development of offsetting mechanisms, such as creating carbon-sink forests, will significantly increase the natural spaces and biodiversity in the city, with all the co-benefits that this brings.

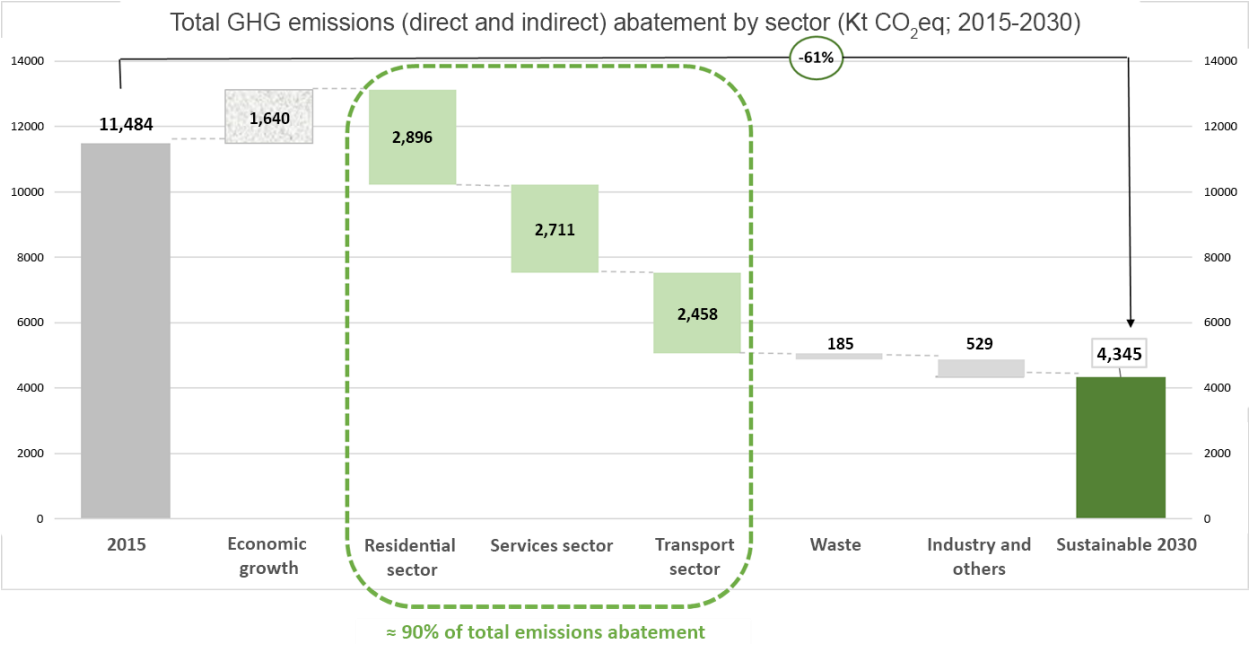
The mitigation actions will be accompanied by climate change adaptation measures which, in addition to strengthening the city's response to climate risks, provide a whole range of co-benefits, from improving the health of the population to increasing the quality of public spaces, stimulating local economies, improving water management and reducing insurance costs, to name a few of the many positive effects.

| LEVERS FOR DECARBONISATION |
|---|
| Reduced travel (remote working, urban proximity planning) |
| Reduced use of private vehicles |
| Modal shift |
| New transport technologies |
| Energy-efficiency renovation |
| Electrification of heating systems |
| Reduced volume of waste |
| Improved waste recovery rates |
| Emission offsetting |

| CO-BENEFITS |
|---|
| Health |
| Biodiversity |
| Urban rewilding |
| Air quality |
| Equity and social inclusion |
| Water management |
| Energy accessibility |
| Clean energy |
| Reduced sound pollution |
| Economic growth and increased employment |
| Local economies; new business models |
| Promotion of the circular economy |

# 4 | Sectors and levers for transformation

It is the sum of the GHG abatements achieved by each sector that will enable Madrid to meet its overall emissions reduction target. The trajectory set out in the sustainable scenario includes the contribution by sector in the 2015–2030 period shown in the figure below.

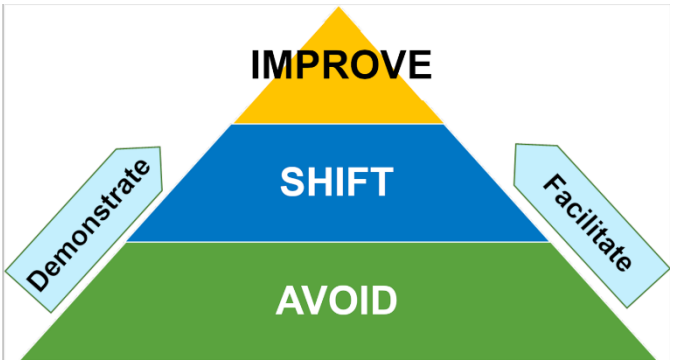



The sum of the proposed GHG abatements for each sector from 2015 to 2030 is equivalent to an emissions reduction of 61%, and 65.3% compared to 1990 (meeting EU targets).

The **residential sector** is expected to contribute the largest volume of emissions reductions (**2.9 $MtCO_2eq$**), followed by the services sector (**2.7 $MtCO_2eq$**) and transport (**2.4 $MtCO_2eq$**) sector. As shown in the figure above, the sum of the emissions abated by the transport, residential and services sectors accounts for most of the required emissions reductions, at over 91%.

It is in these sectors that action should therefore be redoubled, albeit without failing to act in the other areas, given the need for decarbonisation strategies to be comprehensive, taking on board the interrelationships and complexities of the urban system.

While the primary aim of this Roadmap is to identify and accelerate those measures that offer the greatest potential for GHG reduction, it is important to stress that the Roadmap's general framework must not overlook the need for a **hierarchy of interventions** working towards a new urban model and the development of flagship policies, irrespective of the short-term GHG reduction potential of the levers for transformation. This hierarchy of policies working towards sustainability uses the **AVOID – SHIFT – IMPROVE** approach, which has been widely implemented in this field:




**1. AVOID**: Sometimes the alternative term 'reduce' is used. It refers to the decision not to use a resource or to use it less. Installing insulation, building renovation and improving energy efficiency in the building sector, the reduction of travel in general and motorised transport specifically, or reduced waste generation are all basic examples of a sustainable urban model, although their impact on GHG emissions may be gradual or difficult to quantify.

2. **CHANGE**: The second level in this hierarchy refers to the selection of a more efficient option or method than the one currently in use. Adopting active modes of transport (walking, cycling) or public transport, making use of high-efficiency heating and air-conditioning technologies such as heat pumps, or implementing schemes for reusing materials are examples of actions that fit into this category.

3. **IMPROVE**: The third step in the transformation process is the incorporation of improved technologies or sources to reduce the emissions impact. This should take place after the actions focused on avoiding consumption and adopting more efficient options have been taken. Actions in this category include electric transportation, electric and thermal power generation from renewable sources, the recovery of materials through recycling, and extracting value from waste.

The role of the City Council in this hierarchy of actions is twofold. Firstly, it will facilitate implementation of actions through enabling regulations, urban planning that aligns with the objectives, and municipal services that help scale up the actions. Secondly, it will have a demonstrative role, setting an example and acting as a test case for innovative climate solutions. The City Council also plays an essential role in providing support (information, financing, guidance, etc.), particularly to people in situations of vulnerability, to enable them to participate in the transition.

This document defines the concepts below as follows:

- **Strategy**: each of the intended series of actions with emissions abatement potential included in this Roadmap. It is proposed that these be structured within the Avoid-Shift-Improve framework described above. Each of these strategies is made up of decarbonisation levers, which themselves consist of lines of actions.
- **Lever**: each sector or themed line of action proposed within a strategy.
- **Action**: a specific, measurable proposal intended to abate GHG emissions. Sets of these actions create levers, grouped by theme or line of work.

The following section analyses the primary emissions-abatement levers for the main sectors. A table summarising these decarbonisation levers and the key actions associated with them is included at the end of the section, while section 7 provides a more in-depth description of the key actions and processes from a municipal perspective.

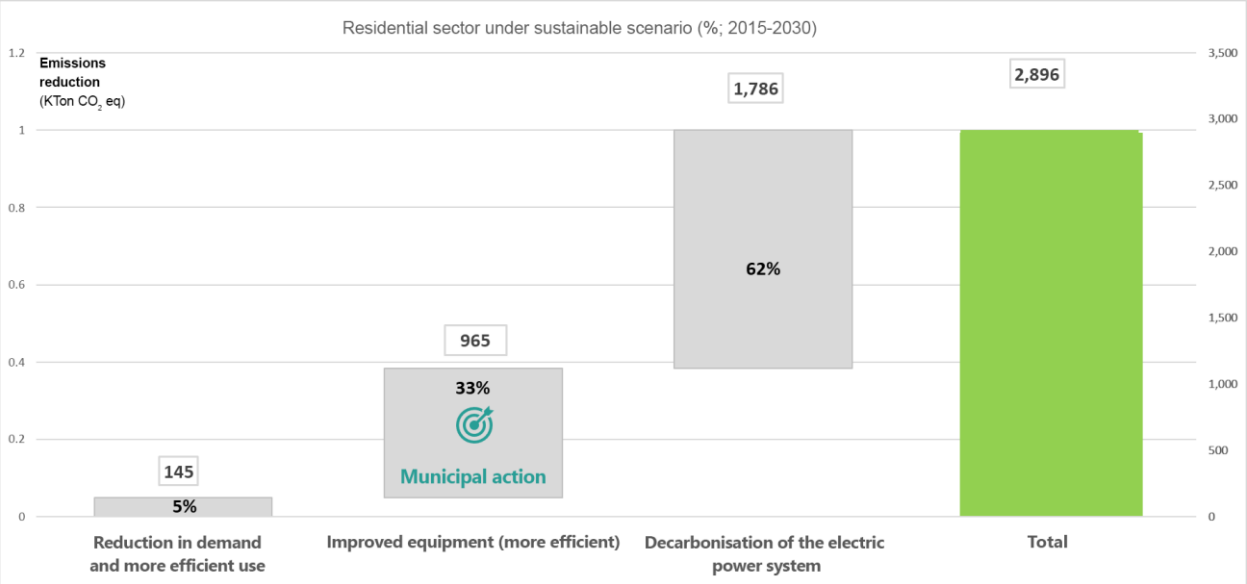
## Analysis of emissions reductions in the main sectors from 2015 to 2030

### Residential sector

Given the predominance of indirect emissions resulting from electricity consumption in the residential sector, along with the increasing electrification of the energy demand to meet air-conditioning needs, reducing emissions related to the electricity mix by incorporating renewable energy sources is a particular priority. In the sustainable scenario, the expected decarbonisation of the energy matrix in the 2015–2030 period will reduce emissions by **1.8 $MtCO_2eq$** in this sector, a decrease of over 60%.

The second line of action should be upgrading heating equipment to NG condensing boilers or, preferably, to electric systems based on heat pumps. With the resulting improvements in performance and energy efficiency, this will provide a further **1 $MtCO_2eq$** reduction: 33% of this sector's emissions in the 2015–2030 period.

Other energy efficiency actions (upgrading household appliances, lighting, etc.), building renovation and insulation make a smaller contribution to decarbonisation of the sector in this limited timeframe. Nevertheless, taking action in these areas is essential due to the co-benefits they bring related to efficient energy use, comfort and quality of life in the housing stock, and their foundational position within the hierarchy of actions working towards a sustainable urban model, as described above.



The Housing Policy Area recognises that the decarbonisation commitments[1] will require a tenfold increase in the rate of energy-efficiency renovation before 2030. Bearing in mind that the public will also need to make considerable investments in terms of economic resources, effort and time, reducing emissions in the residential sector is a significant challenge. Considering the current situation in this sector helps understand the scale of this task. According to data from the Renovate Madrid Agenda (2022):

- The city of Madrid contains 1.5 million homes, 70% of which were built before the current building insulation regulations came into force (1979).
- Madrid needs to go from renovating 2,040 homes in 2021 to 20,400 in 2040, in order to reach a total of over 80,000 renovated buildings by 2030, meeting its commitment under the National Climate Emergency Strategy, as part of the National Integrated Energy and Climate Plan (INECP).
- Between 2017 and 2019, only 16% of the subsidies requested were used for energy-efficiency measures.
- Energy-efficiency renovation is not a requirement to pass the Technical Building Inspection, and consequently the public do not view it as necessary.
- Renovation processes are complex, making it necessary to provide support and guidance to the public, and to simplify administrative procedures.
- Most households live in their home under a property regime (68.1% already paid and 13.8% with a mortgage) compared to 15.2% that rent them.
- Renovation policies have mobilised private investment and generated over 6,000 jobs per year in the specialised construction sector.

The reduction of emissions in the residential sector is directly affected by the decisions made by citizens in their private lives, and by the need for substantial investments. Municipal efforts are therefore focused on raising awareness and providing information to the population through spaces such as the Green Office, creating incentives for the adoption of efficient technologies, and providing financial support for renovation and energy-efficiency projects ('Plan Rehabilita' [Renovate Plan]), focused particularly on the segments of the population with the fewest resources.

## Services sector

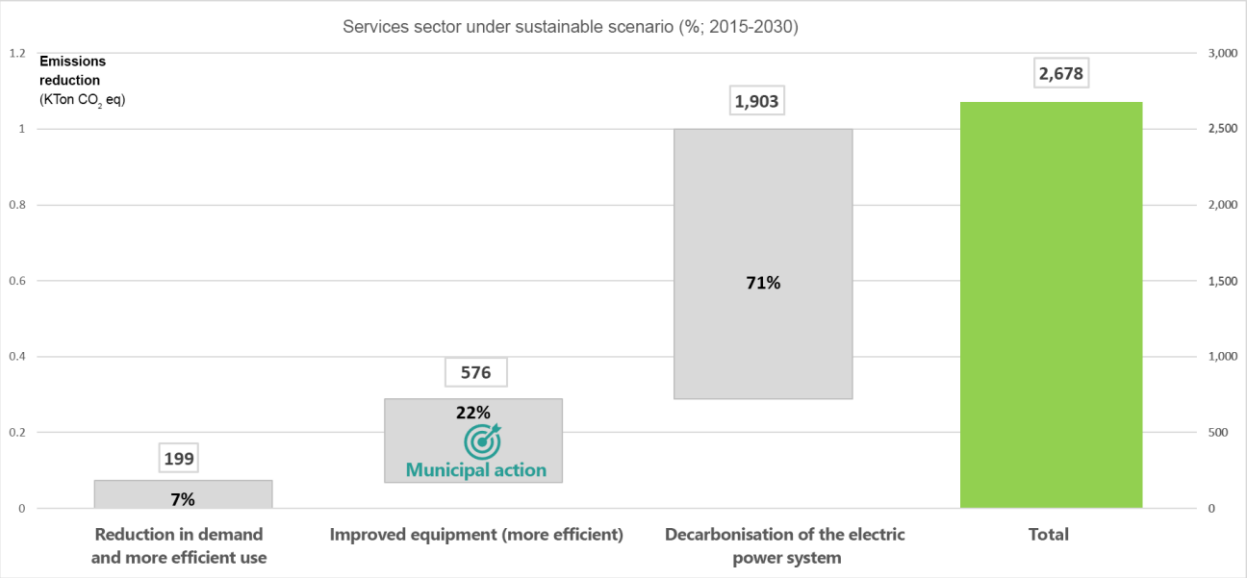
The services sector includes commercial, administrative, cultural and sports buildings belonging to the private sector as well as public bodies and institutions, in addition to fixed assets pertaining to municipal services (street lighting, tunnels, traffic lights, fountains, etc.). A very significant contribution (**2.7 $MtCO_2eq$.**) to the total emissions reduction has been assigned to this sector for the 2015–2030 period. Like the residential sector, the prevalence of indirect emissions means that largest emissions abatement will be secured through decarbonisation of the electricity mix, at **1.9 $MtCO_2eq$** (71%), and the renovation/replacement of heating equipment, at **0.6 $MtCO_2eq$** (22%).

