



ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)
MASTER IN THE ELECTRIC POWER INDUSTRY (MEPI)

**STRATEGIC PLAN TO REDUCE THE
POLLUTING ELEMENTS IN MADRID CITY
BY MEANS OF THE TRANSPORT SECTOR.**

Author: Nicolás Triviño Carver

Director: Óscar Barrero Gil

Madrid

July 2017

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THE STUDENT:

Nicolás Triviño Carver

.....


THE SUPERVISOR

Oscar Barrero Gil

Signed:  Date: 30 / June / 2017

THE CO-SUPERVISOR

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Authorization of the Master's Thesis Coordinator

Dr. Luis Olmos Camacho

Signed: Date://

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Strategic plan to reduce the polluting elements in Madrid city by means of the transport sector

1. Justification and motivation of the project

In Europe, emissions of polluting gases have declined markedly during the last decades thanks to the measures adopted by the European Commission and the increasing penetration of renewable energies in the energy mix of each country.

In 2014, the statistics proved that the total emissions in the European Union since 1990 have been reduced a 22%, which corresponds to approximately 1.100 millions of tones of CO₂ – equivalents, surpassing the target set for 2020 of 20% and close to the 30% set for 2030 in comparison to the levels of 1990.

Amongst all the EU countries, Germany leads the table with a total amount of 21.9% followed by the UK, France, Italy, Poland and in next position Spain.

Although we are following the correct lines, the level of atmospheric concentration in urban areas, which is where a big percentage of the population lives, are in some cases very high with respect to the adequate. This is the case of Madrid, where we have already seen measures adopted by the town hall such as allowing only certain vehicles to circulate inside the city center to comply with the maximum levels permitted.

In this context, one of the measures that is now being adopted and which this report will discuss is the development of electric vehicles (EV) to combat the above problems mentioned.

The introduction of these type of vehicles will suppose a big transformation in society since the utilization of the EV will be a great opportunity to improve the entire electric system, reduce the CO₂ emissions and many other pollutant elements and to reduce our dependence in outside energy.

This report is then conformed as a tool to contribute to the reduction of the atmospheric pollution and will define some strategies of action to guarantee the quality of the air the citizens of Madrid breathe.

The actions proposed in this document aim to make the Community of Madrid a sustainable urban environment focusing in the reduction of the pollution. The improvement of the city's air quality implies not only the improvement of the environmental quality but also the quality of life of the habitants and for this reason this report will try to build a strategic plan that will help to reduce the most problematic pollutants such as the NO_x. Out of all the scenarios that will be proposed in the document, only the most viable and the one that best fits with the European and Spanish framework will be analysed into dep, carrying out a cost/benefit analysis in based in a model we have built up in order to understand all the impacts it can generate.

First, we will explain what is the current regulatory framework in the European and Spanish context related to the air quality, analysing what has been the evolution and which of them are being fulfilled and in which of them the government needs to put a bigger effort to comply with them.

Then, we will see what is the current situation the Community of Madrid and we will breakdown the emissions per sector. We will then analyse the main responsible, which in our case will be the transport sector in terms of Greenhouse effects and the main responsible of the high levels of NO_x, PM_{2.5} and PM₁₀ in the city of Madrid.

Once we know all the problems the city of Madrid is facing, we will propose few scenarios that could help to solve the high level of polluting elements but we will focus in scenario four, which is in our opinion the most suitable adequate. This scenario introduces the

Electric Vehicle (EV) as the solution to combat the pollution and will be the chosen to carry out the cost/benefit analysis mentioned above. We will also present the strategic plan to facilitate the entrance of these type of vehicle to the current park and what are some of the measures the town hall of Madrid could adopt.

The idea of the electric vehicle has been working for years to make cities more sustainable, thus achieving a more environmental transport sector that contributes to economic and social development and to the improvement of citizens' well-being.

In addition, the electric vehicle plays an important role because it not only achieves a reduction of dependence on fossil fuels, but also manages to optimize the electrical system, flattening the demand curve (if an efficient demand management is done) resulting in economic savings for end users and businesses.

