Plan

MADRID

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A. JUSTIFICATION OF PLAN A. INTRODUCTION

A.1. Introduction

Plan A: *The air quality and climate change plan for the city of Madrid (hereinafter Plan A)* is a local level tool aimed at reducing air pollution, helping to prevent climate change, and defining adaptation strategies. The main objective is to ensure the quality of the air breathed by Madrid-dwellers and to guard the city against future climate impacts.

These actions, aimed at reducing pollution and adapting to climate change, are designed to help turn the city of Madrid into an urban environment characterized by a high quality of life while consolidating a shift in the city towards sustainable urban model. Plan A is conceived as a fundamental part of a far-reaching *Sustainable Urban Development Strategy* in order to address the environmental and social challenges facing Madrid as a major conurbation. Air quality improvement and preparing for the effects of climate change are two key aspects of the city's environmental enhancement. The actions forming part of Plan A are characterized by their cross-cutting nature and have been designed with the foremost objective of reducing air pollution while considering other additional elements aimed at effecting a change from a conventional development model to a sustainable one.

The structure of Plan A calls for an initial diagnostic of the present situation in terms of pollutants, regulatory framework, physical and socioeconomic characteristics, etc. An analysis is made of the baseline air quality and emissions of pollutants and greenhouse gases, together with their contribution broken down by sources. The results of the previous 2011-2015 air quality plan are evaluated and future scenarios are constructed under different hypotheses. The measures are broken down into various action programmes: sustainable mobility, urban regeneration, climate change adaptation, and citizen awareness-raising and collaboration with other public authorities. Finally, Plan A also calls for an impact analysis and monitoring and evaluation plan.

The time frame of Plan A considers two horizons; 2020 for the achievement of the air quality targets required by legislation and a longer term horizon, to 2030, for the necessary energy transition and consolidation of a low emission city model.

A.2. Justification and premises

Premise 1: Integrated actions targeting air quality and climate change which generate synergies and prevent inconsistencies

Traditionally air quality and climate change policies and strategies have been addressed independently and in isolation. However, scientific studies and the analysis of policies in these matters have shown that the challenges related to air pollution and climate change need to be addressed jointly and require a coherent and integrated management policy. This Plan subscribes to this view; one of its hallmarks is the strategic combination of air quality and climate change.

As early as 2005 the European Thematic Strategy on Air Pollution issued recommendations underlining the advisability of considering the synergies and possible conflicts between the management policies for air quality and for climate change, due to the fact that certain measures already in place to reduce greenhouse gas emissions have a negative impact on air quality and *vice versa*. Although our understanding of the way in which climate change can affect air quality is still incomplete, recent research has shown that this relationship may be more direct than was originally thought. The climate change assessments carried out by the Intergovernmental Panel forecast a worsening of air quality in cities, partly due to climate change. In many regions of the world climate change is expected to have an effect on local climate, mainly in the form of more frequent heatwaves and an increase in anticyclonic periods giving rise to episodes of air stagnation and increased pollution. More sunlight and higher temperatures may not only lengthen the duration of ozone episodes but may also heighten their intensity.

Premise 2: To act on air quality and climate change is a public health priority

In 2015, a report from the World Health Organization highlighted the pressing need to reduce emissions of black carbon, ozone and methane, collectively known as short-lived climate pollutants, not only because they are the cause of a considerable rise in the planet's temperature, but also due to their significant contribution to the number of premature deaths due to air pollution every year. Many other studies confirm that effective air quality and climate policies may have mutual effects and benefits. Policies aimed at reducing atmospheric pollutants may help keep the increase in average global temperatures below 2ºC. Similarly, climate policies aimed at reducing emissions of short-lived climate pollutants such as black carbon and methane may make a significant contribution to improving air quality.

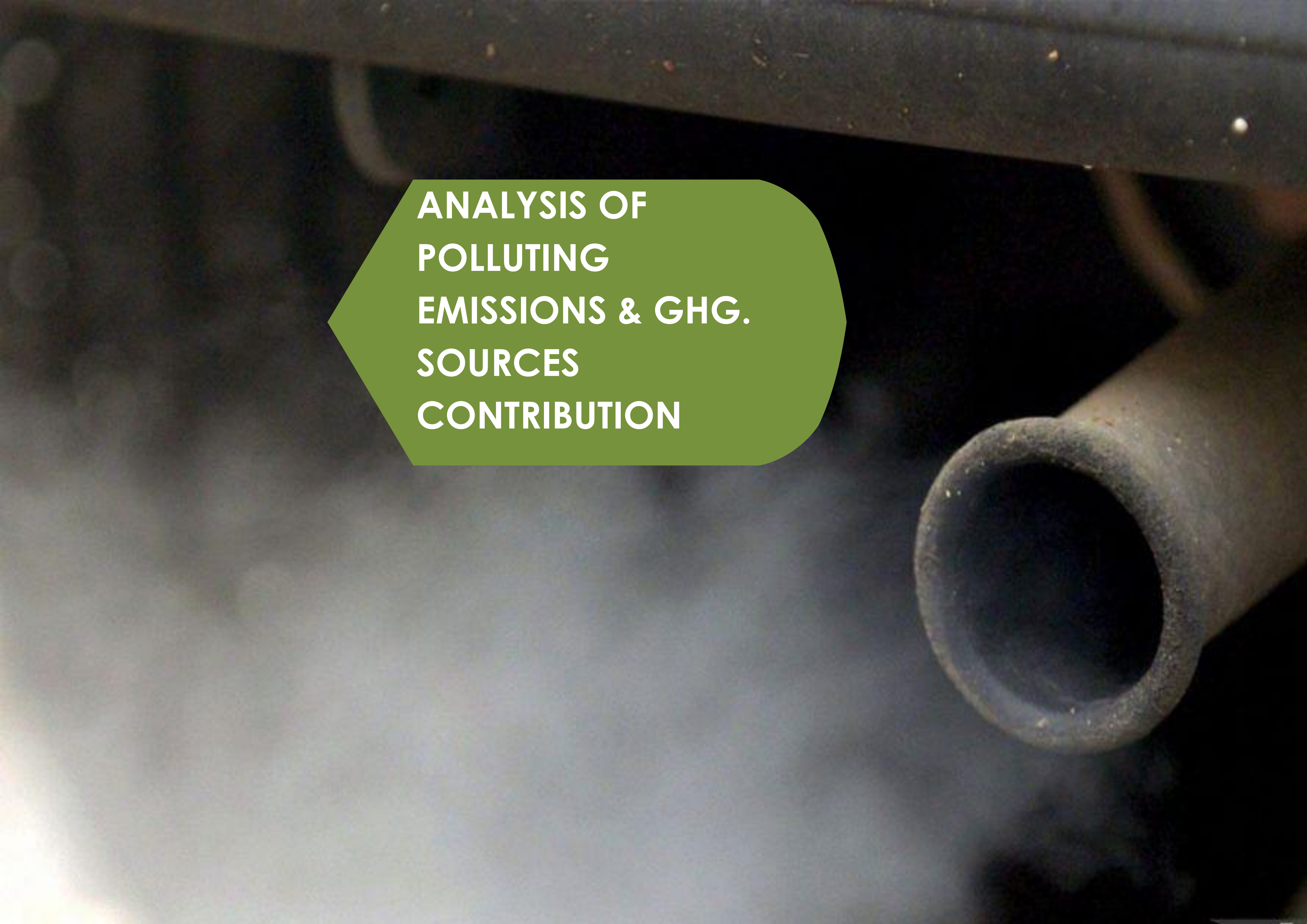
A.2. Justification and premises

International agencies such as the Climate and Clean Air Coalition (CCAC), the C40 Cities Climate Leadership Group, and the United Nations agency, UN-Habitat, have highlighted the need for cities to develop integrated policies to reduce the impact of air pollution and climate change in terms of their impact on public health. This approach, whereby air quality and climate change impacts are addressed as a public health and quality of life problem, is another of the guiding principles of this document.

Premise 3: A new low emission city model requires a combined action on mobility, urban development, and the management of energy and resources

In urban environments greenhouse gas emissions and atmospheric pollutants often have the same origin, mainly diffuse sources such as road traffic, the residential sector, or waste. It would therefore be logical for any action on these sources to lead to a parallel improvement in air quality and help mitigate climate change. This is why these two challenges are addressed in combination, enabling us to prioritize synergistic measures of mutual benefit and avoid inconsistencies since, given the connection between the two phenomena, we need to be mindful of the fact that the implementation of initiatives and strategies in one field may have negative effects on the other. The drive towards diesel fuel for automotive use, the widespread use of biomass instead of fossil energies, and certain waste management practices are examples of potential contradictions. The development of diesel-powered vehicles, because diesel is a more energy efficient fuel than petrol, has had a negative impact on air pollution in cities due to their higher emission factors.

Given the complexity of urban systems and the diffuse nature of emission sources, the transition to a low emission city model requires action on a great many fronts. Firstly, priority action is required on the basic elements of the urban metabolism, mobility and energy, by acting on demand and promoting non-fossil fuel dependent sustainable alternatives. Secondly, in a consolidated city like Madrid, a process of urban regeneration is necessary to achieve a more cohesive territory, one better adapted to foreseeable climate impacts.



ANALYSIS OF POLLUTING EMISSIONS & GHG. SOURCES CONTRIBUTION

A.3. Analysis of polluting emissions & GHG. Sources

Emissions trend

In order to analyse the distribution of emission sources by sector we have grouped SNAP categories into the following **'Activity sectors'**:

GROUPING BY SECTOR

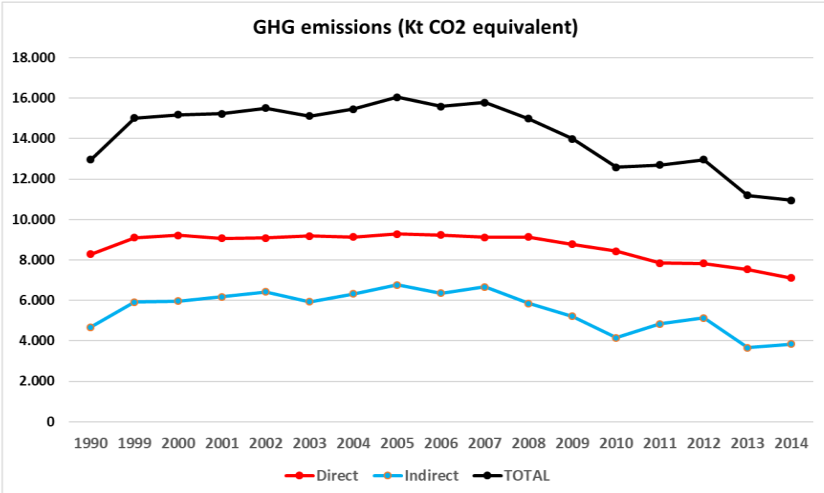
ACTIVITY SECTOR	SNAP GROUPS
RCI (Residential/Commercial/Institutional)	02
Industry	03 and 04
Road transport	07
Other modes of transport	08
Waste treatment (including treatment of wastewater)	09
Other	05, 06, 10 and 11

Greenhouse gas (GHG) emissions trend

In our analysis of GHG emissions in the municipality of Madrid we have taken into account both **'direct emissions'** arising from emitting activities (snap groups) and **'indirect emissions'** arising from the generation of electricity consumed in the municipality of Madrid and from the losses occurring in the transmission of the electricity consumed in the city from the point of generation to the point of final consumption.

In the following graph we show the annual trend in total GHG emissions, direct and indirect, in the period 1999 to 2014. We see that total GHG emissions have diminished by 27% while direct emissions have shrunk by 21.88% in the same period.

Direct emissions are greater than indirect; they account for between 58% and 67% of total emissions in the inventoried period.



If we analyse the trend by activity sector, 'Road transport' is responsible for the highest volume of emissions with 31.5% of direct emissions in 2014, followed by the 'RCI' sector with 30.4% of the total. We see an increasingly smaller contribution from the 'Industry' and 'Waste treatment' sectors, and a stable and growing participation from the sectors 'Other modes of transport' and 'Other', respectively.

A.3. Analysis of polluting emissions & GHG. Sources

Direct emissions by activity sector (kt CO2-eq)

ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	2,603	2.558	2,486	2,364	2.564	2,680	2,699	2.561	2,617	2,614	2.510	2,327	2,137	2,383	2,400	2,160
Industry	623	579	516	471	517	485	482	491	514	506	393	359	316	279	324	329
Road transport	3,436	3,471	3,423	3,543	3,442	3,602	3,592	3,467	3,233	3,110	2,948	2,796	2,461	2,327	2,236	2,240
Other modes of transport	682	751	771	728	680	717	742	909	940	878	803	745	742	687	605	611
Waste treatment	1,414	1,431	1,372	1,423	1,350	951	983	963	917	944	987	976	906	860	752	619
Other	347	422	495	554	628	698	778	844	902	1,089	1,130	1,234	1,285	1,284	1,217	1,154

Indirect emissions arising from the consumption of electricity, by activity sector (kt CO_2)

ACTIVITY SECTOR	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	5,187	5,420	4,802	4,502	3,438	4,016	4,373	3,142	3,298
Industry	734	726	572	414	348	380	301	204	214
Road transport	--	--	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Other modes of transport	407	479	442	268	344	430	437	299	312
Waste treatment	--	--	--	--	--	--	--	--	--
Other	32	37	29	27	18	20	20	13	12

Indirect emissions fell by 39.68% in the period 2006-2014, mainly due to a reduction in emissions of the electricity production mix at a domestic level. The 'Residential, Commercial and Institutional' (RCI) sector is the biggest emitter with an 86% share of total indirect emissions in 2014. The 'Industry' sector has gone from accounting for 12% of indirect emissions in 2006 to 6% in 2014, as a result of the drop in the electricity consumption of the sector (due to savings and energy efficiency measures and a decrease in activity levels).

Conversely, the contribution of the sector 'Other modes of transport', the second in importance, grew from 6% in 2006 to 8% in 2014.

Distribution of total GHG emissions by sector (2014)

ACTIVITY SECTOR	Kt CO2-eq			Contribution by sector (%)	
	DIRECT	INDIRECT	TOTAL	DIRECT	INDIRECT
RCI	2,160	3,298	5,458	30,4	86,0
Industry	329	214	543	4,6	5,6
Road transport	2,240	0,1	2,240	31,5	0,0
Other modes of transport	611	312	922	8,6	8,1
Waste treatment	619	12	630	8,7	0,3
Other	1,154	0	1,154	16,2	0,0

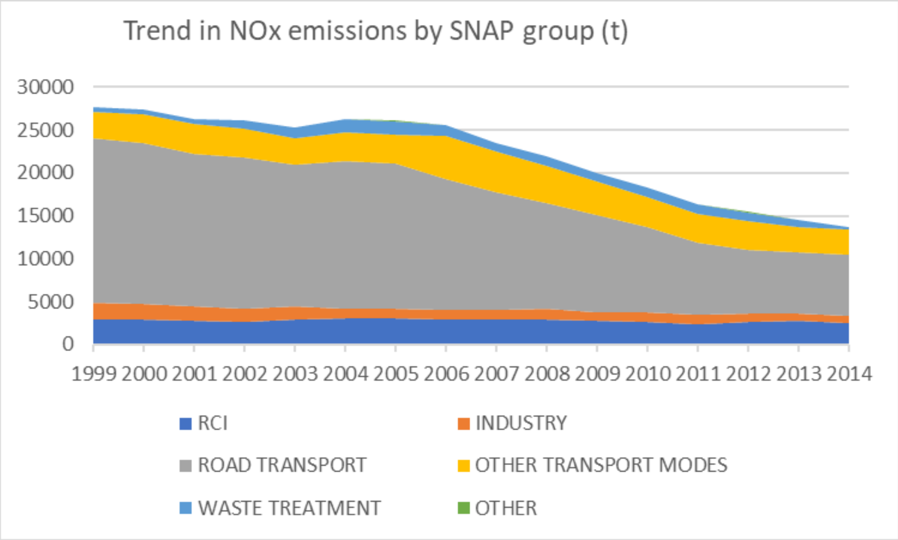
If we analyse the breakdown of total GHG emissions (direct + indirect) by 'activity sector' for 2014, the most recent year for which we have data, we can see that the sector with the highest total emissions in the municipality of Madrid is the 'RCI' sector (50%), followed by the 'Road transport' sector (20%). In terms of direct emissions, over which the Madrid City Council has the greatest scope for action, the 'Road transport' sector is the biggest contributor with 31%, while the 'RCI' sector contributes 30%. The great importance of the 'RCI' sector as a contributor to total emissions is because this sector is associated with 86% of indirect emissions due to the municipality's consumption of electricity, while indirect emissions from the 'Road transport' sector are minimal due to the as yet scant importance of electricity consumption in that sector.