The greater prevalence of electric power in this sector, and its capacity to incorporate efficient electrical equipment such as heat pumps, means that improving the emission factor of the electricity mix will play a more important role in emissions reduction. This

[1] Very stringent targets have been undertaken for housing renovation within the framework of the Long-term Strategy for Energy Renovation in the Building Sector in Spain (ERESEE), under European mandate via Directive (EU) 2018/844, through the Integrated National Energy and Climate Plan, and through the Recovery, Transformation and Resilience Plan (EU funds).

sector therefore has an important role to play in demonstrating electric solutions for buildings with zero local emissions, in which municipal buildings and services should lead the way, given their mobilisation capacity and duty to set a positive example.

In this context, the City Council's role in using materials with a low carbon footprint in renovations and new municipal building developments is also important.



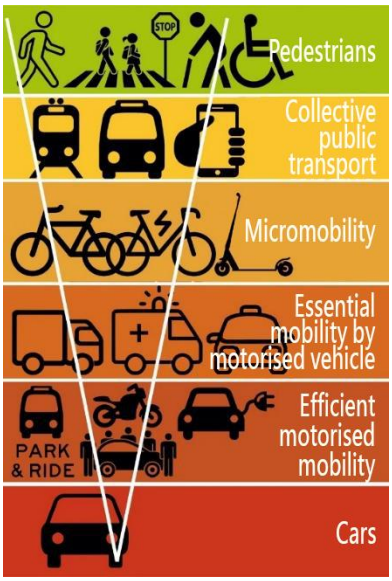

## Transport sector

The emissions-reduction strategy in the transport sector provides a clear example of the AVOID–SHIFT–IMPROVE (ASI) approach. The hierarchy includes the combined action of decreasing demand (urban proximity planning, remote working, etc.), which accounts for a 0.6 $MtCO_2eq$. (23%) reduction, shifting journeys by private vehicle to more sustainable modes of transport, for 0.3 $MtCO_2eq$. (14%), and the penetration of new lower-emission technologies such as electric vehicles.

Replacing the fleet of vehicles in circulation is included within the IMPROVE strategy. This decarbonisation lever provides the largest emissions reduction at 1.2 $MtCO_2eq$. (50%), although most of the fleet is already expected to be replaced in the current-trend scenario, meaning that the sustainable scenario only adds a small part of this change. Nevertheless, the fact that this action is factored into the current-trend scenario indicates that there is a high level of certainty about its completion.

As noted above, the AVOID-SHIFT-IMPROVE strategy has been widely implemented in the field of transport and mobility. In this context, the SHIFT concept refers primarily to measures designed and implemented to promote a modal shift from the use of private vehicles to sustainable modes of transport. There are two types of such measure, both of which are necessary to create the desired effect. PULL measures are designed to improve the quality and appeal of public transport or forms of active mobility, while PUSH measures aim to dissuade or prevent people from using private vehicles.

In both cases, the actions need to be accompanied by effective, coordinated planning between government agencies and those responsible for mobility at the local, regional and national scales.




Regarding the potential for a modal shift, the current modal split between the use of cars and other forms of transport is relatively even, and very similar to other European cities of a similar size. However, analysis at the level of zones of residence reveals a different situation, with modal splits that differ by area: the split is very evenly distributed in the city centre, whereas cars have a large modal share in travel within the suburbs, and in journeys from Madrid's Metropolitan Area into the city itself. After this breakdown by geographical area, the most ambitious target is that aiming to make travel within the city's suburbs more sustainable, by reducing residents' car journeys from 30% to 22%.

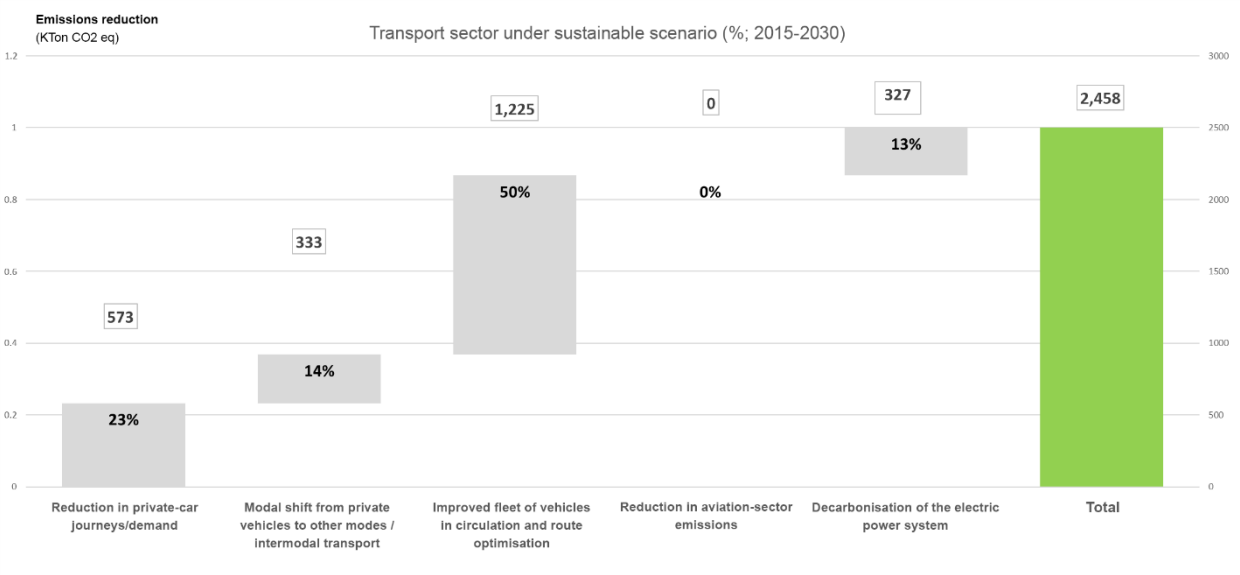
***Source: Inventory of Municipal Land Ownership (PMS), Madrid (2021). Multimodal pyramid.***

In this sector, there is great potential for action by the City Council, primarily focused the modal shift, since it is only possible to act on this with the participation of local and regional government agencies. The City Council can take a wide range of actions to facilitate this modal shift, from metropolitan sustainable-mobility plans at a regional level (given the City Council's key role in the region) to interventions designed to make the city more walkable, improvements to the cycling infrastructure and public-transport network, and restrictions on traffic and parking in public highways.

***Distribution of modes of transport for travel by zone of residence (PMS 2021)***

| Residential Zone | Walking | Public Transport | Private Vehicle | Others |
|---|---|---|---|---|
| City of Madrid (inside the M30) | 40.0% | 34.8% | 20.3% | 4.9% |
| City of Madrid (outside the M30) | 32.2% | 32.8% | 32.4% | 2.6% |
| Madrid periphery of the metropolitan area | 34.0% | 16.4% | 47.7% | 1.9% |
| Rest of the regional zone | 29.6% | 10.8% | 56.2% | 3.4% |
| **Community of Madrid** | **34.0%** | **24.3%** | **39.0%** | **2.7%** |

This table provides the breakdown of modes of transport used for travel in each zone (with reference to the fare zones used by the Madrid Regional Transport Consortium, CRTM), clearly showing the need for mobility planning at the metropolitan scale. In line with the aforementioned potential for emissions reduction at this level, reducing the modal share of private vehicles at the metropolitan scale will have a much greater impact on total emission abatement, given that journeys by residents in this zone are much longer on average.




Emissions derived from the aviation sector deserve special mention, given the significant contribution made by Adolfo Suárez-Barajas airport to the transport sector's total emissions and the fact that no significant reduction is expected in the short term.

## Waste sector

In this sector, organic waste collection and management has a key role to play in reducing direct emissions of greenhouse gases (such as methane and carbon dioxide). Minimising organic waste, which also involves ethical considerations related to food waste, proper separation and selective collection, and processing at Valdemingómez Technology Park, are the primary levers for achieving considerable emissions reductions. The primary processing method should be anaerobic digestion, followed by biogas upgrading to generate biomethane for injection into the gas network, accompanied by harnessing the solid byproduct of anaerobic digestion (digestate) for composting. It is also important to control and make use of the methane produced by the waste-management site.

However, the Roadmap also includes actions that do not directly impact the GHG emission inventories, given the methodology and scope of these reports, but do contribute to creating a more sustainable urban model with a more responsible use of resources and materials. Minimising construction waste is one such action that is worth highlighting, given the significant carbon impact of its production and transport processes, along with other actions on responsible consumption, as part of a strategy to generate a circular economy and raise awareness about the carbon footprint created by products and materials.

## Industrial sector and carbon sinks (nature)

The industrial sector has a low impact on the city's greenhouse gas emissions, making its potential contribution to the emissions-reduction targets very limited. The most important actions are a necessary reduction in the impact of refrigerant gases, and the progressive electrification of industrial processes.

Regarding other emission sources and sinks (nature), the carbon-capture capacity of urban wooded areas is important to note. Green spaces make up a particularly large proportion of Madrid's surface area, approximately a third of which consists of wooded areas or gardens, with an estimated current carbon-sequestration capacity of 30,000 t/year (Source: "*El Valor del Bosque Urbano* [The Value of the Urban Forest]" AG Medio Ambiente y Movilidad, 2018).

# Emissions abatements by decarbonisation lever and line of action 2030/2050

## LINE OF ACTION 1: Decarbonisation of the electric power system; 100% renewable energy

**Objectives**

1. Promote the use of renewable energy in the residential, commercial and transport sectors
2. Improve on the national targets for the generation of renewable electrical energy that is consumed in the city
3. Facilitate the general public's access to this type of energy (energy communities)

| DECARBONISATION LEVERS | ACTIONS | EMISSIONS REDUCTIONS ($kt CO_2eq$) | | PARTNERS AND ALLIANCES | SOURCE OF FINANCING |
|---|---|---|---|---|---|
| | | by 2030 | by 2050 | | |
| **Call on the national government to increase renewable energy generation within the electricity mix** **AVOID** | - In the residential sector.<br>- In the transport sector.<br>- In the services, commercial and institutional sectors. | 3,997 | | Regional and national government<br>Private sector | National plan |
| **Research and study new forms of self-consumption** **SHIFT** | - Study the system potential and the legal formulas to define roles in shared self-consumption schemes.<br>- Design, implement and evaluate demonstration projects in public facilities that can be replicated in the residential sector. | N/A | N/A | Regional and national government<br>Private sector<br>Universities<br>citiES2030 | Regular budget and plan |
| **Local actions for decarbonisation of the electric power system** **IMPROVE** | - Increase generation of energy from renewable energy sources in municipal buildings and facilities: plan for roll-out of solar energy self-consumption in municipal buildings, in order to facilitate the generation of renewable energy distributed for self-consumption in the city.<br>- Partner with other government bodies (regional and national) to work in the city's buildings as nearly zero-energy consumers and self-consumers of own energy production. | 19 | 19 | Regional government<br>Energy companies | Specific national plans<br>Private financing<br>'Plan Rehabilita' [Renovate Plan] (subsidies)<br>Madrid 360 Solar |

## LINE OF ACTION 2: Zero-emission residential buildings

**Objectives**

1. Raise awareness in the population about the need to increase renewable energy sources and the use of high-efficiency systems and facilities. The aim is to support the public in becoming responsible and aware about their energy consumption.
2. Stimulate the demand for electric heating, air-conditioning and domestic hot water (DWS) supply through affordable and socially accessible solutions.
3. Incentivise the generation of electricity distributed within the city by promoting self-consumption, helping to decentralise and diversify the energy matrix.
4. Stimulate energy-efficiency renovation of buildings, especially those in categories E, F and G, in order to improve efficiency, reduce energy poverty and guarantee healthier living conditions.
5. Take comprehensive urban-regeneration actions in the city's most disadvantaged neighbourhoods.
6. Integrate circular-economy principles into building renovation and new building developments.
7. Promote training and job generation in the building renovation and energy efficiency field.

| DECARBONISATION LEVERS | ACTIONS | EMISSIONS REDUCTIONS ($kt\ CO_2eq$) | | PARTNERS AND ALLIANCES | SOURCE OF FINANCING |
|---|---|---|---|---|---|
| | | by 2030 | by 2050 | | |
| **Improvements in insulation and energy efficiency of existing buildings.** (***Reduction of energy consumption in housing***) **AVOID** | - Measures and support to incentivise renovation of roofs, façades and windows, as well as installation of new control systems, such as for air conditioning or heating ('Plan Rehabilita').<br>- Monitoring of renovated buildings to obtain indicators on improvements to consumption and emissions ('Plan Rehabilita').<br>- Establishing public information, awareness-raising and support points (Green Office and other municipal facilities) on efficient energy use and the public benefits available.<br>- Support, awareness-raising and training for property managers and companies in the sector. | 145 | 134 | Regional and national government<br>Private sector<br>Third sector<br><br>Professional associations<br>Property management bodies | Specific national plans<br>Private financing<br>'Plan Rehabilita' (subsidies) |

| | | | | | |
|---|---|---|---|---|---|
| | - Establishing strategic alliances with companies and neighbourhood associations able to lead renovation processes in the top-priority neighbourhoods.<br>- Identifying top-priority areas for energy-efficiency renovation, taking into account criteria on emissions reduction (category E, F or G energy certification, etc.) and energy vulnerability. | | | | |
| **New nearly zero-energy buildings**<br>**AVOID** | - Measures to incentivise the construction of nearly zero-energy housing and the use of low-carbon-footprint materials (financial incentives, benefits and subsidies, education and awareness-raising campaigns, public-private partnerships). | | | | |
| **Upgrading to more efficient equipment and facilities**<br>**SHIFT** | - Actions to stimulate innovation and the development of efficient solutions that are affordable and socially accessible.<br>- Measures to support and incentivise replacement of air conditioning and heating equipment with more efficient devices (heat pumps), upgrading natural gas condensing boilers and other equipment such as lifts and garage ventilation systems.<br>- Upgrading household appliances (from A++ to A+++) and lighting systems.<br>- Sustainable management of replaced items (equipment, household appliances, lighting systems), incorporating reuse and recycling, especially when they have not reached the end of their life cycle. | 965 | 751 | Regional and national government<br>Private sector | Specific national plans<br>Private financing<br>'Cambia 360' [Change 360] plan<br>(subsidies)<br>ReMad programme |
| **Decentralisation of renewable energy generation**<br>**(see Line of Action 1)**<br>**IMPROVE** | Development of innovative models of distributed generation of renewable energy for self-consumption in the city. | See Line of Action 1 | | | |