2. Regulatory framework

In the mid-nineties, the European Union (EU) started to write and design a legal document with the aim of improving the quality of the air of the European cities. Directive 96/62/CE established which were the pollutants that had to be measured, how to measure them and which were the authorities in charge of making assuring the quality of the air and to inform the public. In 1998, appears the first directive in charge of regulating the emissions of the vehicles by establishing a series of rules concerning the performance of the vehicle and the fuel it used. Also, In the same directive of 1998, it was stated some regulations on the quality of petrol and diesel (98/70/CE) commonly known as “Euro rules”. Later, appears directives 1999/30/CE and 2000/69/CE whose objective was mainly to fix the upper limits that any European city could not surpass at any given moment with the objective of ensuring the quality of the urban areas.

In terms of national regulatory framework, on the 18th of October of 2002, Spain approves the Royal Decree 1073/2002 in which it was included all the directives approved by the European Commission and established that each autonomous community was the responsible of ensuring the quality of the air of their cities.

In may 2008, a new European directive appears, the 2008/50/CE, which basically fused the anterior directives. The approval of such directives meant, according to different experts, a regression in the air quality standards and health protection of the citizens in the European Union since it set very lax limit values on some of the most problematic pollutants.

This legislative setback is unjustifiable from a social and environmental point of view, since in the end it allows to remain within the legal limits numerous zones or regions that do not comply with adequate standards of protection to the health, that is, they surpass those recommended by the World Health Organization (WHO).

The directive was transposed into Spanish legislation with the approval on January 28, 2011, of the R.D. 102/2011 to improve air quality. So, today, the legal texts that deal with everything related to air quality in the Spanish state are: The European directive 2008/50; Law 34/2007, of Air Quality and Protection of the atmosphere and the R.D. 102/2011 relating to the improvement of air quality.

In order to know which are all the regulations related to the quality of the air, below, it is presented in greater depth those existing at European level and at national level.

2.1 European framework

At the European context, we can distinguish mainly two directives related to the quality of the air:

- Directive 2008/50/ CE of the European Parliament and of the Council, 21st may 2008, related to the quality of the air and a cleaner atmosphere in Europe.
- Directive 2004/107/CE, of the European Parliament and of the Council, December 15, 2004, relative to the arsenic, the cadmium, the mercury, the nickel and the aromatic polycyclic hydrocarbons in the air sets.

Both directives have been modified by the directive 2015/1480 of the Commission of August 28, 2015, by which several annexes of the directives are modified 2004/107/CE and 2008/50/CE of the European Parliament and of the Council in that there are established the procedure relative to the methods of reference, the validation of giving itself and the location of the points of sampling. Even this way, the European regulation includes much more relative to the quality of the air.

- Decision of execution of the Commission of December 12, 2011 by which dispositions(regulations) are established for the directives 2004/107/CE and 2008/50/CE of the European Parliament and of the Council in relation by the reciprocal exchange of information and the notification on quality of the air sets.

- Directive 2010/75/UE of the European Parliament and of the Council of November 24, 2010 on the industrial emission (issues).
- Decision of the Commission of November 13, 2006 relative to the way of avoiding the double calculation of the reductions of emission(issues) of greenhouse effect in the community regime(diet) of trade of rights of emission(issue) in relation with the activities of projects derived from the protocol of Kioto of conformity with the Board(Directive) 2003/87/CE/of the Commission.
- Regulation (CE) n ° 1195/2006 of the Advice(Council), of July 18, 2006, by which it is modified the attached IVth of the Regulation (CE) n ° 850/2004 of the European Parliament and of the Advice(Council) on organic persistent pollutants.
- Directive 2006/40/CE of the European Parliament and of the Council of May 17, 2006 relative to the emission(issues) proceeding from systems of air conditioning in vehicles of engine and by that the Directive is modified 70/156/CEE of the Council.
- Regulate (EU) n ° 517/2014 of the European Parliament and of the Council of April 16, 2014, on the fluored gases of greenhouse effect and for that repeals the Regulation (CE) n ° 842/2006.
- Directive 2004/101/CE of the European Parliament and of the Advice(Council), of October 27, 2004, by that the Directive is modified 2003/87/CE, by that it is established for the trade of rights of emission issues of greenhouse gases in the Community regarding the project mechanisms of the Protocol of Kioto.
- Directive 2004/42/CE of the European Parliament and of the Council of April 21, 2004 relative to the limitation of the emission issues of organic volatile compounds (COV) due to the use of organic solvents in certain paintings and glazes and in the

products of renovation of end of vehicles, by that the Directive is modified 1999/13/CE.