Although the remaining sectors make a smaller contribution to total emissions, it is important to note the increasingly greater contribution from the 'Other' sector, with a 10% share. This sector includes emissions from the 'Extraction and distribution of fossil fuels', 'Use of solvents and other products', 'Agriculture' and 'Nature' (excluding absorptions of carbon dioxide by carbon sinks).

Trend in the emissions of acidifying pollutants and ozone precursors

Here we analyse the pollutants NOx, SO_2, NH_3, NMVOC, PM10, and PM2.5

The following table and graph shows the trend data for **NOx** since 1999 by activity sectors. Generally speaking we can see a clear and progressive trend, especially after 2006, towards a reduction in NOx. Road transport (SNAP 07) is the activity sector with biggest impact on nitrogen oxide emissions. However, emissions have diminished from 19,226 tonnes in 1999 to 7,012 tonnes in 2014.



TREND IN EMISSIONS OF NOx (t) BY ACTIVITY SECTOR

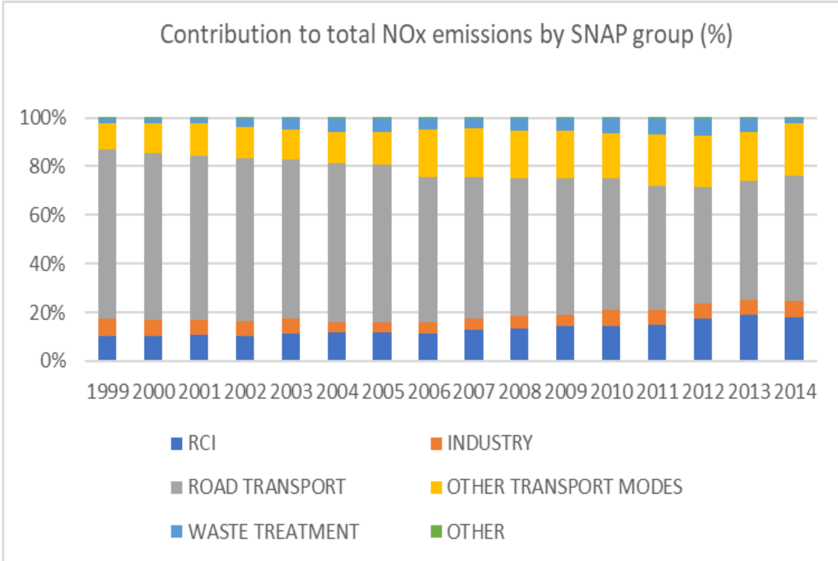
ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	2,874	2,863	2,810	2,659	2,894	3,042	3,067	2,909	2,970	2,959	2,838	2,622	2,403	2,697	2,723	2,451
Industry	1,925	1,820	1,632	1,578	1,494	1,071	1,48	1,087	1,119	1,141	947	1,174	1,048	945	956	940
Road transport	19,226	18,740	17,752	17,612	16,535	17,221	16,954	15,319	13,614	12,388	11,279	9,887	8,344	7,380	7,093	7,012
Other modes of transport	3,015	3,353	3,475	3,293	3,142	3,325	3,429	4,991	4,792	4,336	3,908	3,450	3,425	3,296	2,913	2,933
Waste treatment	592	606	600	995	1,255	1,572	1,543	1,208	992	1,110	1,038	1,129	1,106	1,095	853	290
Other	20	19	18	18	19	18	17	18	17	17	17	17	18	18	17	18

The second most important sector is ‘Other modes of transport’ (SNAP 08) in which emissions have remained more or less the same throughout the period under study (2,933 t in 2014 versus 3,015 in 1999).

The ‘Industry’, ‘Residential/Commercial/Institutional’ (RCI), and ‘Waste treatment’ sectors are the next most important in terms of emissions, all with very similar values. The ‘Industrial’ sector has been decreasing over the years, from nearly 2,000 t in 1999 to 940 t in 2014. Annual emissions of the ‘RCI’ sector have remained constant at above the threshold of 2,400 ton/year. Emissions of the ‘Waste treatment’ sector increased significantly in the early years of the inventory before falling again until 2014.

The following graph shows the trend in the percentage contribution by each activity sector to total NOx emissions. The sector with the largest relative importance is ‘Road transport’ (07), which contributed over 50% to total NOx emissions in the period 1999-2014, the contribution being **51.4%** in 2014.

The next pollutant of the acidifiers group we analyse is **SO_2,** for which we provide a table and a graph showing the relevant emissions trend.



A.3. Analysis of polluting emissions & GHG. Sources

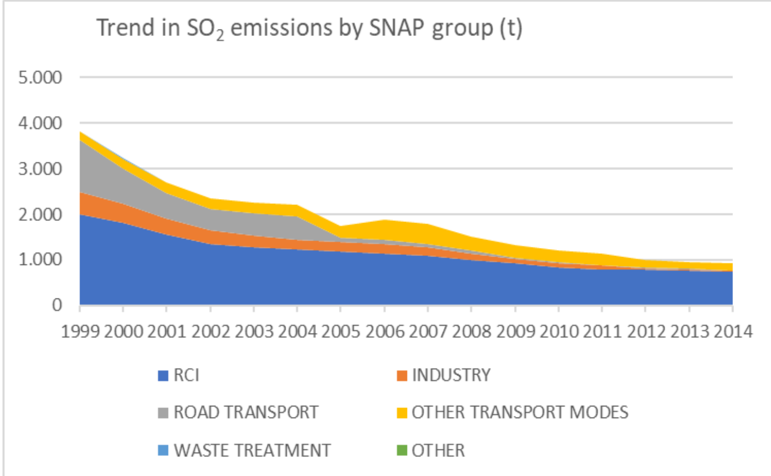
TREND IN SO2 EMISSIONS (t) BY ACTIVITY SECTOR

ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	1,998	1,804	1,568	1,349	1,275	1,226	1,182	1,144	1,082	998	928	846	797	782	763	739
Industry	487	433	330	290	262	211	207	212	191	135	100	92	74	28	24	21
Road transport	1,136	757	562	477	476	509	89	86	80	77	15	17	15	14	14	14
Other modes of transport	201	224	238	237	244	252	260	445	430	305	280	244	243	169	152	155
Waste treatment	4	12	6	3	3	3	1	1	0	0	1	1	1	1	1	1
Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

We can clearly see the general drop in SO_2 emissions for all activity sectors. This is due to the reduction of the sulphur content of fuels and a lower consumption of fuels such as coal and fuel oil, both of which contain a high percentage of sulphur.

The 'Road transport' sector is where the sharpest decline can be seen over the years, down from 1,136 t in 1999 to 14 t/year between 2012 and 2014. The 'Residential, commercial and institutional' sector also reduced its emissions significantly, from 1,998 t/year at the beginning of the period under study to 739 t in 2014. Even so, it accounts for between 52% and 80% of total SO_2 emissions.

The values and trend of the last of the acidifiers, NH_3, are set out in the following graph.



A.3. Analysis of polluting emissions & GHG. Sources

TREND IN EMISSIONS OF NMVOC (t) BY ACTIVITY SECTOR

ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	893	870	836	772	821	854	860	821	829	816	792	757	711	782	791	732
Industry	1,180	1,240	1,277	1,311	1,382	1,649	1,640	1,745	1,893	1,924	1,801	1,819	1,875	1,842	1,808	1,771
Road transport	17,155	13,876	11,652	9,011	7,551	6,045	4,901	3,773	2,970	2,409	2,193	2,810	2,623	2,924	2,843	2,863
Other modes of transport	168	181	188	185	187	189	190	343	304	258	226	182	178	173	150	147
Waste treatment	7	12	12	18	93	139	151	140	105	125	119	120	114	123	97	7
Other	29,581	30,245	28,835	27,526	28,304	27,879	26,934	25,346	24,605	22,673	20,283	18,875	17,979	16,882	16,143	16,107

The activity sectors which emit this pollutant are 'Road transport', 'Other modes of transport', 'Waste treatment' and 'Other', with a clear predominance of the 'Waste treatment' sector, followed by 'Road transport'.

In 2012 waste started to be composted by biomethanization at the Las Dehesas and La Paloma plants, which explains the drop that year. For this sector, emissions grew steadily before peaking in 2006 when they once again started to drop gradually, until 2012 when they dropped sharply.

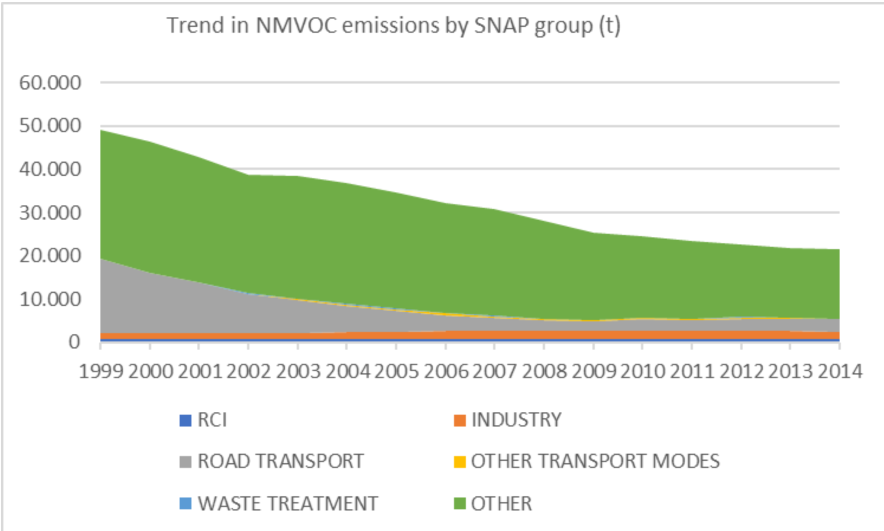
The trend in emissions by the 'Road transport' sector, with an importance far below that of 'Waste treatment', is characterized by a gradual decline, which becomes more prominent between 2006 and 2007.

With regard to non-methane volatile organic compounds (NMVOC), the following table shows emissions for the period 1999-2014.

We can see that the biggest emitter, with 74.5% of total emissions in 2014, is what we are referring to as 'Other' (which includes 'Use of solvents and other products' and 'emissions from nature', corresponding to SNAP groups 06 and 11 respectively), followed by the 'Road transport' sector.

Regarding the trend in NMVOC, in the period 1999-2014, the 'Industry' sector showed an upward trend with a significant increase in 2006, before starting to fall to levels close to those of 1999. The 'Other modes of transport' sector displays a steady gradual upward trend, reaching a 152% rise in 2014 over 1999. The other groups either remained constant or fell steadily over the period under study.

As for emissions of carbon monoxide (CO) whose values are shown in the following table, we can see that 'Road transport' accounted for the highest volume of emissions in 2014,



54.6% of the total, although in the period under consideration levels have dropped very significantly, from 90,200 tonnes in 1999 to 6,234 tonnes in 2014. Next in importance comes the ‘RCI’ sector, with a value of 4,136 t/year in 1999 and 2,163 in 2014, accounting for 18.9% of the total.

TREND IN EMISSIONS OF CO (t) BY ACTIVITY SECTOR

ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	4,136	3,881	3,509	3,090	3,056	3,043	2,974	2,861	2,797	2,655	2.502	2,318	2,176	2,291	2,290	2,163
Industry	3,886	4,446	3,882	4,032	4,323	4,783	4,720	5,716	5,678	5,321	2,913	4,830	4,041	1,003	947	917
Road transport	90,204	74,794	61,211	53,345	41,641	35,745	27,920	21,423	17,355	14,283	12,438	8,432	6,725	6,536	6,330	6,234
Other modes of transport	2,739	2,786	2,661	2,491	2,362	2,389	2,379	2,866	2,836	2.582	2,392	2,226	2,235	2,010	1,805	1,847
Waste treatment	52	85	67	64	528	961	986	944	761	835	808	902	921	765	739	256
Other	40,4	16,1	7,5	7,3	6,4	3,1	1,6	2,2	0,9	0,7	0,6	0,2	0,8	3,1	2,4	0,8

Trend of the emissions of particulate matter

In this section we analyse emissions of particulate matter with a diameter of less than 10 µm (PM10) and 2.5 µm (PM2.5).

TREND IN EMISSIONS OF PM10 BY ACTIVITY SECTOR

ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	622	557	485	425	407	394	383	372	359	337	323	313	302	303	299	291
Industry	72	68	58	56	51	35	34	39	38	30	22	21	16	7	5	5
Road transport	1,297	1,278	1,225	1,230	1,175	1,196	1,155	1,073	973	910	849	752	653	601	577	572
Other modes of transport	49	52	5	51	50	50	49	141	110	87	72	46	45	51	42	38
Waste treatment	26	33	11	10	20	41	33	25	25	22	20	21	22	16	26	23
Other	4.4	4.3	4.3	4.3	4.5	4.3	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1

TREND IN EMISSIONS OF PM2.5 BY ACTIVITY SECTOR

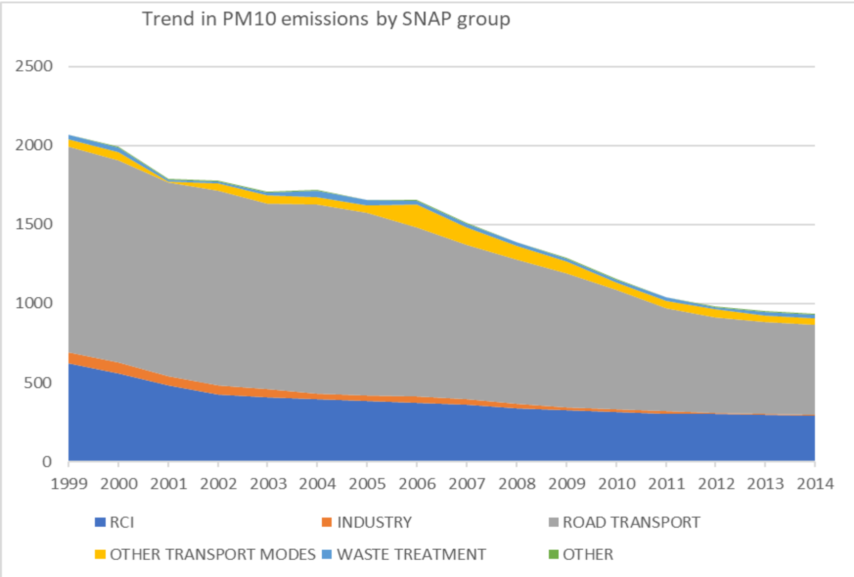
ACTIVITY SECTOR	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
RCI	597	534	465	407	392	379	369	358	346	325	313	304	293	294	290	283
Industry	67	63	54	52	47	33	32	37	36	28	21	20	15	7	5	5
Road transport	1,133	1,111	1,054	1,050	997	1,011	969	892	801	744	688	590	496	450	433	428
Other modes of transport	49	51	52	51	50	50	49	141	110	87	72	46	45	51	42	38
Waste treatment	26	33	11	10	20	41	33	25	25	22	20	21	22	16	26	23
Other	0.8	0.8	0.8	0.8	0.9	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6

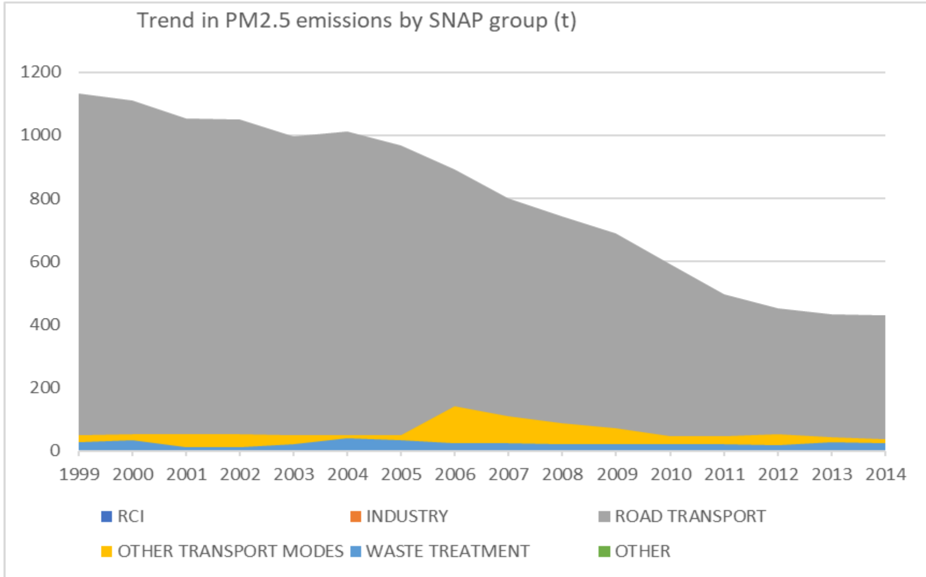
A.3. Analysis of polluting emissions & GHG. Sources

The group with the highest emissions of both PM10 and PM2.5 is 'Road transport'; it is responsible for 61.3% and 55.0% of the total respectively, followed a long way back by the 'RCI' sector

The following graphs show the trend in the two types of particles analysed, by sector.