## LINE OF ACTION 3: Zero-emission transport

**Objectives**

1. Offer sustainable transport options that enable all members of the public to reach key destinations and services
2. Improve the efficiency and cost-effectiveness of passenger and goods transport
3. Engage in balanced development of all modes of transport, giving each its own space on public highways
4. Promote flexible-working policies that reduce travel
5. Promote the electrification of the fleet of public and private vehicles in circulation
6. Raise awareness in the population about the need to reduce travel by private motorised vehicles and encourage the public to use sustainable modes of transport, supporting them in becoming responsible and aware about mobility.

| DECARBONISATION LEVERS | ACTIONS | EMISSIONS REDUCTIONS ($kt\ CO_2eq$) by 2030 | EMISSIONS REDUCTIONS ($kt\ CO_2eq$) by 2050 | PARTNERS AND ALLIANCES | SOURCE OF FINANCING |
|---|---|---|---|---|---|
| **Low Emission Zones at several scales**<br>*(Measures to deter motorised traffic)*<br>**AVOID** | - Pedestrianisation and traffic-calming actions in secondary centres (district-level centres).<br>- Creation/consolidation of Low Emission and Special Protection Zones (ZBEDEP). | | | | |
| **Policies on parking and a sustainable transport hierarchy for public highways**<br>*(Measures to deter motorised traffic)*<br>**AVOID** | - Restrictive parking policy on public highways<br>- Implementation of controlled parking zones (CPZ) in neighbourhoods where they are not yet established, addressing the displacement effect.<br>- Redistribution of public space towards sustainable-mobility models in urban-redevelopment projects, push towards rebalancing public space by reducing spaces for traffic in order to incorporate more public space for nature, leisure and services. | 573 | 296 | Regional and national government | Regular budget and plan<br>Specific national plans |
| **Policies on urban proximity planning and alternative ways of working**<br>*(Reduction of the demand for mobility)*<br>**AVOID** | - Promote existing or new neighbourhood centres, connected to intermodal hub facilities and/or stations or areas<br>- Incorporate a mixed-use perspective into new developments (avoid segregated urban planning).<br>- Reduce work-related travel (cars) in connection with an increase in remote-working schemes, supporting the development of company mobility plans for large centres of employment. | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Actions focused on infrastructure for active forms of personal mobility**<br>**SHIFT** | - Improvement of the municipal cycling network by fulfilling the existing Cycling Plan (expanding the network and improving existing infrastructure, signage and security).<br>- Expanding the bicycle and PMV (Personal Mobility Vehicle) parking network: open-access facilities and those with some type of security.<br>- Actions to secure pedestrian and cycling connection at large urban boundaries (motorways, railway infrastructure, etc.).<br>- Improvement of the public space for walking in the city. Zones with 30 km/h limit, school safety zones, pavement widening, pedestrianisation, traffic-calming measures, etc. | | | | |
| **Actions focused on the public-transport network**<br>**SHIFT** | - Promoting the use of collective public transport (bus, train and metro).<br>- Increasing peri-urban and non-radial public transport lines. Improving the commercial speed of public buses by introducing bus-only or bus–HOV (High Occupancy Vehicle) lanes with priority at traffic lights in the main structural highways, and by improving existing lanes. New BRT (Bus Rapid Transit) lines.<br>- More frequent scheduling in rush hours to facilitate work-related mobility and expansion of sustainable options at off-peak times, as well as expanding the nighttime network. | 333 | 389 | - Regional government<br>- Private companies Shared modalities | - Regular budget and plan<br>- Specific national plans |
| **Actions focused on intermodal transport**<br>**SHIFT** | - Improvement of bicycle and PMV (Personal Mobility Vehicle) access to metro stations, commuter-rail stations and transport hubs, through specific infrastructure and policies on secure and sufficient parking.<br>- Promotion of new second-level intermodal areas in suburban neighbourhoods.<br>- Developing new park-and-ride areas on the outskirts of the city that are connected to the metro or commuter rail network.<br>- Expansion of the BiciMAD public bicycle-sharing system and partnership with private operators to improve the range of shared mobility options on offer: PMV, carpooling/car sharing or motorbike/moped sharing. | | | | |
| **Replacement and electrification of the fleet of vehicles in circulation**<br>**IMPROVE** | - Electrification of Madrid's municipal transport company (EMT) fleet, its operating centres and other municipal fleets of vehicles.<br>- Support for conversion of the fleet of taxis and private hire vehicles (PHV) in circulation to electric vehicles. | | | | Specific national plans<br>'Cambia 360' plan (subsidies) |

| | | | | | |
|---|---|---|---|---|---|
| | - Measures to support the replacement and electrification of the fleet of private vehicles in circulation. | | | | |
| **Roll-out of charging infrastructure** **IMPROVE** | - Planning and expansion of the public electric vehicle charging (EVC) network.<br>- Measures to support the introduction of private charging infrastructure in buildings and car parks.<br>- Urban service stations for charging electric vehicles (charging stations). | 1225 | 884 | Regional and national government<br>Private sector | Specific national plans<br>'Cambia 360' plan (subsidies) |
| **Actions related to Urban Freight Distribution (UFD)** **IMPROVE** | - Electrification of the fleet of UFD vehicles belonging to individuals, companies and logistics centres (Mercamadrid).<br>- Improving the efficiency of logistics in the urban space and evaluating the impact of new models (e-commerce). | | | | |
| **Transport innovation and digitalisation** **IMPROVE** | - Promoting mobility tools such as MaaS (Mobility as a Service) as a means for integrating all operators and substantially improving the information available to travellers at all entry points into the network. On-demand public transport systems and optimisation of routes.<br>- Optimising logistics processes (reverse logistics).<br>- Digitalisation, apps for mobility (APP), IoT and autonomous mobility, and for encouraging shared use of private vehicles. | | | | |
| **Actions related to decarbonisation of the aviation sector.** **AVOID/SHIFT/IMPROVE** | - Urge the national government to put in place plans and programmes aiming to reduce aviation emissions, by reducing short-haul flights and those for which alternative transport routes are available, use of alternative fuels, and improving aircraft take-off and landing operations. | N/A | N/A | National | National programmes |

## LINE OF ACTION 4: Zero-emission buildings and commercial premises in the services sector

**Objectives**

1. Promote the use of more efficient systems and facilities in institutions and activities
2. Encourage the generation of electricity distributed within the city by promoting self-consumption
3. Share a vision of municipal and institutional buildings as nodes for generating energy that is distributed within the city

| DECARBONISATION LEVERS | ACTIONS | EMISSIONS REDUCTIONS (kt $CO_2$eq) | | PARTNERS AND ALLIANCES | SOURCE OF FINANCING |
|---|---|---|---|---|---|
| | | by 2030 | by 2050 | | |
| **Reduce the energy demand of existing buildings by improving insulation and energy efficiency**<br>**AVOID** | Improve insulation and energy efficiency of buildings through:<br>- Actions focused on commercial and institutional buildings and facilities outside the municipal remit.<br>- Actions focused on buildings and facilities within the municipal remit.<br>- Smart heating and smart lighting in buildings and facilities. | 232 | 145 | Regional and national government<br>Private sector | Regular budget and plan<br>Specific national plans |
| **Upgrading to more efficient equipment and facilities**<br>**SHIFT** | **Improvements in heating and air conditioning:**<br>- Replacement with / incorporation of heat pumps.<br>- Improvements in the energy efficiency of existing equipment.<br><br>**Other equipment:**<br>- Other facilities such as garage ventilation systems or lifts.<br>- Upgrading to more efficient household appliances (A++ to A+++) and lighting. | 576 | 253 | Regional and national government<br>Private sector | Specific national plans<br>Private financing<br>'Cambia 360' plan (subsidies) |
| **Local actions for decarbonisation of the electric power system**<br>**IMPROVE** | - Generation of renewable energy that is distributed at a municipal scale: plan for roll-out of solar energy self-consumption in municipal buildings.<br>- Partner with other commercial and institutional entities to promote zero-emission buildings that self-consume the energy they generate. | See Line of Action 1 | | | |

## LINE OF ACTION 5: Reduce the impact of waste

**Objectives**

1. Raise awareness about the need for source reduction
2. Improve waste-recovery processes
3. Improve the efficiency of processing

| DECARBONISATION LEVERS | ACTIONS | EMISSIONS REDUCTIONS ($kt\ CO_2eq$) | | PARTNERS AND ALLIANCES | SOURCE OF FINANCING |
|---|---|---|---|---|---|
| | | by 2030 | by 2050 | | |
| **Reduction of waste generated**<br>**AVOID / SHIFT** | - Mechanisms, platforms and procedures for reusing products for the public.<br>- Reduction of packaging and identification of reverse logistics processes in supply chains.<br>- Reduction of food waste.<br>- Minimising demolition and construction waste in building works within the municipality.<br>- Promotion of circular-economy initiatives and products with a low carbon footprint. | 37 | 36 | Regional and national government<br>Private sector | Regular budget and plan<br>Specific national plans<br>Private financing |
| **Increase in waste-recovery rates in residential, services and municipal sectors**<br>**IMPROVE** | - Update and review procurement specifications for processing plants with ambitious recovery targets.<br>- Improving rates at city- and neighbourhood-level recycling points. | 19 | 18 | Regional government | Regular budget and plan |
| **Collection and processing of organic waste**<br>**MEJORAR** | - Increasing the quantity of waste processed through digestate composting plants for organic waste from selective collection and plant waste.<br>- Reducing emissions through waste energy recovery, improving the biomethane production process and increasing plants' electrical energy generation for self-consumption.<br>- Improve the purity of organic waste from selective collection through public awareness-raising campaigns.<br>- Increase the quantity of biogas injected into the natural gas network. | 129 | 125 | Regional government<br>Private sector | Regular budget and plan<br>Specific national plans<br>Private financing |

## LINE OF ACTION 6: Reduce emissions in other sectors

**Objectives**

1. Reduce the impact of refrigerant gases and solvents
2. Reduce emissions in the industrial sector
3. Promote and support reforestation in the municipality

| DECARBONISATION LEVERS | ACTIONS | EMISSIONS REDUCTIONS ($kt\ CO_2eq$) | | PARTNERS AND ALLIANCES | SOURCE OF FINANCING |
|---|---|---|---|---|---|
| | | by 2030 | by 2050 | | |
| **Reduction of the impact of refrigerant gases and solvents** **AVOID / SHIFT** | - Support lines of research to reduce the impact of refrigerant gases and solvents in the atmosphere.<br>E.g. replacement of these gases with less polluting substances | 426 | 171 | Regional and national government<br>Private sector | Specific national plans<br>Private financing |
| **Reduction of industrial-sector emissions** **AVOID / SHIFT / IMPROVE** | - Improvement in the efficiency of industrial processes.<br>- Electrification of the consumption derived from these processes and of the sources necessary to carry out the activity. | 100 | 120 | Regional and national government<br>Private sector | Specific national plans<br>Private financing |
| **Rewilding and reforesting the municipality** | - Tree planting: promoting the Madrid Compensa (Madrid Offsetting) initiative as a programme for offsetting greenhouse gas emissions.<br>- Integration of nature into urban planning and regeneration projects (implementation of nature-based solutions, NBS). | 3 | 3 | Governments and private sector | Regular budget and plan |

## Main hypotheses

The city of Madrid's Roadmap to Climate Neutrality sets out six key areas of action to achieve a drastic reduction in emissions:

- Establish governance and financing models that are consistent with the climate sustainability objectives.
- Foster renewable sources of electricity generation (decarbonisation of the electricity mix), increasing the generation of energy that is distributed locally.
- Promote energy efficiency and electrification of the energy demand in residential buildings and services.
- Facilitate the sustainable transport of people and goods.
- Improve the sustainability of waste management and industry.
- The municipal government to act as a role model, providing an example of sustainable energy models.

Taking these six key areas as the starting point, the path to climate neutrality was defined by developing strategic hypotheses for each of the sectors analysed. These hypotheses were then applied to the main levers for emissions reduction, as follows.

### Electric power sector hypotheses

Future changes in the electric power sector will be instrumental in achieving decarbonisation targets. A reduction in the emission factor of the electricity mix due to the penetration of renewable energy sources and the gradual closure of conventional thermal power plants (coal-fired and combined-cycle plants) are the main hypotheses for how this sector will change.

| DECARBON-ISATION LEVERS | SCENARIOS | | | | |
|---|---|---|---|---|---|
| | CURRENT-TREND | SUSTAINABLE | | ENHANCED | |
| | | 2030 | 2050 | 2030 | 2050 |
| **Emission factor of the electric power sector** | •Reduction of ~60% (2030 vs. 2015) (according to the INECP baseline scenario)<br>• Reduction of 100% (2050 vs. 2030)<br>•Electricity generation from renewable sources: 51% by 2030 and 100% by 2050 | • Reduction of ~85% (2030 vs. 2015) (according to the INECP target scenario)<br>• Electricity generation from renewable sources: 73% | • 100% reduction of emissions by 2050<br>• Zero-emission electricity generation | • Reduction of ~85% (2030 vs. 2015) (according to the INECP target scenario)<br>• Electricity generation from renewable sources: 73% | • 100% reduction of emissions by 2050<br>• Zero-emission electricity generation |
| **Annual emissions reductions in other sectors** | • Annual emissions reduction of 5.9% (according to the INECP baseline scenario, which coincides with the target scenario). | • Annual emissions reduction of 5.9% (according to the INECP target scenario) | • Annual emissions reduction of 5.9% (according to the INECP target scenario) | • Annual emissions reduction of 5.9% (according to the INECP target scenario) | • Annual emissions reduction of 5.9% (according to the INECP target scenario) |

## Residential sector hypotheses

The penetration of **heat pumps** as a replacement for conventional heating and air-conditioning systems (powered by combustion or electricity) is vital, given the greater energy efficiency of these systems (≈200-300% compared to 90-100% for electric heaters). The current-trend scenario envisages the replacement of conventional thermal boilers (those powered by gas and other fuels such as petroleum products and coal) with **efficient natural gas condensing boilers** in the short term, significantly improving the efficiency of these appliances (≈110% compared to 70-90% for conventional boilers).

Energy-efficiency renovation of buildings is another key lever for decarbonisation. Relevant interventions include window replacement (10-15% savings), façade renovation 30-50% savings) and roof renovation (5-15% savings). Comprehensive building renovation including all these actions can reduce heating consumption by 60-70%.[2]

| DECARBONISATION LEVERS | SCENARIOS | | | | |
|---|---|---|---|---|---|
| | CURRENT-TREND | SUSTAINABLE | | ENHANCED | |
| | | 2030 | 2050 | 2030 | 2050 |
| **Penetration of heat pump technology** | Only renovations, no additional installations | Annual increase in surface area **~0.9 %**<br>12,000 new units/year | From 2030 to 2050: annual increase in surface area **~0.9 %**<br>14,000 new units/year | Annual increase in surface area **~1.2 %**<br>17,000 new units/year | From 2030 to 2050: annual increase in surface area **~1.5%**<br>24,000 new units/year |
| **Replacement of natural gas boilers** | Replacement at the end of useful life (~15 years)<br>~40,000 boilers/year | Replacement every **~13 years.**<br>~50,000 boilers/year | Replacement every **~13 years.**<br>~50,000 boilers/year | Replacement every **~12 years.**<br>~60,000 boilers/year | Replacement every **~8-9 years.**<br>~80,000 boilers/year |
| **Renovation** | Renovations are not considered | Renovation **~1%** surface area/year<br>13,000 renov./year | Renovation **~1%** surface area/year until 2050<br>16,000 renov./year | Renovation **~1.5%** surface area/year<br>20,000 renov./year | Renovation **~1.5%** surface area/year until 2050<br>24,000 renov./year |

[2] Estimates based on residential buildings built before 1980.