- Decision of the Commission of March 19, 2004 relative to the directives of application of the Directive 2002/3/CE of the European Parliament and of the Council relative to the ozone in the air sets.
- Decision of execution of the Commission, of December 12, 2011, which establishes dispositions/regulations in relation with the reciprocal exchange of information and the notification on the quality of the air sets.
- Directive 2003/87/CE of the European Parliament and of the Council of October 13, 2003 by that a regime is established for the trade of rights of emission issues of greenhouse gases in the Community and by that the Directive is modified 96/61/CE of the Council.
- Directive 2003/4/CE of the European Parliament and of the Council of January 28, 2003 relative to the access of the public to the environmental information.
- Directive 2008/50/CE of the European Parliament and of the Council, of May 21, 2008 relative to the quality of the air set and to a cleaner atmosphere in Europe.
- Directive 2001/81/CE of the European Parliament and of the Council of October 23, 2001 on national ceilings of emission issues of certain atmospheric pollutants.
- Directive 2010/75/UE, of November 24, on the industrial emission issues prevention and control integrated(repaid) of the pollution).
- Decision of the Commission of July 17, 2000 relative to the accomplishment of an European inventory of pollutant emission(issues) (EPER) in accordance with the

article 15 of the Board(Directive) 96/61/CE of the Council relative to the prevention and to the control integrated(repaid) of the pollution (IPPC).

- Directive 2000/14/CE of the European Parliament and of the Council of May 8, 2000 relative to the approximation of the legislations of the members states on sonorous emission issues in the environment owed to the machines of use outdoors.
- Managerial (EU) 2016/802 of the European Parliament and of the Council, of May 11, 2016, relative to the reduction of the content of sulphur of certain liquid fuels.

2.2 Spanish framework

To incorporate the European regulatory framework, Spain designed the following legislation:

- Law 34/2007 of November 15, of quality of the air and protection of the atmosphere.
- Royal decree 102/2011, of January 28, relative to the improvement of the quality of the air, modified by the Royal decree 39/2017, of January 27.

More legislation related to the quality of the air at the national level we can find the following:

- Royal decree 815/2013, of October 18, by which there is approved the Regulation of industrial emission issues and of development of the Law 16/2002, of July 1, of prevention and control integrated repaid of the pollution.

- Royal decree 100/2011, of January 28, by which there is updated the catalogue of potentially contaminating activities of the atmosphere and they establish the basic regulations for his application.
- Royal decree 101/2011, of January 28, by which there are established the basic procedure that must govern the systems of accreditation and check of the emission issues of greenhouse gases and the information tons - kilometres of the air operators and of the requests of free transitory assignment of fixed facilities in the area of application of the Law 1/2005, of March 9, by that there is regulated the regime of trade of rights of emission issues of greenhouse gases.
- Royal decree 795/2010, of June 16, by which the commercialization and gas manipulation of fluorated gases and equipment for the same use is regulated as well as the certification of the professionals who use them.
- Royal decree 1402/2007, of October 29, by which the Royal decree is modified 1370/2006, of November 24, by which there is approved the National Plan of Assignment of rights of emission issues of greenhouse gases, 2008-2012.
- Royal decree 1030/2007, of July 20, by which the Royal decree is modified 1370/2006, of November 24, by which there is approved the National Plan of Assignment of rights of emission issue of greenhouse gases, 2008-2012.
- Royal decree 1031/2007, of July 20, for which there develops the frame of participation in the mechanisms of flexibility of the Protocol of Kioto.
- Royal decree 508/2007, of April 20, by which there is regulated the supply of information about emission issues of the Regulation E-PRTR and of the environmental integrated authorizations.

