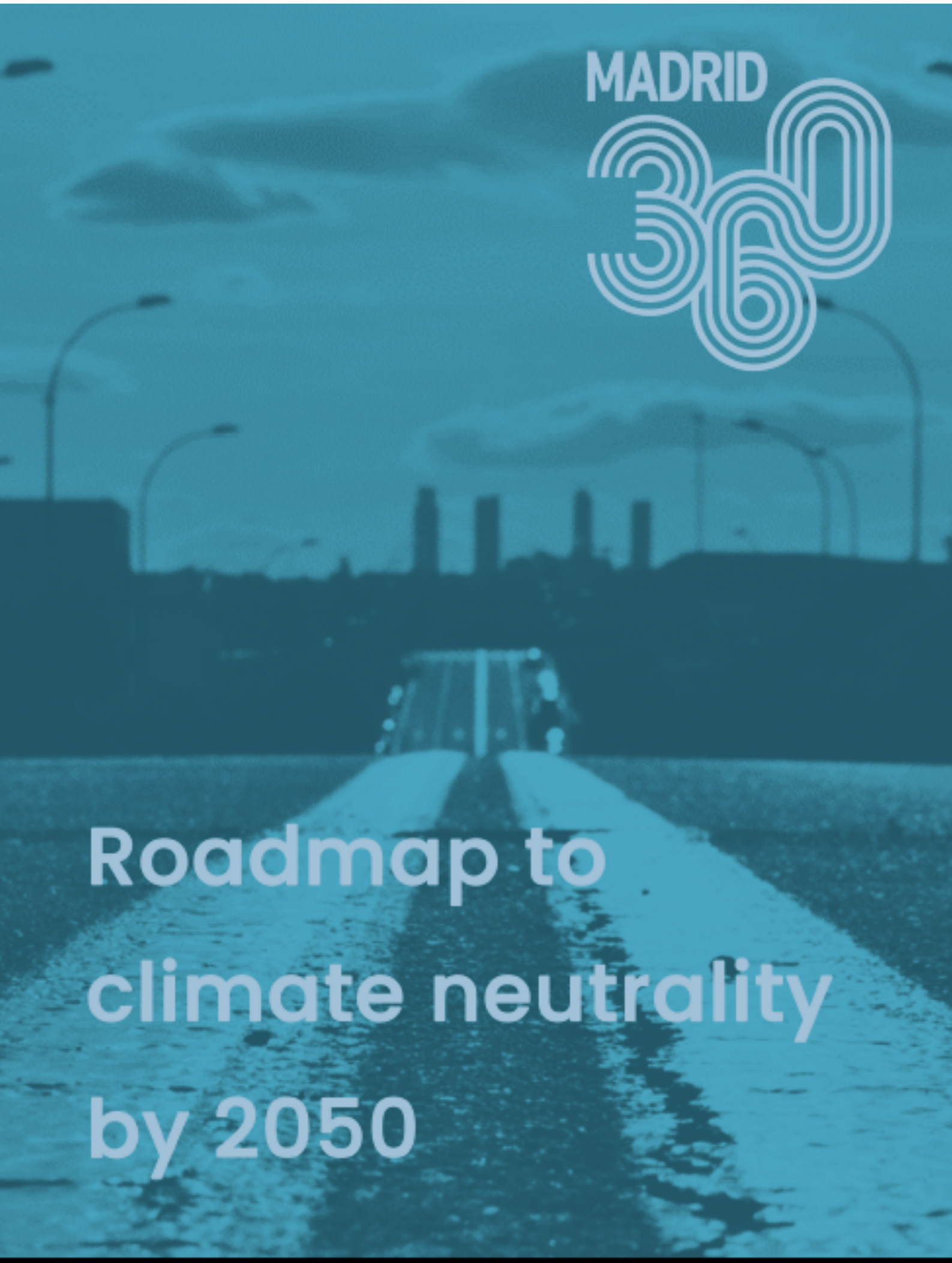

Roadmap to climate neutrality by 2050

MADRID

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Roadmap to Climate Neutrality by 2050

1 Vision and commitment
2 Starting situation
3 Emission reduction targets
4 Industries and transformation drivers
5 Economic analysis
6 Coordination between administrations and public-private partnership
7 Key actions at municipal level
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1 Vision and commitment

Climate Change is the greatest environmental challenge that our planet is currently facing. However, its consequences transcend the environment and have a direct and intense impact on society and the economy. The climate crisis materialises in different forms and magnitudes both globally and locally.

Cities are key elements in this crisis. They are high-energy-intensity centres and, consequently, they are responsible for a large part of the greenhouse gas emissions released into the atmosphere. But at the same time, they are subject to the impacts derived from climatic alterations that jeopardise urban systems – from those related to the supply of essential resources such as water, energy or food, to those related to health, migratory flows or economic activity. If the resources and knowledge in cities can be further developed, cities have the potential to be a key solution to the climate change crisis.

The Madrid 360 Environmental Sustainability Strategy, presented in September 2019, already pointed out in its introduction 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 2020, the European Council endorsed the new binding target for the EU to reduce net greenhouse gas emissions in the EU by at least 55% by 2030 – compared to 1990 levels (European Green Pact) – and, consequently, the Madrid 360 Strategy developed this Roadmap, which not only responded to this call, but also established a higher level of ambition, as befits those cities that want to be at the forefront of the fight against Climate Change.

Thus, the climate action reflected in this Roadmap derives from the general objective established by the Madrid 360 Environmental Strategy to transform Madrid into a more environmentally sustainable city. This would directly affect an improvement in the quality of life, the development of a low-carbon economy and greater security and resilience in the face of climate risks. The Roadmap identifies and develops those actions especially relevant to Madrid 360 in terms of reducing greenhouse gas emissions in order to stop, revert and mitigate the effects of Climate Change.

The **Roadmap to Climate Neutrality by 2050 of the City of Madrid** aligns municipal policies with European and state policies, while taking the most ambitious challenges for reducing greenhouse gas emissions as its own**.** This Roadmap aims at **reducing emissions in the city of Madrid by 65% by 2030, as compared to 1990, and to achieve climate neutrality by 2050** (sustainable scenario).

But this journey does not start at this point in time; Madrid has already begun a path in this direction. This Roadmap adds to a set of commitments, plans and instruments that make up the climate planning of the city of Madrid, a living plan that is in constant evolution and expansion with the addition of new initiatives.

The Roadmap is, therefore, a technical analysis that aims to support the political commitment to fight climate change in the city of Madrid. This commitment responds, above all, to movements and tools of an international nature, among which we highlight:

European Green Deal. On 11 December 2019, the Commission presented its Communication on the **European Green Deal**. It is a new growth strategy for the EU that leads to a climate-neutral, equitable and prosperous society with a modern, resource-efficient and competitive economy. At the European Council meeting in December 2019, EU leaders reiterated their commitment to playing a driving role in the global fight against climate change, confirming the goal of climate neutrality by 2050. In December 2020, the European Council endorsed a new EU binding target to reduce the EU's 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. EU leaders have urged the Council and Parliament to reflect this new target in the proposed European Climate Law and to pass this law as soon as possible.

Recovery, Transformation and Resilience Funds (Next Generation EU). Ambitious financing plan that includes, as one of the main objectives in Spain's programme, "A country committed to decarbonisation, investing in green infrastructure and moving from fossil fuels to a clean energy system", with the ecological transition being one of its four core elements. The climate variable is therefore one of the focal points for allocating 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, which establishes, in accordance with the conclusions of the scientific community (IPCC), the objective of limiting the rise in global temperature to below 2°C, recommending that this increase be kept below 1.5°C in order to avoid irreversible consequences and which, in terms of emission reductions, must be translated into the specification of nationally determined contributions. It is also worth highlighting Madrid's

The challenge taken on by the Madrid City Council as a member of the **C40** Cities Climate Change Leadership Network, which requires the development of a roadmap by 2020 (Deadline 2020 Initiative) to achieve greenhouse gas emission neutrality by 2050, with an interim target

Covenant of Mayors for Climate and Energy, of which Madrid is part since its foundation in 2008 with the purpose of bringing together local governments that voluntarily commit to achieve and exceed the EU climate and energy targets.

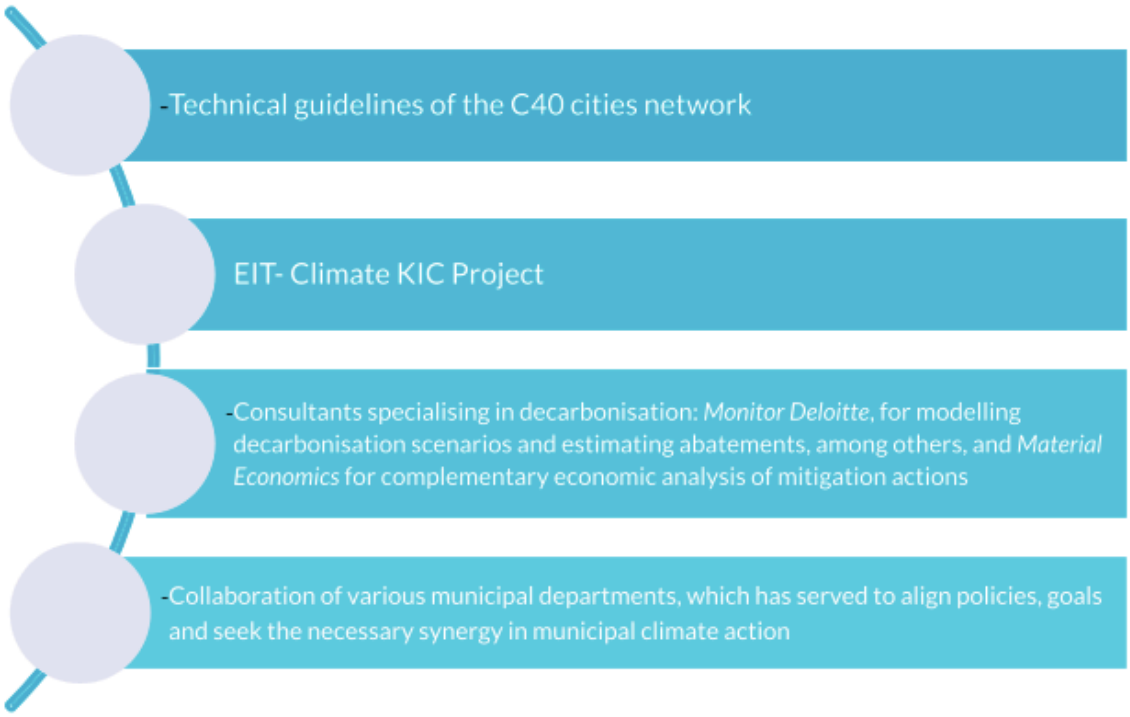
The Roadmap develops the climate action already reflected in a generic way in the **Madrid 360 Environmental Strategy and in the Air Quality and Climate Change Plan** which is also specifically included in different institutional declarations such as:

- Villa 2020 Agreements, with the MEC.GT1.067/274 Agreement pointing out the need for specific municipal actions to fight against Climate Change in order to achieve at least the national and European goals for the years 2030 and 2050 on decarbonisation and climate neutrality.

- Declaration of Climate Emergency (25/09/2019), by which the municipal plenary approved the need to establish the political commitments, regulations and resources necessary to ensure the progressive reduction of greenhouse gases.

The Roadmap means for Madrid a great challenge that implies an urban transformation and the integration of climate action in municipal policies at all levels. To this end, the city has recently joined the **Deep Demo Climate-KIC** project of the European Institute of Innovation and Technology. This adhesion, approved by the Municipal Plenary in July 2020, involves assessing and innovating in the processes and mechanisms of collaboration that will accelerate the transition to climate neutrality.

The following document is the result of an analysis, coordinated by the Environment and Mobility Area, with the contribution of different sources:



2 Starting situation

In recent years, the city of Madrid has implemented policies, plans and actions to reduce greenhouse gas (GHG) emissions. Usually these actions have been associated with other municipal plans such as air quality, mobility or urban regeneration, using resources, developing synergies and trying to guide the different municipal policies in the same direction.

In order to know the status and evolution of these emissions into the atmosphere, the Madrid City Council prepares an annual GHG Inventory of the city of Madrid. The inventory provides information on direct emissions (scope 1) and indirect emissions due to electricity consumption and distribution losses (scopes 2 and 3), broken down by sector of activity.

The Inventory follows the methodology of 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 Working Group on Atmospheric Emission Inventories and Projections of the United Nations Economic Commission for Europe (TFEIP–UNECE). The collection, analysis and consolidation of information implies a time lag in the publication of the inventory. Therefore, the latest report corresponds to 2018. The 2018 GHG Emissions Inventory values show a total volume of emissions of **11,125 ktCO2eq**, of which **7,416 ktCO2eq** (66.7%) are direct emissions and **3,708 ktCO2eq** (33.3%) are indirect emissions.