## Services sector hypotheses

The penetration of **heat pump** technology may occur faster in the services sector than the residential sector, given the more favourable circumstances in this type of building, with a greater demand for heating and air-conditioning and better construction conditions for installation.

Efficiency improvements are also expected in this sector due to the **replacement of conventional thermal boilers with high-efficiency natural gas boilers. Smart control of lighting and heating systems** makes it possible to achieve consumption reductions of 15% to 30%.

Similarly to the residential sector, **energy-efficiency renovation of buildings in the services sector** could reduce heating consumption by 60% to 70% through actions focused on windows (10-15% savings), façades (30-50% savings) and roofs (5-15% savings).

| DECARBONISATION LEVERS | SCENARIOS | | | | |
|---|---|---|---|---|---|
| | CURRENT-TREND | SUSTAINABLE | | ENHANCED | |
| | | 2030 | 2050 | 2030 | 2050 |
| **Heat pump penetration** | Current penetration rate | Annual installation of **2.7%** of the surface area | Annual installation of **2.7%** of the surface area | Annual installation of **3%** of the surface area | Annual installation of **3%** of the surface area |
| **Smart heating & cooling**<br>**Smart lighting** | No installations considered | Annual installation of **2.7%** of the surface area | Annual installation of **2.7%** of the surface area | Annual installation of **3%** of the surface area | Annual installation of **3%** of the surface area |
| **Renovations** | No renovations are carried out | Annual renovation of **1.5%** of the surface area | Annual renovation of **1.5%** of the surface area | Annual renovation of **1.5%** of the surface area | Annual renovation of **1.5%** of the surface area |

## Transport sector hypotheses

The transformation of current mobility patterns and lifestyles is also necessary to achieve decarbonisation. These new models should focus on **reducing demand for transport** through promotion of remote working, development of urban proximity planning, and changing transport and consumption behaviour, as detailed in the table of decarbonisation levers and actions earlier in this section.

The **modal shift of travel from private vehicles** (≈104 $gCO_2$/passenger-km) **to public transport** would enable a reduction in GHG emissions per passenger-km of up to 35% when the shift is to conventional buses (≈68 $gCO_2$/passenger-km) and almost 90% if the change is to train or metro travel (≈14 $gCO_2$/passenger-km).

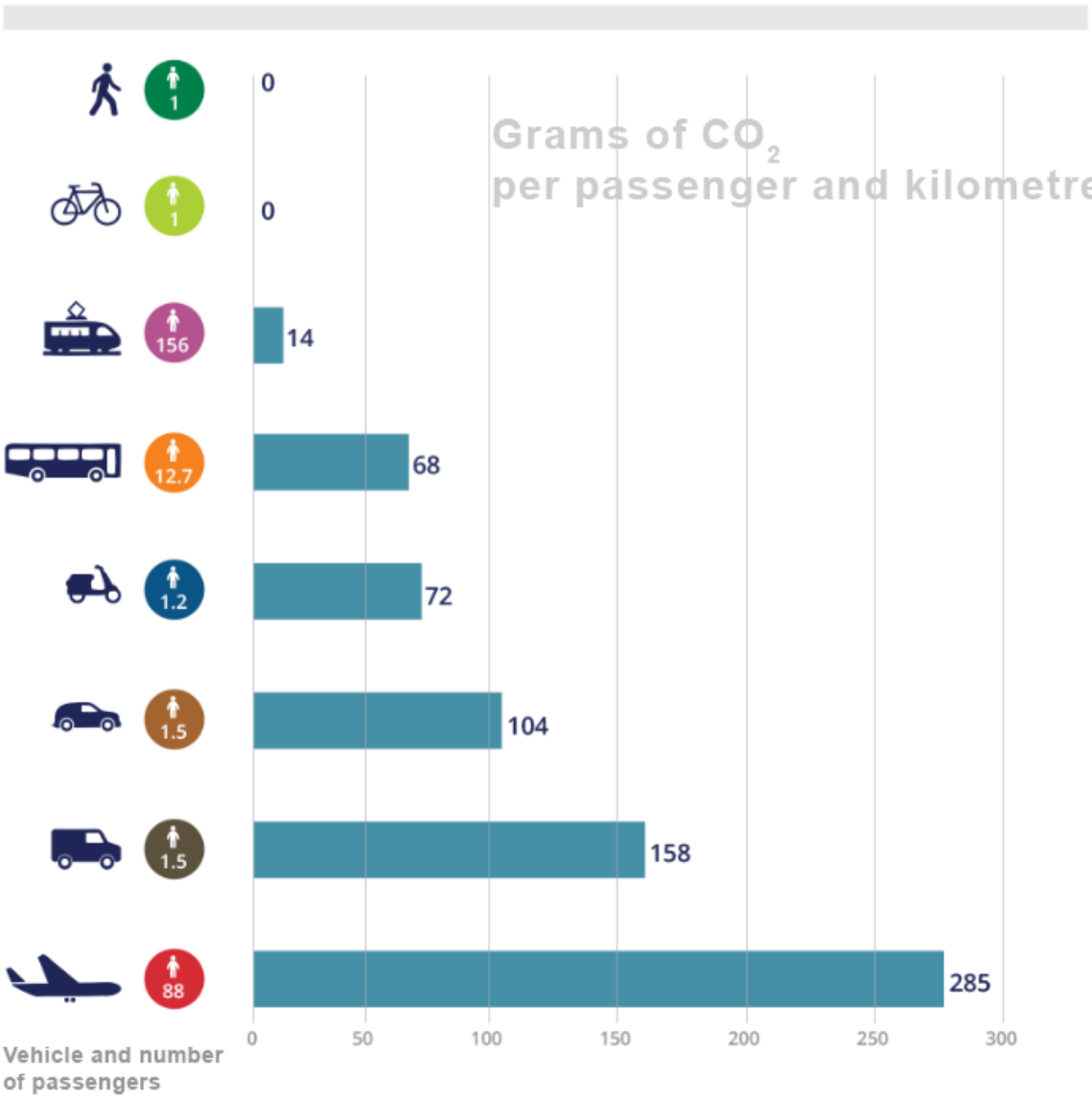



*Figure 1: Study carried out in 2019 by the European Environment Agency (EEA)*

The **modal shift to non-motorised transport** (walking, cycling, etc.) is expected to be facilitated by measures such as developing specific lanes for these modes of travel, promoting dedicated parking spaces, and fostering rental systems.

The **penetration of electric vehicles to replace vehicles using conventional technologies** results in a reduction in emissions. The GHG emissions of electric vehicles are 6 to 7 times lower than those of a conventional EURO III vehicle, 4 to 5 times lower than those of a EURO IV vehicle, and 2 to 3 times lower than those of a EURO VI vehicle.

**Replacing the fleet of old conventional vehicles in circulation with more efficient and less polluting vehicles** is the decarbonisation lever with the greatest emissions-abatement potential in the 2030–2050 period. Replacing most of these vehicles is already included in the current-trend scenario, with replacement of the remaining vehicles added in the sustainable scenario. An old Euro III diesel vehicle emits twice as much as a new EURO VI diesel vehicle.

The **aviation sector** is expected to grow in proportion to the annual growth in flights and passengers. Emissions-reduction actions on the use of lower-emission fuels that are not yet commercially available are included in the enhanced scenario for 2050.

| DECARBONISATION LEVERS | SCENARIOS | | | | |
|---|---|---|---|---|---|
| | CURRENT-TREND | SUSTAINABLE | | ENHANCED | |
| | | 2030 | 2050 | 2030 | 2050 |
| **Reduction in transport demand** | Annual increase in travel<br>0.5 % | Annual reduction in travel<br>1.5% | Annual reduction in travel<br>1.5% | Annual reduction in travel<br>1.5% | Annual reduction in travel<br>1.5% |
| **Modal shift: passengers** | Non-motorised 31%<br>Public transport 32%<br>Private vehicles 37% | Non-motorised 30%<br>Public transport 40%<br>Private vehicles 30% | Non-motorised 46%<br>Public transport 45%<br>Private vehicles 9% | Non-motorised 46%<br>Public transport 45%<br>Private vehicles 9% | Non-motorised 47%<br>Public transport 45%<br>Private vehicles 8% |
| **Electric vehicle penetration** | Current penetration<br>≈ 0% | ≈ 20%<br>≈290,000 | ≈ 100%<br>≈1,450,000 | ≈ 40%<br>≈ 580,000 | ≈ 100%<br>≈1,450,000 |
| **Replacement of the fleet of vehicles in circulation** | Increase in the current age of the fleet to<br>11-12 years | Decrease in the average age of the fleet to<br>9-10 years | Decrease in the average age of the fleet to<br>6-7 years | Decrease in the average age of the fleet to<br>6-7 years | Decrease in the average age of the fleet to<br>6-7 years |
| **Aviation sector** | Annual growth in emissions of<br>0.5% to 2030 and 0.25% to 2050<br>Growth rates proportional to the increase in flights | Annual emissions reduction of<br>1.50%<br>Growth rates proportional to the increase in flights | Annual emissions reduction of<br>1.50%<br>Growth rates proportional to the increase in flights | Annual emissions reduction of<br>1.50%<br>Growth rates proportional to the increase in flights | Annual emissions reduction of<br>5.10%<br>Potential to use non-polluting fuels, pilot phase |

## Hypotheses for other sectors (waste treatment, industry, forestry)

The **reduction of emissions from waste treatment** will be secured by: decreasing the amount generated by promoting waste prevention and implementing circular-economy schemes; improving selective collection and increasing material-recovery rates; and, most importantly, given its contribution to local emissions, improving organic-waste collection and treatment.

The **reduction of emissions in the industrial sector** will be achieved by improving energy efficiency through improvements in technology and industrial-process management systems, and by increasing the proportion of electrical energy in the final consumption mix.

The enhanced scenario includes the decentralisation of industry as a decarbonisation factor in the municipality. The decarbonisation hypothesis includes the replacement of high global-warming-potential fluorinated gases with gases that have little or no global warming potential.

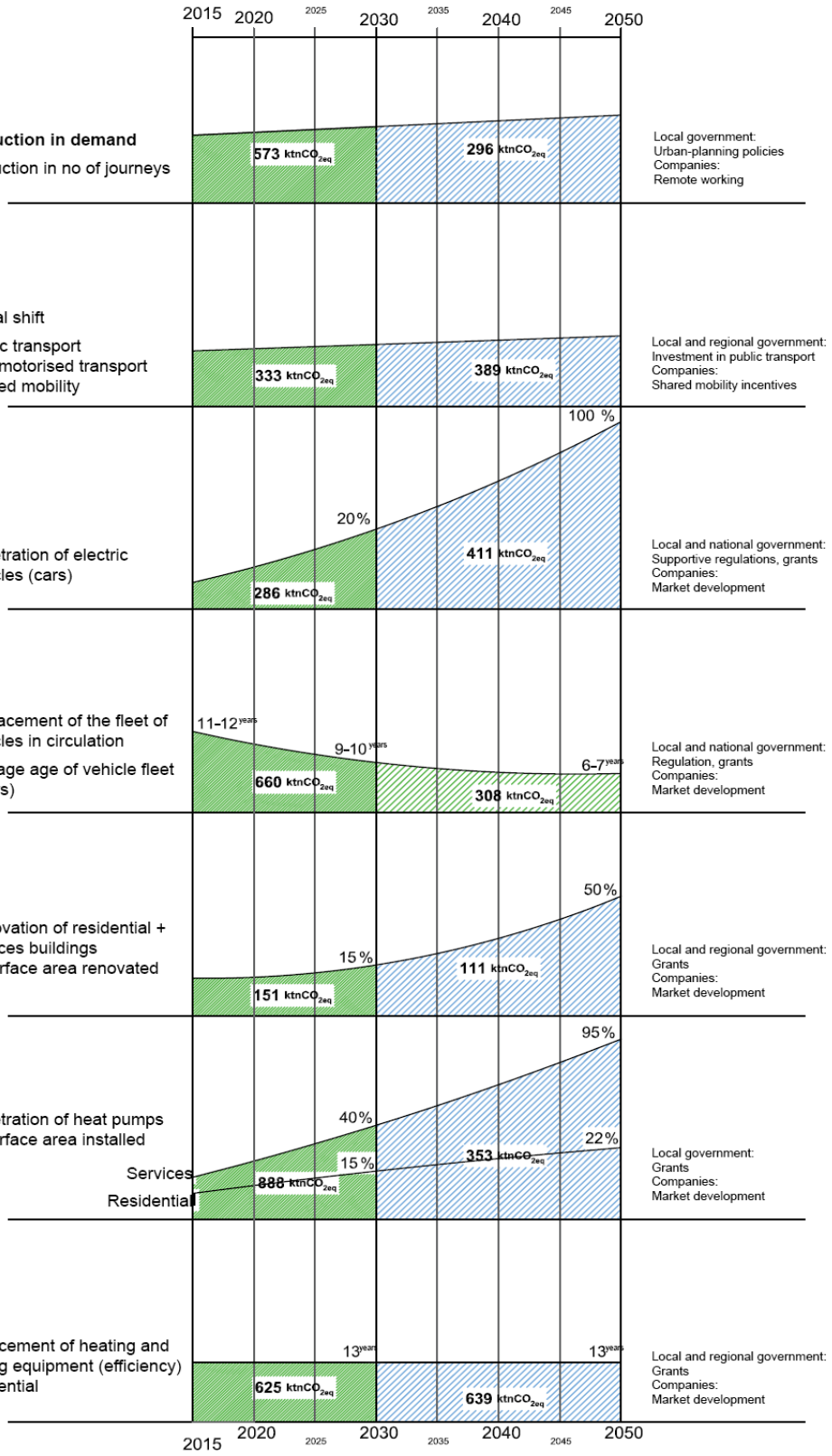
The hypotheses on carbon sinks are based on an increase in forest cover, with the concomitant increase in absorption capacity.

| DECARBONISATION DRIVERS | SCENARIOS | | | | |
|---|---|---|---|---|---|
| | CURRENT-TREND | SUSTAINABLE | | ENHANCED | |
| | | 2030 | 2050 | 2030 | 2050 |
| **Annual emissions reduction in waste treatment** | •1.1% annual reduction in emissions (according to the INECP baseline scenario) | •2.6% annual reduction in emissions (according to the INECP target scenario) | •2.6% annual reduction in emissions (according to the INECP target scenario) | •2.6% annual reduction in emissions (according to the INECP target scenario) | •5.2% annual emissions reduction<br>• Envisages the use of advanced waste treatment technologies together with ambitious recycling and circular-economy rates |
| **Annual emissions reduction in industry** | •0.7% annual reduction in emissions (according to the INECP baseline scenario) | •1.3% annual reduction in emissions (according to the INECP target scenario) | •1.3% annual reduction in emissions (according to the INECP target scenario) | •8.3% annual emissions reduction<br>• Envisages a certain level of decentralisation of industry from the city of Madrid to surrounding areas | •6.7% annual emissions reduction<br>• Envisages a certain level of decentralisation of industry from the city of Madrid to surrounding areas |
| **Reforestation** | •No additional tree planting is considered | •A 10% increase in forest cover is expected | • A 20% increase in forest cover is expected | • A 15% increase in forest cover is expected | • A 25% increase in forest cover is expected |

## EMISSIONS ABATEMENT FROM THE MAIN DECARBONISATION LEVERS

2015 - 2030 period

2030 - 2050 period



# 5 | Economic analysis

A study carried out within the framework of Climate-KIC's demonstration project (Madrid Deep Demo) provided an initial economic analysis in 2021. The 'Economic case for decarbonisation in Madrid' study was partly conducted by the Material Economics consultancy firm. It used a shared methodology in several European cities to provide some comparability between the different economic scenarios, maintaining the same analytical premises for the abatement potential and costs of the proposed levers in terms of total volumes of $CO_2$eq in the 2020–2050 period. The abatement cost is defined as the additional costs (or perceived benefits) of replacing a baseline technology (one in common use) with a low-emissions alternative.