- Royal decree 1370/2006, of November 24, by which there is approved the National Plan of Assignment of rights of emission issues of greenhouse gases, 2008-2012.
- Law 27/2006, of July 18, by that there are regulated the rights of access to the information, of public participation and of access to the justice as for environment.
- Royal decree 777/2006, of June 23, by which the Royal decree is modified 1866/2004, of September 6, by which there is approved the national Plan of assignment of rights of emission(issue), 2005-2007.
- Royal decree 227/2006, of February 24, for which the juridical regime(diet) complements itself on the limitation of the emission(issues) of organic volatile compounds in certain paintings and glazes and in products of renovation of end of vehicles.
- Royal decree 1315/2005, of November 4, by which there are established the bases of the systems of follow-up and check of emission(issues) of greenhouse gases in the facilities included in the area of application of the Law 1/2005, of March 9, by that there is regulated the regime(diet) of the trade of rights of emission(issue) of greenhouse gases.
- Royal decree 1264/2005, of October 21, by which there is regulated the organization and functioning of the national Record of rights of emission issues.
- Law 1/2005, of March 9, by that there is regulated the regime of the trade of rights of emission issues of greenhouse gases.
- Royal decree 60/2005, of January 21, by which the Royal decree is modified 1866/2004, of September 6, by which there is approved the national Plan of assignment of rights of emission issues, 2005-2007.

- Royal decree 117/2003, of January 31, on limitation of emission issues of organic volatile compounds owed to the use of solvents in certain activities.

3. Diagnostic of the situation and measures of action

Traditionally, policies and strategies related to air quality and climate change have been dealt with separately. However, scientific studies and the review of the policies related to these issues show that the challenges related to air pollution and climate change should be dealt with together under a coherent and integrated management policy. This report follows this idea and presents a study that combines the strategies for both air quality and climate change.

In 2005, recommendations included in the European strategy subject for air pollution highlighted the need to consider synergies and the discrepancies between air quality and climate change management policies, as certain measures put in place to reduce greenhouse gas emissions can have a negative impact on air quality and vice versa. Although we still do not have a comprehensive understanding of how climate change can affect air quality, recent research shows that there could be a stronger correlation than previously thought.

The assessment carried out by Intergovernmental panel about climate change that air quality in cities would deteriorate partly due to climate change. Climate change is expected to have an effect on local climate all over the world, mainly on the frequency of heatwaves and the increase in anticyclonic periods, which cause the air to come to a standstill and an increase in pollution. An increase in sunlight and temperatures could extend the duration of the periods in which we could see loads of ozone as well as increase their intensity.

In 2015, a report released by the World Health Organisation (WHO) emphasised the urgent need to reduce black carbon, ozone and methane all of which are considered as

short life climate pollutants as they cause a significant increase in the earth's temperature and contribute to early deaths related to air pollution. Many other studies confirm that effective air quality and climate change policies can provide mutual benefits. The policies that have the objective of reducing air pollutants can contribute to maintaining the average worldwide temperature increase at below 2°C. Similarly, climatic policies that have the aim of reducing short life climate pollutants such as black carbon, ozone and methane can have a significant impact on improving air quality.

International organisations, such as the Climate & Clean Air Coalition (CCAC), the C40 Cities Climate Leadership Group (C40) and the United Nations Agency UN-Habitat, have stated the need for cities to develop integrated policies to face air pollution and climate change due to their negative health impacts.

In the urban areas greenhouse gas emissions and air pollutants mainly tend to come from the same sources, such as road traffic, residential areas and residues/waste. It is, therefore, logical that action taken on these sources lead to an improvement in air quality and slowing down climate change. For that reason, dealing with both issues together allows certain mutual beneficial measures to be put in place as a priority.

It also helps to avoid inconsistencies, as implementing initiatives and strategies for one material may have an effect on the other. Potential contradictions include the increase in the use of diesel in vehicles, the widespread use of biomass instead of fossil fuels and some practices for the management of residues/waste. The development of diesel vehicles as a fuel with greater energy efficiency than petrol has had a negative impact on air pollution in cities due to its greater emissions factors.

Given the complexity of the urban hierarchy and the unknown sources of the pollutants, the transition towards a city with low emissions requires action to be taken on various issues. It is, therefore, a priority to act on the fundamental elements of urban metabolism, mobility/movement and energy, focusing particularly on demand and encouraging the use of sustainable alternatives that do not depend on fossil fuels.