For both PM10 and PM2.5 the sectors with the highest values are 'Road transport' and 'RCI', with the trend in all cases being downwards. The 'Industrial sector', which is the sector with the next highest values, also shows a downward trend, falling from an average of 65 tonnes a year in 1999 for the 2 types of particles to only 5 tonnes in 2014. The other groups present very low values or are responsible for no emissions of this type.





A.3. Analysis of polluting emissions & GHG. Sources

Analysis of sources contribution to air quality levels

The study of sources contribution to concentration levels of nitrogen dioxide (NO_2) and particulate matter was carried out using a system of high resolution air quality modelling conducted by the Universidad Politécnica de Madrid for the area of study; an area measuring 40 km (X) x 44 km (Y), which included the metropolitan area of Madrid (**¡Error! No se encuentra el origen de la referencia.**).

The baseline data for emissions corresponds to 2012, chosen as the reference year due to its being the most recent year with available data in terms of official emissions inventories common to all domains at the time the work began, i.e. international, national, regional and local. All emissions are treated in a consistent manner using scales, and they all involve specific estimate and processing methods for each type of source.

The procedure implemented for the analysis of the sources contribution followed the methodology known as 'zero-out'. This method is based on the analysis of the variation in air quality concentration from the baseline scenario when emissions from a particular emitting sector or region whose contribution is to be assessed are zeroed out. This type of studies allow us to identify any improvement in air quality by reducing emissions in the most important activities.

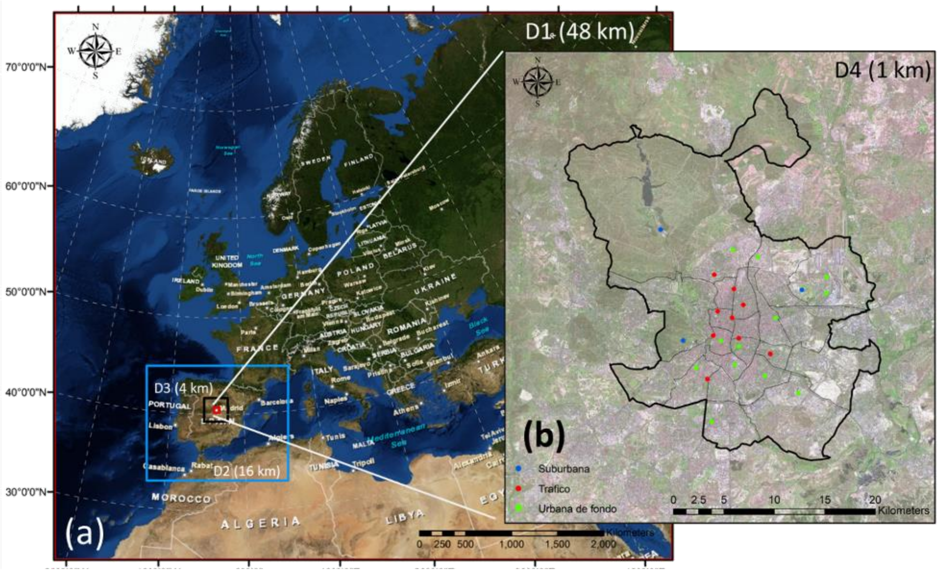


Figure 1. Domains used in the simulation. (a) Domain D1 (Europe, resolution 48x48 km²), D2 (Spain, 16x16 km²) and D3 (Madrid Community, 4x4 km²). (b) Domain D4, (Madrid City Council 1x1 km²) indicating the position of the air quality monitoring network stations of the Madrid City Council.

To do this a total of eight scenarios were defined. These enabled us to determine contributions from the most important sectors (4 scenarios) and geographic regions (4 scenarios) plus the baseline scenario, which considers the emissions from all sources in every geographic area.

Nitrogen dioxide (NO_2)

The results of the simulation for the annual average concentration of NO_2 for 2012 ('base case') for the domain D4 are shown in **¡Error! No se encuentra el origen de la r eferencia.**. It shows how the highest levels of concentration in the municipality of Madrid are to be found in the city centre and most especially in areas surrounding the main road infrastructures such as the Paseo de la Castellana (a multi-lane avenue running through the north of Madrid), Calle 30 (the Madrid inner ring road), and the

M-40 (the innermost of two orbital motorways), on which much of the traffic in the area under study is concentrated. The annual average concentration of NO_2 in the total area of the municipality of Madrid is 17.2 µg/m³. The value for the entire municipality is relatively low, mainly due to the fact that in the northwest part (Fuencarral-El Pardo district) there is no population and no major transport links, and this helps lower the average for the municipality as a whole. However, we can see that there are significant spatial gradients within the municipality with maximum levels of close to 50 µg/m³

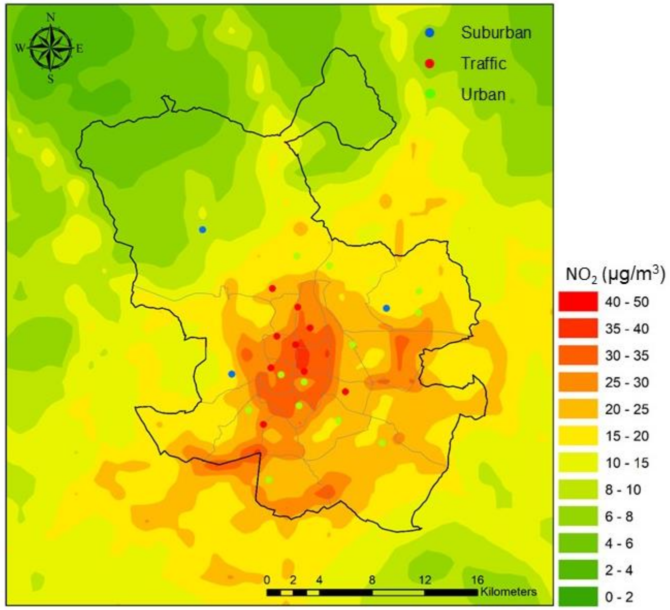


Figure 3. *Average annual concentrations of NO_2 for base year*

The different contributions to this concentration are shown in Figure 2. Here we see that the contribution for the municipality of Madrid as a whole is dominated by local sources (71.7%), mainly road traffic, which contributes 9.2 µg/m³, the equivalent of 53.3% of total contributions and 74.4% of contributions from local sources; i.e. those emitted within the municipality of Madrid itself. The remaining local sources contribute much less significantly. The second most important sector according to the results is the residential/commercial/institutional (RCI) sector with a contribution of 5.9% of total sources, followed by the Adolfo Suarez Madrid-Barajas Airport with 2,7% (variability within the municipality is especially high due to it being a point source), and industry with an overall minimal contribution (0.3%). Meanwhile, with regard to contributions external to the Municipality of Madrid, the regional contribution regional (Community of Madrid) is especially predominant with a 23.6% contribution (4.1 µg/m³), while the national and international contribution together accounts for less than 1 µg/m³. Given that what we call regional mainly refers to the municipalities making up the metropolitan area of Madrid, it would be normal to expect its internal contribution structure to be similar to the one described for Madrid and for road traffic to also be the predominant contributor.

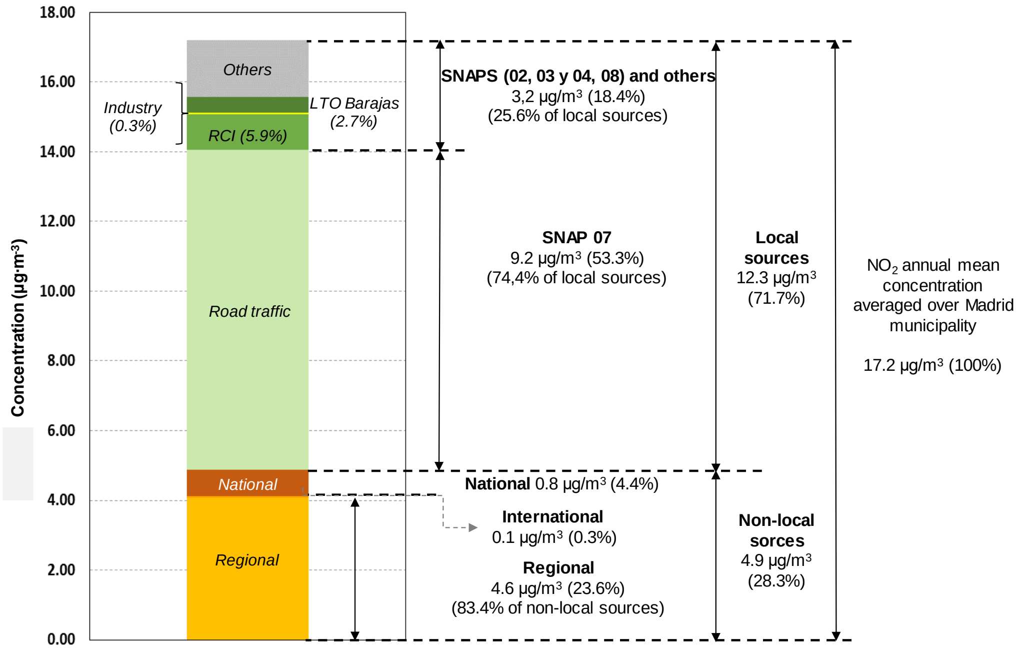


Figure 2. *Results summary of the sources contribution analysis (average annual concentrations of NO_2 for the Municipality of Madrid as a whole)*

Particulate matter (PM10 and PM2.5)

We deal with both pollutants (PM10 and PM2.5) in conjunction due to the fact that their behaviour, both in spatial and in level of contribution terms, is similar. Figure 4 shows the annual average for both pollutants according to the mesoscale simulations carried out. We see that the spatial patterns are very similar to those for NO_2, mainly due to the impact that road traffic emissions have on the two pollutants (particles and NO_2).

Below we can see the results of a sources contribution analysis for the annual average concentration of particles $PM_{2.5}$ (Figure 5) in the municipality of Madrid, shown in a similar way as for NO_2 earlier.

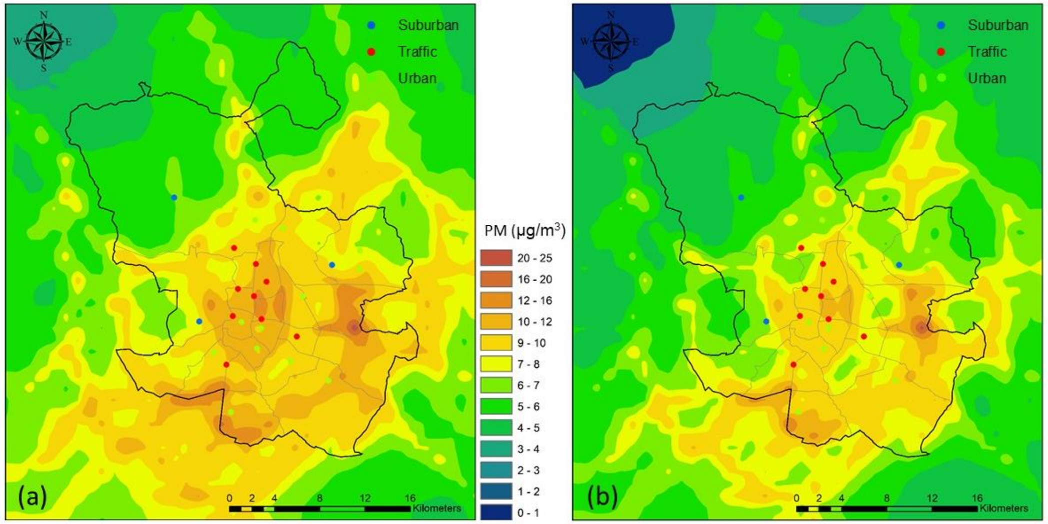


Figure 4. *Predicted annual average concentrations of PM_{10} (a) and of $PM_{2.5}$ (b) for the base year*

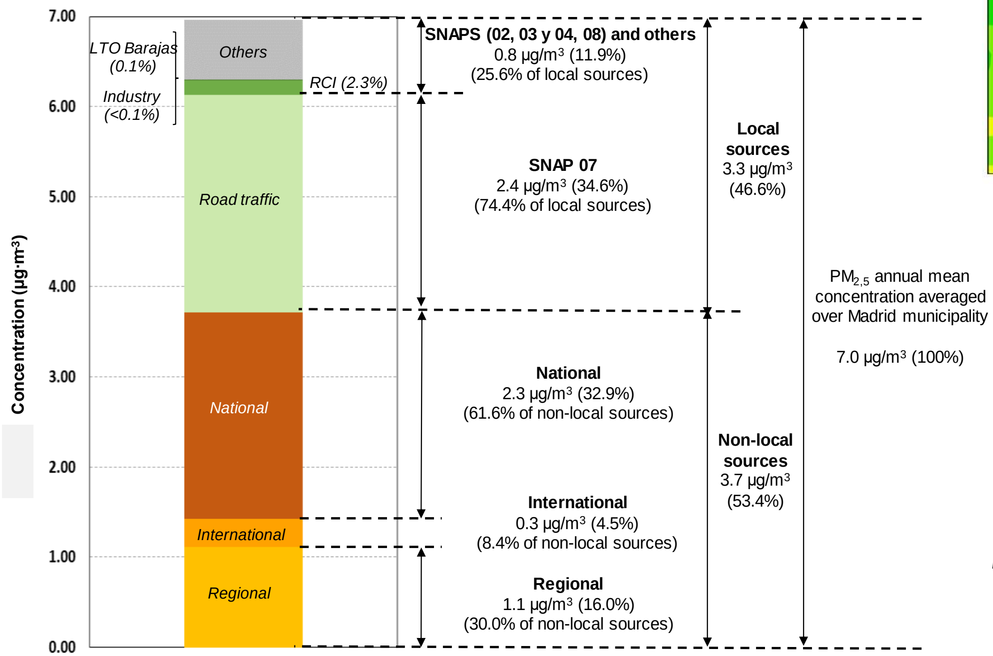


Figure 5. *Results summary of the sources contribution analysis (average annual concentrations of $PM_{2.5}$ for the Municipality of Madrid as a whole)*

The main difference in the case of particles is that average external contributions increase considerably in the municipality of Madrid, reaching contributions in excess of 50%.

With regard to local sources (≈46%), contributions are dominated by road traffic, in the region of 35%. Meanwhile, the RCI sector makes the least significant contribution to PM concentrations with a contribution of approximately 2%. The sum of the contributions from air traffic and the industry sector is less than 1% while, conversely, the 'Other' sector (mostly non-road mobile machinery and the waste sector) contributes approximately 11%.