The tool used to show the efficiency of the decarbonisation levers and measures proposed, in terms of their potential emissions reduction ($CO_2$eq) and cost (€), is the abatement chart. In this graph, different technologies are shown in order of least to greatest cost per metric tonne of $CO_2$eq abated (height of the bar) along with the potential emissions reduction (width of the bar) of each lever. The analysis shows that many of the proposed decarbonisation levers have negative costs, meaning their implementation could save money.

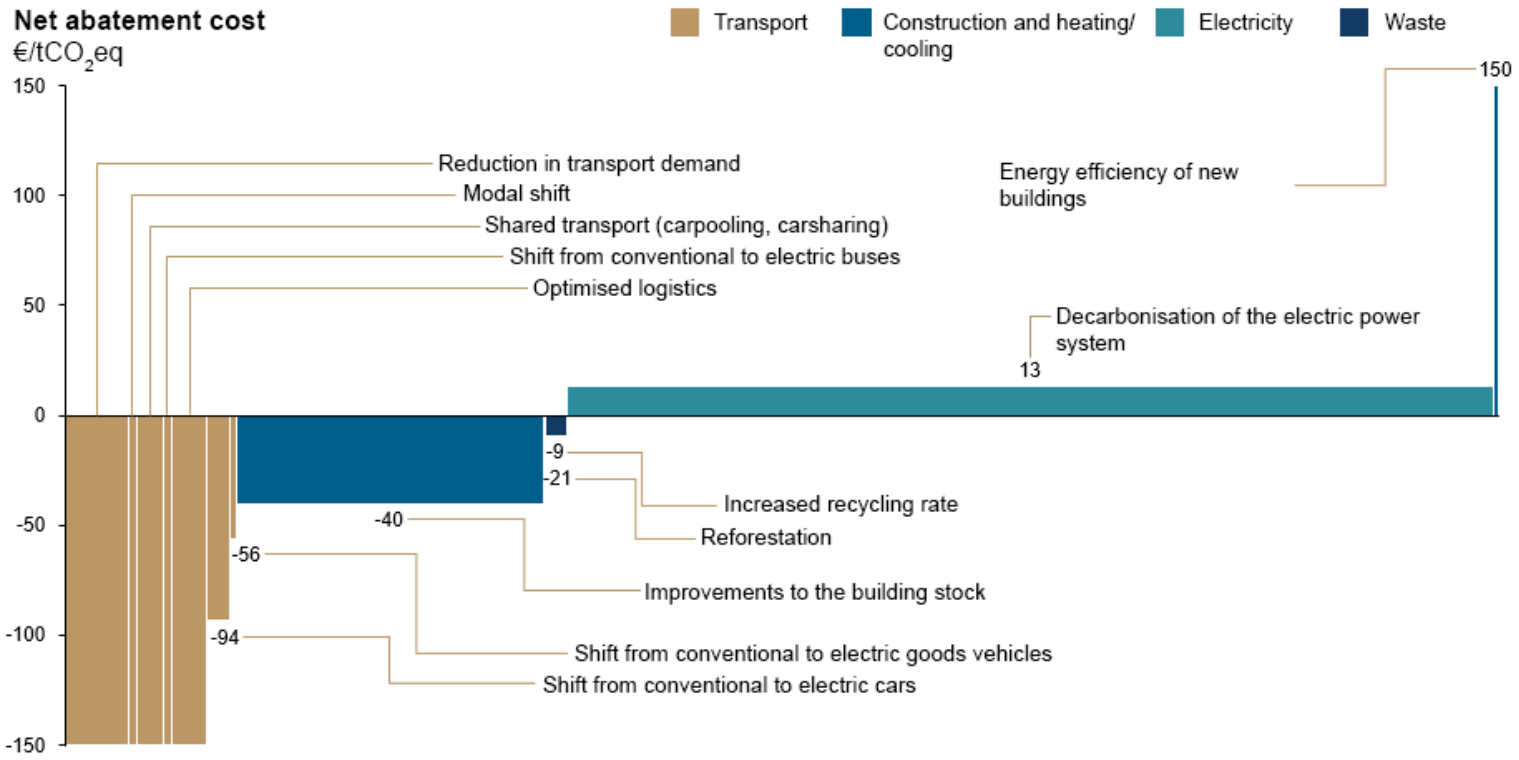
The analysis provides an overarching vision of the full set of decarbonisation levers proposed in the city of Madrid's Roadmap to Climate Neutrality, enabling prioritisation of the measures that offer the largest potential direct $CO_2$ emissions reductions for the lowest cost.

Some of the actions proposed that offer the greatest potential direct emissions reductions in the 2015–2030 period will require support from the relevant governmental agencies to enable incentives to be provided for upgrading technology or changing behaviour.

The most significant conclusion of the report is that decarbonisation of the electric power system is the most important action in the city of Madrid's Roadmap to Climate Neutrality. While it has a positive abatement cost in terms of €/t$CO_2$eq, its considerable GHG emissions-reduction potential makes it a strategic decarbonisation lever on which the success of other measures depends. The decarbonisation of heating, air-conditioning and domestic-hot-water systems in the residential and services sectors, as well as the incorporation of energy-efficient equipment, will also play an important role, given their negative abatement costs and significant emissions-reduction potential. It is also worth underlining the positive economic scenario associated with the measures and decarbonisation levers proposed for the transport sector.

**Abatement chart**

Emissions (kton $CO_2$eq) in 2030, abatement of costs and benefits per year based on investments in 2020-2030, recurrent costs/savings and co-benefits in 2020-2050




*'Economic case for decarbonisation in Madrid July 2021*

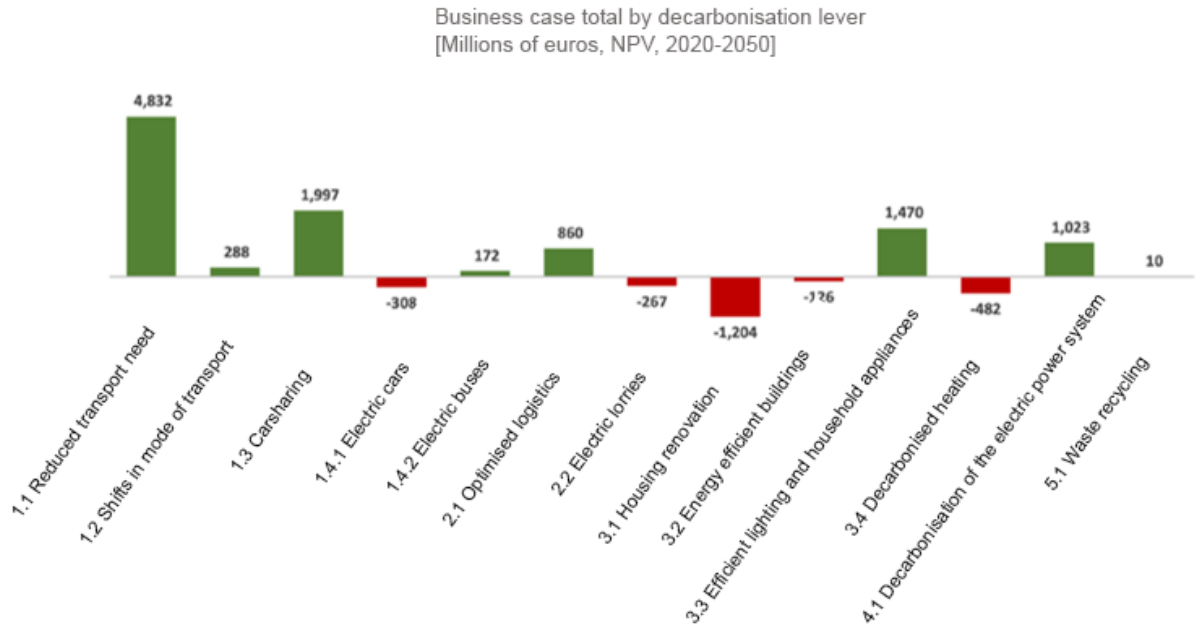
*Madrid Deep Demonstration, Material Economics – EIT Climate-KIC*

On the basis of Madrid's Climate City Contract and as part of its commitments within the 'EU Mission for climate-neutral and smart cities', a series of economic studies were carried out in April 2023 within the Investment Plan and were included in that document.

These studies enabled the priorities and key principles for securing climate neutrality in the city to be modelled. This contract provided the economic case for the main decarbonisation levers established, and also analysed the financing needed from the various actors.

**Abatement cost chart**

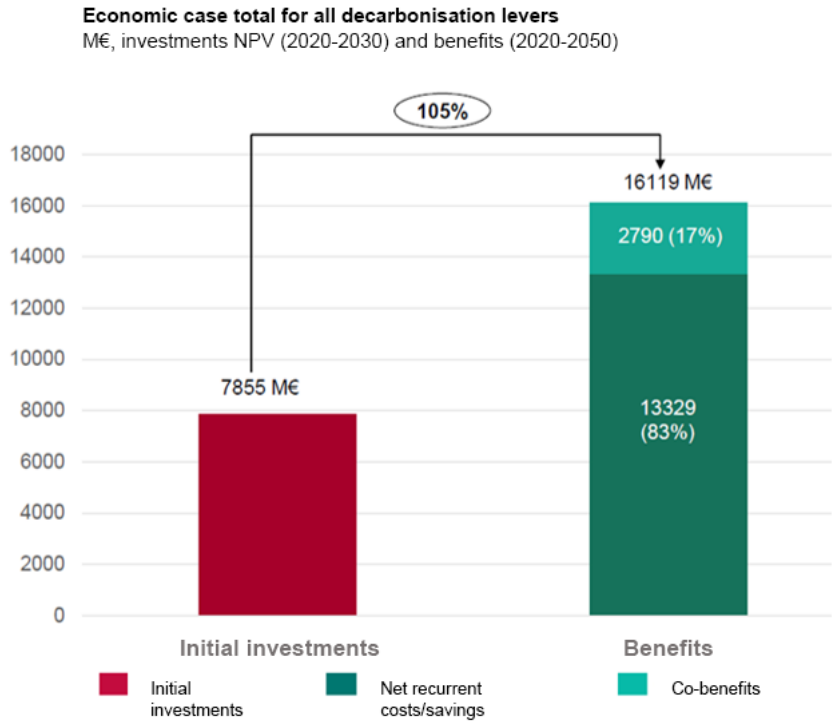
Emissions (kton $CO_2$eq) in 2030, abatement of costs and benefits per year based on investments in 2020-2030, recurrent costs/savings and co-benefits in 2020-2050




As the chart above shows, the economic case for most of the decarbonisation levers is favourable or very close to neutral, whereby the savings obtained compensate for the investment made.

This new study confirmed that the scenarios for the levers associated with the transport sector are favourable and, importantly, also showed the abatement cost of decarbonising the electric-power system to be favourable.

This study also estimated the investment needed to implement the measures and decarbonisation levers set out in the Roadmap, bearing in mind the co-benefits associated with these measures and the various actors involved.



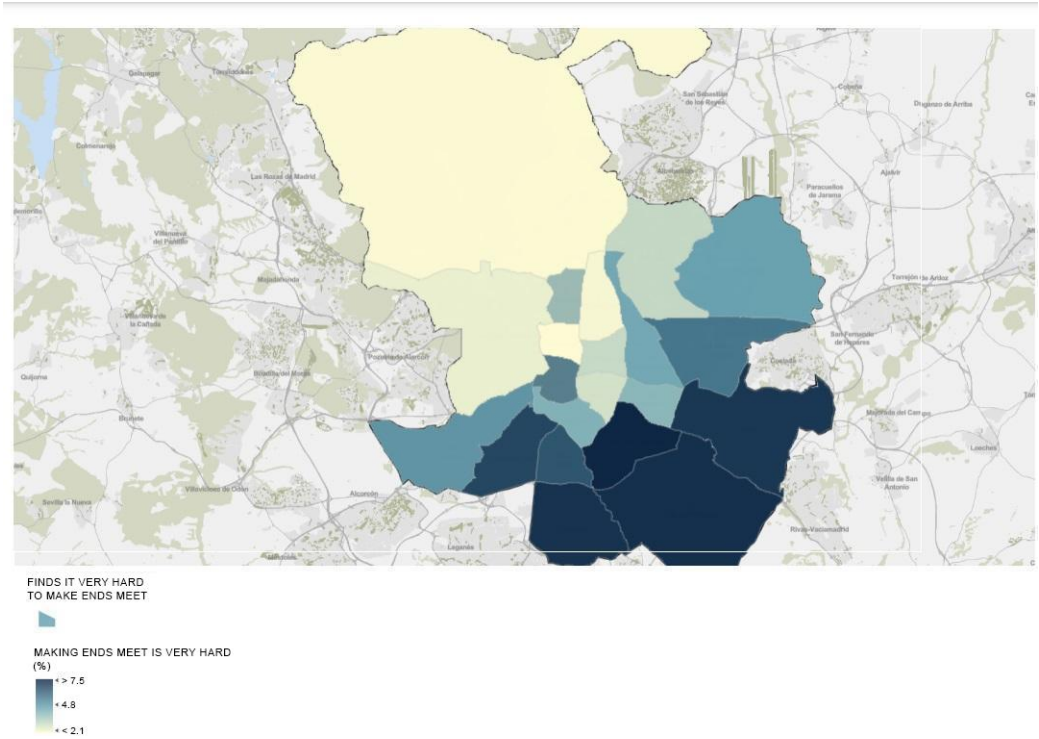

The direct investment (NPV) needed up to 2030 is estimated to be €7.9 bn with a return on investment (ROI) of 105%.

# 6 | Social analysis

The social variable is particularly important for climate policies, both in terms of their effectiveness and social impact. On the one hand, the efficacy of the decarbonisation levers proposed will depend primarily on the public's willingness to make decisions on behaviour, domestic consumption and investment that align with the Roadmap's objectives. On the other hand, putting in place measures aiming to reduce emissions without first evaluating their social implications creates the risk of exacerbating existing social inequality, widening the so-called 'climate gap'. It is therefore vital to carry out a social analysis that enables policymakers to design climate actions according to diversity, equity and inclusion criteria and to identify the potential barriers to access and acceptance of these measures by people in the wide range of social situations that exist in the city.