Sectoral breakdown of total GHG emissions (year 2018)

Sector	Emissions kt CO_2 eq	Contribution (%)
Residential, Commercial and Institutional	5,576	50.1
Industry*	653	5.9
Road transport	2,653	23.9
Other transport	1,064	9.6
Waste treatment and disposal**	772	6.9
Other***	406	3.6
TOTAL	11,125	100

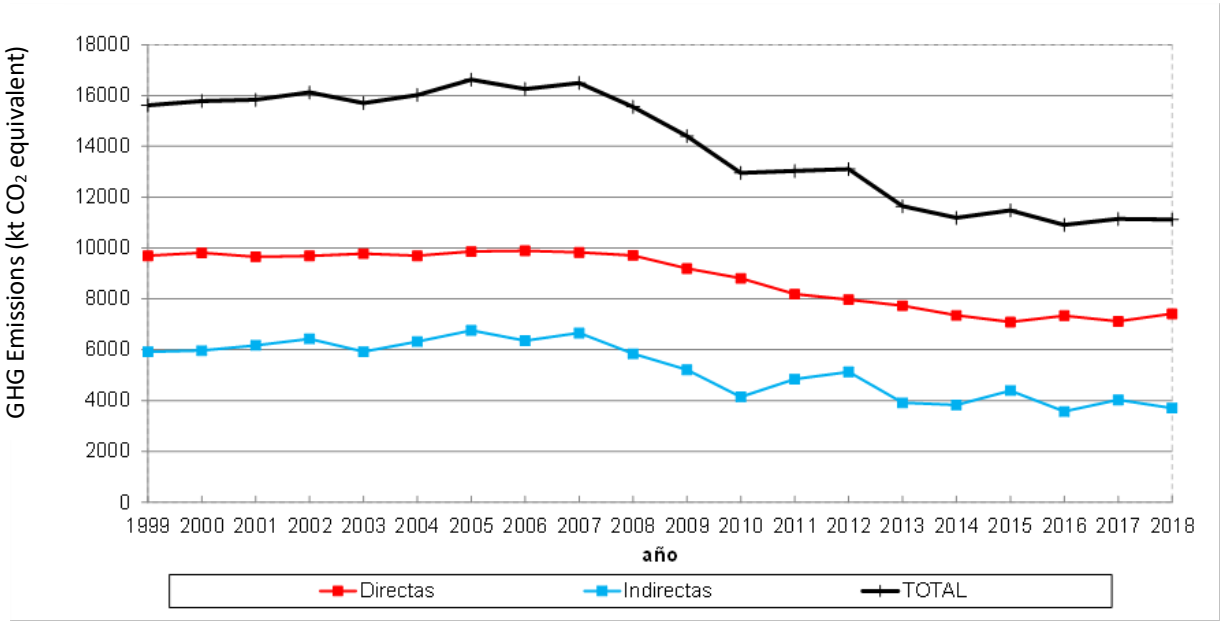
(*) Includes industrial emissions from combustion and non-combustion processes (SNAP groups 03 and 04)
(**) Includes waste treatment and wastewater treatment
(***) Includes extraction and distribution of fossil fuels, use of solvents and other products, agriculture and nature (excluding CO_2 absorption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

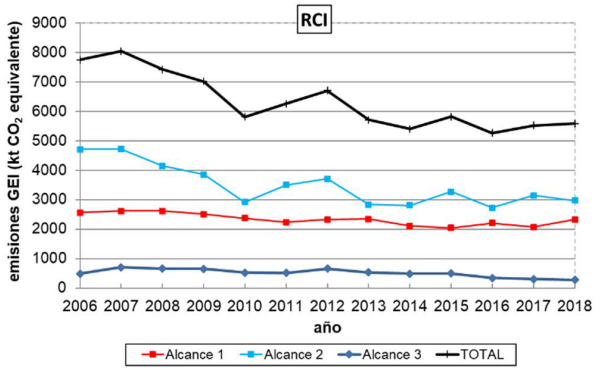
Direct and indirect GHG emissions (year 2018)

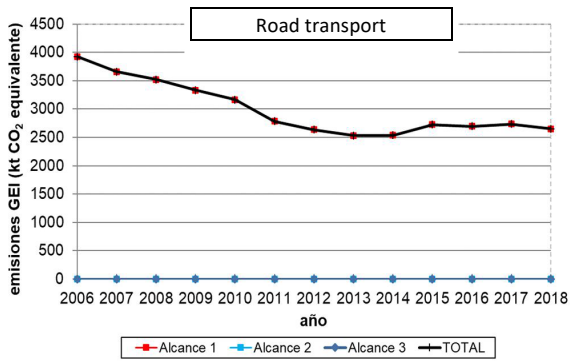
Year 2018	Emissions kt CO_2 eq	Contribution (%)
Direct	7,416	66.7
Indirect	3,708	33.3
TOTAL	11,125	100

By activity sectors, Residential, Commercial and Institutional (RCI) is the one with the highest emissions **5,576 ktCO2eq** (50.1%), followed by Road Transport **2,653 ktCO2eq** (23.9%) and other means of transport **1,064 ktCO2eq** (9.6%), given the influence of Barajas Airport in the overall municipal contribution.

Compared to 1990, in 2018 the municipality's direct GHG emissions decreased by 10.5% and indirect emissions by 20.6%, which implies a reduction in total emissions of 14.1%. In the 2000–2018 period, direct emissions from the RCI sector decreased by 9% (despite last year's growth) and those from the Road transport sector by 32.4%.







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

In 2018 the municipality of Madrid hosted 7% of the national population and generated 3% of total GHG emissions. Thus, municipal per capita emissions were 52% lower than the national average (3.5 vs 7.2 t/inhabitant). Similarly, Madrid generated 13% of the national GDP, so its "emission intensity

per unit of GDP" was 73% lower than the national value (79 vs 298 t/M€2010). These important differences are largely due to the productive structure of the municipality, whose economic activity is based on the tertiary sector (services) and not on industry, which generates more emissions due to its higher energy consumption.

Municipal and national emission indicators (year 2018)

Year 2018	Per capita emission ($t\ CO_2\ eq/inhab$)	Emission per unit of GDP ($t\ CO_2\ eq/M€_{2010}$)
Madrid	3.5	79
Spain	7.2	298
Ratio Madrid/Spain	0.48	0.27

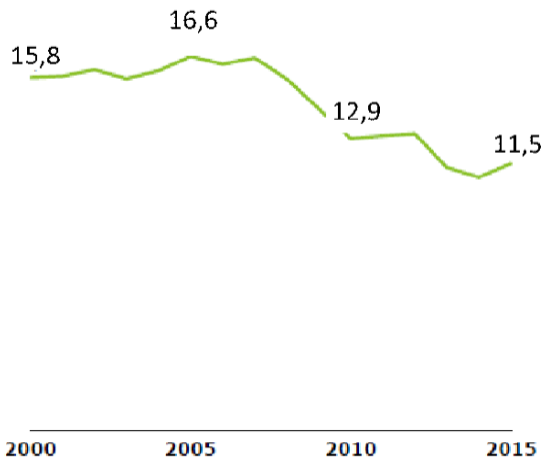
During the period assessed (2000–2018), municipal per capita emissions have decreased by 37% and, from the point of view of emissions per unit of GDP, this indicator shows a reduction of 52% in Madrid in the 2000–2018 period.

Mitigation efforts have focused on the most highly emitting sectors, such as transport and building, associated with the development of convergent policies such as Air Quality, building refurbishment or energy efficiency.

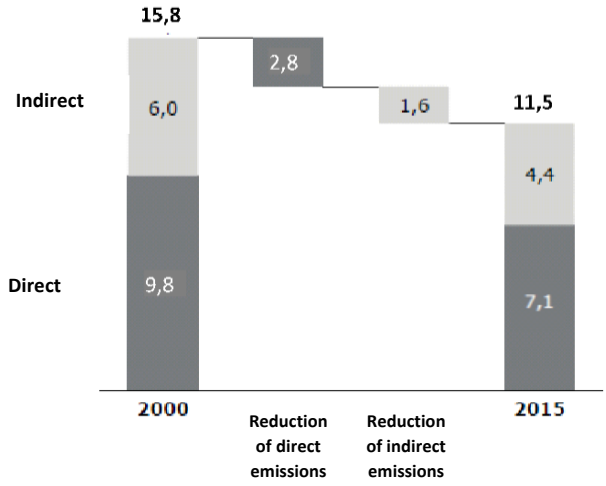
In general, the city of Madrid, thanks to the set of municipal actions and those of other institutions and sectors, is following a successful path in the reduction of emissions. However, trends show the need to accelerate and increase the reduction rates.

Regarding the 2000–2015 period, the evolution of GHG emissions shows a downward trend, from 15.8 MtCO2eq at the beginning of the period to 11.5 MtCO2eq in 2015. The reduction of indirect emissions (those associated with electricity consumption and distribution losses) exceeds 26.4%, while that of direct emissions has reached 27.7%.

Evolution of total GHG emissions in Madrid
Mt Co_2eq; 2000-2015)



Evolution of direct and indirect emissions in Madrid between 2000 and 2015
Mt Co_2eq; 2000-2015)



Source: Inventory of greenhouse gas emissions in the municipality of Madrid

In any case, the achievement of the goals set out in this roadmap stresses the need to continue and intensify policies to mitigate emissions, facing challenges such as **detaching economic growth from increased energy consumption and emissions**, and promoting inclusive development that involves citizens and helps social cohesion, driving urban transformation towards sustainable models.

Socio-economic context

The fulfilment of the objectives set out in the Roadmap will be closely linked to the evolution of the socio-economic context in which the process develops. The implementation of many of the measures will require financial investment, both from the public and private sectors, and an explicit goal of social cohesion and inclusive development.

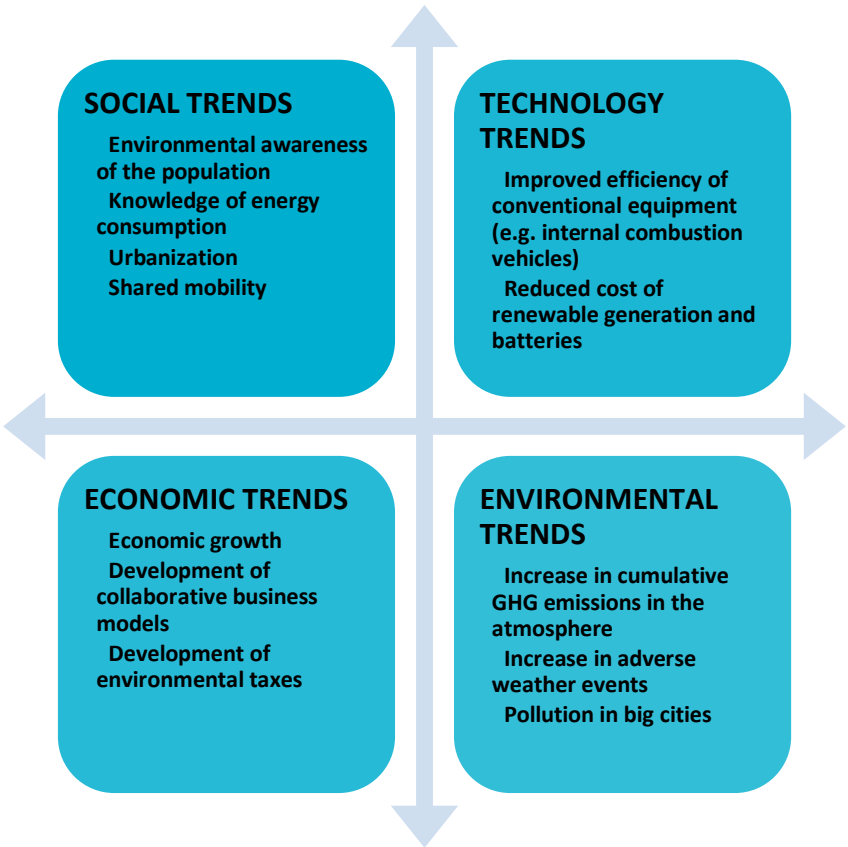
The City Council publishes the annual report Madrid Economía, which analyses the city's socio-economic situation and provides an overview of the current situation and trends. The 2020 edition shows a situation of sustained economic growth in recent years, on a clear path of recovery from the crisis at the end of the first decade of this century. However, the health crisis caused by the pandemic is generating a great amount of uncertainty and a discontinuation of this trend in the short term, due to the fall in employment and activity in some strategic sectors.

In demographic terms, the city's population has experienced five years of growth, reaching 3,334,730 inhabitants in 2020, with an increased percentage of foreign population in the last year. The arrival of people from outside Spain has allowed the incorporation of workers into productive activity, with a widening of the population pyramid in the most active age groups and a rejuvenation of the population.

The city's productive structure is dominated by services (88.6%), followed by industry (6.9%) and construction (4.5%). Within services, the most outstanding branches are Information and Communications, Professional, Scientific and Technical activities, Real Estate Activities 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, accompanied by an upward business dynamic. GDP grew by 2.4% in 2019, the highest in Spain, although this trend is uncertain due to the health crisis. The analysis highlights the importance for the city of strategic sectors such as tourism, transport infrastructures, research and training or the financial sector and exports. Beyond this general image, the Roadmap's principle is to incorporate, in the development of actions and measures, methodologies for the analysis of the socio-economic context. This analysis is fundamental, both in the scope of mitigation and adaptation, although it is especially relevant in the latter and specifically in actions located in high vulnerability neighbourhoods and areas. The City Council has numerous tools at its disposal that allow it to approach an urban diagnosis, such as the socio-economic analysis, diagnostic reports by district, or the city diagnosis carried out on the occasion of the PGOUM Revision works, among others.

The preparation of this Roadmap and the estimation of abatement potentials has incorporated the socio-economic context through the analysis of the following variables.



3 Emission reduction targets

The urgency to accelerate emission reduction processes has led to the need to increase the level of ambition in terms of decarbonisation targets and reduce the deadlines for achieving carbon neutrality.

The Paris Agreement and the objectives set by the European Union in the Framework on Climate and Energy for 2030 are the references at European level. At the local level, Madrid City Council initially adopted the objectives set out in Plan A, the Air Quality and Climate Change Plan for the city of Madrid. However, in order to reach the most advanced European targets and observing the context of the European Green Pact, the City of Madrid not only takes up the challenge of the European Commission to intensify Europe's climate ambition for 2030, but also seeks a more ambitious commitment within its Madrid 360° Environmental Strategy:

65% reduction in greenhouse gas emissions by 2030 (compared to 1990), exceeding the European objective by 10 points and placing Madrid on the path to climate neutrality by 2050

Therefore, considering that emissions in 1990 were **12,954 ktnCO2eq (13 MtCO2eq)** and that, in accordance with the evolution experienced to date and the foreseeable trajectory (trend scenario) it is not possible to achieve the targets set, the following GHG emission reduction scenarios are proposed for the city of Madrid:

Following the **sustainable scenario**, which involves accentuating the reduction measures with the greatest abatement capacity and establishing innovative implementation tools as described below, the volume of emissions forecast for **2030** will be **4.5 MtCO2eq**, which represents a reduction of **65.3% MtCO2eq** compared to 1990, reaching **1.4 MtCO2eq** in **2050**, and achieving neutrality through offsetting mechanisms.

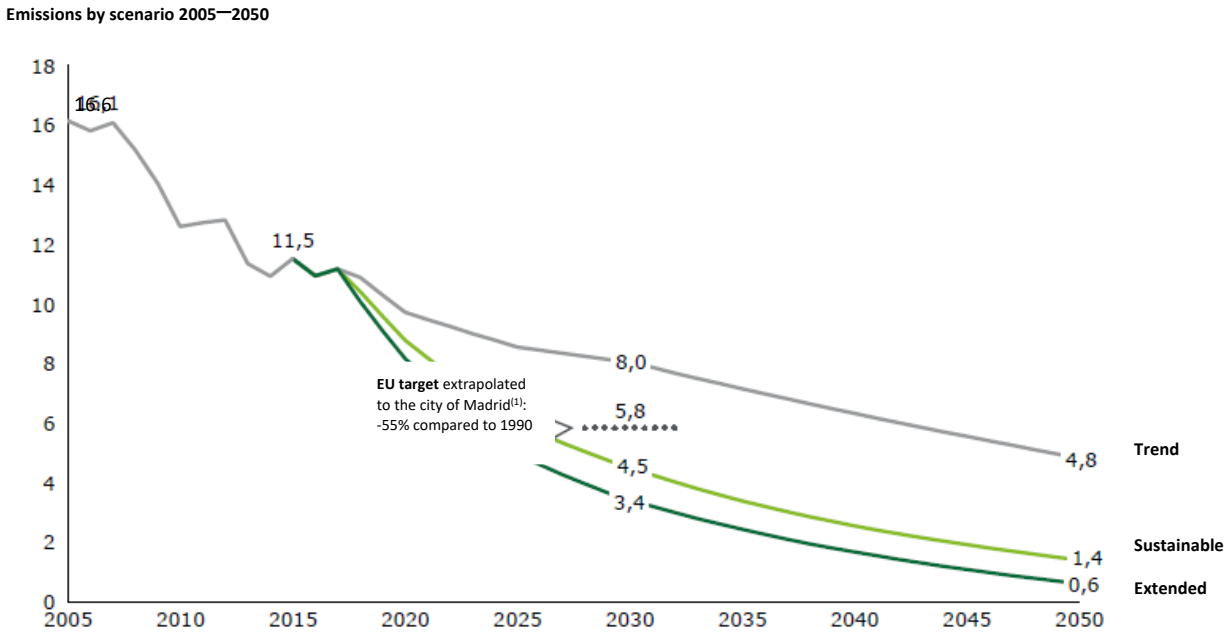
Following the **extended scenario**, which requires unlikely but technically feasible socio-economic changes, the volume of emissions forecast for **2030** will be **3.4 MtnCO2eq**, which represents a reduction of **73.8% MtnCO2eq** compared to 1990, reaching **0.6 MtnCO2eq** in **2050**, and achieving neutrality through offsetting mechanisms.