B. OBJECTIVES OF PLAN A

B. Objetives of Plan A

B. Objectives

The overall objectives of Plan A are to ensure health protection against of the effects of atmospheric pollutants, help in the fight against climate change by reducing greenhouse gas emissions (GHG), and strengthen urban resilience to climate effects.

These objectives are crystallized in other more specific objectives that enable us to make a quantitative evaluation of the development of the Plan. They are pursuant to the fulfilment of a series of obligations that the city of Madrid needs to address immediately, and to voluntary commitments taken on by the municipality with broader time horizons. All in pursuit of a new model for a low emission city, based on principles of sustainability.

Specific objectives:

- To meet European and national legislation regarding air quality.
- To achieve air quality levels for particles in suspension in line with the guideline value of the World Health Organization (WHO).
- To achieve by 2030 an over 40% reduction in total GHG emissions* in the municipality of Madrid compared to 1990, thereby helping to meet the objectives of the Paris Agreement and the EU Climate Agenda, and in line with the new Covenant of Mayors for Climate and Energy.
  *total emissions= direct emissions + indirect emissions arising from electricity consumption
- To fulfil the commitment to reduce GHG emissions caused by urban mobility by 50% by 2030 compared to 2012.
- To develop a climate change adaptation strategy in order to reduce urban vulnerability to the risks associated with global warming.

In order to achieve these ambitious objectives, the Plan promotes the development of a set of measures organized into four action lines: sustainable mobility, urban regeneration, climate change adaptation, and awareness-raising and communication.

Sustainable mobility:

The priority actions are of a structural nature, focusing on the road network and the public space in order to reduce the intensity of private motor vehicle traffic and promote public transport and active mobility modes (pedestrian and bicycle). The design of a car parking policy using air quality criteria is another key element for the achievement of objectives.

A zero emissions central area is mapped out, for which a set of specific measures are designed in order to act as a catalyser for the necessary transition of the city as a whole towards a model of low emission mobility.

The Plan also calls for measures targeting the vehicle pool and key sectors with a high impact on mobility patterns (EMT, taxi, urban goods distribution, municipal fleet and employee mobility) in order to achieve greater efficiency and technological innovation, together with the promotion of electric mobility and shared mobility.

Urban regeneration:

Urban regeneration and neighbourhood rehabilitation strategies driven by the Madrid City Council, combined with energy efficiency actions, the promotion of distributed generation, the use of renewable energies, and measures aimed at reducing emissions from the residential, commercial and institutional sector, forge the path towards low emission urban management.

Climate change adaptation:

The Plan promotes interventions aimed at increasing the city's resilience to the effects of climate alterations. This climate adaptation programme, called Madrid + Natural, proposes the implementation of solutions based on nature to combat the urban heat island, the loss of biodiversity, and water management during episodes of intense precipitation.

Citizen awareness-raising

The fourth vital pillar of the Plan is the raising of citizens' awareness regarding the problems of air pollution and climate change. The Plan aims to make citizens' aware of the impact these problems have on the environment and on people's health, and of the tools that they themselves have to help build a more sustainable and healthy city.

It is designed as a cross-cutting tool that will run through all the Plan's various action lines. Its main objective is to raise citizen awareness of the consequences that poor air quality and rising greenhouse gases have in the short, medium and long term, and so encourage a change of behaviour towards more sustainable habits.

Collaboration with other public authorities

Achievement of the Plan's objectives requires us to find the means of coordination with central and regional public authorities that will enable us to address these challenges, the scope of which extends beyond the municipality.

C. EVALUATION OF THE IMPACT OF MEASURES

The evaluation of the foreseeable effect of the measures included in the Plan must be carried out in a differentiated manner, taking into account the nature of each one, the sector involved, and the pollutants of interest. While the methods used are diverse, the evaluation is based on the use of a combined approach for the main atmospheric pollutants and greenhouse gases, taking into consideration the relevant time scales in each case in relation to the objectives of Plan A.

The methodological approach proposed consists of a prior iterative process of evaluation of the measures before they are included in the final version of the document. In the case of the main compounds relevant to air quality, such as nitrogen dioxide or particles, the ultimate objective is to determine what the resulting concentration in ambient air will be for the city as a whole, which means making an air quality simulation. Given the complexity of this exercise and the need to incorporate the combined effects and possible synergies of all the measures, the first thing to do is to make an estimate, whenever possible, of the foreseeable effect of each measure in terms of emissions, as an indicator of the contribution that each measure might make to the improvement of air quality and the reduction of climate change impact.

The analysis will be completed with an estimate of the impact of air pollution on the health of the population of Madrid

Methods for the quantification of the effect of measures in terms of emissions

The measures proposed can be divided into two blocks depending on the source which is the main target for reduction. Measures 1 to 21 are aimed at reducing emissions of the road traffic. In the sources contribution analysis, road traffic is identified as the most important sector for levels of NO_2, PM10 and PM2.5 in Madrid. Emissions from traffic depend on many factors among which are those relating to traffic conditions, such as flows of different types of vehicles, congestion conditions, and journey speeds.

Therefore, for many of the proposed measures it is essential to determine what the effect will be on these parameters that bear nonlinear relationships among one another and require a detailed estimate based on a traffic simulation model on a regional scale. For this purpose we use the PTV Visum model implemented for Madrid by the municipal bus company *Empresa Municipal de Transportes* (EMT), which covers the entire Community of Madrid network.

This model allows us to make an estimate of the variation of both traffic intensity and speed in the various sections of the network, assuming variation hypotheses for both demand from private car users and supply of the network. Depending on the characteristics of the measure under consideration, a single scenario or a range of scenarios will be tested to enable a sensitivity analysis to be conducted. Traffic will be assigned to the network by means of a balancing algorithm. This algorithm assigns each traveller with the route that minimizes the generalized travel cost, which in this case is time. The result is an estimate of vehicle flow and the average speed in each section making up the network.

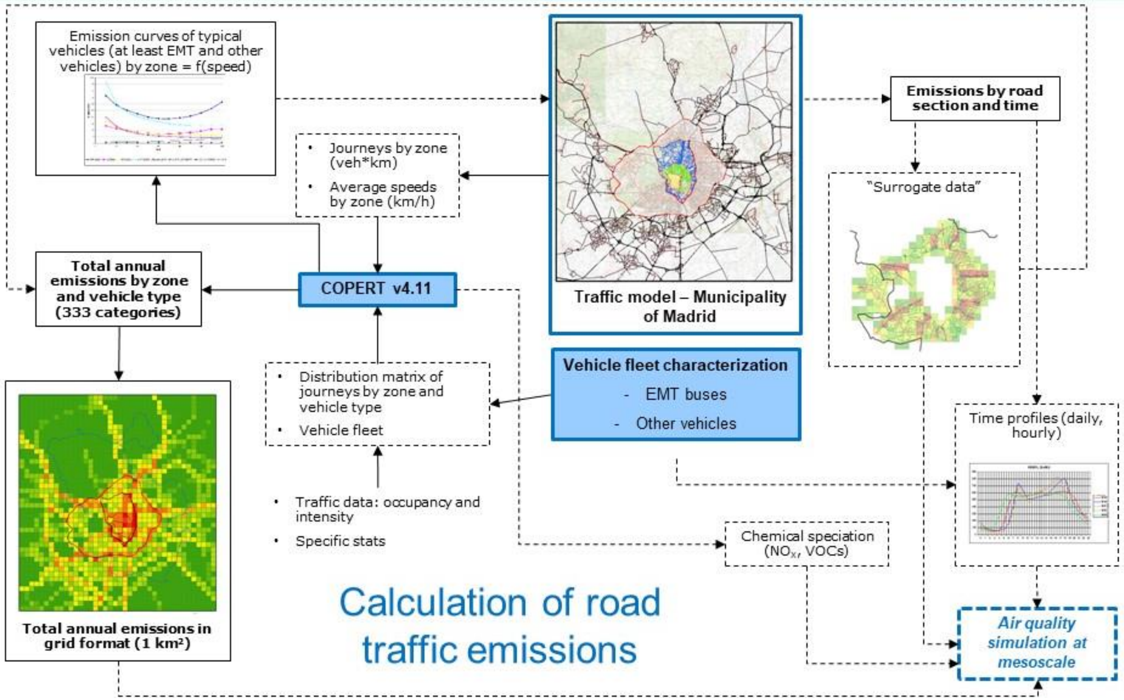


Figure 1. *Diagram showing of the methodology used to estimate emissions from road traffic in Madrid and preparation for its use in the air quality simulation system at mesoscale*

C.1. Effect on atmospheric emissions

Once we have obtained the changes to traffic flows in the network, we apply the emissions estimation methods used in the Madrid City Council's emissions inventory, which is based on the COPERT model (*COmputer Programme to calculate Emissions from Road Transport*) and includes highly detailed data regarding the characteristics of the vehicle pool, both private and public use vehicles (according to 5 concentric zones). The conceptual scheme of this approach is shown in **Figure 1.**

In this way emissions are calculated for a base case reflecting present day traffic characteristics, and for each scenario, taking into account the change in traffic conditions in each of the sections making up the city's road network (around 14,000 in total). The resulting emissions refer to the 1 km^2 air quality model grid to be used later for the overall assessment of the Plan. The difference between the two traffic model simulations allow us to quantify not only the total difference but also the spatial distribution, as illustrated in **Figure 2**, and time distribution.

As a general rule, a drop in the number of journeys has a direct proportional influence on emissions. However, fewer journeys also affect traffic speed, since a drop in the number of journeys may affect congestion conditions (associated with very low average speeds) which are those that cause the greatest amount of emissions per unit of distance travelled. By way of example, the Figure shows the effect of average speed on the emissions per unit of distance travelled of a diesel car, which is the predominant type of vehicle in Madrid according to characterization studies on the vehicle pool carried out to date. In general, it is interesting to note that while increasing average speeds under congestion conditions reduces emissions, in the case of free-flowing traffic (without frequent stopping and accelerating due to congestion) reducing speeds also causes emissions to decrease.

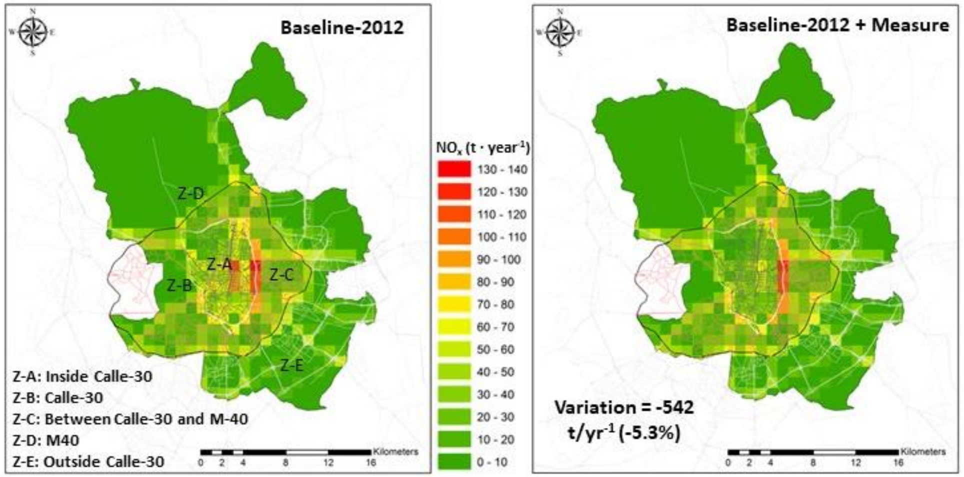


Figure 2. *Example of the quantification of annual emissions of NOx of a measure applicable to road traffic in the Municipality of Madrid*

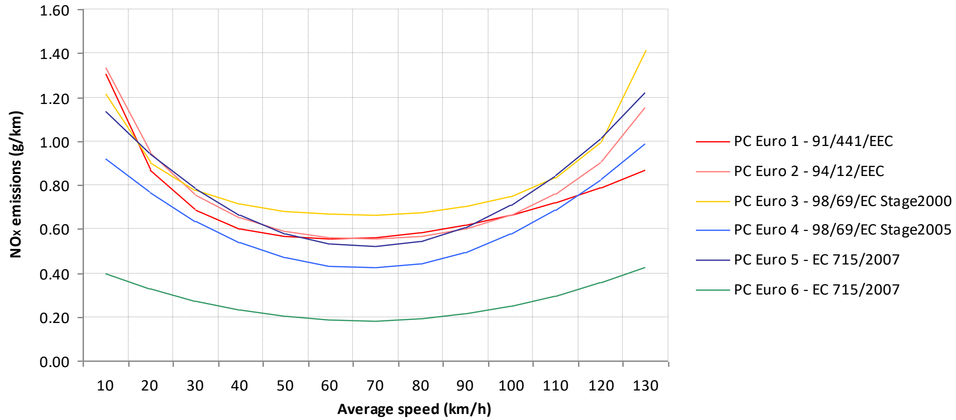


Figure 3. *Example of an emissions curve based on speed considered in emissions calculation models such as COPERT for road traffic at different average speeds*

C.1. Effect on atmospheric emissions

The other measures called for by the Plan affect residential, commercial and institutional (RCI) sectors (measures 22 to 27), municipal solid waste (MSW) management (25), or are of a cross-cutting nature (28 and 30). The plan also includes a measure (29) related to climate change adaptation.

Whenever possible they are quantified according to the municipal emissions inventory, using specific calculation methods for each sector or for each activity within each sector.

The following tables summarize **the overall impact of Plan A for the main pollutants relevant to air quality**

Variation of emissions of the main substances relevant to air quality due to Plan A (absolute)

Variation of emissions in 2020 with respect to base year (t/year); negative values mean a reduction						
CO	NMVOC	NH3	NOX	PM10	**PM2.5**	**SO_2**
-3972.8	-1688.2	-26.3	-3011.3	-223.0	**-221.6**	**-426.0**

Variation of emissions of the main substances relevant to air quality due to Plan A (relative)

Variation of emissions in 2020 from the base year (%); negative values mean a reduction						
CO	**NMVOC**	**NH_3**	**NO_X**	**PM10**	**PM2.5**	**SO_2**
-31.5	**-7.4**	**-2.6**	**-19.5**	**-22.7**	**-27.1**	**-42.8**

Variations are mainly due to the SNAP 07 (road transport) sector, which is affected by the measures of the sustainable mobility action programme. NOx emissions are down by 40%.

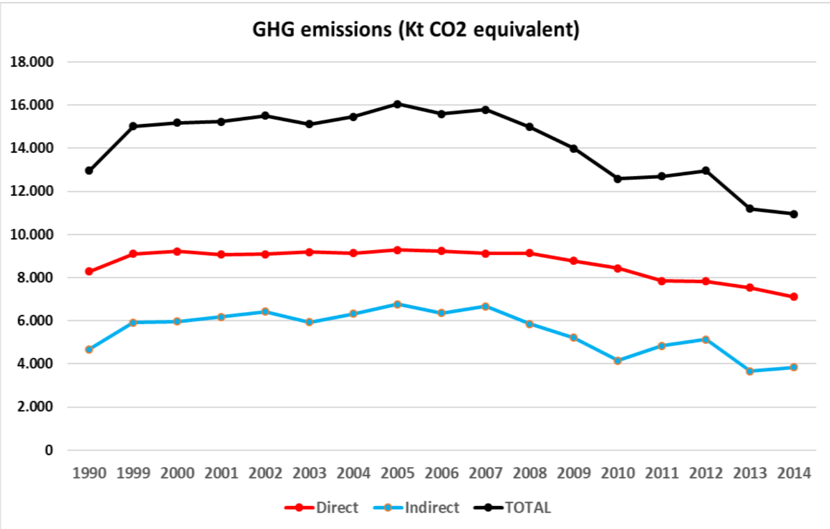
The promotion of efficient, low emissions heating and cooling systems, which forms part of the urban regeneration programme, calls for a significant reduction in emissions from the SNAP 02 (non-industrial combustion) sector. We expect a very positive effect on particulate emissions (over 30%) and SO_2 (over 50%), and a 4% reduction in NOx.