As a minimum, this social analysis should include a description of demographic structure and dynamics, broken down geographically, with indicators such as the structure of the population according to age and sex, household composition and characteristics, and migratory movements. For this purpose, the social diagnosis report and household panel survey that are produced within the framework of the Strategic Plan of Madrid City Council's Public Social Service System (2023–2027) is particularly relevant, providing data and analyses that enable climate actions to be adapted to the socioeconomic contexts of distinct geographical areas (see the figure below). In addition to this general contextual information, the inclusion of data and indicators related to the risk of exclusion, such as the EU's AROPE (At Risk of Poverty and/or Exclusion) indicator, and tools incorporating the principle of creating no associated harm, such as the EU's DNSH (Do No Significant Harm) principle, enable an ethical criterion to be applied to the Roadmap. This is used to steer resource allocation towards the specific measures and actions that not only generate environmental benefits but also promote social equity.

This social analysis enables decarbonisation actions to be modulated and adapted to the different social contexts that exist in our city, differentiating between efforts targeting the population sectors responsible for the most emissions, who therefore have a crucial role to play in the effectiveness of any strategy, and actions aiming to facilitate the transition for people who lack the economic capacity to invest in reducing their own emissions. Finally, it is important to identify population groups or sectors that have greater incentives for decarbonising, whether due to economic, environmental or social motivations, who can therefore play a key role as proponents of positive change and role models for the general population to follow.




*Source: Madrid City Council (2022). Social diagnosis report 2021–2022.*

In the specific context of emissions reduction in the residential sector, some of the collectives identified as facing particular challenges are:

- households living in low energy-efficiency housing (categories E, F and G), which are a critical target of energy-efficiency measures;
- individuals and households with lower purchasing power, particularly single-parent families and large families who may find it difficult to incorporate cleaner, more efficient technologies into their homes since they lack the necessary financial resources;
- individuals or households with low education levels, who face barriers when it comes to applying for subsidies and other forms of assistance, exacerbated by the digital divide;
- individuals or households that plan to start renovation work on their housing, given that they may be open to incorporating new, more efficient technologies;
- property managers and companies in the construction sector, which play an essential role in raising awareness about the importance of emissions reductions among property-owner associations;
- owners of rental properties, as these individuals, unlike their tenants, have the capacity to make decisions that have an impact on emissions, but they may often lack incentives to invest in energy-efficiency improvements.

When it comes to reducing emissions in the transport sector, a wide range of collectives face particular challenges:

- individuals or households with lower purchasing power, who may find it hard to access more efficient vehicles and switch to more sustainable forms of transport, due to economic limitations;
- individuals with low levels of education or elderly people, who may have problems with the digital procedures necessary to acquire public-transport tickets or to apply for grants for purchasing electric vehicles, as a result of the digital divide;
- communities in areas with limited access to public-transport options, which may create greater dependence on private vehicles;
- workers, self-employed people and companies in the transport sector, for whom updating their fleets of vehicles to incorporate cleaner technologies creates economic and logistic challenges;
- elderly people and individuals with reduced mobility, single-parent families and large families, who face greater challenges when it comes to accessing more sustainable modes of transport;
- medium and large companies, which have a crucial role to play through work-mobility plans, offering incentives to employees who use public, shared or company transport, or other actions, such as upgrading company fleets to electric vehicles;
- universities, which are key agents, causing hundreds of thousands of people to travel on a daily basis, including students, teaching staff and non-teaching staff.

Attending to the specific needs of these collectives (and their intersectionalities) is vital in order to develop more equitable and effective emissions-reduction policies.

It is important to underline that the energy transition to climate neutrality has an enormous potential to generate a positive social impact, tackling fundamental issues such as the improvement of living and mobility conditions, creation of high-quality jobs, and reduction of energy poverty.

# 7 | Cross-governmental partnerships and public–private–social partnerships

Taking action on the sources of GHG emissions is not enough to reach carbon neutrality. To achieve this goal, a social transformation that shifts current paradigms and changes lifestyles is also required. This is a collective enterprise in which a wide range of actors need to participate, from governmental agencies to the private sector, academia, the third sector, and the general public.

The strategic vision, legal and regulatory framework and economic stimulus provided by the various levels of government are crucial. The local actions open to city councils are often conditioned by the contexts created at higher levels of government. In this sense, EU policies such as the European Green Deal, the European Commission's call to increase Europe's climate ambition for 2030 by proposing an emissions reduction of 55% by 2030 (vs 1990), and the EU Missions on adaptation and climate-neutral, smart cities, while not binding, all signpost the path that municipal policies should take.

National policies are vital for achieving objectives and developing local plans. They are essential to underpin the development of legal bodies, regulations and technical guidelines and, specifically, to configure the energy and electricity mix that will form the basis of the new energy model and strategies for achieving carbon neutrality. The national policies for the coming years are mapped out in the National Law on Climate Change, the National Integrated Energy and Climate Plan (INECP) and the Long-Term Strategy (ELP), all of which set the objective of achieving carbon neutrality by 2050.

This Roadmap integrates national-level plans into local action. It includes the target of increasing the proportion of renewable-energy sources in electric power generation to 74%, the principle of energy efficiency within a 2030 time limit, as set out in the INECP, and the ELP's objective of carbon neutrality by 2050.

The Ministry for the Green Transition and Demographic Challenge (MITERD) and the Spanish Climate Change Office are key actors in this process, given their responsibility for developing national policies. There is therefore constant communication with these stakeholders from a local level, in order to ensure that actions are aligned.

The academic community is another pillar for climate action in the city of Madrid. There is an active relationship with this actor at several levels, which has resulted in a genuine university–city partnership. The City Council has been collaborating with a number of universities in the municipality for several years to produce sector-level studies that are of great value to the city, including the inventories of polluting emissions and greenhouse gases, the research on the fleet of vehicles in circulation that informs these inventories, and several other studies.

From a municipal perspective, a tool for interdepartmental collaboration was developed in 2021 – the 'Climate Group 360' (Grupo Clima 360) – which connects several services within the municipal structure that are considered key to implementing climate action, such as environment, urban planning, innovation, economic and budgetary management, energy, mobility, heritage and culture. This teamwork makes it possible to take an integrated approach to climate challenges and to create connections between projects that are underway.

Third-sector organisations, such as NGOs, foundations and civil-society associations have a crucial role to play in progressing towards climate neutrality, due to their ability to understand the real situation on the ground, get communities involved, and ensure an inclusive transition. Over the course of 2023, significant efforts were made to engage a range of non-profit organisations in the city with this Roadmap. These organisations made valuable suggestions for improvement that have been incorporated into this updated version of the document, consolidating an integrative approach focused on representing the needs of society.

Implementing the Roadmap also entails profound social change, making it important for the public to take part in this process, by changing behaviour and lifestyles, but also by participating in decision-making.

While no direct mechanism for such relationships or stable frameworks for collaboration have been established, given the structural complexity involved, participatory processes have been established in relation to specific projects, such as 'intervention in school settings with criteria for climate-change adaptation and air-quality improvement' and

'intervention in school settings in Puente and Villa de Vallecas'. Working together on the needs of the different population groups targeted by interventions is key for project success.

The global and complex nature of the climate crisis makes it vital to work as part of a network, meaning that we cannot travel along the path laid out by this Roadmap alone. Joining with other cities to share knowledge and experience will be vital. At the national level, Madrid is a member of the 'citiES 2030' initiative, created in 2021 as a platform to translate the work of the EU Mission for climate-neutral and smart cities to the national level, as well as the Network of Cities for Climate set up by the Spanish Federation of Municipalities and Provinces. At the international level, Madrid participates in initiatives such as the Covenant of Mayors for Climate and Energy, the EUROCITIES network and the C40 Cities Climate Leadership Group.

# 8 | Processes to drive implementation and scaling-up

Once the main levers for transformation have been identified and the framework of powers has been delineated, it is necessary to establish priorities for municipal action that create the maximum impact in those areas where the City Council can intervene most directly. This involves two levels of action: identifying the key levers for municipal action, and processes that facilitate implementation and scaling-up.

When prioritising these actions, the municipality clearly has to consider their potential impact in terms of emissions reduction, but this should not be the sole criterion. It is important to focus particularly on **transformative actions** that move the 'business as usual' model towards more sustainable systems that are commensurate with the ambitious scenario the city is aiming to follow. A systemic transformation is needed, involving innovation that is not limited to technology, but alters the social, political, economic, financial and institutional spheres as well. It is therefore vital to create new enabling tools that can facilitate the processes of implementation and scaling-up.

To put this Roadmap into effect, the city of Madrid has established the following actions, focused on driving processes forwards:

- INTERDEPARTMENTAL WORKING GROUP (**Climate Group** 360): made up of representatives of various municipal areas (Urban Planning, Environment and Mobility, Economy, Innovation, Tax, Culture, International, etc.) that provide the range of visions required by the Roadmap.

- REGULATORY REVIEW: processes of reviewing municipal regulations, ordinances and plans from the perspective of climate neutrality. This is an opportunity to generate spaces for regulatory innovation (regulatory 'sandboxes') enabling experimentation with decarbonisation models that are not considered or difficult to implement within the existing regulatory framework. The **'Climate action demonstration areas'** included in the Air Quality and Sustainability Ordinance in March 2021 are worth highlighting, where measures will be taken to accelerate decarbonisation and enable climate-neutrality targets

to be met. These areas will have an action plan including the measures necessary to secure an emissions reduction that surpasses that required by existing regulations, thereby providing an additional boost to air quality in these localities that can be extended to the entire city.

- CLIMATE FINANCING: implementation of financing schemes that enable the Roadmap to be carried out on the basis of the economic analysis. Incorporation of the climate variable into municipal budgets.

- MULTI-STAKEHOLDER PARTNERSHIP PLATFORM: on the basis of Madrid's experience as a demo city for the Climate-KIC 'Clean and healthy cities' programme, a platform will be consolidated that promotes systemic innovation, accelerating portfolios of transformative projects. The City Council, scientific community, private sector and general public will all form part of this platform.

- COLLABORATIVE NETWORKS AT THE NATIONAL AND INTERNATIONAL SCALES
- MEASURES THAT DRIVE OTHER PROCESSES FORWARDS: such as the organisation of public space for pedestrians/cyclists to prioritise sustainable forms of mobility, installation of solar-energy and collective self-consumption systems to engage the public in energy consumption and the electrification process, and rewilding the city to increase awareness and engagement with the issue of climate change and its impacts.

# 9 | Vulnerability and adaptation to climate change

Reducing GHG emissions should be the top-priority objective of climate-related action. Nevertheless, the consequences of global warming make it necessary to respond to the threats and impacts that are already occurring. The alteration of the global climate system generates impact chains that reach the local scale and are not limited to environmental matters, but also impact social and economic life.

This Roadmap aims to guide the city of Madrid along a path enabling it to comply with the Paris Agreement, reducing its emissions with the target of reaching climate neutrality by 2050, while also incorporating the objectives set out in article 2 of the agreement: '*increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience*'.

The European Green Deal, which expresses the political commitment to transforming the EU into an equitable and prosperous society, with a modern economy that is competitive and uses resources efficiently, also includes the goal of protecting, maintaining and improving the EU's natural capital, in addition to protecting the health and wellbeing of its citizens against environmental risks and impacts.

At a national level, the Climate Change and Energy Transition Law creates the institutional framework for meeting the Paris Agreement objectives and expands the role of adaptation in the development of these policies. More specifically, the National Climate Change Adaptation Plan (PNACC) provides a set of guidelines to shape local plans and actions.

The local scale at which adaptation to climate change takes place needs to be underlined. The impacts derived from the alteration of the climate translate into real risks that are close at hand, affecting urban systems from resource supply to water management, energy demand and the degradation of natural spaces, but the greatest effects are felt by the most vulnerable social groups and in economic activity.

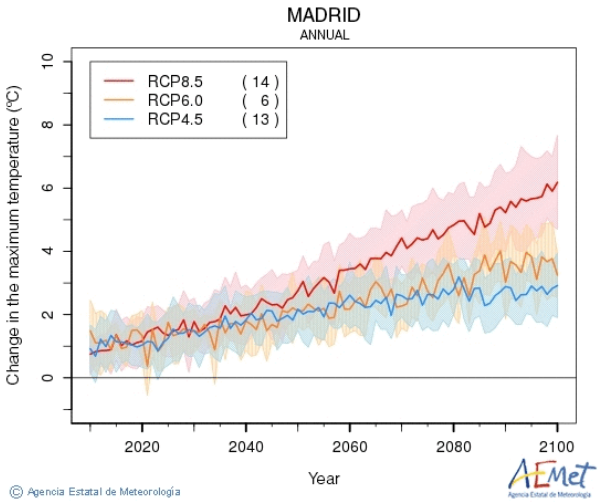
## Climate scenarios and risk assessment

The changes in Madrid's climate over time are inferred from regional-level climate scenarios. Despite the city's influence on certain meteorological variables, Madrid's climate depends on the regional climate. The regional projections offered by Spain's State Meteorological Agency (AEMET) and the Spanish Climate Change Office's Adaptation Platform (AdapteCCa) enable us to determine the future scenarios that the city will face.

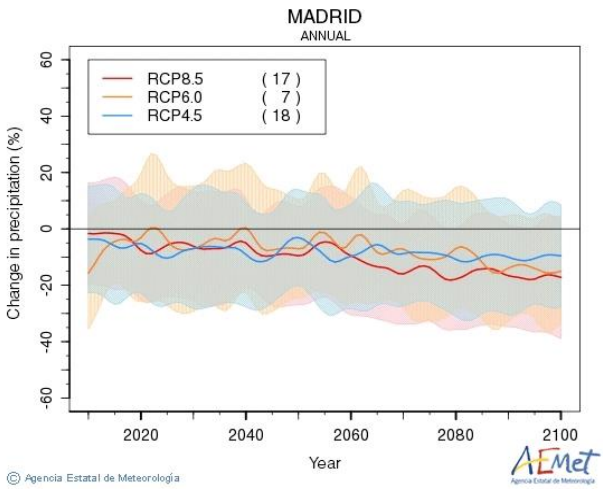
The trend observed in temperatures is an increase in maximum temperatures, and a growing number of hot days with hot or very hot nights, when the minimum temperature exceeds 20º, as well as an increase in the length of heat-wave episodes. The trends in these variables are more pronounced in the highest representative concentration pathway (RCP 8.5) with increases of over 5ºC in maximum temperatures by the end of this century and increases in heat-wave episodes.

Regarding precipitation, the trend is a decreasing volume of rainfall along with fewer rainy days, while dry periods are expected to increase in duration.