Emission reduction scenarios

Achieving the proposed objectives implies the development of policies, plans and actions that, from all spheres of society, but especially from the different administrations, promote a transformation of the industries and drivers responsible for emissions.

Carbon neutrality for the year 2050 means a gradual annual reduction that will have to meet partial targets until then. The intensity in the reduction of emissions will be determined by the set of measures that are applied, both at the local level and in the supra-municipal context.

Depending on the implementation of measures and context conditions, three trajectories are defined for the decarbonisation pathway:



According to the development of the scenarios, both in the sustainable scenario and in the extended scenario, the EU's ambitious targets for 2030 are met. The sustainable scenario shows a level of emissions in that year of **4.5 MtCO2eq**, reducing the volume of tonnes by 61% compared to 2015 and 65.3% compared to 1990, thus improving on the targets proposed by the EU.

The extended scenario increases this ambition to 3.4 MtCO2eq in 2030, 70.4% less than in 2015 and 73.8% less than in 1990.

In 2050, there would still be residual emissions of **1.4 MtCO2eq** in the sustainable scenario and **0.6 MtCO2eq** in the extended scenario, which should be neutralized through complementary offsetting measures such as absorption through forest plantations.

As the graph shows, the 2020–2030 period is particularly relevant in the decarbonisation trajectories, with a marked intensity in the implementation of measures and in creating the conditions to bring about inertial decarbonisation in the second period, 2030–2050.

Co-benefits of mitigation policies

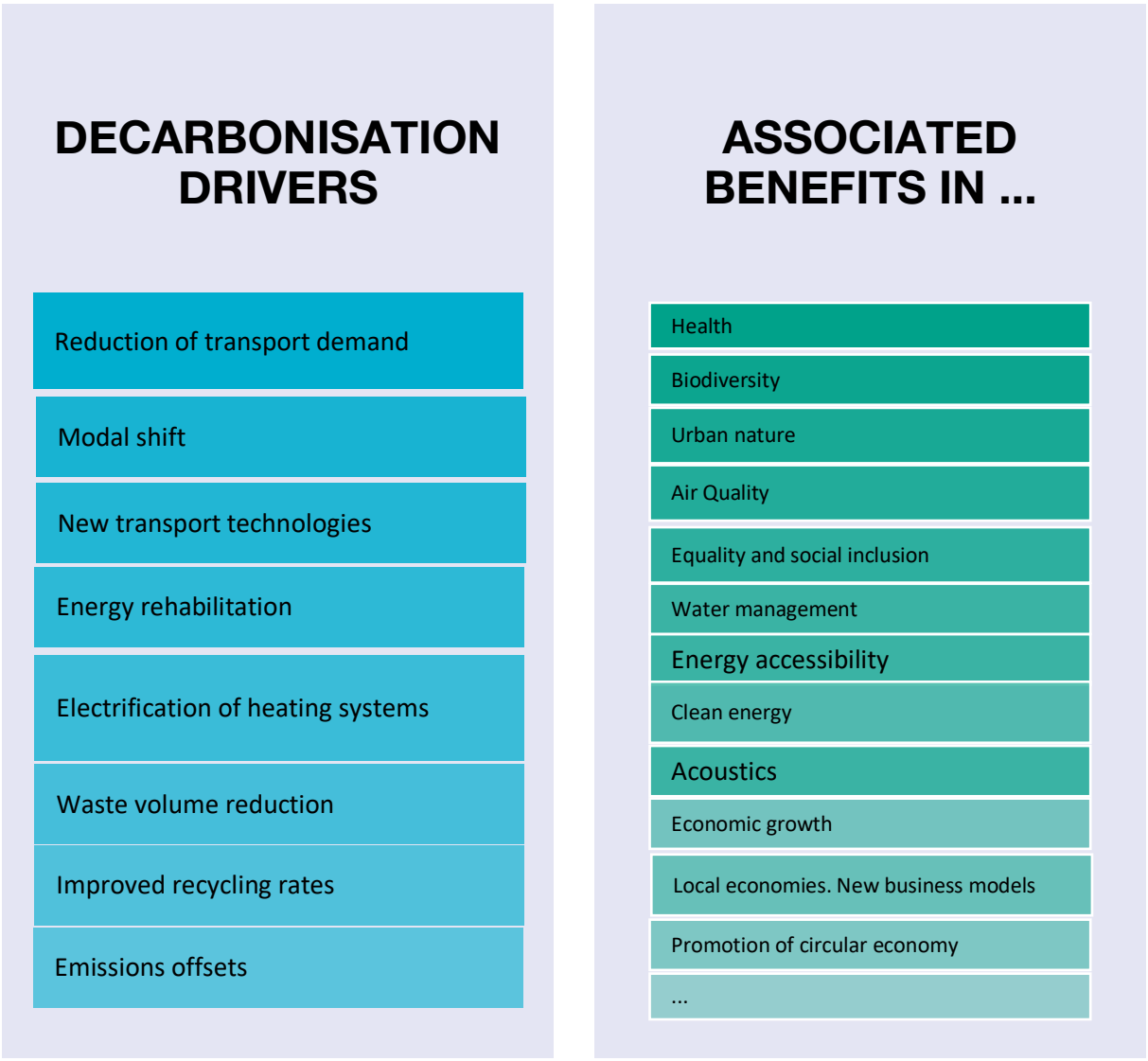
The road to neutrality implies an evolution of many of the current urban models and a social and economic transformation. In this process, the importance of the co-benefits that will occur in association with decarbonisation actions should be highlighted.

Energy efficiency actions on the building stock will have the associated effect of improving the quality of housing, especially in the most vulnerable buildings and areas of the city, and will also improve the conditions of access to energy, reducing situations of energy poverty.

The evolution in mobility will have a direct effect on the city's air quality and noise impact, due to the reduction in demand and the penetration of new technologies. The incorporation of behaviours such as teleworking or the development of proximity urban planning will lead to a reduction in the demand for travel and will increase the presence of non-motorised transport such as pedestrians and cyclists.

The development of offsetting mechanisms, such as the creation of carbon sink forests, will substantially increase the presence of nature and biodiversity in the city with all the associated benefits that this entails.

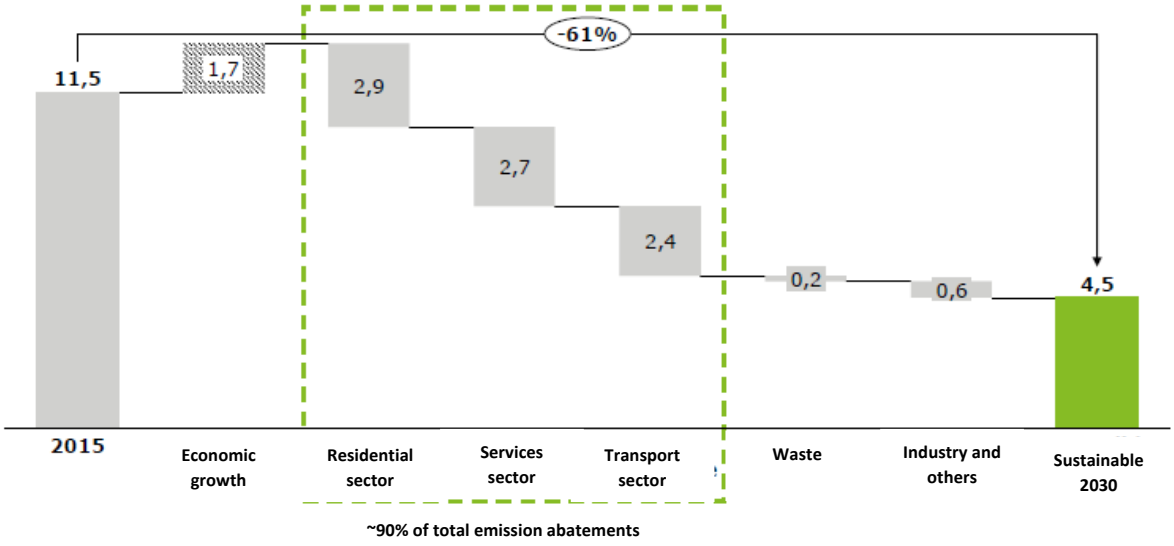
In addition to the mitigation actions, there will also be Climate Change Adaptation actions in the city. To the reduction of climate impacts produced by these measures, we should add the multiple benefits they provide, from the improvement of citizens' health, the quality of public spaces, the stimulation of local economies, water management or the reduction of insurance costs, among a myriad of other effects.



4 Industries and transformation drivers

The overall GHG emission reduction target will be achieved by aggregating the abatements produced in each of the sectors (1). The trajectory set by the sustainable scenario shows a contribution by sector in the 2015–2030 period as shown in the graph below.

Total GHG emission abatement (direct and indirect) by sector



The sum of sectoral abatements from 2015 to 2030 is equivalent to an emission reduction of 61%, and 65.3% compared to 1990. (Compliance with EU objectives).

The **residential sector** is to contribute the largest volume of reductions (**2.9 MtCO2eq**), followed by the services sector (**2.7 MtCO2eq**) and transport (**2.4 MtCO2eq**). As shown in the graph, the sum of abated emissions from the transport, residential and services sectors accounts for most of the emissions to be reduced: 91%.

It is, therefore, in these sectors where action must be intensified, without failing to act in other areas, since decarbonisation strategies must be comprehensive, understanding the interrelationships and complexities of the urban system.

Analysis of emission reductions in the main sectors in the period 2015–2030

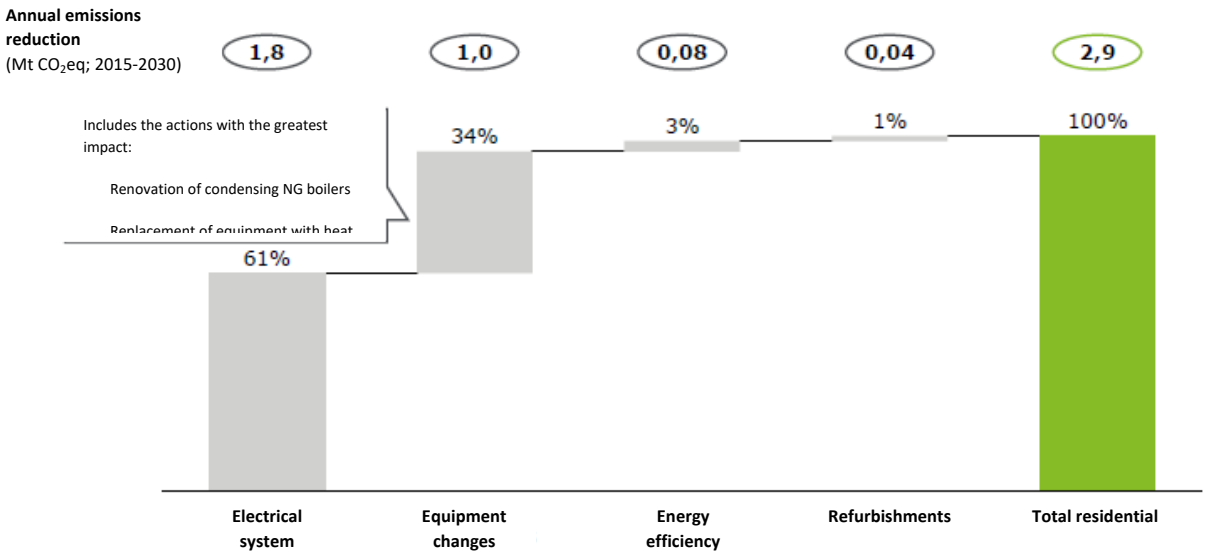
Residential sector

In the residential sector, the reduction of emissions associated with the electricity mix is particularly relevant. In the sustainable scenario, the expected decarbonisation of the energy matrix in the period 2015–2030 implies a reduction in emissions of **1.8 MtCO2eq**, more than 60% in this sector.

Secondly, the renewal of thermal equipment to NG condensing boilers and heat pumps, with the consequent improvement in performance and energy efficiency, will reduce **1 MtCO2eq**, 34% of emissions, in this sector in the period 2015–2030.

Other energy efficiency actions (renovation of household appliances, lighting, etc.) and refurbishment participate to a lesser extent in the decarbonisation of the sector. However, action in these areas is essential for the additional benefits they bring in efficient energy use, comfort and air quality in buildings.

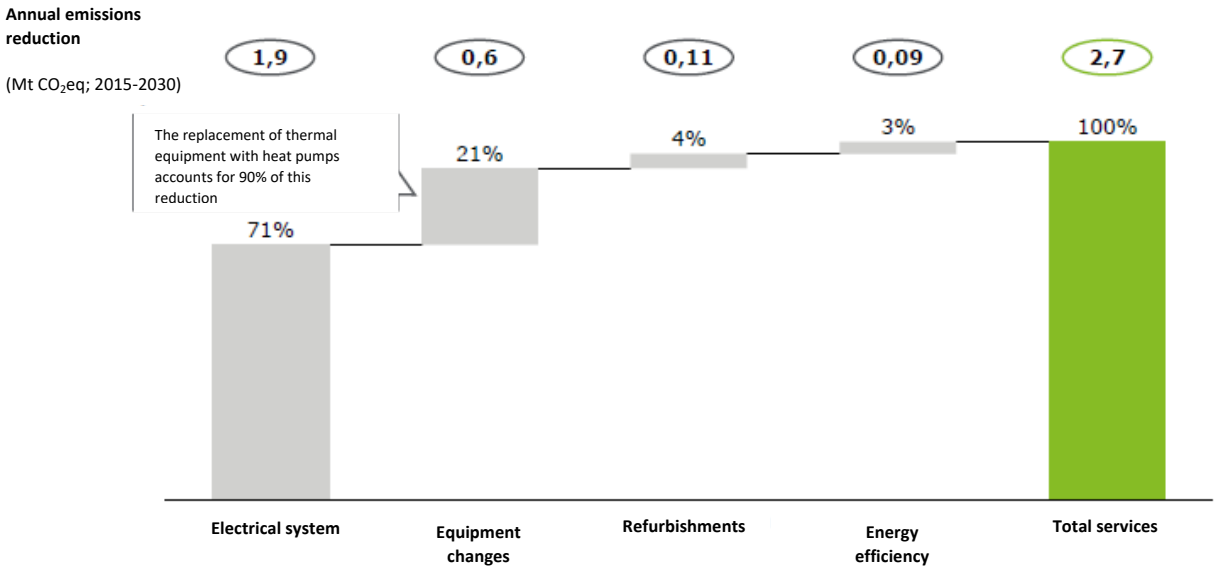
Emission reductions from decarbonisation actions in the residential sector under the Sustainable scenario
(%; 2015–2030)



The services sector, which includes institutional and commercial activity, also makes a significant contribution to emission reduction (**2.7 MtCO2eq**) in the 2015–2030 period. Similarly to the residential sector, the largest volumes of abatement occur through the decarbonisation of the electricity mix **1.9 MtCO2eq** (71%) and the renewal/replacement of thermal equipment **0.6 MtCO2eq** (21%).