Roadmap for the reduction of greenhouse gas emissions

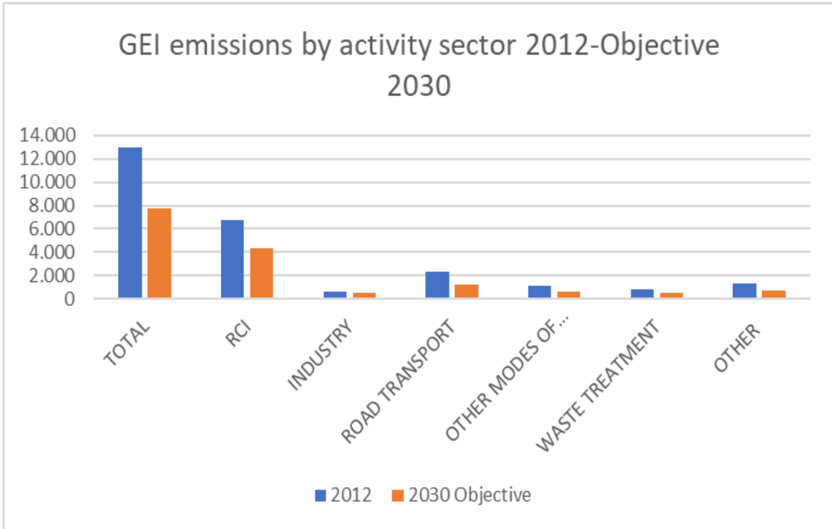
According to the Plan's objectives and greenhouse gas (GHG) emissions inventory data, total emissions of the City of Madrid in 2030 should be in the region of 7,800 kt CO_2-eq, meaning a reduction of 5,200 kt CO_2-eq over total emissions corresponding to 1990. A roadmap has been designed with this objective in mind, in which sector targets are defined and the main areas of action are mapped out.

The following graph shows the trend in total greenhouse gas emissions in the period 1990-2014.

Trend in GHG emissions 1990-2014:



Variation in total emissions by activity sector in the periods 1990-2012-2030:



In the design of this roadmap for the reduction of GHG emissions by 2030, special attention will be paid to the following aspects:

C.1. Effect on atmospheric emissions

Road traffic: Change in the modal split by reducing the presence of private cars and incorporating new technologies to the city's vehicle pool. Not only will GHG emissions be taken into account but also black carbon emissions from traffic, since it is estimated that one third of the total mass of PM2.5 is made up of the primary aerosol, black carbon, which has a global warming potential (GWP) of between 330 and 2,240 times that of CO_2.

Residential, commercial and institutional sector (RCI): Energy efficiency, the progressive electrification of energy demand, and generation from renewable sources on a national scale are the main lines of action to achieve the proposed objectives.

Other modes of transport: The reduction of greenhouse gas emissions from the Spanish electricity mix during the Plan's implementation period will enable indirect emissions of CO2-eq to be reduced in railway and metro transport. Meanwhile, AENA has set up a Carbon Management Plan for the period 2016-2021 which aims to reduce greenhouse gas emissions from airport activities.

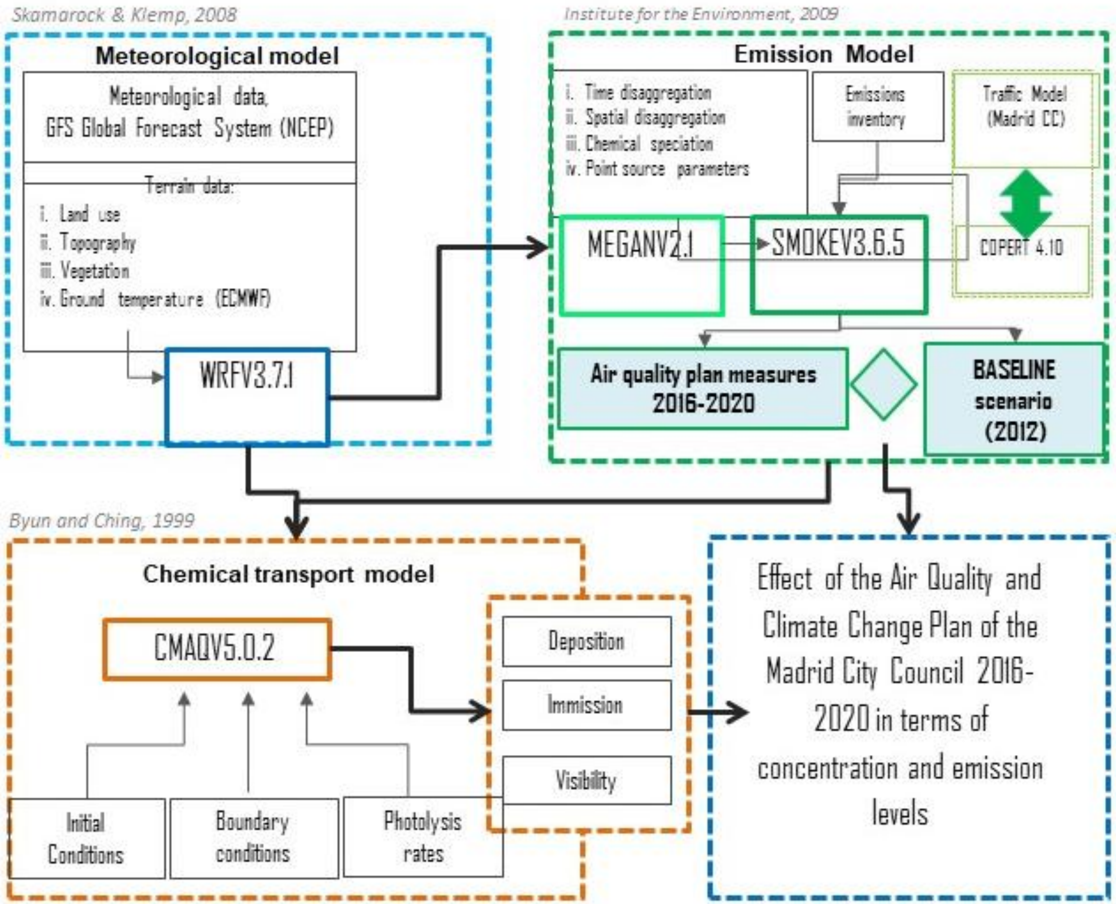
Waste: The optimization of the waste collection service, together with other actions focused on reducing consumption and promoting composting on a neighbourhood scale, will reduce emissions associated with this sector.

Other: Other actions planned are aimed at minimizing greenhouse gas emissions associated with the use of fluorinated gases in the RCI sector, given their high global warming potential.

C.2. Impact on air quality levels

The purpose of the impact evaluation of the 30 measures previously described in this Plan is to estimate the improvement in air quality in the City of Madrid and so be able to assess compliance with the limit concentration values for the various pollutants established in Royal Decree 102/2011 and the guideline concentration values defined by the World Health Organization (WHO) for both nitrogen dioxide (NO_2) and particulates (PM_{10} and $PM_{2.5}$) in 2020, the target year.

In order to meet these objectives within the specified time horizon (2020), in the region of 3000 t of NO_X and 220t of $PM_{2.5}$ (on an annual basis) could be knocked off the estimate made of the effect of the measures included in Plan A, which represents an overall reduction of close to 20% and 23% respectively (over the emissions in 2012, the base year). These reductions constitute a reasonable commitment for an ambitious objective, but one that is viable in the short term (horizon 2020). However, it is necessary to estimate the expected effect in terms of ambient air concentration of the main substances relevant to air quality. To this end a state-of-the-art Eulerian-type atmospheric simulation system was used. This enabled us to identify the quantitative and qualitative changes in emissions and their mesoscale evolution in ambient air, taking into account the main processes of transportation and transformation of pollutants. In addition to serving as a guide to the possibility of meeting the targets set in terms of air quality, this evaluation will also form the basis of subsequent evaluations on impacts on health.



C.2. Impact on air quality levels

This model has previously been used by the Madrid City Council in the evaluation of plans and a large number of measures, thus ensuring its effectiveness and the comparability of results.

The simulation domain (**Figure 1**) used for the evaluation of Plan A has a horizontal resolution of 1 km^2. East to west the area measures 40 km while north to south Figure is 44 km, sufficient to cover the entirety of the municipality of Madrid and provide an overview of Plan A for the urban area as a whole. Due to the irregular shape of the municipality's administrative boundaries, the domain includes some nearby municipalities, with the result that the domain covers the entire metropolitan area of Madrid including the capital and a number of satellite urban communities.

The results obtained from this modelling exercise can be broken down into two major blocks:

- Concentration levels of nitrogen dioxide (NO_2), which includes two indexes governed by current legislation: the annual average, which may not exceed 40 µg/m^3, and the hourly average which may not exceed 200 µg/m^3 more than 18 times a year.
- Annual average concentration levels of PM_{10} and of $PM_{2.5}$, for which current legislation sets limit values of 40 µg/m^3 and 20 µg/m^3 respectively. In the case of PM_{10} there is also a daily limit value of 50 µg/m^3 which may not be exceeded more than 35 times a year.

In all cases, differences between the **base year (2012)** and the **target year (2020)** are shown in relative terms in order to analyse the spatial patterns of the differences and so locate in which part of the domain the measures adopted under the Plan are most effective.

This system provides an optimal tool for evaluating interactions between all the sources and the geographic areas, and so obtain an overview of concentrations at city level. That is to say, it is an approach whose resolution essentially allows us to evaluate variations in urban background concentrations. It is therefore not possible to accurately predict concentrations at very specific points.

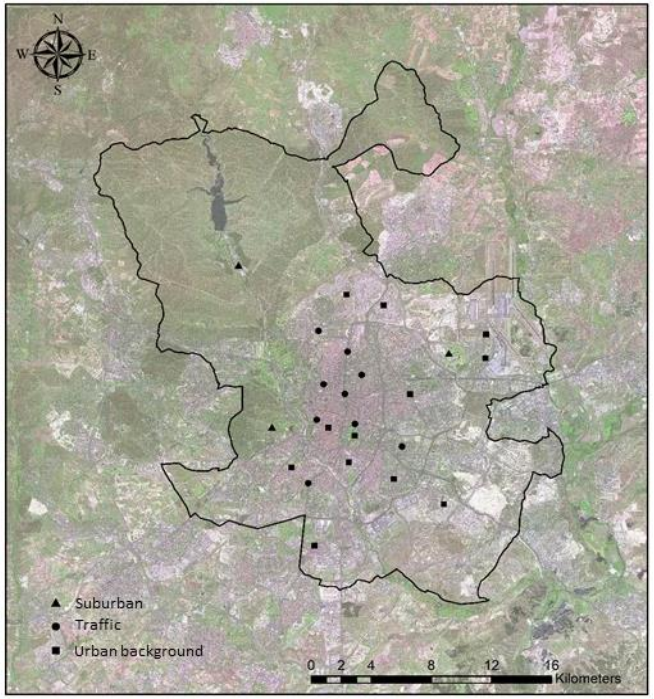


Figure 1. *Simulation domain used to evaluate Plan A and the siting of the air quality measuring stations forming part of the monitoring network of the Madrid City Council*

Nitrogen dioxide (NO2)

Annual average (40 µg/m³)

The results of the simulation call for a clear drop in NO_2 concentration levels by 2020 for the entire domain and, more specifically, for the municipality of Madrid. The maps below **¡Error! No se encuentra el origen de la referencia.**show the values for the annual average (the legally established limit value, coincident with the guideline v alue defined by the WHO) for both the base year (2012) and the target year (2020) (**Figure 2**). If we examine the spatial patterns of the two maps we see that NO_2 concentration levels are dominated by road traffic, with the highest values being in the centre of the city.

The annual average concentration of NO_2 corresponding to the entire area of the municipality of Madrid would fall from 17.2 µg/m³ in 2012 to 13.2 µg/m³ in 2020, equivalent to a 23% drop, slightly higher than Figure for the reduction in NO_X emissions (19.5%).

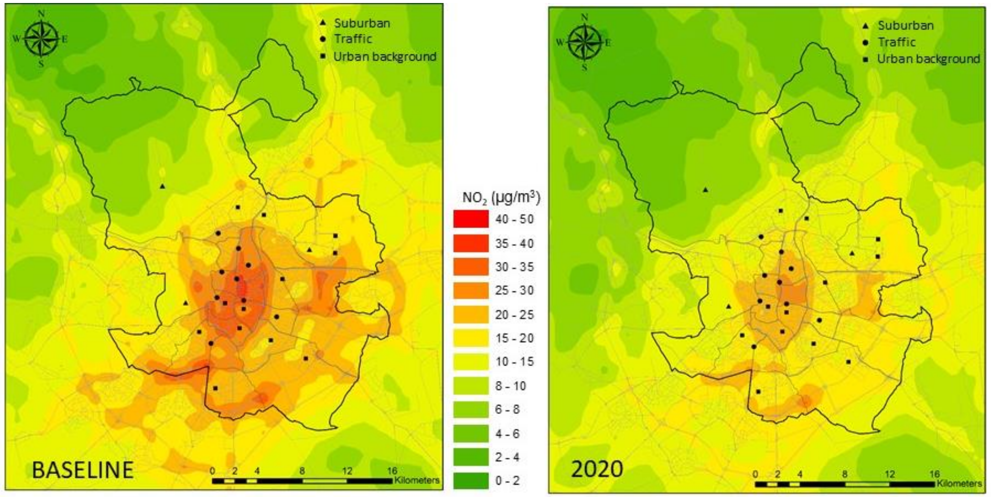


Figure 2. *Average annual concentrations of NO_2 predicted for base year 2012 left) and 2020 (right)*

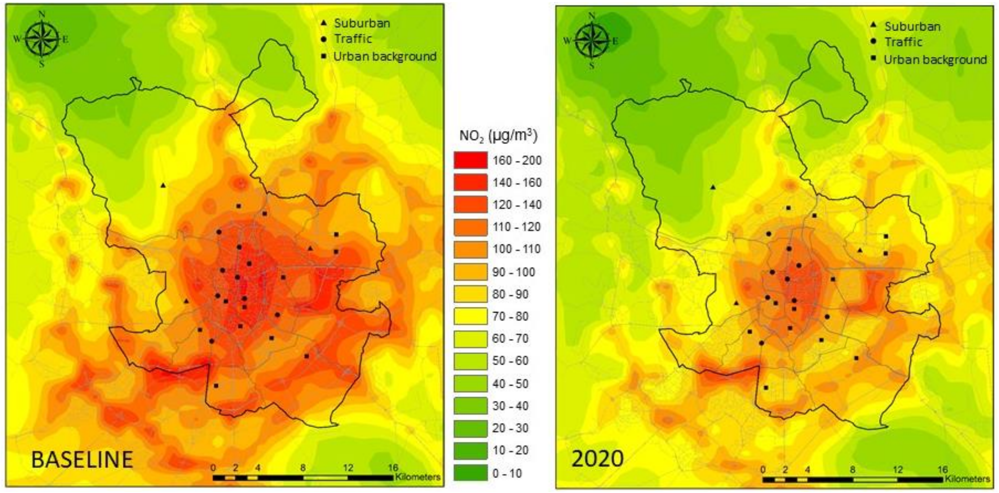


Figure 3. *Hourly limit value of NO_2 of the annual series predicted for base year 2012 left) and 2020 (right)*

Hourly mean (200 µg/m^3, which may not be exceeded more than 18 times/year)

The spatial patterns corresponding to when this hourly value is exceeded are primarily dictated by the influence of the road traffic, as is the annual value. **Figure 3** shows the simulations carried out for the two years. As in the case of the annual average there is a generalized drop; the average reduction for the domain as a whole is 18%. In the municipality this reduction is slightly higher, in the order of 20 µg/m^3 in absolute terms.

Particles (PM10 and PM2.5)

Annual average of PM10 (40 µg/m3)

The results of the simulation for the base year and the simulation predicting the various measures implemented in the emissions scenario to 2020 reveal much lower concentrations, as shown in **Figure 4**.