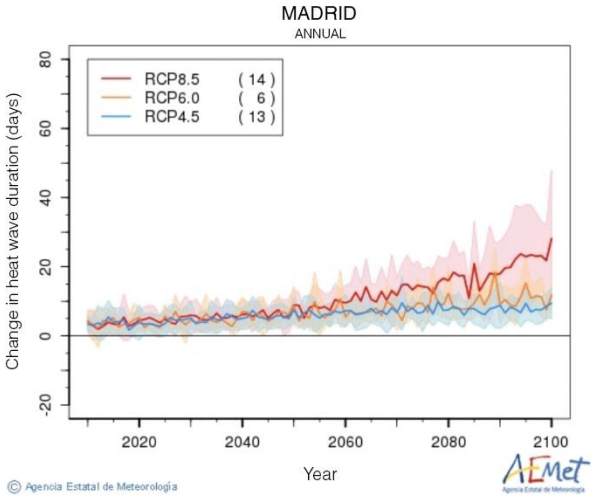
**Change in maximum temperature**



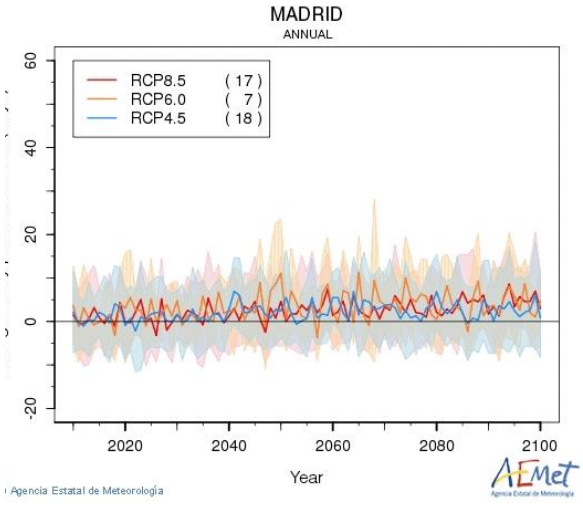

**Change in precipitation**




**Change in heat-wave duration**




**Change in dry-period duration**




*Graphs showing the regional-level climate change projections (temperature and precipitation). Source: AEMET.*

*Available at: http://www.aemet.es/en/serviciosclimaticos/cambio_climat/result_graficos*

The changes in climate conditions shown in the projected scenarios are the source of a series of impact chains. According to the municipal study '*Analysis of the municipality of Madrid's vulnerability to Climate Change*', the city is affected by the following impacts:

- **Heat waves:** direct effects on health, mortality and morbidity; increase in energy demand; increase in water consumption; reduced efficiency at work; effects on tourism, etc.
- **Droughts:** restrictions on drinking-water supply and reduction in its quality, impact on the economy, business and tourism, degradation of natural spaces, etc.

- **Extreme climate events:** Floods, storms, strong winds, snowstorms, hailstorms, etc., leading to personal harm, impacts on infrastructure and buildings, reduced water quality, increase in security incidents, emergencies and mobility-related incidents.
- **Environmental degradation:** alteration or modification of ecosystems and biodiversity loss, increase in contagious vectors, plagues and diseases.

These impact chains create a cascading effect felt across multiple aspects of life and activity in the city, from health to air quality, working conditions and the economy. This analysis provides a neighbourhood-level assessment of which areas in Madrid are most vulnerable, showing how climate vulnerability coincides spatially with social and economic vulnerability.

While the city of Madrid's climate is framed within the regional climate, its urban morphology, materials and activities create specific microclimate conditions and phenomena such as the 'urban heat island' effect, like other major cities.

The '*Detailed Study of the Urban Climate of Madrid*', produced by the urban climate research group at the Autonomous University of Madrid (UAM) and commissioned by the City Council, details the existing knowledge on the urban heat island effect, which is closely related to the impact of heat waves. The study incorporated the trends projected in the regional climate scenarios and included a city heatmap enabling the 'hot points' that are exposed to the greatest effects to be located.

The impacts resulting from the changing climate are already a reality in the city of Madrid, occurring in different areas at differing magnitudes and intensities. The impacts can be acute, as in emergency situations, or chronic, with less evident but constant, enduring effects that gradually worsen certain aspects of urban life.

Like mitigation actions, adaptation requires an integrated, coordinated response, given the multiple factors involved and the myriad effects resulting from the changes to climate.

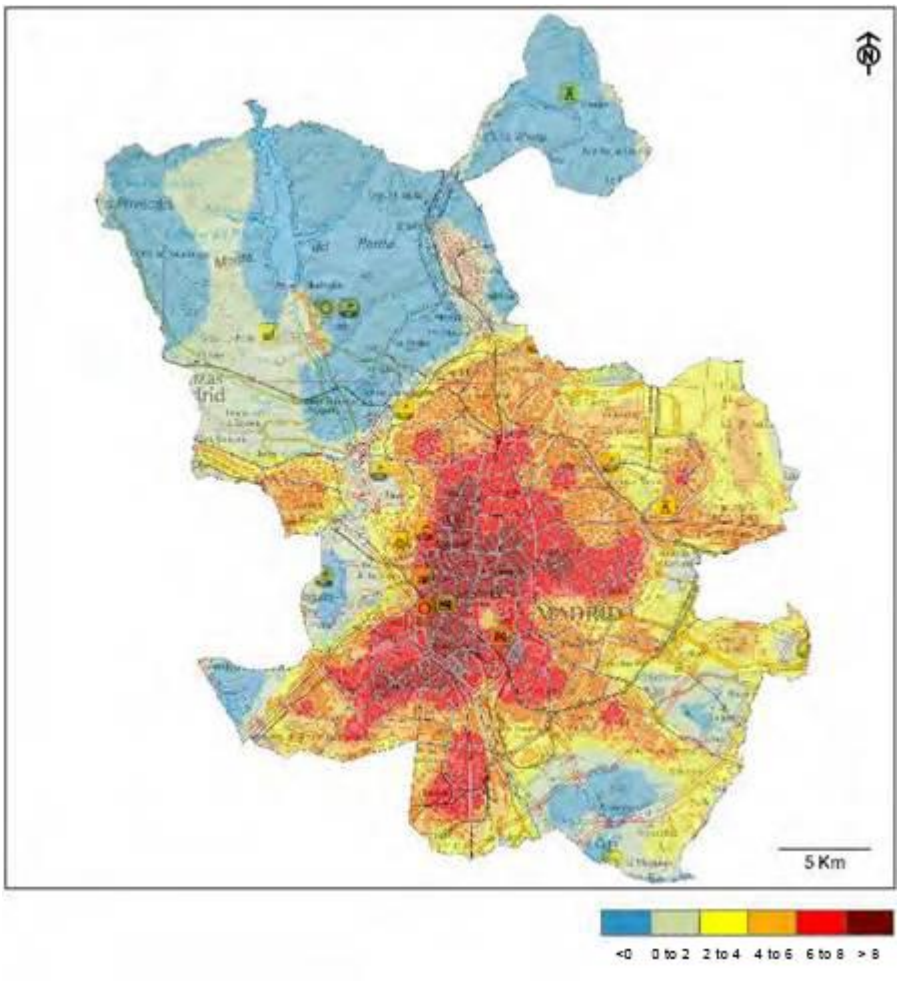
Municipal action on adapting the city to climate change can be broken down into the following components.

- Observation and monitoring of climate variables and the key related impacts.
- Risk assessment in economic sectors, infrastructure and the population.
- Developing actions to respond to impacts: emergencies and chronic effects.
- Putting adaptation measures into practice.
- Monitoring vulnerability of the city to climate change and of the measures implemented.
- Knowledge transfer.

## Adaptation objectives

Madrid's climate is changing and, according to the environmental projections, can be expected to continue along the same trend over the coming decades. The changing environmental conditions are creating risks to public health, the economy and the equilibrium of natural and urban systems.

To successfully respond to current and future climate impacts, Madrid needs to adapt, **transforming itself into a more resilient, sustainable and healthy city.** Adaptation is a comprehensive, cross-cutting transformation, requiring policy alignment across sectors and a coordinated effort by multiple actors from all sectors of society.




*Distribution of the physiological heat island in summer.*

*Detailed Study of the Urban Climate of Madrid, April 2016, Madrid City Council. Felipe Fernandez et al., UAM.*

The city's climate-change adaptation objectives, which are described more fully in 'Climate adaptation measures of the city of Madrid' (2023), are outlined below:

Objective 1: Cool down the city

Objective 2: Protect and increase biodiversity in the city

Objective 3: Optimise water-resource management

Objective 4: Adapt municipal services and facilities

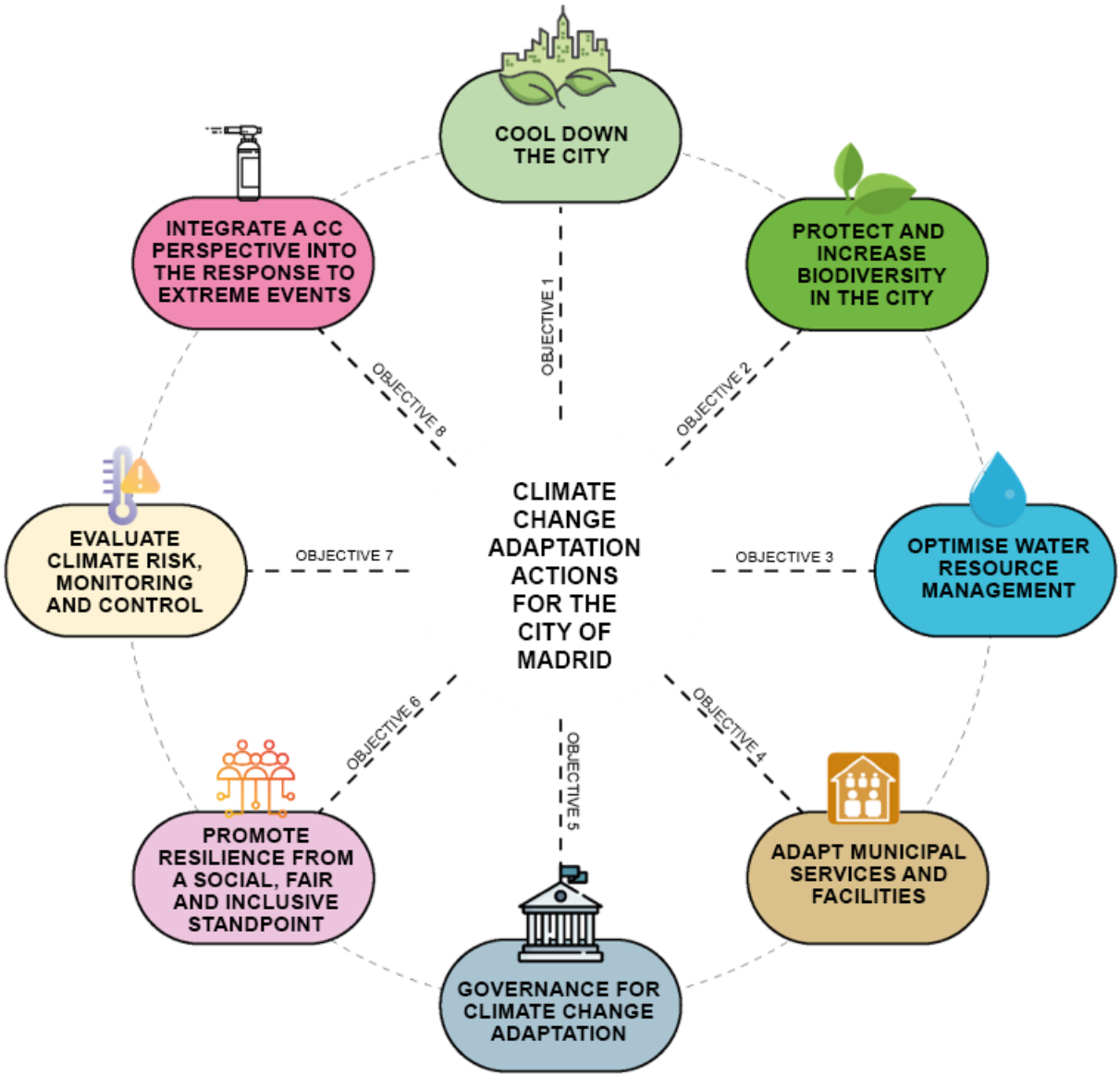
Objective 5: Governance that fosters climate adaptation

Objective 6: Promoting resilience from a social, fair and inclusive standpoint

Objective 7: Assessing climate risk, monitoring and control

Objective 8: Integrating a climate-change perspective into the emergency response to extreme events.

Each of these eight objectives has its own targets and lines of work, which will guide the city's improvements in its response to climate impacts.




Like mitigation actions, adaptation requires a **coordinated, cross-cutting response**, given the large number of factors involved and the myriad effects resulting from an altered climate. The interdepartmental 'Climate Group' (Grupo Clima) working group makes it possible to take an integrated approach to certain flagship projects in the city related to the development of green infrastructure and biodiversity, while also acting as a platform for promoting the necessary stable alliances with actors from the private sectors, academia and the general public.

# 10 | Monitoring and communications

A three-part system has been established for monitoring progress on the Roadmap to climate neutrality, which covers the full range of monitoring needs and objectives:

1) The city of Madrid's progress along the path to climate neutrality can be observed annually through the results obtained using the **Greenhouse Gas Emissions Inventory.** This tool, which has been in use since 2006, provides year-on-year data on the volume of scope 1 and 2 (direct and indirect) emissions generated by the city, as well as historical changes and trends in these emissions. The inventory, which is produced according to the internationally accepted methodology, offers data on total emissions and emissions per economic sector, and is the main mechanism for checking the results of climate action against emissions-reduction targets.

   The inventory's base data is obtained through surveys conducted directly with the main emitters, to which data from the regional and national government are added, as well as specific studies, such as the City of Madrid's Fleet of Vehicles in Circulation, the Traffic Model, and the Energy Balance.

   Annex I contains the indicators identified for monitoring progress on this Roadmap. The GHG Emissions Inventory provides the general monitoring indicators that can be found in this annex.

2) The emissions inventory has certain limitations, such as the one- to two-year time lag resulting from the data-collection methodology and the difficulty of evaluating the impact of specific emissions-reduction levers. It was therefore considered beneficial to supplement it with a system of urban indicators that enable more detailed analysis of whether the hypotheses and scenarios are being fulfilled, the extent to which measures are being implemented, and the prognosis for change in the coming years. This trend monitoring will include evaluation of adaptation actions using resilience and/or vulnerability indicators.
   In addition to the general monitoring indicators, Annex I provides a series of sector-specific indicators that evaluate and show the trends and impacts corresponding to the decarbonisation levers and lines of action set out in the Roadmap.

3) Finally, an advanced system called SIMAD Climate and Air (SIMAD Clima y Aire) has been developed to diagnose and evaluate the emission sources of greenhouse gases and atmospheric pollutants in the city of Madrid, making it possible to monitor, simulate and evaluate how different environmental policies and scenarios of changing urban dynamics impact atmospheric-pollutant emissions. This tool, which uses multiple urban data sets from public and private sources, offers a geographic visualisation of emissions at a high level of detail.

The Roadmap, inventory data and periodic evaluation reports will be made available on the City Council website and in specific publications, to ensure that the information is transparent and accessible to any interested party.

## Communications strategy

The Roadmap is a guide for all the people and organisations involved in mitigation and adaptation in the city. Ensuring that it reaches as many stakeholders as possible is therefore considered integral to the implementation and development process. As part of the communications strategy, its contents will be adapted to the audience, communications channel and objective of each informative action.

Sharing the Roadmap internally within Madrid City Council is important to ensure that the policies of the different municipal areas are aligned, but involving the private sector, civil society organisations and the general public is particularly crucial. This message and mission should reach each of these stakeholders in a form that is tailored to their position and capacity for action.

# 11 | Threats and barriers

The climate crisis is defined by its complexity and the interconnection between multiple factors from apparently distant fields. This means that threats and barriers can arise in similar ways from multiple sources.

When it comes to fulfilling the Roadmap's objectives, the uncertainty centres on the pace and timeframe necessary to achieve them.

Technically, the progress achieved points to the viability of scenarios in which cities become climate neutral in the timeframes proposed in this Roadmap and, while there are uncertainties about some aspects (progress in battery development; adaptation of distribution networks; development of hydrogen technology; waste classification and treatment techniques, their implementation costs, development of markets for recycled materials, etc.), these do not appear to jeopardise the end goal.