Analysis of the breakdown of emissions from greenhouse gases (GHG) in the Community of Madrid shows that, since at least 2004, pollution levels have been notably higher than the levels permitted by the European Commission (EC). Currently, the most problematic

pollutants are nitrogen oxide, particulate matter (PM₁₀ and PM_{2.5}) and tropospheric Ozone (O₃), which have recently started to present a problem due to the levels that have been registered. In their latest report, the European Environment Agency (EEA) estimate that around 24,000 people die in Spain as a result of pollution, approximately 15 times more than deaths caused by road traffic accidents. ¹

In 2016, like previous years, the upper limit recommended by the WHO were exceeded. The transport sector was the main source of pollution due to its extensive use of fossil fuels.

figure 1. Break down of the greenhouse gases (expressed in Kt of CO₂ eq) per sector of activity in the city of Madrid - 2014

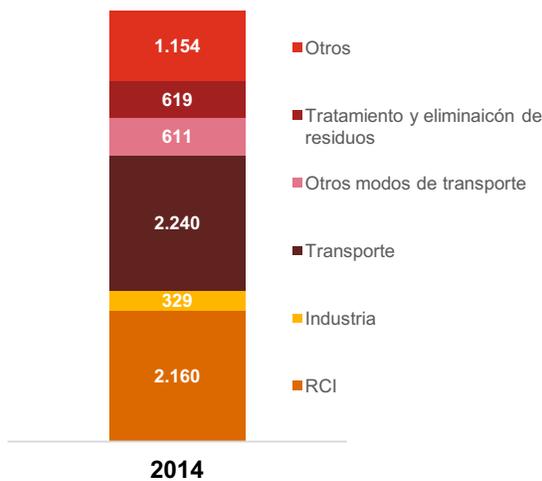
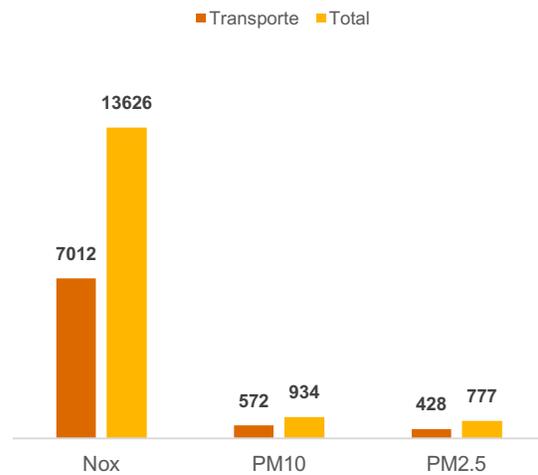


figure 2. breakdown of the emissions of the transport sector with respect to the total GHG (expressed in tons) - 2014



As shown in the figures above, the transport sector emits 2,240 kilotons of CO₂ equivalent, which accounts for 31.5% of total emissions (7,113kt of CO₂ eq.).

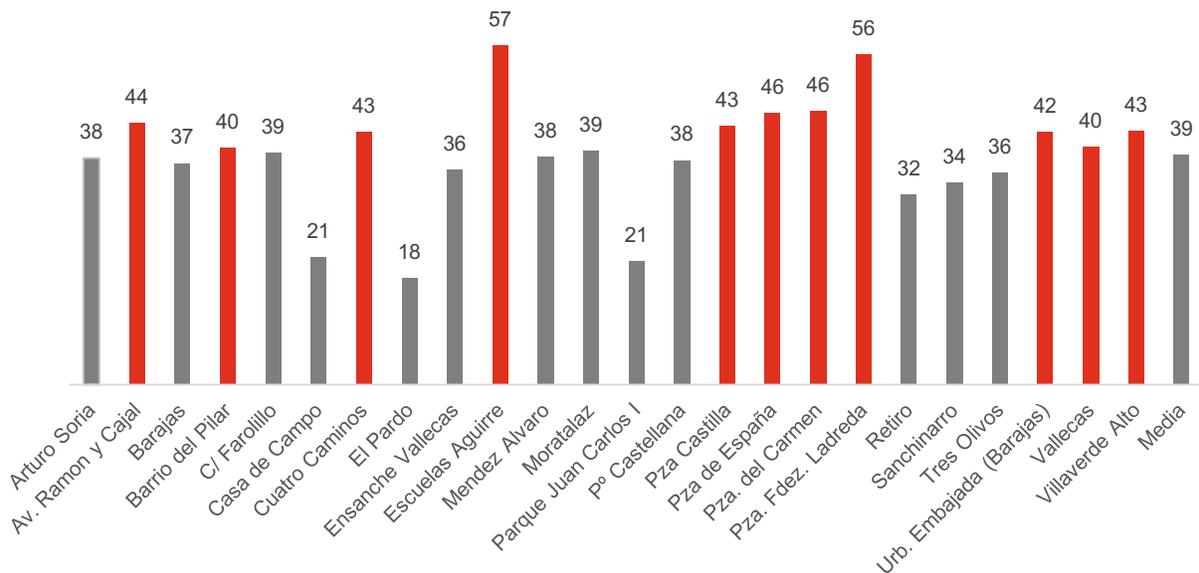
If special attention is paid to nitrogen oxide pollutants and fine particles, it can be seen that the transport sector is the source of 51% of all NO_x gases, 61% of total PM₁₀ and 55% of total PM_{2.5}, which are very high levels for just one sector. Therefore, it is essential to approach the scenario with respect to vehicles in Madrid as they are the main source of emissions and they cause a high level of pollution in the city.