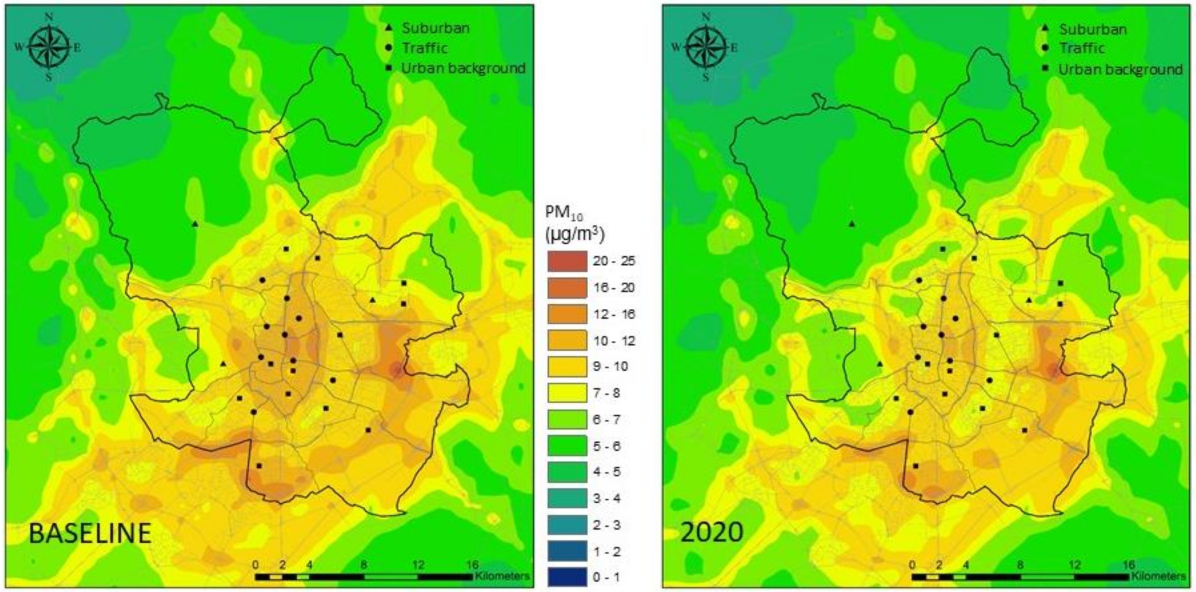


Figure 4. *Annual average concentrations of PM_{10} predicted for 2012 (left) and 2020 (right)*

Once again there is a clear relationship between the maximum concentration and road traffic emissions; for the base year and for 2020 the spatial pattern is practically the same, with absolute maximum values being under 23 µg/m^3 in both cases. We can see a generalized drop in concentration levels of PM_{10}, especially in the centre of the domain in the area referred to as the 'central zero emissions zone', defined in Plan A. In this zone the reductions are as high as 24%, which means reductions of up to 2.5 µg/m^3. In the rest of the municipality the average reduction is 8%, equivalent in absolute terms to 0.7 µg/m^3.

Daily average (50 µg/m3,which may not be exceeded more than 35 times/year)

In both scenarios (2012 and 2020) we see a spatial pattern in which concentration levels are clearly influenced by road traffic and to a lesser extent by the RCI sector. We also see a clear drop in these levels as a result of the Plan A measures, which succeed in reducing this value for the municipality as a whole by around 9%, the equivalent to nearly 2 µg/m^3 in absolute terms (See **Figure 5**).

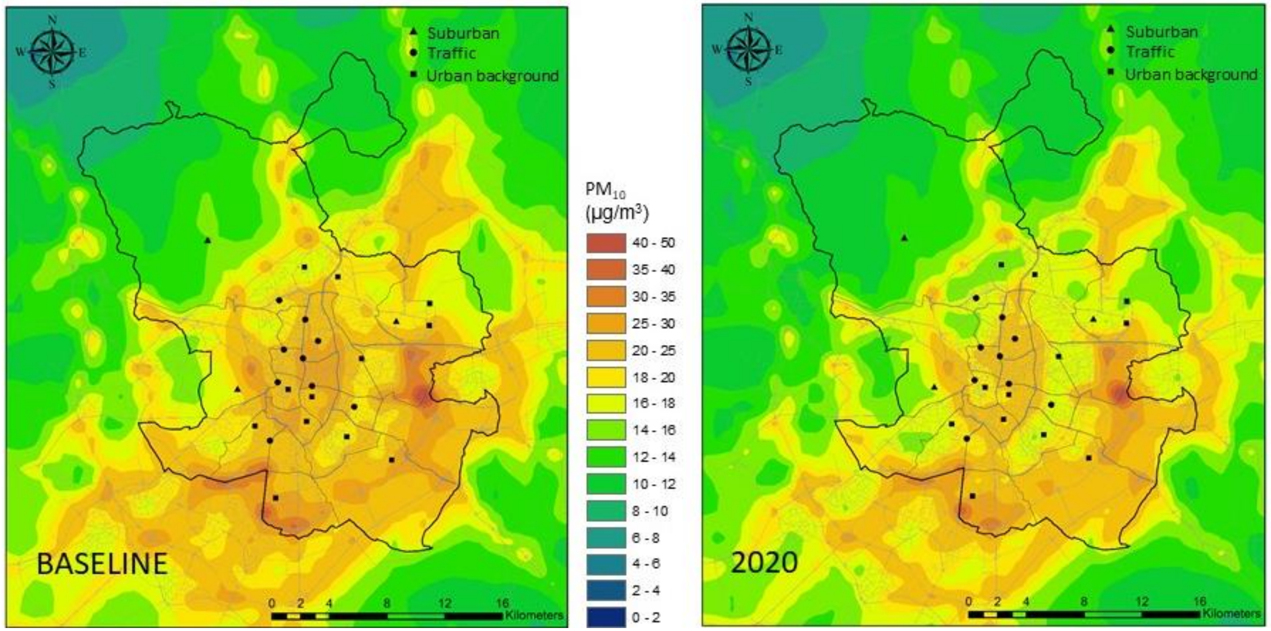


Figure 5. *Hourly limit value of PM_{10} of the annual series predicted for 2012 (left) and 2020 (right)*

Annual average PM2.5 (20 µg/m3)

Fine particles (diameter < 2.5 µm) are a very serious pollutant due to their adverse impact on human health. **Figure 6** shows the maps for annual average concentration according to the simulations carried out for both scenarios.

In general, the values obtained are much lower. The annual average concentration of $PM_{2.5}$ corresponding to the total area of the municipality of Madrid would fall from 7.0 µg/m^3 in 2012 to 6.3 µg/m^3 in 2020, representing an average drop of 9%. We see that the zones with greatest reductions are to be found in the area defined as the zero emissions zone, with reductions of up to 20%, or approximately 2.5 µg/m^3 in absolute terms.

C.2. Impact on air quality levels

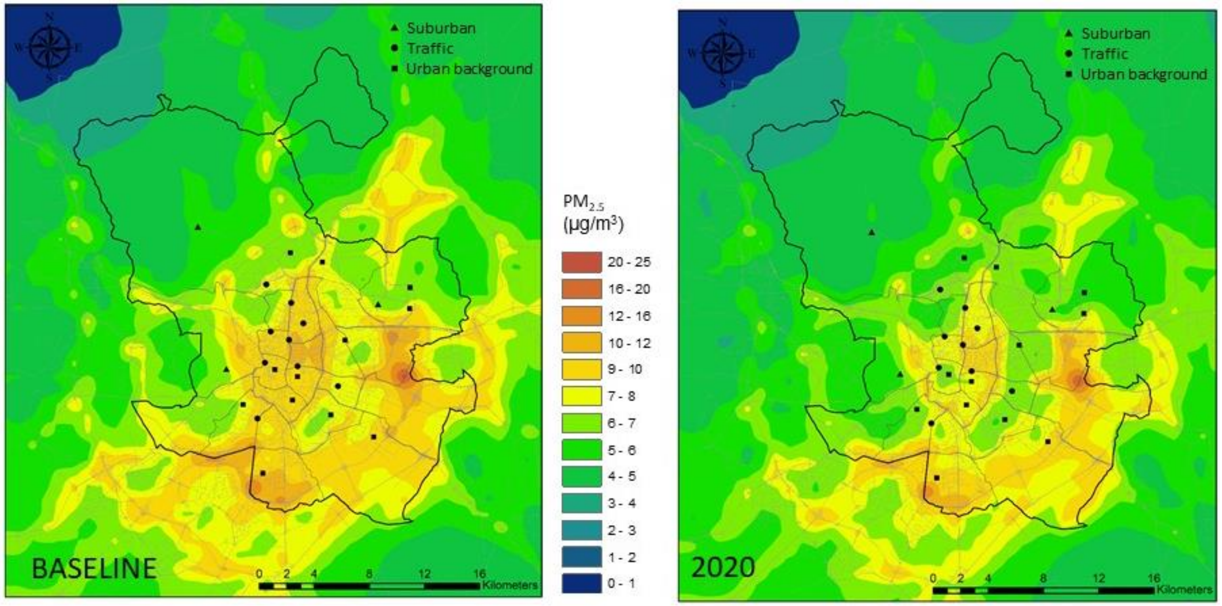


Figure 6. *Annual average of $PM_{2.5}$ predicted for 2012 (left) and 2020 (right)*

It should be noted that, according to the simulation carried out, approximately a third of the total reduced mass of $PM_{2.5}$ (approximately 78 tonnes/year) consists of the primary aerosol black carbon. As well as being a fraction which is very harmful to health, these particles are especially damaging in terms of global warming. Unlike other atmospheric aerosols, black carbon has a powerful net warming effect. Although its average lifetime in the atmosphere is much shorter than that of the main greenhouse gases, various authors consider that its potential warming effect is between 330 and 2240 times higher than CO_2. In the light of these references we may assume that the reduction of $PM_{2.5}$ concentrations observed may also make a considerable contribution to Plan A's climate change objectives (in the same order of magnitude as the improvement achieved by the reduction of GHG).

Conclusions

The simulation system used provides us with a consistent overview of the trend in air quality in Madrid resulting from the application of Plan A. **Table 1** summarizes the reduction in concentrations of the various limit values of NO_2, PM_{10} and $PM_{2.5}$ in three geographic areas: municipality of Madrid as a whole, inside Calle-30, and the central zero emissions zone for 2020 with respect to the base year (2012).

In general, the results show that by using measures of a structural nature to reduce emissions it is possible to reduce the annual average concentration of all the main pollutants. However, these measures would also have a very considerable effect on the moderation of concentration peaks, which would doubtless help reduce high concentration episodes and limit the effects on health of an acute nature.

For the annual average concentration of NO_2, the reduction in the municipality as a whole is 23%, which means we would achieve reductions in the order of 4 µg/m³. Inside Calle-30 these reductions are even greater, slightly over 7 µg/m³. In the area we call the 'Central zero emissions zone' these reductions could be as much as 10 µg/m³, which is a very considerable amount considering recent efforts and current levels.

POLLUTANTS AND AVERAGE PERIODS		REDUCTION (%) (µg/m³)		
		In the Municipality	Inside Calle-30	Central zero emissions zone
NO_2	Annual average	23%/4.0	26%/7.3	30%/9.6
	Percentile 99.8	20%/1.8	18%/24.7	20%/27.9
PM_{10}	Annual average	8%/0.7	14%/1.5	24%/2.5
	Percentile 90.4	9%/1.7	15%/3.6	24%/5.7
$PM_{2.5}$	Annual average	9%/0.6	16%/1.4	24%/2.2

Table 1. *Summary of the analysis of the reduction in concentration for the different limit values of NO_2, PM_{10} and $PM_{2.5}$ in three geographic areas: Municipality of Madrid, inside Calle-30, and the* central zero emissions zone defined by the City Council in Plan A.

C.2. Impact on air quality levels

In short, the implementation of Plan A will mean significant progress in the reduction of the adverse effects of air pollution and will bring Madrid nearer to achieving the targets set. We assume a reduction in the order of 25% in NO_2 concentrations observed at monitoring network stations. The results suggest that Madrid will have no difficulty in complying with the required legal values for particulate matter if the actions called for by Plan are implemented and levels could be close to those proposed by the World Health Organization, especially in the case of $PM_{2.5}$, which is the most dangerous fraction for human health in general.

The improvement in air quality expected from the application of Plan A would be enhanced by measures that fall outside the geographic and administrative scope of the municipality and contribute to the reduction of the contribution from external sources (regional and national). These represent 28.3% in the case of nitrogen dioxide and 53.4% in the case of PM 2.5, as described in point 3.4 ‘Analysis of sources contribution to air quality levels’.

C.3. Impact on health

Air pollution impacts on the health of the population

Air pollution is a key factor in people's quality of life and state of health. It causes a wide range of effects of different degrees of severity, from mild (such as coughing or sore throat and eyes) to serious (such as hospitalization or premature death). These are mainly related to cardiovascular damage (heart attacks, heart failure, etc.) and respiratory damage (asthma, COPD, etc.), and antenatal effects (e.g. low birth weight). The International Agency for Research on Cancer has established that air pollution is carcinogenic for humans (Group 1), more specifically causing lung cancer. Scientific research is now providing fresh evidence of other effects on health, such as retarding neurological and psychomotor development in infants and even accelerating cognitive impairment in the elderly.

Impact on health is distributed unevenly throughout the population

Effects on health are observed especially among the most susceptible and vulnerable groups, which suffer the most from the consequences of living in unhealthy environments.

Breathing polluted air is a special threat to children, the elderly, pregnant women, and the chronically ill. Other groups may also be at a higher risk from being exposed to pollutants, such as workers or athletes who work or train in the open air, or residents of neighbourhoods close to busy roads. In order to prevent the effects on health caused by air pollution we need to reduce the most vulnerable populations' exposure to that pollution.

Protecting the health of the population means following the recommendations of the World Health Organization (WHO)

Although air quality is gradually improving in European cities, there is still evidence of significant adverse effects on health. In the city of Madrid we continue to see breaches of European regulations, as in the case of nitrogen dioxide. Additionally scientific evidence shows that health is not protected by meeting the regulations, because the limits specified for some pollutants are higher than those recommended by the World Health Organization. A more ambitious approach and a closer adherence to WHO guidelines is required, as was set out in the 'Pure air for Europe' Programme of 'Air Puro' for Europe in 2013. For this reason we believe it necessary to review the effectiveness of the measures already adopted and consider implementing new ones to control air quality.

a. The Clean Air Policy Package - Environment - European Commission [Internet] [consulted on 01/02/2017]. Available at: http://ec.Europe.eu/environment/air/clean_air_policy.htm

C.3. Impact on health

<u>Evaluation studies of air pollution and health in Madrid</u>

1. **Epidemiological research into the effects of air pollution on the health of the population of Madrid**

   Madrid is the most populous city in the country, with 3,165,541 registered inhabitants according INE (National Statistics Institute) figures for 2016 (15% are under 16 years and 21% over 65). The integration of existing municipal information in different areas (environmental and health data) allows us to make the initial diagnostic of the effects of air pollution on health. This Plan proposes the design and development of an epidemiological study capable of analysing various causes of mortality and morbidity, taking into consideration age groups and gender. These analyses will be used for the various atmospheric pollutants.

2. **Evaluation of the impact on health of the implementation of the measures forming part in the Plan**

   Health Impact Assessment (HIA) is a tool whereby a policy, programme or project may be assessed in terms of its potential effects on people's health. We propose using it to evaluate the benefits to health that the adoption of the measures called for in this Plan might bring. Its main purpose will be to support decision making processes in order to maximize the positive effects on health of the application of these measures.

3. **Economic evaluation of the impact on health attributable to air pollution**

   Air pollution also has an economic impact since it reduces the quality of life of the population, which in turn increases the cost of healthcare and reduces labour productivity. Additionally, in order to take a better informed decision it is essential to evaluate the social benefits associated with better air quality. Given that the entire population is exposed to this environmental risk, the impact on health tends to give rise to a not inconsiderable economic burden in terms of health care and public health.

   This Plan calls for an estimate of the economic cost of the mortality and morbidity attributable to air pollution in the city of Madrid.