The greater ease of electrification of this sector, as well as the implementation of heat pump equipment, implies a greater impact of the improvement of the emission factor of the electricity mix in the reduction of emissions.

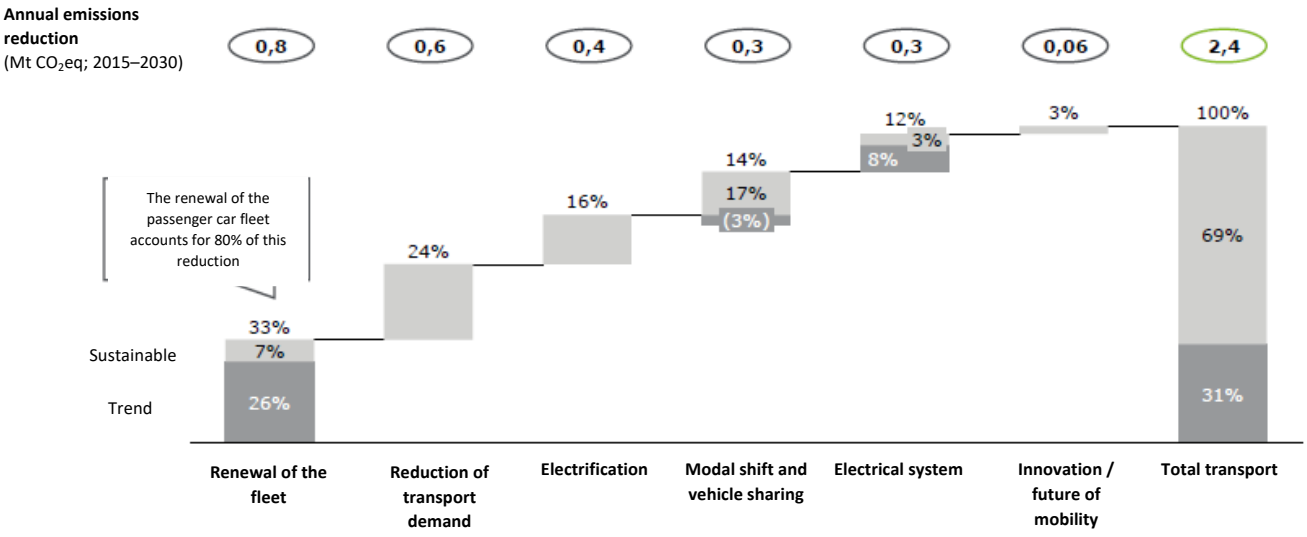
Emission reductions from decarbonisation actions in the residential sector under the Sustainable scenario
(%; 2015-2030)



The strategy to reduce emissions from the transport sector is developed following the Avoid-Shift-Improve (ASI) scheme. The combined action of demand reduction (proximity urban planning, teleworking, efficiency, etc.) **0.6 MtCO2eq** (24%), the transfer of journeys from private vehicles to other shared means of transport **0.3 MtCO2eq** (13%), or the penetration of new, less emitting technologies.

The renewal of the vehicle fleet requires a special mention. This driver contributes with the largest emission reduction– – **0.8 MtCO2eq** (32%) – –although the trend scenario already includes a large part of this renovation and therefore the sustainable scenario will address a smaller part of this change. Furthermore, the fact that the trend scenario envisages this action indicates a high degree of certainty in its achievement.

Emission reductions from decarbonisation actions in the transport sector under the Sustainable scenario
(%; 2015–2030)



Abatements by drivers and main lines of action 2030–2050

Transport sector

SECTORS (1)	DRIVERS	LINE OF ACTION	ABATEMENT OF EMISSIONS Ktn CO_2 eq				ECONOMIC RETURN	LOCAL	AUTONOMIC	STATE	EUROPEAN
			2030		2050						
			Totals	Direct / Indirect	Totals	Direct / Indirect					
Transport	Reduction of demand	Reduced commuting	573	567	296	295	-	X	X		
		Proximity urban planning (Reduced domestic commuting)						X			
		Low Emission Zones and parking policies		6		1		X			
	Modal shift	Public transport (bus)	333	330	389	389	+	X	X		
		Public transport (train)						X	X		
		Non-motorized mobility		3		0	-	X		X	
		Vehicle sharing (carpooling, car sharing)					+	X		X	X
	Electrification	Electrification of the vehicle fleet (passenger cars)	286	276	441	409	+	X	X	X	
				10		3					
		Circulating fleet electrification (Goods)	51	49	50	50		X		X	
				2		0					
		Circulating fleet electrification (Bus)	68	65	53	52		X			
				3		1					
		Municipal fleet electrification	8	7	3	2		X			
				<1		<1					
	Fleet renovation	Renewal of the circulating fleet (passenger cars)	660	660	308	308	-	X		X	X
		Circulating fleet renewal (goods)	123	123	59	59		X		X	
		Circulating fleet renewal (CNG Buses)	<1	<1	27	27		X		X	
	Innovation / Future of mobility	Public transport on demand	2	2	<1	0	+	X			
		Route optimization				0		X			

		Logistics hubs and logistics optimization	58	58	31	0		X			
	Reduction of emissions in the aviation sector	Mobility as a service	0		0					X	
(1) Following the EMEP-CORINAIR classification Madrid City Council Emission Inventory											

Abatements by drivers and main lines of action 2030–2050

Residential, services + institutional, city services sectors

SECTORS (1)	DRIVERS	LINE OF ACTION	ABATEMENT OF EMISSIONS Ktn CO_2 eq				ECONOMIC RETURN	LOCAL	AUTONOMIC	STATE	EUROPEAN
			2030		2050						
			Totals	Direct / Indirect	Totals	Direct / Indirect					
RESIDENTIAL	Refurbishments	Restoration of roofs, facades and windows	40	37 / 3	46	45 / 1	-	X	X	X	
	Energy efficiency	Climate control systems	83	77 / 6	91	89 / 2	+	X	X		
	Equipment changes	Replacement with heat pump	330	295 / 35	76	73 / 3	-	X	X	X	
		Renewal of natural gas condensing boilers	625	625 / 0	639	639 / 0	-	X	X		
		Renewal of electrical appliances and lighting	102	0 / 102	26	0 / 26					
	Self-consumption	Residential self-consumption	6	0 / 6	6	0 / 6	+	X	X	X	
INSTITUTIONAL SERVICES	Refurbishments	Restoration of roofs, facades and windows (Service sector)	111	104 / 7	65	62 / 3	-	X	X	X	
		Restoration of roofs, facades and windows (Institutional sector)	n/a		n/a						
	Energy efficiency	Smart heating and cooling, Smart lighting (Services sector)	88	65	47	38	+				

				23		9					
		Smart heating and cooling, Smart lighting (Institutional Sector)	n/a		n/a		+				
	Equipment changes	Replacement with heat pump (Service sector)	558	533 25	277	265 12	-				
		Replacement with heat pump (Institutional sector)	n/a		n/a		-				
		Renewal of electrical equipment and lighting (Service sector)	68	0 68	22	0 22					
		Renewal of electrical equipment and lighting (Institutional Sector)	n/a		n/a						
		Improve efficiency of existing equipment	n/a		n/a						
	Self-consumption	Self-consumption	13	0 13	13	0 13	+				
CITY SERVICES	Street lighting	LED street lighting and Smart lighting	33	0	0			X			
	Other installations (tunnels, fountains, traffic lights...)	Equipment control and renewal system		33				X			

(+) Actions with economic return in the short/medium term. Can be self-financed

(-) Actions requiring financial support

Abatements by drivers and main lines of action 2030–2050

Waste, industry+other sectors

SECTORS (1)	DRIVERS	LINE OF ACTION	ABATEMENT OF EMISSIONS Ktn CO_2 eq				ECONOMIC RETURN	LOCAL	AUTONOMIC	STATE	EUROPEAN
			2030		2050						
			Totals	Direct Indirect	Totals	Direct Indirect					
WASTE	Reduction of waste generation	Promotion of circular economy	185		179			X		X	
		Composting rate						X			

	Increase in recycling rates	Increase in recycling rates in residential, services and municipal sectors						X			
INDUSTRY OTHERS	Reduction of the impact of refrigerant gases and solvents	Reduction of the impact of refrigerant gases	426		171					X	
	Reducing emissions in the industrial sector	Improving the efficiency of industrial processes and electrification of consumption	100		120						

SECTORS (1)	DRIVERS	LINE OF ACTION	ABATEMENT OF EMISSIONS Ktn CO_2 eq				ECONOMIC RETURN	LOCAL	AUTONOMIC	STATE	EUROPEAN
			2030		2050						
			Totals	Direct / Indirect	Totals	Direct / Indirect					

Emission reduction volume by drivers and lines of action.

Administration with the greatest impact on the development of actions

Main assumptions

The roadmap of the city of Madrid towards climate neutrality is developed through fine lines of action:

- Establish governance models and energy sustainability targets.
- Promote sustainable transport of passengers and goods.
- Promote energy efficiency and renewable energy sources in buildings.
- Contribute at the municipal administration level, setting an example of sustainable energy models.
- Improve the sustainability of waste management, industry and Barajas Airport.

Based on these lines of action, the neutrality roadmap is proposed according to strategic assumptions for each of the analysed sectors. These assumptions apply to the main emission reduction drivers.

Residential sector assumptions

The penetration of **heat pumps** to replace conventional air conditioning systems (combustion and electric) is essential given the superior energy efficiency of these systems (≈ 200–300% compared to 90–100% of electric heaters).

The trend scenario envisages the replacement in the short term of conventional thermal boilers, both gas and other fuels (oil products, coal) to **efficient condensing natural gas boilers,** significantly improving the performance of this equipment (≈ 110% compared to 70–90% of conventional boilers).

The energy retrofit of buildings is another key driver. These interventions include window replacement (10–15% savings), façade renovation (30–50% savings) and roof renovation (5–15% savings). The integral intervention of a building that includes all these actions can achieve savings in heating consumption of 60–70%[1].

[1] Estimates for residential buildings built prior to 1980.

DRIVERS	TREND	SCENARIOS			
		SUSTAINABLE		EXTENDED	
		2030	2050	2030	2050
Heat Pump Penetration	Renewals only, no additional installations	Annual increase in surface area **~0.9%** 12,000 new units per year	Between 2030-2050 Increase in surface area **~0.9%** 14,000 new units per year	Annual increase in surface area **~1.2 %** 17,000 new units per year	Between 2030–2050 Increase in surface area **~1.5%** 24,000 new units per year
Replacement of natural gas boilers	End-of-life replacement (~15 years) ~40,000 boilers/year	Replacement every **~13 years**. ~50,000 boilers/year	Replacement every **~13 years**. ~50,000 boilers/year	Replacement every **~12 years**. ~60,000 boilers/year	Replacement every **~8–9 years**. ~80,000 boilers/year
Refurbishments	Refurbishments are not considered	Refurbishment **~1%** surface/year 13,000 refurb./year	Refurbishment ~1% surface/year until 2050 16,000 refurb./year	Refurbishment **~1.5%** surface/year 20,000 refurb./year	Refurbishment **~1.5%** surface/year until 2050 24,000 refurb./year

Service sector assumptions

The **heat pump** can have a faster penetration in the service sector than in the residential sector, given the more favourable circumstances of this type of building with higher air conditioning demands and better construction conditions for installation.

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

Similarly to the residential sector, the **energy refurbishment of buildings dedicated to services,** with actions on windows (10–15% savings), façades (30–50% savings) and roofs (5–15% savings) can achieve savings in heating consumption of 60–70%.

DRIVERS	SCENARIOS				
	TREND	SUSTAINABLE		EXTENDED	
		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. **Smart lighting**	Installations are not 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
Refurbishments	No refurbishments are to be carried out	Annual installation of **1.5%** of the surface area	Annual installation of **1.5%** of the surface area	Annual installation of **1.5%** of the surface area	Annual installation of **1.5%** of the surface area

Transport sector assumptions

Decarbonisation must also be a consequence of the transformation of current mobility patterns and lifestyles. These new models should be oriented towards **reducing the demand for**

transport through the promotion of teleworking, the development of proximity urban planning or the change of transport and consumption behaviour.

The **modal shift in mobility from private vehicles** (≈180–200 gCO2/passenger-km) **to public transport** allows for a reduction in emissions per passenger-km up to 70% in the case of conventional buses (≈50gCO2/passenger-km) and over 90% in the case of trains or subways (≈5gCO2/passenger-km).

The **modal shift to non-motorised transport** (walking, cycling, etc.) is considered to be encouraged by the development of dedicated lanes, promotion of dedicated parking, promotion of rental systems, etc.

The **penetration of the electric vehicle, replacing the conventional technology vehicle**, implies a reduction in emissions. The GHG emissions of the electric vehicle are six to seven times lower than those of a conventional EURO III vehicle, four to five times lower than those of a EURO IV vehicle and two to three times lower than those of a EURO VI vehicle.

The **replacement of the fleet of older conventional vehicles with more efficient and less polluting ones** is the driver with the greatest potential for reducing emissions in the period 2030–2050. Most of this renovation is already contemplated in the trend scenario, to which the additional effort is added in the sustainable scenario. An older Euro III diesel vehicle emits twice as much as a new Euro VI diesel vehicle.

The **airline industry** is expected to grow in proportion to the annual growth in routes and passengers. The following are emission reduction actions envisaged in the 2050 extended scenario using fuels with lower emissions not yet commercially available.