Success in securing climate neutrality depends to a great extent on **decarbonisation of the electricity mix,** where failure to progress at the necessary speed or meet the milestones established would slow down the entire process.

Adapting infrastructure, transforming the city's fleet of vehicles in circulation, improving the energy efficiency of buildings, expanding the use of heating and air-conditioning systems based on clean energy, and improving waste collection and treatment processes will all require technological improvements and extensive timeframes for completion that could alter the expected rate of progress.

However, the greatest threats and barriers are related to social and economic factors. The objective of creating a carbon-neutral city cannot be met without **public–private–social collaboration** in all parts of the process. This urban development will only work in an inclusive society and a favourable, sustainable economic context.

**Governance** models are another key aspect: climate action puts comprehensive transformations on the table that are sometimes difficult to enact in overly rigid and compartmentalised governmental and organisational structures, or regulatory systems designed without considering the climate variable.

The **disconnect between different scales** of action is another potential threat. Climate action in the city should be connected to the metropolitan, regional and national contexts. A wide range of urban activities and systems (mobility, food and drink, energy, water, etc.) are greatly influenced by these larger-scale contexts. Similarly, the process can be derailed or slowed down if **policy alignment** is not secured between the local, regional, national and European levels of government.

**Policy harmonisation** will not only be necessary at the legal and strategic levels. The urban transformation needed will require financial and budgetary policies that are responsive and efficient, for which **institutional coordination** will be crucial.

Putting actions into practice will require major investments, some involving direct economic returns and timeframes that are manageable for investors, but these returns will often come over a long timeframe, as shown in the economic analysis. In other cases, such as many urban-resilience actions, there will be no returns in a purely economic sense. A favourable **economic context** and, more broadly, an approach that establishes the value of the returns obtained will therefore facilitate the implementation of measures.

The process of moving towards climate neutrality requires a profound urban transformation that encompasses the social, economic and environmental spheres. The challenge is to overcome the various sources of inertia and resistant attitudes that hold back this progress, in order to create new paradigms and momentum that can drive Madrid naturally forwards to climate neutrality, economic prosperity and social inclusivity. In a prior analysis, the following local barriers affecting the necessary climate action and potential corrective actions were identified.

*Table 5: Local barriers to the Roadmap and measures to overcome them*

| Local barriers to the Roadmap | Measures to overcome them |
|---|---|
| Lack of climate-related criteria in urban regulations and planning and in the residential sector's renovation strategy.<br>Lack of professionals in the sector. | Review of regulations and governmental management tools from a climate perspective.<br>Zones of climate-related experimentation and innovation (regulatory sandbox) and regulatory modification.<br>Awareness-raising and training among urban planning and construction technicians and professionals. |
| Lack of specific budgets and financing instruments for climate actions. | Economic assessment of co-benefits.<br>Instruments for channelling private investment. |
| Overly compartmentalised municipal structure and management that frustrates attempts to conduct integrated actions. | Creation of spaces for coordination and interdepartmental groups.<br>Modification of powers.<br>Inclusion of the climate variable in the various municipal fields and plans. |

| | |
|---|---|
| Difficulties with coordination between distinct governmental agencies. | Set up boards and channels for coordinating powers and resources. |
| Inertia and routine ways of working. Difficulties with incorporating technical and organisational innovation. | Create working groups for knowledge transfer and training.<br>Conduct training activities within the municipal organisation.<br>Promote local, national and international networks and platforms. |
| A shortage of risk- and impact-assessment tools. Evaluation of economic aspects, impacts on health, energy consumption, etc. | Development of tools for monitoring the effects of climate change: both its risks and the co-benefits of measures. |
| A lack of knowledge among the general public about climate risks and the available mitigation and adaptation actions. Difficulties with engaging urban agents. | Informing the general public about the aspects of climate-change impacts that are most relevant to them.<br>Educate the public about the efficient use of energy and new technologies.<br>Simplify administrative procedures for applying for grants and subsidies.<br>Facilitate the transformation of environments and behaviour.<br>Involve population groups, particularly those who are most vulnerable, in projects and initiatives addressing the impacts of climate change. |

ROADMAP TO
CLIMATE NEUTRALITY
IN MADRID BY 2050

**Revision history**

| Date | Summary of revisions |
|---|---|
| 2021 | First version |
| 2022 | Proposed indicators, analysis of climate-related risks and climate adaptation measures: co-benefits. |
| 2024 | Revision and update of the context, objectives, decarbonisation levers and indicators for a socially inclusive Roadmap. |

The Roadmap sets Madrid a great challenge that requires an urban transformation and the cross-cutting integration of climate action into municipal policies.

Cover-page image:
Title: *De Madrid al cielo (o hacia las cuatro torres)* [From Madrid to the sky (or towards the four towers)]
Author: Juan Carlos Rodán González
*Fifth municipal photography competition.*

# 12 | Annexes and related documents

## Annex I: Indicators for monitoring trends towards climate neutrality

The table below provides the indicators identified for monitoring the various decarbonisation levers and lines of action.

| 1. General monitoring indicators | | | |
|---|---|---|---|
| **Action** | **Indicator** | **Trend** | **Unit** |
| **General** | Total greenhouse gas (GHG) emissions | Available | kt $CO_2$eq |
| | Direct GHG emissions | Available | kt $CO_2$eq |
| | Indirect GHG emissions | Available | kt $CO_2$eq |
| | Municipal emissions intensity (emissions/unit of GDP) | Available | t $CO_2$eq/M€ |
| | Municipal energy intensity (Final energy consumption/unit of GDP) | Available | toe/M€ |
| **Residential** | Total GHG emissions in the residential sector | Available | kt $CO_2$eq |
| | Direct GHG emissions in the residential sector | Available | kt $CO_2$eq |
| | Indirect GHG emissions in the residential sector | Available | kt $CO_2$eq |
| **Services** | Total GHG emissions in the services sector | Available | kt $CO_2$eq |
| | Direct GHG emissions in the services sector | Available | kt $CO_2$eq |
| | Indirect GHG emissions in the services sector | Available | kt $CO_2$eq |

| | | | |
|---|---|---|---|
| **Road transport** | Total GHG emissions in the road transport sector | Available | kt $CO_2$eq |
| | Direct GHG emissions in the road transport sector | Available | kt $CO_2$eq |
| | Indirect GHG emissions in the road transport sector | Available | kt $CO_2$eq |
| **Industrial** | Total GHG emissions in the industrial sector | Available | kt $CO_2$eq |
| | Direct GHG emissions in the industrial sector | Available | kt $CO_2$eq |
| | Indirect GHG emissions in the industrial sector | Available | kt $CO_2$eq |
| **Absorption by carbon sinks** | Change over time of $CO_2$ absorption (carbon sinks) | Available | kt $CO_2$ |
| **Electricity** | Change over time of the electricity emission factor (national level) | Available | kt $CO_2$/MWh |
| | Generation of renewable energy | Available | ktoe |
| | Contribution of electrical energy to the final energy consumption total | Available | % |
| **Renewable thermal energy** | Change over time of the generation of renewable thermal energy | Available | ktoe |
| **Socioeconomic context and a fair transition** | Indicators on the demographic structure and dynamics of the population | Available | Various |
| | Household income by district | Available | € |
| | Percentage of households that cannot afford to keep their home at an adequate temperature by district | Available | % |
| | Percentage of household spending on energy by district | Under development | % |

| **2. Residential sector:** Zero-emission residential buildings | | | |
|---|---|---|---|
| **Action** | **Indicator** | **Trend** | **Unit** |
| **Reduce the energy demand of existing buildings by improving insulation and energy efficiency** | Change over time in the number of renovated homes | Under development | No of homes |
| | Change over time in the renovated surface area | Under development | $m^2$ |
| **Upgrade equipment and systems with more efficient replacements** | Change over time in the number of coal-fired boilers | Available | No of systems |
| | Change over time in natural gas consumption | Available | ktoe |
| | Contribution of electrical energy to the final energy consumption total in the residential and services sectors | Available | % |
| **Local actions for decarbonisation of the electric-power system** | See 'General monitoring indicators' | - | - |

| **3. Transport sector**: Zero-emission transport | | | |
|---|---|---|---|
| **Action** | **Indicator** | **Trend** | **Unit** |
| **Reduce travel by / demand for private cars** | Change over time in traffic intensity | Available | Thousands of vehicles/day |
| | Change over time in travel by private car | Available | Millions of vehicles·km/year |
| | Change over time in remote working | Under development | Under development |
| | Change over time in total surface area of low emission zones (LEZ) | Under development | $m^2$ |
| | Change over time in percentage of controlled parking zones (CPZ) | Under development | $m^2$ CPZ/$m^2$ total urban area |
| **Modal shift from private vehicles to other modes of transport / intermodal travel** | Change over time in pedestrian mobility (weekdays, Saturdays, Sundays and public holidays) | Available | Thousands of people/day |
| | Change over time in travel by public transport | Available | No of users (millions/year) |
| | Change over time in travel by bicycle (no of BiciMAD stations) | Available | No of docking posts |
| | Change over time in travel by bicycle (use of the BiciMAD service) | Available | Thousands of uses/year |
| | Change over time in zero-emission carsharing or carpooling | Under development | No of vehicles/year |
| **Replacement and electrification of the fleet of vehicles in circulation. Optimisation of services (public transport and urban freight distribution)** | Change over time in cars registered in the zero-emission category compared to the total number of registrations | Available | % |
| | Change over time in taxis registered in the zero-emission category compared to the total number of taxis | Available | % |
| | Change over time in buses registered in the zero-emission category compared to the total number of buses (EMT buses) | Available | % |
| | Change over time in the General Traffic Directorate (DGT) emission categories in the fleet of registered vehicles (cars) | Available | No of cars (thousands) |

| | | | |
|---|---|---|---|
| | Change over time in DGT emission categories in new vehicle registrations (cars) | Available | No of cars |
| | Change over time in DGT emission categories in the fleet of registered vehicles (motorbikes) | Available | No of motorbikes |
| | Change over time in DGT emission categories in new vehicle registrations (motorbikes) | Available | No of motorbikes |
| | Change over time in registered zero-emission vehicles in the municipal fleet | Available | % 'ZERO' category vehicles |
| **Reduce emissions in the aviation sector** | Change over time in aviation fuel consumption (kerosene in landing and take-off cycles) | Available | ktoe |
| | Change over time in total operations per year | Available | Thousands of operations/year |

| **4. Services sector:** Zero-emission buildings and premises for the services, commercial and institutional sector | | | |
|---|---|---|---|
| **Action** | **Indicator** | **Trend** | **Unit** |
| **Reduce the energy demand of existing buildings by improving insulation and energy efficiency** | Change over time in energy consumption in a representative sample of municipal buildings | Under development | Energy consumption/$m^2$ |
| **Upgrade equipment and systems with more efficient replacements** | Change over time in number of heat pumps | Under development | No of devices |
| | Change over time energy consumption of public street lighting | Available | kWh |
| | Change over time in number of public streetlights (city, monuments, roads and tunnels over 200 metres in length) | Available | No of streetlights |
| | Change over time in the relationship between energy consumption of public street lighting and number of streetlights | Available | kWh/no of streetlights |
| | Change over time in power of public street lighting (city, monuments, roads and tunnels over 200 metres in length) | Available | kWh |
| **Local actions for decarbonisation of the electric-power system** | Change over time in solar power installed in the municipality | Available | kWp |
| | Change over time in solar energy generation in municipal buildings and centres | Available | MWh |

| **5. Waste sector:** Reduce the impact of waste | | | |
|---|---|---|---|
| **Action** | **Indicator** | **Trend** | **Unit** |
| **Reduce waste generation** | Change over time in the rate of waste generation per capita | Available | kg/(inhabitant·year) |
| **Increase waste-recovery rates in the residential, services and municipal sectors** | Change over time in the waste-recovery rate in the residential, services and municipal sectors | Available | % |
| **Organic waste collection and treatment** | Change over time in the total mass of organic waste collected selectively | Available | t/year |
| | Change over time in the relationship between the biogas generated through biomethanisation and the organic waste that enters the biomethanisation process | Available | $Nm^3/t$ |
| | Change over time in the relationship between the biomethane injected into the grid and the total biogas generated through biomethanisation | Available | $Nm^3$ biomethane/$Nm^3$ biogas |

| **6. Industrial sector and others:** Reduce emissions in other sectors | | | |
|---|---|---|---|
| **Action** | **Indicator** | **Trend** | **Unit** |
| **Reduce the impact of refrigerant and solvent gases** | Change over time in fluorinated gas emissions | Available | t |
| **Reduce emissions in the industrial sector** | Change over time in final energy consumption of the industrial sector | Available | ktoe |
| | Contribution of electrical energy to the final energy consumption total in the industrial sector | Available | % |
| **Rewild and reforest the municipality** | Change over time in tree canopy cover | Under development | Under development |
| | Change over time in the 'green factor' | Under development | % |

# Annex II: Related documents

## Municipal documents

- *Inventario de Gases de Efecto Invernadero de la Ciudad de Madrid* (2019) [Greenhouse gas inventory of the city of Madrid, 2019], Madrid City Council, 2021
- *The total economic case for decarbonisation in Madrid*. Material Economics, November 2020
- *Adaptación climática mediante soluciones basadas en la naturaleza: Madrid + Natural* [Climate adaptation through nature-based solutions: Madrid + Natural], Madrid City Council, 2020
- Declaración de emergencia climática [The climate emergency declaration], 25/09/2019
- Acuerdos de la Villa ['La Villa' agreements], 2020
- Estrategia de Sostenibilidad Ambiental Madrid 360 [Madrid 360 environmental sustainability strategy] Available here.
- Agenda Rehabilita Madrid [Renovate Madrid programme], 2022. Available here.
- Informe Madrid Economía [Madrid economy report]: 2023 edition available here; and Informe Mensual de Coyuntura Económica [Monthly economic situation report]: November 2024 available here.
- *Diagnóstico social 2021-2022. Primera ola del panel estable de hogares del Ayuntamiento de Madrid* [Social diagnosis 2021–2022: Wave 1 of the Madrid City Council stable household panel]. Available here.
- *Estado de la movilidad 2020* [The status of mobility 2020]. Available here.
- Medidas de adaptación climática de la ciudad de Madrid [Climate adaptation measures of the city of Madrid] (pending publication).

## Community of Madrid documents

- Estrategia de Energía, Clima y Aire de la Comunidad de Madrid, 2023-2030 [The Community of Madrid energy, climate and air strategy]. Available here.

## National documents

- *Estrategia a largo plazo para la Rehabilitación Energética en el Sector de la Edificación (ERESEE)* [Long-term strategy for energy renovation in the building sector in Spain]. Available here.
- *Plan Nacional Integrado de Energía y Clima, 2021–2030* [Integrated national energy and climate plan, 2021–2030]. Available here.
- *Empleo y transición ecológica. Yacimientos de empleo, transformación laboral y retos formativos en los sectores relacionados con el cambio climático y la biodiversidad en España* [Employment and the green transition: Sources of jobs, the transformation of employment and training-related challenges in the sectors related to climate change and biodiversity in Spain], The Biodiversity Foundation and Spanish Climate Change Office, Ministry for the Green Transition and Demographic Challenge. Available here.
- *La percepción social sobre la transición ecológica en España, 2023–24* [The social perception of the green transition in Spain, 2023–24], Fair Transition Observatory. Available here.
- Encuesta de población activa [Economically active population survey]. Available here.