D. Executive summary

What is the city of Madrid's Plan A?

Plan A is the Madrid City Council's air quality and climate change plan of. It is Plan A because it targets the 'Air' we breathe and because there is no Plan B if we wish to build a sustainable city which assures the health of its inhabitants by meeting the challenge of pollution, and if we wish to protect the city against the impacts of climate change.

Why is an air quality and climate change plan necessary?

- **Because acting on air quality and climate change is a public health priority**

- **Because integrated actions targeting air quality and climate change generate synergies and prevent inconsistencies**

Traditionally air quality and climate change policies and strategies have been addressed in an independent and isolated manner. However, scientific studies and the analysis of policies in these matters show that the challenges linked to air pollution and climate change need to be addressed jointly, under a coherent and integrated management policy.

- **Because a new low emission city model requires combined action on mobility, urban development, and the management of energy and natural resources. What are the Plan's objectives?**

The overall objectives of Plan A are to ensure health protection against the effects of atmospheric pollutants, to help in the fight against climate change by reducing greenhouse gas emissions (GHG), and to strengthen urban resilience to climate effects.

These objectives are crystallized in other more specific objectives that enable us to make a quantitative evaluation of the development of the Plan and are pursuant to the fulfilment of a series of obligations that the city of Madrid needs to address immediately, and to voluntary commitments taken on by the municipality, with broader time horizons. All in pursuit of a new model for a low emission city, based on principles of sustainability.

Specific objectives:

· To meet European and national legislation on air quality.
· To achieve air quality levels for particles in suspension in line with the guideline value of the World Health Organization (WHO).
· To achieve by 2030 an over 40% reduction in total GHG emissions in the municipality of Madrid compared to 1990, thereby helping to meet the objectives of the Paris Agreement and the EU Climate Agenda, and the new Covenant of Mayors for Climate and Energy.

· To fulfil the commitment to reduce GHG emissions caused by urban mobility by 50% by the year 2030, the base year being 2012.
· To develop a climate change adaptation strategy, reducing urban vulnerability to the risks associated with global warming.

In order to achieve these ambitious objectives, the Plan promotes the development of a set of measures organized into four action lines: sustainable mobility, urban regeneration, climate change adaptation, and awareness-raising and cooperation with other public authorities.

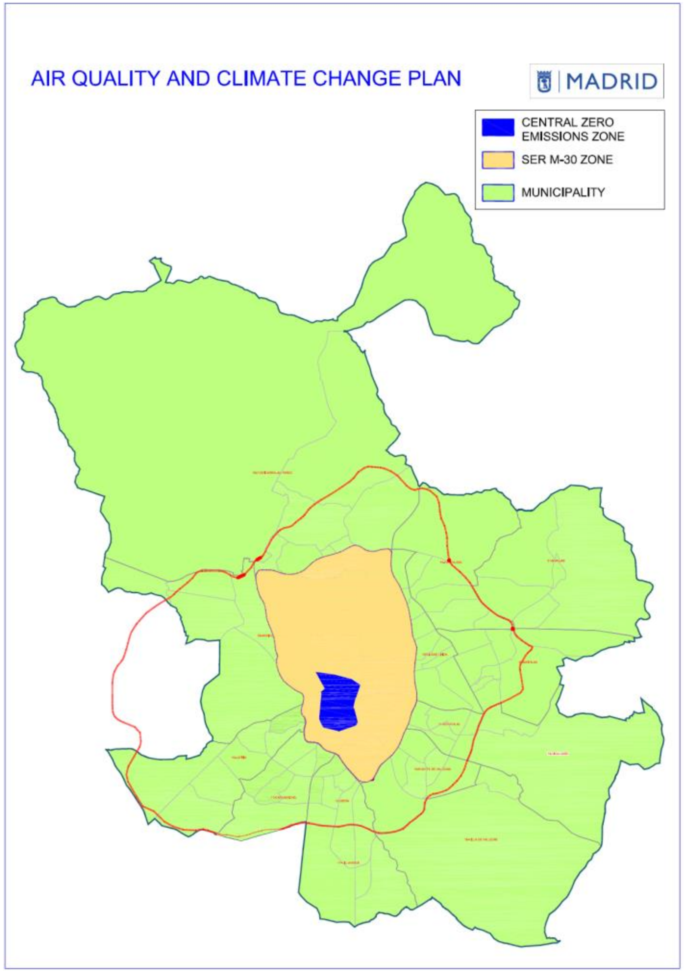
And what is to be the time frame?

The Plan's time frame calls for two horizons; 2020 for the implementation of specific structural and technological measures resulting in a significant reduction of emissions, as required by air quality regulations, and a longer term horizon, to 2030, for the necessary urban regeneration, energy transition, renewal of the vehicle pool and consolidation of a low emission city model that will ensure that Plan A's set of objectives is achieved.

Towards a new model of city: main action lines

The Plan's action lines are designed to address jointly two major challenges of the city: response to climate change and improvement of air quality. This joint approach provides interesting synergies that will make it easier to meet the objectives pursued by the complementary action lines.

The first two action lines are key to achieving the necessary reduction of polluting emissions of the both gases and toxic particles, such as greenhouse gases which cause climate change. The third action line focuses on achieving the necessary conditions to ensure the optimal adaptation of the city to climate change by means of nature-based solutions. The fourth and final line is of cross-cutting nature, addressing both climate change and air quality objectives by raising citizen awareness, collaborating with other public authorities, and providing incentives for change.



MORE SUSTAINABLE MOBILITY:

- Reduction of the intensity of private motorized traffic: measures targeting the road network and public space to promote active modes of mobility (pedestrian and cyclist) and public transport.

- Measures promoting low emissions technology:
  - Promotion of electric mobility
  - Actions on emissions from strategic fleets (buses, taxis, municipal services fleets) and urban distribution of goods

- Measures targeting private motorized cars: tax incentives and the gradual introduction of restrictions on access, parking, and the vehicles that pollute the most.

- Production of a sustainable municipal mobility plan.

LOW EMISSION URBAN MANAGEMENT AND HIGHER ENERGY EFFICIENCY

- Promotion of the replacement of polluting heating fuels: prohibition of the use of coal and regulation of the use of biomass
- Promotion of the use of renewable energies

CLIMATE CHANGE ADAPTATION

Promotion of projects and implementation of solutions based on nature, in order to adapt the city to the environmental threats arising from climate alterations.

Interventions in buildings, neighbourhoods and the cities major infrastructures.

CITIZEN AWARENESS-RAISING AND COLLABORATION WITH OTHER PUBLIC AUTHORITIES

The main aim here is to raise citizen awareness regarding the consequences in the short, medium and long term of both poor air quality and increasing greenhouse gases, and to seek the necessary channels of coordination with central and regional public authorities that will enable us to address these challenges, the scope of which extends beyond the municipality.

The 30 measures of Plan A:

Sustainable mobility

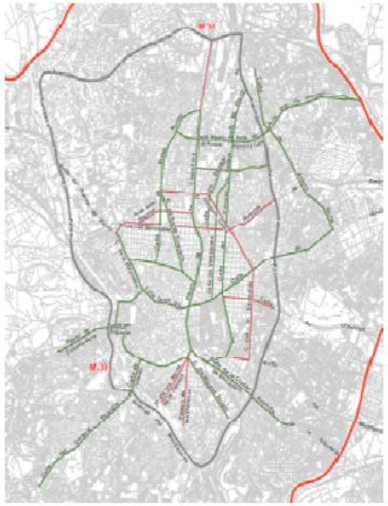
Actions targeting the road network and public space aimed at reducing the intensity of private vehicle traffic and the promotion of the public transport and active modes of mobility.

Measure 1. Central Zero Emissions Zone:

Delimitation of a closed perimeter Central Zone with restricted access in which through traffic will be banned. The aim is to promote a new model of low emission mobility which prioritizes pedestrians, cyclists, public transport and, in general, the least polluting vehicles.

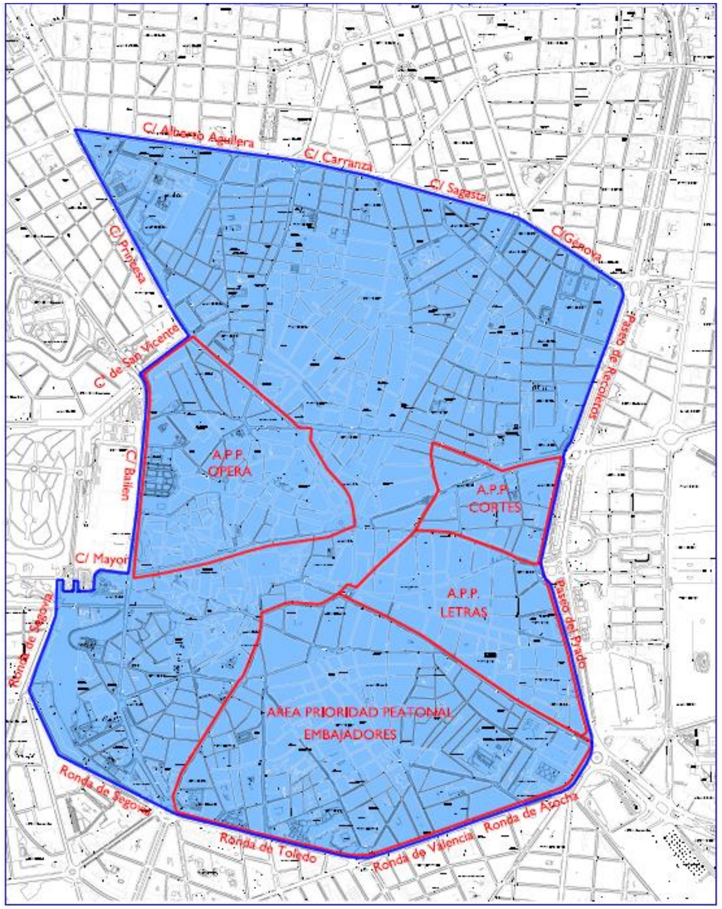
Measure 2. Redesign of the main traffic distribution channels and periphery-centre connections:

Action targeting the main urban axes, aimed at reducing the space dedicated to cars in favour of more sustainable modes of transport, by promoting specific infrastructures supporting public transport, cycle mobility, and the recovery of space for pedestrians.



Measure 3. Prioritization of pedestrian mobility:
Interventions in the public space related to urban regeneration, with a direct impact on short-distance mobility in neighbourhoods, improving the quality of the public space, reducing noise and air pollution and the accident rate, all aimed at creating pedestrian-friendly environments. Identification and characterization of the pedestrian network and creation of 30 km/h zones.

CENTRAL ZERO EMISSIONS ZONE

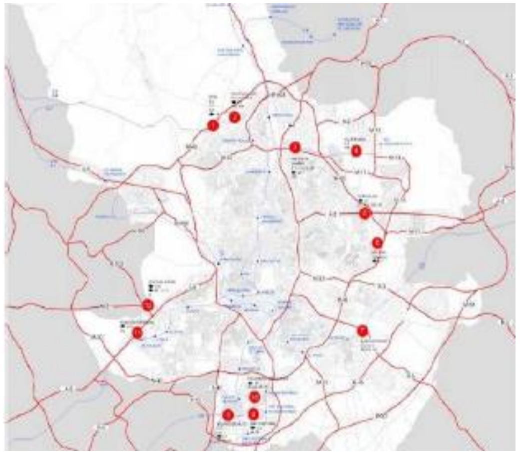


Measure 4. Improvement and extension of the cycle network and cycling mobility: Review and extension of the network. Creation of a network of safe, effective cycle routes which are integrated with other transport modes, with the aim of achieving a 5% share in the modal distribution of journeys by 2025. In the first phase (2017) 36 km of new cycle lanes will be built along the main roads of the city.

Measure 5. Extension of the public bicycle system and coordination with the Madrid Regional Transport Consortium (CRTM): To increase the number of bicycles and extend the scope of action of BiciMAD to zones with high demand that enable cycles to be used as a regular daily and recurring mode of transport. The cycles are to be renewed and technological means developed to enable BiciMAD to be fully integrated in the public transport network of Madrid.

Measure 6. Regulation of car parking using air quality criteria: Management of the supply of destination car parking using air quality criteria, both for surface parking, with an increase of discounts and penalties according to the vehicle's emissions in SER (regulated parking) zones and the implementation of new systems regulating destination car parking, and for underground car parks, with a gradual increase in spaces for residents at the expense of the supply of short-stay spaces.

Measure 7. Speed limits on metropolitan accesses and the M-30: With the aim of channelling traffic to and from sectors of the urban and metropolitan periphery on orbital roads around the city (M-40 and M-45), 70 km/h is to be set as the maximum speed on access roads to the city from where they intersect with the M-40, and the 70 km/h speed limit is to be extend to the entire length of the orbital M-30 road (underground + surface).



Measure 8. Network of intermodal car parks in the metropolitan ring: Establishment of a network of car parks in the metropolitan ring, connected to public transport nodes, facilitating transfer from private car to collective transport, comprising twelve new car parks in the city of Madrid providing 9,570 places.

The car parks will be sited at a minimum distance of 200 metres from the point of access to collective transport and will offer fare systems tailored to intermodality.

Measure 9. Priority roads and traffic light priority for EMT buses: Functional redistribution of the road network in order to establish roads giving effective priority to EMT buses through the use of bus-only lanes, and the introduction of traffic light priority systems. These measures will improve journey times and ensure a more frequent and regular bus service.

These combined actions will raise the commercial speed and quality of service of surface public transport.

Measure 10. Infrastructures reserved for public transport: To establish a framework of collaboration and coordination with other public authorities enabling the city's radial access and egress roads to be provided with bus lanes (BUS-VAO-ECO lanes for buses, high occupancy vehicles, and low pollution vehicles) connecting with modal interchange points and, in particular, with a network of park-and-ride car parks.

Creation of high capacity bus corridors or BRT (Bus Rapid Transit) to interconnect districts.

Actions targeting the vehicle pool of key sectors with a high impact on air quality and the promotion of sustainable employee mobility and shared mobility.

Measure 11. Extension and renewal of the EMT fleet of buses: towards a 100% low emission fleet: Renewal of the EMT fleet via an investment programme (2017-2020) with the acquisition of 750 new buses (natural gas, hybrid and electric). Large scale introduction of electric buses (Operating base: Elipa).

Measure 12. Taxi: incentives to convert to low emission vehicles: Annual municipal grants for the acquisition of vehicles with a ZERO or ECO label. As from 2018 only replacement by this type of vehicles will be authorized.

Measure 13- Optimization of the taxi service using environmental criteria: Increase of the efficiency and sustainability by means of the optimization of routes and other structural actions to improve the service and reduce empty taxi cruising time.

Measure 14. Urban distribution of goods: Optimization of the management of loading and unloading spaces on public roads: Creation of a system of management and control of loading and unloading spaces on roads in the city of Madrid by means of a specific application and a municipal register of urban goods distribution vehicles (UGD register).

Measure 15. Urban distribution of goods using low emission vehicles: Application of measures prioritizing access and timetables for low emission vehicles in the Central Zone and SER regulated parking zones.

Measure 16. Public-private collaboration for innovation and efficiency in urban logistics processes: Formulas for public-private collaboration in sustainable and innovative urban logistics.

Measure 17. Renewal of the vehicle pool: Actions aimed at the gradual replacement of motor vehicles with the objective of restricting the circulation of the most polluting vehicles (without a DGT sticker) throughout the municipality of Madrid by 2025.

Measure 18. Low emission municipal services fleets: Increase of ZERO and ECO vehicles in Madrid City Council's fleet until by 2030 they account for 90% of the fleet of moped, motorcycle, and passenger car type vehicles with a permitted gross vehicle mass of less than 3,500 kg, and for 80% of the fleet of vehicles a permitted gross vehicle mass of over 3,500 kg, used either for subcontracted services or for those managed directly by the various municipal departments.

Measure 19. Sustainable employee mobility plans: Promote the development of sustainable mobility plans in companies and also in public administrations, taking advantage of the role they play as leaders by example, starting with the drawing up of a municipal sustainable mobility plan. Complementarily, encourage the Regional Government of the Community of Madrid to pass a law on sustainable mobility.