DRIVERS	SCENARIOS				
	TREND	SUSTAINABLE		EXTENDED	
		2030	2050	2030	2050
Reduction of transport demand	Annual growth of journeys	Annual reduction of journeys	Annual reduction of journeys	Annual reduction of journeys	Annual reduction of journeys
	0.5 %	1.5%	1.5%	1.5%	1.5%

Passenger modal shift	Non-motorized 31% Public transport 32% Private vehicle 37%	Non-motorized 30% Public transport 40% Private vehicle 30%	Non-motorized 46% Public transport 45% Private vehicle 9%	Non-motorized 46% Public transport 45% Private vehicle 9%	Non-motorized 47% Public transport 45% Private vehicle 8%
Electric vehicle penetration	Current penetration ≈ 0%	≈ 20% ≈290,000	≈ 100% ≈1,450,000	≈ 40% ≈580,000	≈ 100% ≈1,450,000
Renewal of the vehicle fleet	Increase in the current age of the fleet to 11–12 years	Decrease in the average age of the fleet up to 9–10 years	Decrease in the average age of the fleet up to 6–7 years	Decrease in the average age of the fleet up to 6–7 years	Decrease in the average age of the fleet up to 6–7 years
Air sector	Emissions growth 0.5% p.a. until 2030 and 0.25% until 2050 Growth rates in proportion to the growth of journeys	Annual emissions reduction 1.50% Growth rates in proportion to the growth of journeys	Annual emissions reduction 1.50% Growth rates in proportion to the growth of journeys	Annual emissions reduction 1.50% Growth rates in proportion to the growth of journeys	Annual emissions reduction 5.10% Possibility of using non-polluting fuels, pilot phase

Other sectors (electricity sector) assumptions

DRIVERS	SCENARIOS				
	TREND	SUSTAINABLE		EXTENDED	
		2030	2050	2030	2050
Emission factor for the electricity sector	•Reduction of ~60% (2030 vs 2015) (according to the trend scenario of the PNIEC) •Reduction of 100% (2050 vs 2030) •Electricity generation from renewable sources: 51% in 2030 and 100% in 2050	•Reduction by ~85% (2030 vs 2015) (according to target scenario of the PNIEC) • Electricity generation from renewable sources: 73%	• 100% emissions reduction by 2050 • Electricity generation 100% GHG neutral	Reduction by ~85% (2030 vs. 2015) (according to target scenario of the PNIEC) • Electricity generation from renewable sources: 73%	• 100% emissions reduction by 2050 • Electricity generation 100% GHG neutral
Annual emission reductions in other sectors	• Reduction of 5.9% of annual emissions (according to the trend scenario of the PNIEC, matching the target scenario)	• 5.9% annual emissions reduction (according to target scenario of the PNIEC)	• 5.9% annual emissions reduction (according to target scenario of the PNIEC)	• 5.9% annual emissions reduction (according to target scenario of the PNIEC)	• 5.9% annual emissions reduction (according to target scenario of the PNIEC)

The **evolution of the electricity sector** is a determining factor in the achievement of the decarbonisation goals. The reduction of the emissions factor of the electricity mix due to the penetration of renewable energies and the gradual closure of conventional thermal power plants (coal and combined cycle plants) are the main assumptions of its evolution.

Other sectors (waste treatment sector) assumptions

The **reduction of emissions from waste treatment** is addressed by reducing waste generation through the promotion of prevention, improving selective collection, increasing recycling rates, improving treatment technologies and reducing emissions, as well as through progress in circular economy approaches.

The **emissions reduction in the industrial sector** will be achieved by improving energy efficiency through improvements in technologies and industrial process management systems, and by increasing electrification in the final consumption mix.

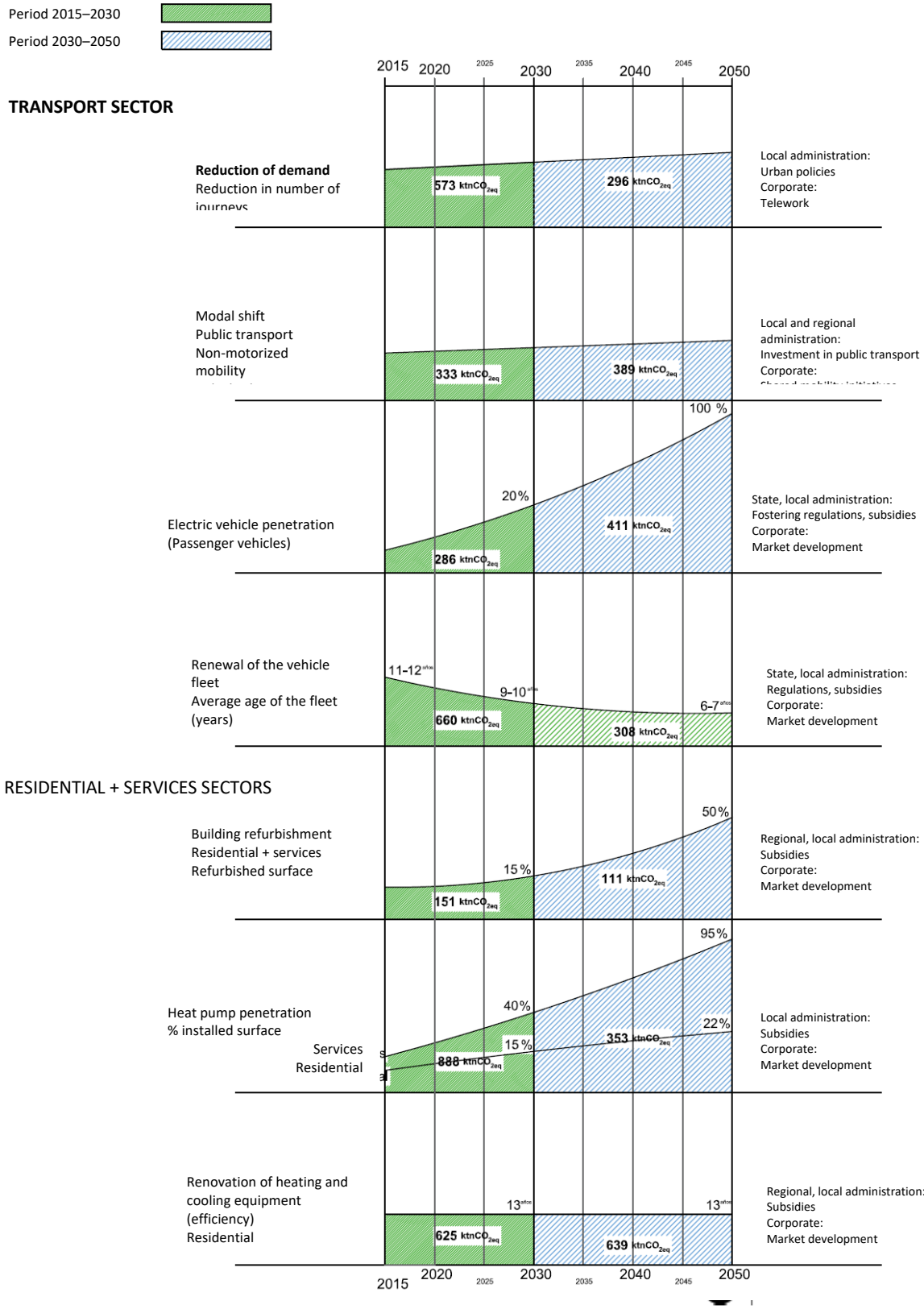
The extended scenario considers the decentralization of industry as a decarbonization factor in the municipality.

The decarbonisation assumption considers the replacement of high-warming potential fluorinated gases with gases with lower or no effect gases.

DRIVERS	SCENARIOS				
	TREND	SUSTAINABLE		EXTENDED	
		2030	2050	2030	2050
Annual reduction in waste emissions	•1.1% annual reduction in emissions (according to the PNIEC trend scenario)	•2.6% annual reduction in emissions (according to the PNIEC target scenario)	•2.6% annual reduction in emissions (according to the PNIEC target scenario)	•2.6% annual reduction in emissions (according to the PNIEC target scenario)	• 5.2% annual emissions reduction •The use of advanced waste treatment technologies and ambitious recycling and circular economy rates are considered

Annual emissions reduction in industry	•0.7% annual reduction in emissions (according to the PNIEC trend scenario)	•1.3% annual reduction in emissions (according to the PNIEC target scenario)	•1.3% annual reduction in emissions (according to the PNIEC target scenario)	• 8.3% annual emissions reduction •A certain decentralization of the current industry from the city of Madrid to surrounding areas is considered	•Reduction of 6.7% per year •A certain decentralization of the current industry from the city of Madrid to surrounding areas is considered
Reforestation	•No additional tree planting is considered	•200,000 additional trees are to be planted	•400,000 additional trees are to be planted	•300,000 additional trees are to be planted	•600,000 additional trees are to be planted

ABATEMENT OF EMISSIONS FROM THE MAIN DRIVERS



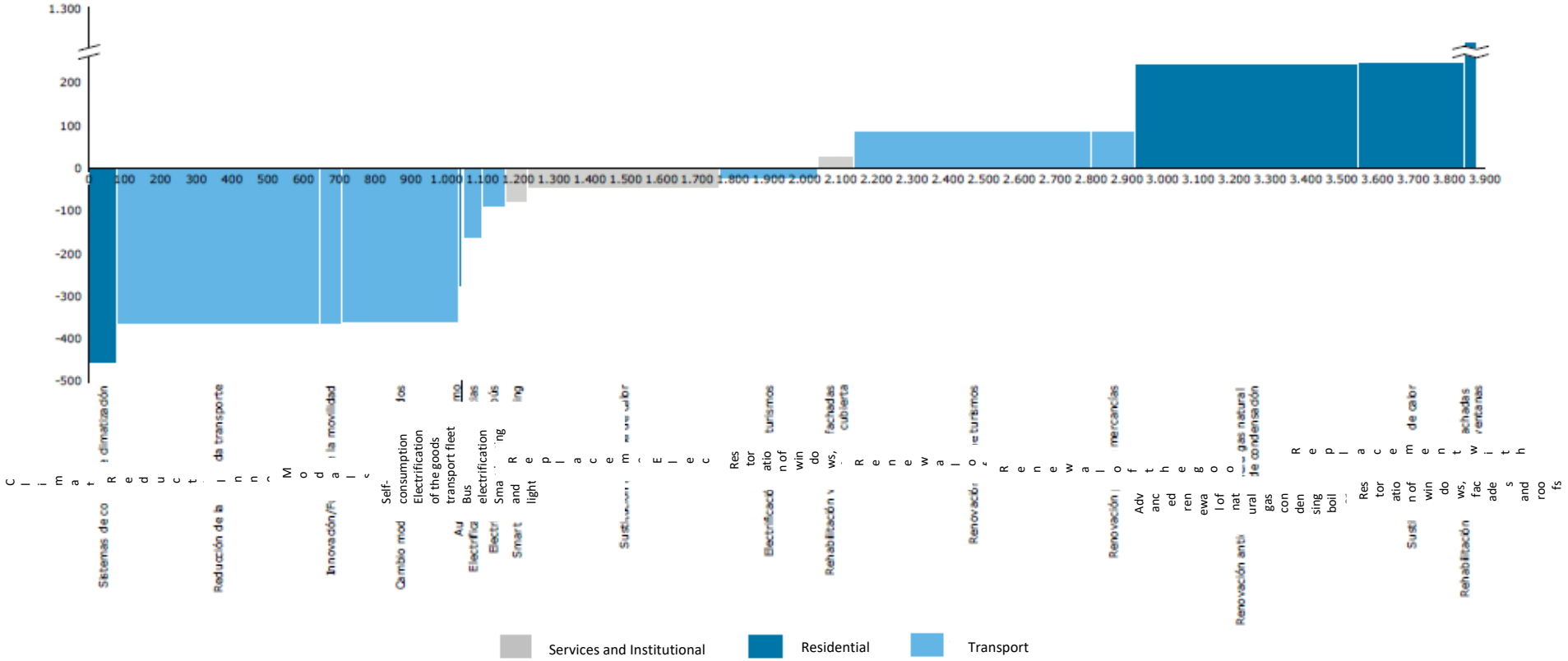
5 Economic analysis

The tool used to measure the efficiency of the proposed drivers and measures, both in terms of their potential to reduce emissions (CO2 eq) linked to their cost (€2016) is the Abatement Curve. This analysis provides us with an overview of the drivers proposed in the roadmap of the city of Madrid towards neutrality and allows us to prioritize the implementation of measures that, at a lower cost, offer a greater potential for reducing direct emissions of CO2 eq. Abatement cost is defined as the additional costs (or perceived benefits) of replacing a reference (commonly used) technology with a low-emission alternative.

Some of the proposed actions that offer the greatest potential for the reduction of direct emissions in the 2015–2030 period will require a boost from the competent administrations to encourage changes in equipment or habits.

Abatement curve (direct emissions) for the city of Madrid between 2030 and 2015(1)

($€_{2016}/tCO_{2e}q$)



(1): Does not include abatement of direct emissions from waste, industry and other sectors
Source: Madrid City Council

24% of the emission reductions by 2030 are achieved with economically viable measures, while 22% are achieved with measures that require financial support from the competent administrations.

It is important to carry out an analysis at sector or driver level to identify which measures offer the greatest potential.

In the transport driver, the action that offers the greatest potential for reducing emissions is the renewal of the vehicle fleet, which will allow a 0.9 Mt CO_2 eq reduction in the period 2015–2030. Its abatement cost is positive (100 $€_{2016}$/ tCO_2eq), which means that it is necessary for its implementation to articulate aid and incentive programs that encourage the renewal of the vehicle fleet by incorporating the most efficient automotive technologies. The electrification of the vehicle fleet, with a negative abatement cost, will also play an important role in the decarbonisation of transport and will make it possible to achieve cumulative direct emissions savings of 0.3 Mt CO_2eq in the 2015–2030 period.

The actions that allow a greater volume of direct GHG emissions to be reduced at a lower cost are those focused on reducing transport demand, modal shift and the promotion of shared mobility, with a joint reduction potential that reaches 0.9 Mt CO_2 eq in the 2015–2030 period.

In the residential sector, actions with the highest direct emission reduction potential (1 Mt CO_2 eq) have a positive abatement cost (≈ 200 $€_{2016}$/tCO_2eq). For its implementation it will be necessary to articulate programs to encourage the replacement of boilers and air conditioning equipment and allow the incorporation of modern natural gas condensing boilers and heat pumps that incorporate aerothermal technology. Measures such as building refurbishments offer little direct emission reduction potential and a high abatement cost, even so, the city of Madrid will continue to articulate aid programs focused on the refurbishment of the housing stock.

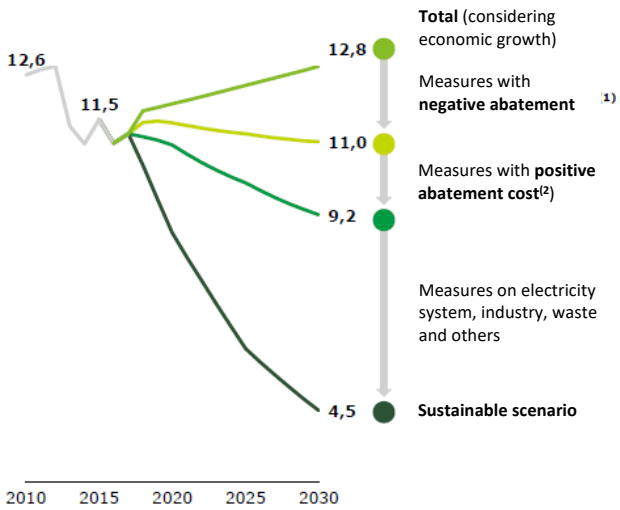
The action that will have the greatest impact on the reduction of emissions in the residential sector is the reduction of emissions in the electricity sector at national level, contemplated in the PNIEC, with a potential of 1.8 $MtCO_2eq$. This has not been included in the abatement analysis because emissions from the electricity sector fall under the category of indirect emissions.

In the services sector, the enormous potential offered by heat pump technology should be highlighted, with an estimated reduction in direct emissions for the period 2015–2030 of 0.5 $MtCO_2eq$ and a negative abatement cost, which will allow the sector to undertake the renovation of the building stock, amortising the investments in a short payback period.

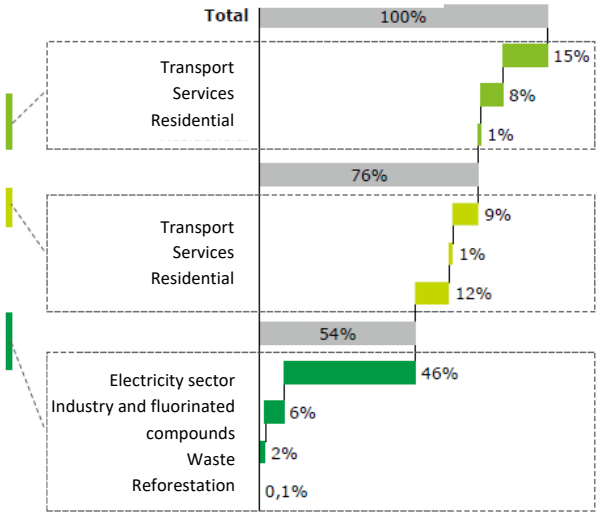
As in the residential sector, the action that will have the greatest impact on the reduction of CO_2 eq emissions. missions in the services sector, is the reduction of emissions from the electricity sector at national level, contemplated in the PNIEC, with a potential of 1.9 Mt CO_2 eq. This has not been included in the analysis as it falls under the category of indirect emissions.

The following table relates the evolution of the different emission scenarios with the abatement potential of the measures proposed in the different drivers:

Evolution of emissions 2010–2030 according to the type of measures applied (economic, technical or on the electricity system) (Mt CO_2eq; 2010–2030)



Emission reductions by sector according to type of measures (%; 2030)



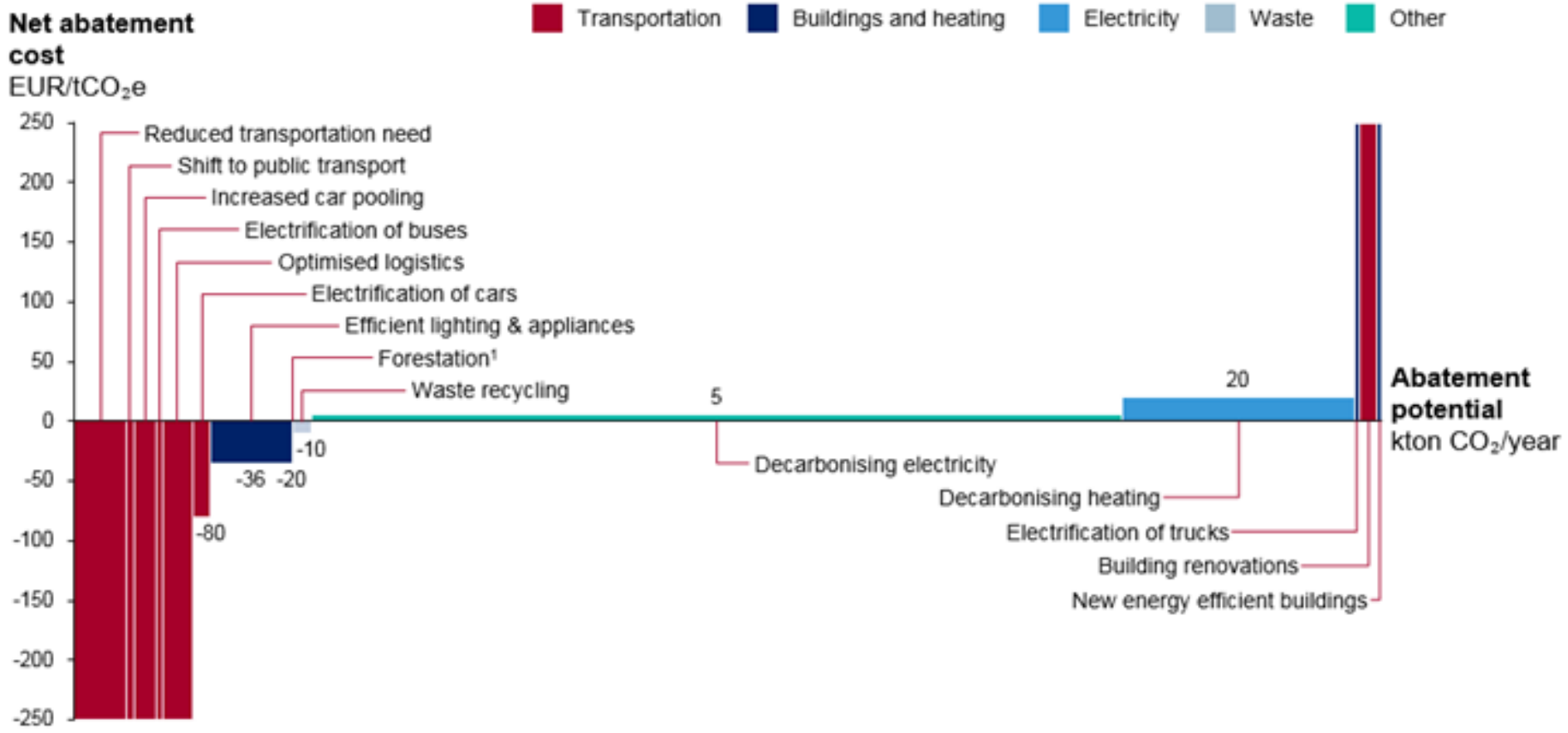
(1): Measures generating economic savings
(2): Measures generating economic costs
Source: Madrid City Council

The economic analysis proposed in the study *Economic case for decarbonisation in Madrid*, by *Material Economics* (Climate–KIC Initiative), focuses its analysis on the abatement potential of the proposed drivers in total CO_2 eq emissions in the 2020–2050 period.

The main conclusion is that the decarbonisation of the electricity system is the most relevant action in the roadmap towards climate neutrality in the city of Madrid. Its low abatement cost in terms of €/tCO2eq and its high potential for reducing GHG emissions make it a strategic driver on which the success of other measures depends. The decarbonisation of air conditioning and domestic hot water systems in the residential and services sector, and the incorporation of energy efficient devices, will also play a relevant role with low abatement costs and high emission reduction potential.

Madrid abatement cost curve

kton CO_2e emissions in 2030, abatement costs and benefits annualised based on investments in 2020-2030, and recurring costs/savings and co-benefits in 2020-2050[1]



1. Very small abatement at 4kt/year, so lever does not show up properly in graph
Source: Material Economics analysis

6 Coordination between administrations and public-private partnership

Carbon neutrality cannot be addressed by acting exclusively on emission sources, but requires a social transformation that changes current paradigms and lifestyles. This is a joint effort in which many actors must be involved, from administrations to the private sector, academia and citizens.

The strategic vision, the legal and regulatory framework and the economic impulse of the administrations are crucial. The local action of local councils is in many cases conditioned by the contexts offered by higher administrations. In this sense, EU policies such as the European Green Deal, or the communication of the European Commission to intensify Europe's climate ambition for 2030, proposing an emission reduction of 55% by 2030 (versus 1990), without being binding, set the pace for municipal policies.

National policies are determinant for the achievement of the objectives and the development of local plans. They are fundamental in the development of legal bodies, regulations and technical guidelines and, specifically, in the configuration of the energy and electricity mix on which the new energy model and neutrality strategies are based. National policies for the coming years are projected in the National Law on Climate Change, the PNIEC or the Long Term Strategy (ELP), all of which coincide in the objective of neutrality by the year 2050.

This roadmap integrates national plans into local action. It integrates the objective of increasing the presence of renewable sources in electricity generation to 74%, or the principle of energy efficiency in the time horizon of 2030, as stated in the PNIEC and carbon neutrality by 2050 of the ELP.

The Ministry for Ecological Transition and Demographic Challenge (MITECO) and the Spanish Office for Climate Change, responsible for the development of state policies, are key actors in this process with whom continuous communication is maintained at local level in order to align actions.

Academia is another pillar of climate action in the city of Madrid. The relationship with this actor occurs on several levels. The Universidad Politécnica de Madrid, commissioned by the City Council, prepares annual emission inventories of the city and other sectoral studies such as the study of the vehicle fleet that provides the basis for the inventories.

In another context, the relationship with the university has been consolidated with the approval, in the Municipal Plenary of July 2020, of the adhesion of the municipality to the European initiative for innovation in climate action Climate–KIC and the Deep Demo project. This initiative, which brings together many actors from various fields, aims to research and test actions to achieve carbon neutrality by 2050. Being part of it has allowed the creation of a working platform in which

there is representation of the local administration, private companies of reference in strategic sectors, especially energy and urban planning, and the academia itself. In this space, the university, through the Centre for Innovation in Technology for Development (ITD), acts as a connector of the public-private relationship, with research and innovation groups in multiple fields.

One of the first actions of this platform was the creation of an interdepartmental collaboration tool ("Grupo Clima 360") that connects different services of the municipal structure considered key in the development of climate action, such as environment, urban planning, innovation, budget and economic management, energy, mobility, heritage, culture, etc. This working team allows climate challenges to be addressed in a comprehensive way and projects under development to be connected.

The roadmap also implies a profound social change. Therefore, citizens must take part in the process, evolve in habits and lifestyles, but also participate in decisions. Citizen participation has precedents in numerous experiences associated with projects, but through the platform created around Climate–KIC, the aim is to systematise the involvement of people, establish direct communication channels and create steady frameworks for collaboration.

The global and complex dimension of the climate crisis requires networking. In this sense, the Roadmap outlines a path that cannot be followed in isolation. It is essential to connect with other cities, sharing knowledge and experience. At state level, Madrid is part of the Cities for Climate Network of the Spanish Federation of Municipalities and Provinces, and on the international scene it is integrated in initiatives such as the Covenant of Mayors for Energy and Climate and the Cities for Climate Leadership Group C40.

7 Key actions and processes at municipal level

Once the main drivers of transformation have been identified and the competence framework has been analysed, it is necessary to establish municipal level action priorities to maximise the impact in those areas in which the City Council can intervene more directly. In this sense, two levels of action can be distinguished: identification of key drivers for municipal action and enabling processes for implementation and scaling.

For the prioritization of these actions at the municipal level, the weight in terms of emission reduction potential must obviously be taken into account, but this should not be the only criterion, and special emphasis should be placed on transforming actions that imply a modification in the established model of behaviour ("business as usual") towards more sustainable schemes in accordance with the ambitious scenario that is being pursued.

Key Actions

Based on the contents of Chapter 4, on the transformation drivers by sector, and taking into account the economic and competence analysis in Chapters 5 and 6, a prioritisation criterion can be established for action on a municipal level.

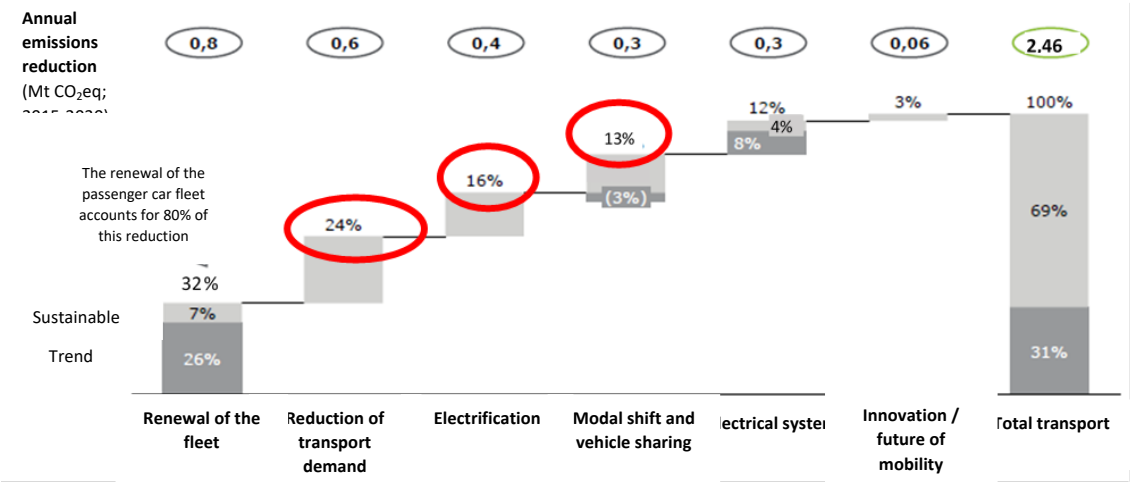
Transport sector

Although the renewal of the vehicle fleet is the action that brings about the greatest reduction in emissions, it should be borne in mind that it is incremental and not transformational in nature, already naturally driven by the trend scenario, so that only the usual measures to shorten the renewal cycles are contemplated, such as subsidies, tax policies fostering the use of less polluting

vehicles and the promotion of demanding regulations relating to the maximum emission values for vehicles.

Furthermore, the roadmap towards climate neutrality assigns an important weight to other lines of action for which it is necessary to generate innovative policies and which follow the hierarchical concept of mobility actions A-S-I (Avoid-Shift-Improve).

Emission reductions from decarbonisation actions in the transport sector under the Sustainable scenario
(%; 2015–2030)



REDUCTION IN TRANSPORT DEMAND

Actions aimed at reducing the need for motorised journeys and the length of journeys through urban planning on a human scale, with mixed and proximity uses, flexible timetables and teleworking, as well as innovative demand management tools are fundamental to the roadmap

MODAL SHIFT AND VEHICLE SHARING

Madrid is in a privileged position in terms of its public transport network, the contribution of pedestrian mobility to the modal split and shared mobility initiatives. This situation is, however, fragile and needs to be boosted by decisive actions towards active mobility, improved public transport service and widespread accessibility to shared transport.