Measure 20. Charging network for electric vehicles and supply of alternative fuels: implementation of an infrastructure of alternative fuels in accordance with Directive 2014/94. Promotion of an electricity charging network in publicly accessible spaces, municipal and residents' car parks, work places and municipal facilities. Extension of publicly accessible networks for other alternative fuels.

Measure 21. Promotion of shared mobility initiatives: Promotion and support of shared mobility initiatives, in order to improve and diversify the transport supply in the city of Madrid.

Urban regeneration

Measure 22. Neighbourhood regeneration and rehabilitation: Development of the urban regeneration strategy 'Madrid Regenerates' which addresses the rehabilitation of the building stock (Plan MAD-RE), the refurbishment of public spaces, local energy production, green and short-distance mobility, the management of water and materials, and the re-naturalization of the city.

Measure 23. Promotion of efficient low emission heating and cooling systems: Promotion of the implementation of technological improvements of heating, air-conditioning and sanitary hot water. Among some specific actions are the elimination of the use of coal by 2020, the promotion of efficient heating and cooling systems, the regulation of the use of biomass throughout the municipality, and the development of high efficiency heating and cooling systems.

Measure 24. Distributed generation and use of renewable energies: Incorporation of less polluting technologies, reduction in demand by mean of energy efficiency and increasing self-sufficiency by means of distributed generation bringing energy production from renewables to consumption centres.

Establishment of a roadmap for the development of renewable energies, review of discounts on the IBI (property tax) for having solar energy facilities, and promotion of the exploration and exploitation of the potential energy from the subsoil.

Measure 25. Reduction of emissions from waste management: Implementation and optimization of the waste management processes at the Valdemingómez technological complex with the aim of reducing the emissions they produce.
Greater recovery of waste materials with new sorting lines, the entry into operation of composting facilities, complemented by the gradual implementation of the selective collection of the organic fraction in the municipality. Upgrade of the performance of the Biogas Treatment Plant (BTP), increasing production of bio-methane, and the use of electricity generated from biogas not injected into the network.

Measure 26. Energy monitoring and consumption management in municipal facilities: Driving the transition towards an energy model based on efficiency and transparency of information, promoting systems for remotely monitoring energy consumption. Creation of an open platform for consumptions in municipal buildings (the target is to have 80% of this consumption monitored) and specific monitoring of high energy consumption municipal services and facilities.

Measure 27. Interventions in buildings and municipal facilities: Moving towards a zero emissions model through energy efficiency and the use of renewable energies, acting on municipally owned buildings and street installations that use energy. Development of programmes to improve heating and cooling installations, implementation of PV systems, technological communication platforms, implementation of environmental management and energy management systems, and fulfilment of the municipal commitment to buildings with nearly-zero positive energy consumption.

Measure 28. Incorporation of sustainability criteria in municipal procurement: Creation of a legal framework within the municipal administration to enable procurement authorities to include criteria aimed at reducing polluting emissions, climate change mitigation and adaptation, and generally promoting sustainable development. Drafting of Environmentally Sustainable Procurement Guidelines, inclusion of clauses in procurement specifications, and implementation of measures to monitor compliance with these measures.

Measure 29. Climate change adaptation: Development of a municipal strategy for climate change adaptation, which will call for the analysis of risks and vulnerabilities and the application of adaptation measures within a framework of urban resilience, with especial emphasis on nature-based measures based (Programme Madrid + Natural). The monitoring (climate monitoring network)

and assessment of the impact of the interventions at a building, neighbourhood and city level form an essential part of the strategy.

Citizen awareness-raising and collaboration with other public authorities

30. Environmental awareness-raising and cooperation with public authorities
Awareness-raising and communication actions cut across the various action lines of the Plan, with the aim of raising awareness of the need to change citizens' behaviour so they can contribute to the improvement of air quality and help in the fight against climate change in the city.

This requires the collaboration of other public authorities, including neighbouring town and city councils, the Community of Madrid, and the central government, to make the legal changes and adopt the right incentive measures to drive the necessary change in people's habits in a coordinated and synergetic manner.

The collaboration of other public authorities is essential to the achievement of the objectives of the Madrid City Council's Plan A, just as the implementation of environmental policies and the meeting of national targets for the reduction of greenhouse gas emissions and atmospheric pollutants requires the cooperation of the towns and cities of Spain.

As shown in the European Commission's opinion prompted by non-compliance with air quality legislation, effective actions on a nationwide scale are required. There is an urgent need to modify Spanish legislation that gives tax advantages to diesel vehicles (both in terms of registration tax and the tax on hydrocarbons) and to put in place an ambitious package of subsidies to incentivize the renewal of the vehicle pool, aimed especially at the urban logistics sector.

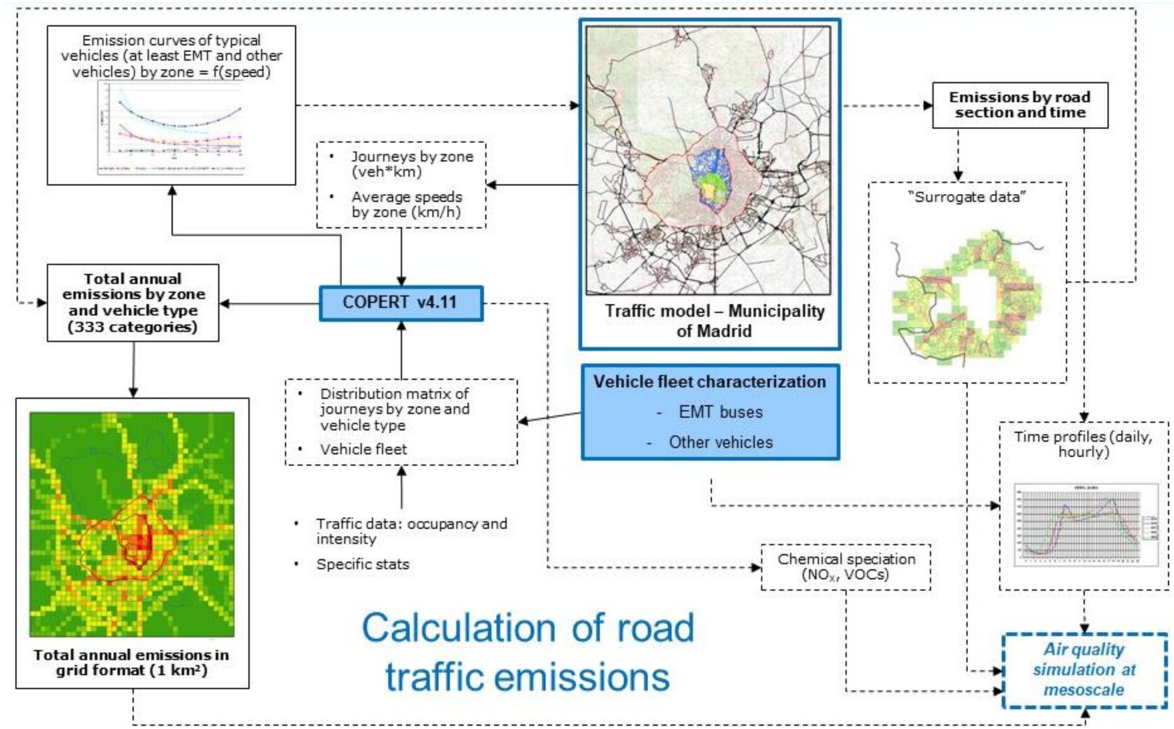
Similarly, the application of effective measures targeting the access of vehicles to public roads (such as the introduction BUS-VAO-ECO lanes), the control of polluting emissions from vehicles (technical inspection of vehicles), and the development of renewable energies all require immediate action within a national and regional legislative framework that will enable cities, and therefore the country, to meet their air quality and climate change targets.

What impact will the measures have?
The methodological approach proposed consists of an iterative process of evaluation of the proposed measures. In order to start this process, we have made a preliminary estimate of the effect that the main measures of the Plan might have in terms of NOx and CO_2 emissions. A detailed quantification requires the highest possible level of definition of the measures and a painstaking evaluation of their additivity and the possible synergetic effects, together with a review of the hypothesis taken into consideration, in order to better reflect the nature of each measure on the basis of its definitive definition. Thus, the preliminary results should be considered as an initial estimate telling us the order of magnitude of the reductions that might be achieved for each of the measures proposed, and they constitute the first essential step to defining a tentative ambition level in terms of reduction, while helping to complete the design of the Plan's measures.

The analysis will be completed by an estimation of the impact of air pollution on the health of the people of Madrid.

Methods for the quantification of the effect of measures in terms of emissions

Emissions from traffic depend on many factors, some of which are related to traffic conditions, such as the flow of vehicles of each type, congestion conditions and journey speeds. For this reason we have made use of the PTV Visum model implemented by the EMT for Madrid covering the Community of Madrid bus network. This model enables us to make an estimate of the variation of both traffic intensity and speed on the various sections of the network, assuming variation hypotheses for both private car user demand and network supply. The result is an estimate of vehicle flows and their average speed on each of the sections making up the network.



Once we have obtained the changes relating to flows in the road network, we apply the emissions estimation methods used in the Madrid City Council emissions inventory, which is based on the COPERT (*COmputer Programme to calculate Emissions from Road Transport*) model. These methods make use of highly detailed data on the characteristics of the vehicle pool, both private and public vehicles (according to a zoning system employing 5 concentric areas).

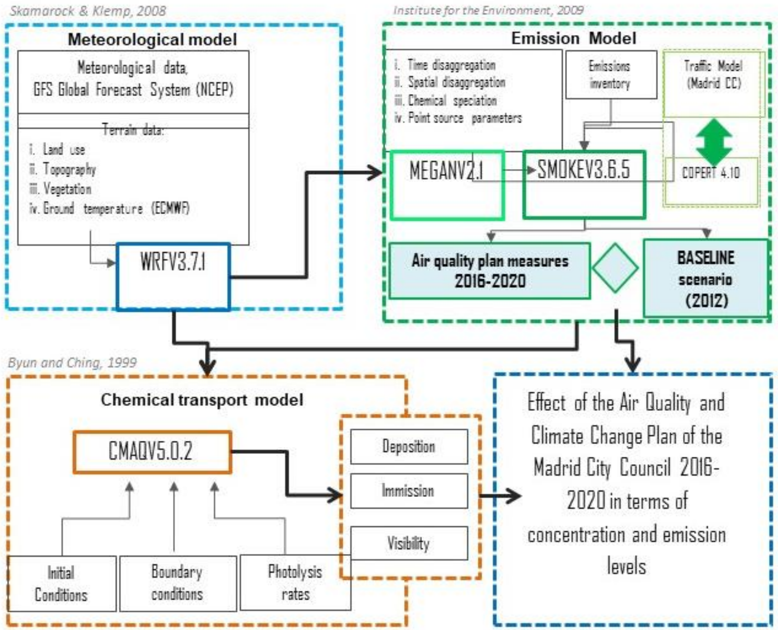
The other measures proposed target the residential, commercial and institutional sector (RCI) (measures 22 to 27), municipal solid waste (MSW) management (25), or are of a cross-cutting nature (28 and 30). The plan also includes one measure (29) related to climate change adaptation.

It is estimated that implementation of Plan A may reduce NOx by in the order of 3000 t/year, and PM2.5 by around 220 t/year, which means an overall reduction of close to 20% and 23% with respect to the base year (2012).

As for the reduction of CO_2 emissions, estimates indicate that this reduction would be compatible with meeting the specific GHG emission objectives (achieving an emission level 40% lower than in 1990 in terms of direct and indirect emissions of CO2-equivalent by 2030). However, for this objective the importance of externalities such as the contribution of renewable energies in the national electricity mix is a significant factor and makes estimating scenarios in the long term a difficult proposition.

Impact on air quality

With regard to compounds relevant to compliance with air quality limit values, it is essential to relate changes in emissions with changes in the composition of the atmosphere in accordance with the legally established values (hourly or daily average annual limit values, etc.). To this end we used a state-of-the-art Eulerian-type atmospheric simulation system that enables us to pinpoint the quantitative and qualitative changes in emissions and their behaviour in the atmosphere, taking into account main processes of transportation and transformation of pollutants. This model has previously been used by the Madrid City Council in the evaluation of plans and a large number of measures, thus ensuring its effectiveness and the comparability of results



The implementation of Plan A will mean a significant step forward in the reduction of the negative effects of air pollution and will bring Madrid nearer to the objectives it has set itself. This reduction will have an appreciable impact in terms of concentrations of NO_2, more noticeable in the more central zone, but with an effect that will extend not only to the city of Madrid but to the metropolitan area as a whole. We assume a drop in the order of 25% in NO_2 concentrations observed at the monitoring network stations. The results suggest that Madrid will have no difficulty in complying with the required legal values for particulate matter if the actions called for by Plan are implemented and levels could be close to those proposed by the World Health Organization, especially in the case of $PM_{2.5}$, which is the most dangerous fraction for human health in general.

The improvement in air quality expected from the application of Plan A would be enhanced by measures that fall outside the geographic and administrative scope of the municipality and contribute to the reduction of the contribution from external sources (regional and national). These represent 28.3% in the case of nitrogen dioxide and 53.4% in the case of PM 2.5.

How is compliance with the Plan and its effectiveness to be monitored?

The air quality and climate change plan has been designed under the premise that there will be citizen participation from the outset, building consensus with the city's various socioeconomic stakeholders in order to arrive at a Plan in which most citizens will feel they are represented.

Monitoring is the responsibility of the Air Quality Commission and the Technical Committee which reports to the commission. These consultation bodies that are essential to the implementation of the Plan. Together with these consultation bodies, and given the horizontal nature of Plan A, which involves a large number of municipal services and competencies, the Plan creates a mechanism which encourages the active collaboration of municipal officers in key areas such as town planning, mobility, energy management, municipal procurement, environmental outreach and awareness-raising, and environmental management contract execution.

In order to monitor the Plan three types of indicators have been established: impact, associated with overall objectives; specific, assessing the real impact of the actions carried out as a whole; and process, evaluating the degree of implementation of the measures.

Fulfilment of the Plan based on the information obtained from the aforementioned indicators will be regularly analysed and assessed in order to track the degree of progress in the implementation of the measures, and the effect of those measures on air quality, greenhouse gas emission mitigation, and the adoption of climate change adaptation measures.

The monitoring of how air quality targets are being reached will allow us to verify the effectiveness of the measures applied and determine whether they are sufficient or whether new additional measures for reducing emissions need to be put in place.

What budget is allocated to this Plan?

The air quality and climate change plan pursues a new, healthier, low emission city model, the transition to which requires a long time horizon. In this framework of long-term action, the Plan's budget cannot be structured in a closed and rigid manner, since it is not viable to establish in detail what annual investment will be required until 2030. Given the cross-cutting nature of the measures intended to transform the Madrid urban model and their projection over time, neither would it be reasonable to 'allocate' exclusively to this Plan many of the actions targeting mobility, urban regeneration or waste management, since, while they are fundamental to the achievement of the objectives of the Plan, they also form an integral part of other strategic municipal policies. In many cases the aim of the measures in Plan A is to align municipal priorities with air quality and climate change criteria, giving a new focus to existing management tools and investment budgets. Finally, it is necessary to consider public and private financing channels other than the municipal budget.

Below we present a first estimate of the principal municipal investments forecast for the effective implementation Plan A in the early years of its implementation. These investments will be complemented by possible financing lines from European, national and regional policies for climate change and air quality that may fund these actions in the municipality of Madrid.

ESTIMATED BUDGET. 2017-2020

MEASURES	TOTAL Millions of euros
Actions targeting the road network and public space aimed at reducing private traffic intensity and promoting active mobility modes	154
Actions targeting air quality targeting the vehicle pool and key sectors with a high impact on mobility patterns	330
Proposal for urban regeneration	
Low emission and energy efficient urban management	46
Energy management energy in municipal buildings and facilities	3.2
Adaptation strategies and solutions based on nature (vulnerability and resilience to climate change)	7.7
Proposal for awareness-raising and communication	
Environmental awareness-raising and education	3.0
TOTAL	**543.9**