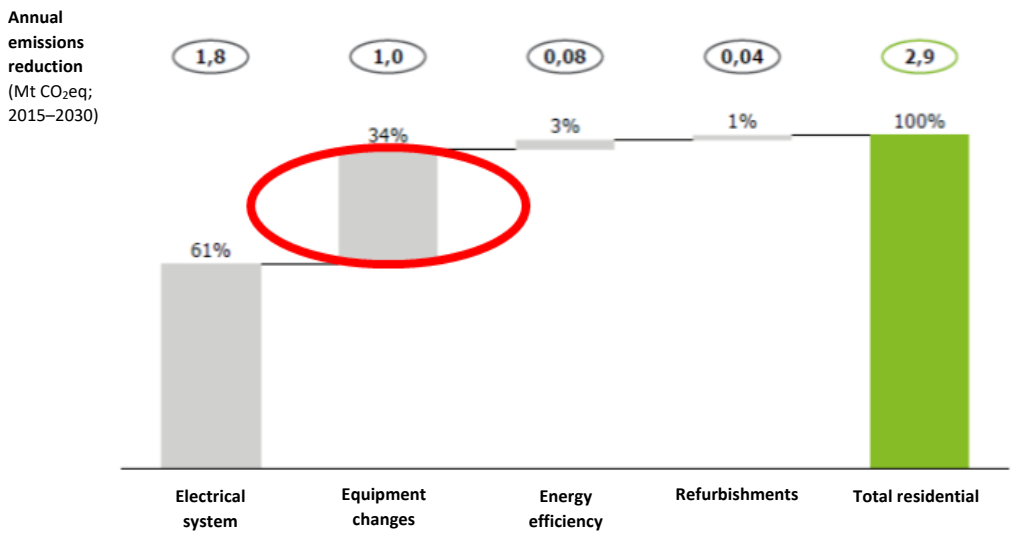
ELECTRIFICATION

The promotion of electric mobility, mainly associated to key fleets such as public transport, urban distribution of goods or shared mobility models, is crucial and will be the main objective of the municipal actions of the roadmap.

Residential sector

Priority is given to actions of technological transformation towards low-emission elements.

Emission reductions from decarbonisation actions in the residential sector under the Sustainable scenario
(%; 2015–2030)



SECTORS (1)	DRIVERS	LINE OF ACTION	ABATEMENT OF EMISSIONS Ktn CO_2 eq				ECONOMICRETURN	LOCAL	AUTONOMIC	STATE	EUROPEAN
			2030		2050						
			Totals	Direct / Indirect	Totals	Direct / Indirect					
RESIDENTIAL	Refurbishments	Restoration of roofs, facades and windows	40	37 / 3	46	45 / 1	-	X	X	X	
		Climate control systems	83	77	91	89	+	X	X		

	Energy efficiency			6		2					
	Equipment changes	Replacement with heat pump	330	295	76	73	-	X	X	X	
				35		3					
		Renewal of natural gas condensing boilers	625	625	639	639	-	X	X		
				0		0					
		Renewal of electrical appliances and lighting	102	0	26	0					
				102		26					
	Self-consumption	Residential self-consumption	6	0	6	0	+	X	X	X	

Replacement of existing equipment with more efficient ones is undoubtedly a necessary line of action in terms of reducing emissions, but it is the transformation of technology and habits that requires greater attention and resources. In accordance with this multi-criteria approach, three priority objectives deserve to be highlighted:

HEAT PUMP INTEGRATION

Promoting the electrification of domestic conditioning demand is the main objective at municipal level, which implies tools to increase accessibility to heating/cooling systems both from the technical perspective – with a necessary boost in technological innovation – and from the economic perspective to allow its widespread implementation.

The accompaniment of the private sector is fundamental.

CLIMATE CONTROL SYSTEMS

The incorporation of consumption control tools entails an awareness, on the part of the citizen, of their capacity in terms of management, consumption and even generation.

Accessible and clear online information on consumption and costs will create a culture of efficiency and empower the consumer.

REPLACEMENT OF NATURAL GAS BOILERS.

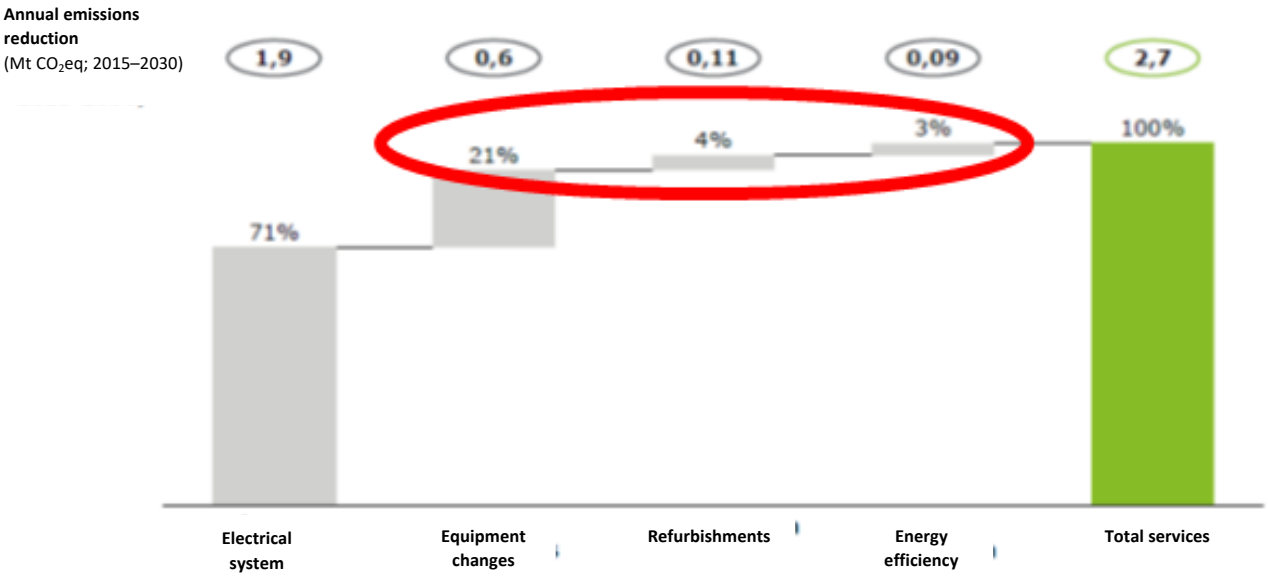
Various municipal support actions can shorten renovation cycles towards more efficient models. Given the widespread use of natural gas in domestic heating, replacement with high-efficiency condensing boilers has a significant potential impact on emissions.

However, natural gas should be considered as a transition fuel towards other technological options that allow climate neutrality to be achieved.

Services sector

Action in the commercial and institutional sector is key in the city of Madrid, with an almost equivalent impact to the residential sector in terms of emissions reduction. The main decarbonisation levers to be prioritised at municipal level include equipment renewal, refurbishment and energy efficiency.

Emission reductions from decarbonisation actions in the services sector under the Sustainable scenario
(%; 2015-2030)



The specific lines of action to be highlighted within these drivers are:

REPLACEMENT OF SYSTEMS USING FOSSIL FUELS (DIESEL AND NATURAL GAS) BY HEAT PUMPS OR OTHER LOW-EMISSION TECHNOLOGIES

The commercial and institutional sector must lead the transformation of the electrification of demand in the building stock and, as far as

ENERGY EFFICIENCY IN LIGHTING

The concept of smart lighting in public lighting services is a high impact action. Likewise, the involvement of the commercial sector in the implementation of efficient lighting systems is also a priority, so specific collaboration channels will be established for

EFFICIENCY AND REHABILITATION OF MUNICIPAL BUILDINGS

Saving and energy efficiency in municipal facilities is an unavoidable objective that will be addressed through monitoring tools, equipment renewal and investment facilities

Other sectors

Along with mobility and building as the main sectors emitting diffuse GHG sources, the roadmap identifies other actions of significant impact that need to be addressed at the municipal level:

WASTE MANAGEMENT

Progress will continue to be made in reducing methane emissions at the Valdemingómez technology complex and the use of biogas will be improved by transforming it into biomethane that can be injected into the natural gas or the electricity grids.

The generation of biomethane and electricity of renewable origin, from the waste produced by citizens and treated at the Valdemingómez Technology Park, contributes to the reduction of fossil fuel consumption in the automotive sector as well as in the residential, industrial or service sectors in general. Therefore, progress will continue to be made in the improvement of the production and transformation processes of these renewable energy sources and in the application of the best available techniques in reducting emissions into the atmosphere.

The City Council will advance in the self-consumption of electricity and biomethane generated from municipal waste in the Valdemingómez Technology Park, so that these can play a key role in the neutrality of

REDUCTION OF THE IMPACT OF REFRIGERANT GASES

Many of the) gases used in refrigeration and air conditioning are fluorinated, have a high global warming potential and their use has increased significantly in recent years. Madrid aims to encourage alternative technologies to fluorinated greenhouse gases, those which use other gases with lower global warming potential, as well as to improve the maintenance and recovery of these gases in existing equipment.

Implementation and scaling driving processes

The transformation drivers structure the roadmap to climate neutrality, but it should not be forgotten that a systemic transformation is necessary, i.e. not only a technological innovation, but also a social, political, economic, financial and institutional one. Therefore, it is essential to create new enabling tools that favour implementation and scaling. The city of Madrid has proposed the following actions for the development of its Roadmap aimed at promoting processes:

- INTERDEPARTMENTAL WORK TEAM (Grupo Clima 360): made up of representatives from different municipal areas (Environment and Mobility, Urban Development, Economy, Innovation, Finance, Culture, International, etc.) who contribute the multiple visions required by the Roadmap.
- NORMATIVE REVIEW: review processes of regulations, ordinances and municipal plans under the perspective of climate neutrality. Opportunity to generate regulatory sandboxes that allow experimentation with decarbonisation models not contemplated or difficult to implement with the existing regulatory framework.
- CLIMATE FINANCING: implementation of financing schemes that allow the Roadmap to be developed based on economic analysis. Integration of the climate variable in municipal budgets.
- MULTI-AGENT COLLABORATION PLATFORM: based on the experience of Madrid as a demonstrator city of the Climate-KIC programme "Clean and Healthy Cities", consolidation of a platform that promotes systemic innovation, accelerating portfolios of transformative projects. This platform is made up of the City Council, the scientific community, the private sector and citizens.

8 Resilience to climate impacts

Reducing GHG emissions should be the priority objective of Climate Action. However, the consequences of Global Warming make it necessary to respond to the existing threats and impacts. The modification of the global climate system generates chain effects that reach the local scale and are not limited to environmental aspects, but also have a social and economic impact.

This Roadmap aims to guide the city of Madrid towards compliance with the Paris Agreement, reducing its emissions with the objective of achieving neutrality in 2050, but also incorporates the other objectives set out in Article 2. "*Enhance adaptive capacity to the adverse effects of climate change and promote climate resilience*."

The European Green Deal, which expresses the political commitment to transform the EU into an equitable and prosperous society with a modern, resource-efficient and competitive economy, also incorporates in its goals to protect, maintain and enhance the EU's natural capital, as well as to protect the health and well-being of citizens from environmental risks and impacts.

At the national level, the draft Climate Change and Energy Transition Law provides the institutional framework for the implementation of the objectives of the Paris Agreement and strengthens the role of adaptation in the development of these policies. More specifically, the National Plan for Adaptation to Climate Change (PNACC) is a reference to guide local plans and actions.

The local dimension of Climate Change Adaptation should be highlighted. The impacts derived from the alteration of the climate affect urban systems, including the provision of resources, water management, energy demand and the degradation of natural spaces. Above all, these effects have an impact on the most vulnerable social groups and on economic activity.

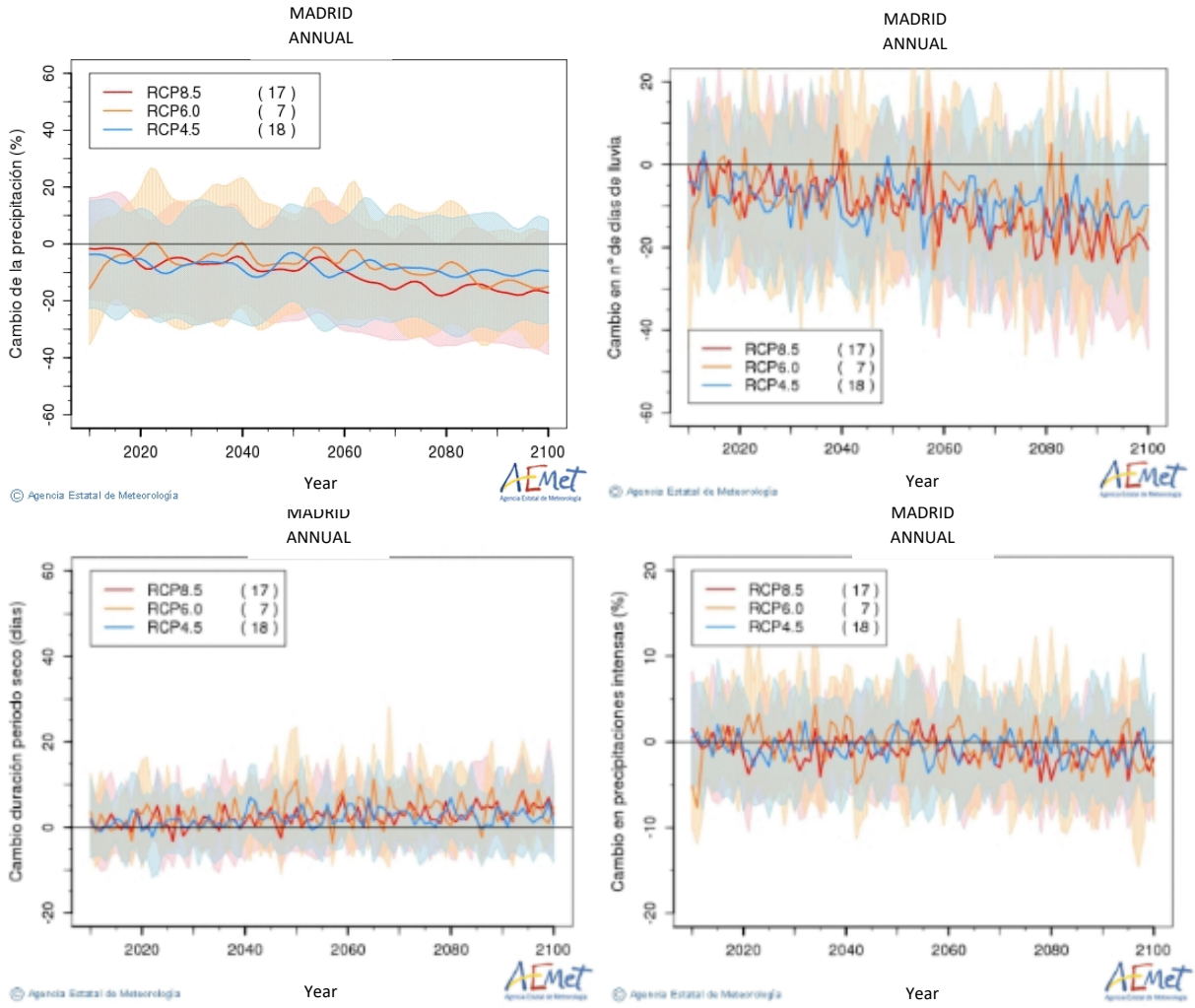
Climate scenarios and risk assessment

The evolution of the climate in Madrid is inferred from the regionalised climate scenarios. Despite the influence of the city on certain variables, the basis of its climate depends on the climate of the whole region. Based on the regionalised projections provided by the State Meteorological Agency (AEMET) and the platform AdapteCCa (Adaptation Platform of the Spanish Office of CC), it is possible to know the future scenarios.

With regard to temperatures, the trend observed is an increase in maximum temperatures, an increase in the number of warm days and hot nights (those exceeding 20º C minimum), and an increase in the duration of heat wave episodes. The evolution of these variables becomes more

pronounced in the representative concentration trajectory (RCP 8.5) with increases of more than 5°C in maximum temperatures at the end of this century or the increase in heat wave episodes.

Regarding rainfall, there is a decreasing trend in the volume and number of rainy days. Furthermore, the dry periods show an increasing evolution.



Graphical results of regionalised projections of climate change (temperature). Source: AEMET.

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

The alteration of climatic conditions shown in the predicted scenarios is at the origin of a series of chains of impacts. According to the municipal study *Análisis de vulnerabilidad ante el cambio climático* (*Vulnerability Analysis in the face of Climate Change*), the city of Madrid will be affected by the following:

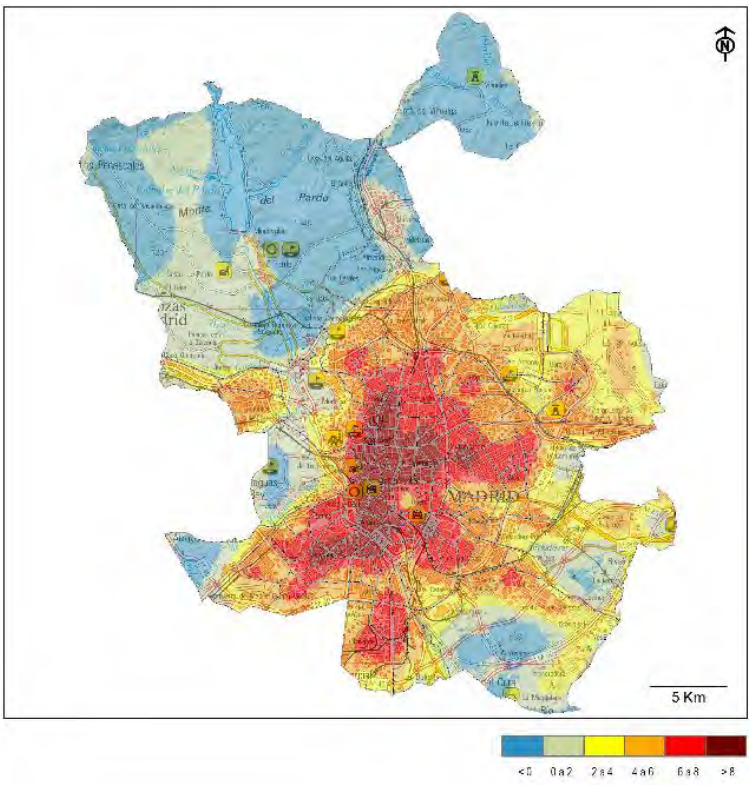
- Heat waves: direct effects on health, mortality and morbidity, increased energy demand, increased water consumption, reduced work output, effects on tourism, attracting tourists, etc.
- Droughts: drinking water supply problems, reduction of quality, impact on economy, business and tourism, degradation of natural spaces, etc.
- Floods: impact on infrastructures, reduction of water quality, damage to buildings, increase in security and emergency incidents, incidents in mobility.
- Environmental degradation: alteration or modification of ecosystems and loss of biodiversity.

These impact chains generate a cascading effect with spin-off effects on multiple aspects of city life and activity, from health to air quality to the economy.

This same analysis assesses, at district level, the areas of Madrid most vulnerable to these effects, showing the spatial coincidence of climate vulnerability with social and economic vulnerability.

Although the climate of the city of Madrid is regional, like other large metropolises, the urban morphology, materials and urban activity, cause particular climatic conditions at a micro-scale and phenomena such as the Urban Heat Island effect.

The study Detalle del Clima Urbano de Madrid (Detail of Madrid's Urban Climate) carried out by the urban climate research group of the Universidad Autónoma de Madrid and commissioned by the Madrid City Council, deepens the knowledge of the Urban Heat Island effect, closely related to the impact of heat waves. The study coincides with the trends of the regional climate scenarios and draws up a map of the heat footprint in the city that makes it possible to locate the most exposed places or "hot spots".



Distribution of the physiologic heat island in summer.

Detail of the Urban Climate of Madrid. April 2016. Madrid City Council. Felipe Fernandez et al. UAM.

Adaptation objectives

The climate in Madrid is changing and, based on environmental projections, is expected to continue to evolve on the same trajectory over the coming decades. Changes in environmental conditions are generating risks to public health, the economy and the balance of natural and urban systems.

To cope with current and future climate impacts Madrid must adapt, transforming itself into a more resilient, sustainable and healthy city. Adaptation is a joint and cross-cutting transformation, which must align sectoral policies and the coordinated efforts of multiple agents from all sectors of society.

The general and strategic objective of adaptation is to make Madrid a resilient, sustainable and healthy city. The sectoral objectives are organized according to expected impacts.

MORE HEAT. Higher temperatures, more frequent and intense heat waves

Minimum and maximum temperatures are expected to continue to rise throughout the century. Heat waves will be more frequent, longer and more intense, aggravating the urban heat island effect.

Strategic objective: A cooler city

Implement economically and environmentally sustainable initiatives that cool the city and prevent it from overheating during the warmer months. Protect the most exposed, most sensitive or least responsive populations from excessive heat. Incorporate green and blue infrastructures into the fabric of the city by taking advantage of vegetation and water to enhance public space through nature-based solutions.

Specific objectives

- Increase green areas and tree canopy (tree cover).
- Replace watertight paved surfaces with permeable or natural ones.
- Encourage the use of high-albedo building materials.
- Develop urban green infrastructure in relation to other systems, building, mobility, energy, etc.

LESS WATER, MORE CONCENTRATED. More frequent and longer periods of drought, slightly less annual rainfall, but with an irregular distribution.

Climate projections point to a continued decline in annual precipitation, longer periods without rain and more days of heavy rainfall per year.

Strategic objective: Reduce and reuse

Maximize efficiency in water management in the city. Harnessing alternative water resources by reducing the demand for potable water. Minimize losses by auditing, repairing, modifying and maintaining supply, irrigation and sanitation networks.

Strategic objective: Ensuring access

Continue to promote responsible consumption and ensure quality and access with special attention to the most vulnerable groups.

Specific objectives

- Reduce water demand and encourage responsible use.
- Extend the reclaimed water network for park irrigation.
- Reduce supply losses.
- Explore new sources of use and reuse alternatives.

MORE EXTREME EVENTS. More frequent storms and floods.

Extreme weather events, storms, strong wind gusts and torrential rains will occur more frequently. Increased risk of flooding and damage to urban facilities and infrastructure.

Strategic objective: Protect and secure

Implement measures to protect the city against floods and extreme events, with special attention to the most vulnerable population. Increase Madrid's response capacity. Increase the resilience of infrastructures and services.

Strategic objective: Transforming rainfall management in Madrid

Increase the retention and permeability of water in the city by means of Sustainable Urban Drainage Systems and the implementation of nature-based solutions that reduce the peak flows when entering the purification systems in order to minimise the discharge of polluted water into natural watercourses. Use water to improve the urban microclimate, recharge aquifers, promote urban biodiversity and enhance the well-being of citizens.

Specific objectives

- Extend the use of sustainable urban drainage systems.
- Increase rainwater retention and infiltration.
- Explore the expansion of greywater uses.

DIMINISHING BIODIVERSITY, NEW CHALLENGES. Degradation of natural areas, alteration of ecosystems

The accelerated change of climatic conditions will endanger the balance of existing ecosystems in the city. Linked to the warmer climate, new vectors of disease transmission could appear, increasing the risk to public health or to the well-being of the flora and fauna of the city.

Strategic objective: Promoting the inclusion of nature in the city

Protect and enhance biodiversity in the city in a sustainable manner through strategic approaches aimed at resilience and adaptation. Promote green infrastructures that facilitate the functioning of ecosystem services, improve connectivity, air quality, energy efficiency or micro-climatic conditions, among other co-benefits.

Strategic objective: Know and control

Adapt municipal protocols and mechanisms to anticipate, detect and control the emergence of new vectors of disease transmission. Study and manage the appearance of new pests and risks for the vegetation and animals of Madrid.

Specific objectives

- Increase the connectivity of urban and surrounding green areas.
- Increase the diversity of plant species in the city.
- Generate attractive and suitable conditions for wildlife.
- Test and extend the design of green areas with natural habitat criteria.

As in the development of mitigation actions, adaptation requires a cross-cutting and coordinated response, due to the multiplicity of factors involved and the effects that derive from climate

change. In this sense, the interdepartmental working team created within the framework of the EIT Climate–KIC Deep Demo initiative will allow some emblematic projects of the city related to the development of green infrastructure and biodiversity to be comprehensively addressed, while acting as a platform to promote the necessary stable partnerships with stakeholders from the private, academic and citizen sectors.

9 Monitoring and communication

The city of Madrid's progress towards neutrality can be observed annually through the results obtained from the GHG Emissions Inventory. This tool, which has been in use since 2006, allows us to know year by year the volume of Scope 1 and 2 emissions (direct and indirect) generated by the city, historical evolution and trends. The inventory provides data on total emissions and disaggregated by sector of activity.

The base information for the inventory is obtained from direct surveys aimed at the main sources of emissions, to which information from the regional and state administration is added, as well as specific studies, such as the City of Madrid's Circulating Vehicle Fleet Study, Traffic Model or Energy Balance, among others.

In addition to this annual monitoring, the evolution of this Roadmap will be evaluated through a report that will be carried out every 5 years from 2020 onwards, in which the emissions register, an analysis of compliance with hypotheses and scenarios, the degree of implementation of measures and the forecast of evolution in the following years will be presented.

The monitoring of the fulfilment of objectives and the implementation of the planned adaptation actions will also be carried out every 5 years, coinciding with the evaluation of the decarbonisation process.

Within 1–2 years, a system of resilience indicators will be developed to evaluate and measure adaptation actions qualitatively and quantitatively, based on systems already developed, but adapted to the specific circumstances of Madrid. In order to guide policies, evaluation systems and indicators that are already being applied in the city of Madrid will be integrated, such as those proposed in the SDG localization strategy for the city of Madrid.

The Roadmap, the inventory data and the periodic evaluation reports will be **published on the municipal website and in specific publications, so that the information will be transparent and accessible to any interested party**.

Communication strategy

The Roadmap is a guide for all those people or entities involved in mitigation and adaptation in the city. In this sense, its dissemination is considered part of the implementation and development process. The communication strategy will adapt its contents according to the target audience, communication channel and objective of each informative action.

Dissemination within the Madrid City Council is important in order to align the policies of the different municipal areas, but it is especially necessary to involve the private sector, organised society and citizens in general. This message and ambition must reach all of them in a way that is appropriate to their position and capacity for action.

10 Threats, barriers

The climate crisis is defined by its complexity and interrelationship between multiple factors in seemingly distant spheres. Because of this, threats and barriers can originate and appear in the same way from different places.

Regarding the fulfilment of the Roadmap objectives, the uncertainty lies in the pace and time needed to achieve the objectives.

Technically, the degree of development achieved seems to allow access to neutral city scenarios within the time horizons proposed in this Roadmap and, although there are uncertainties in some aspects (evolution in the development of batteries, adaptation of distribution networks, development of hydrogen technology, waste classification and treatment techniques, as well as the costs for their implementation, development of the markets for recovered materials, etc.), they do not seem to compromise the purpose.

In this area, success in achieving neutrality depends to a large extent on the **decarbonisation of the electricity mix**, which, if the established rates and milestones are not met, will slow down the whole process.

The adaptation of infrastructures, the transformation of the city's traffic fleet, the improvement of the energy efficiency of buildings, the extension of air conditioning systems based on clean energies or the improvement of waste collection and treatment processes must incorporate technical improvements and require long development periods that could alter the expected pace.

However, the greatest threats and barriers will be those related to social and economic aspects. The goal of a carbon neutral city cannot be achieved if there is no **public-private-social collaboration** in all aspects of the process. This urban development can only be understood in an inclusive society in a favourable and sustainable economic context.

The models of **governance** are also a key aspect. Climate action proposes comprehensive transformations that are sometimes difficult to develop in excessively rigid and compartmentalised administrative and organisational schemes and regulations whose design has not incorporated the climate variable.

A threat can also be posed by the **disconnection between scales**. Climate action in the city must be related to the metropolitan, regional and state context. Many urban activities and systems (mobility, food, energy, water, etc.) are strongly influenced by these other areas. Similarly, the process can be misdirected or slowed down if there is a lack **alignment in the policies of the different** administrations– – local, regional, national and European.

The **harmonization between policies** will be necessary not only in strategic and legal terms. The urban transformation that must be faced will require financial and budgetary policies and strategies that will have to be agile and efficient, for which **institutional coordination** is crucial.

The implementation of actions will require high investments, in some cases with direct economic returns and in a period of time that can be assumed by investors, but in many others this return will occur in the long term, as can be seen in the economic analysis, and will even be non-existent in purely economic terms, as in the case of many urban resilience actions. A favourable **economic context** will enable the implementation of measures. Otherwise, it could slow down progress.

The process towards climate neutrality requires a profound urban transformation, socially, economically and environmentally. The challenge lies in overcoming the inertia and immobile positions that hold back this evolution until we reach new paradigms. This inertia will naturally lead to a climate-neutral, economically prosperous and socially inclusive city.

11 Schedules

I. Study "Desarrollar la Hoja de Ruta de la ciudad de Madrid hacia la neutralidad climática" (Developing the Roadmap for the city of Madrid towards climate neutrality)

Monitor Deloitte. November 2020

II. The total economic case for decarbonisation in Madrid.

Material economics. November 2020

III. Adaptation measures Madrid + Natural

Cover image:
Title: De Madrid al cielo (o hacia las cuatro torres) (From Madrid to the sky (or to the four towers))
Author: Juan Carlos Rodán González
V Municipal Photography Competition.