¹ Data obtained from Ecologistas en acción. “La calidad del aire en la ciudad de Madrid en 2016”

In order to measure the level of pollutants, there is a network of 24 stations/plants located across Madrid. Data from these stations/plants, which is presented in .txt format on the Madrid City Council website, has been accessed and subsequently processed in Excel to obtain a heat map of the places most affected by pollutants. This has led to various important conclusions that are presented below.

If the maximum permitted levels of NO_x are analysed, which is of the three aforementioned pollutants that causes the most problems in Madrid, it can be seen, as demonstrated in figure 3, that nine stations/plants exceed the maximum permitted level of 40 µg/m³ for average annual concentration and that two stations/plants met this level in 2016.

figure 3. Annual average values of the levels of NO_x concentration in the 24 stations of the city of Madrid

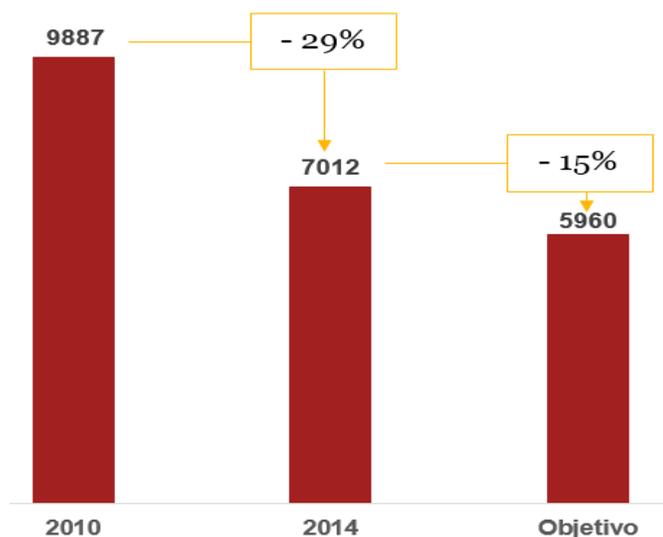


For the seventh year running (2010-2016), Madrid has violated the legal permitted limits that, according to Directive 2008/50/CE, should not have been exceeded since 2010 resulting in a substantial fine for Spain. Therefore, urgent measures should be taken to solve this problem as soon as possible as the aim is that Madrid is a sustainable city, with low emissions and a healthy environment for residents.²

² Data obtained from Ecologistas en acción. “La UE declara ilegal la contaminación en Madrid (Ecologistas en acción, 2013)

Analysing the data and the maximum permitted levels of kilotons of NO_x, it can be seen that the city of Madrid should reduce its levels by 28 µg/m³ in order to comply with the legal levels³ – a 15% decrease in nitrogen oxide emissions⁴ of compared to 2010.

figure 4. Reduction of NO_x levels expressed in kilotons



Reducing a 15% of the total NO_x emissions will mean achieving the permitted levels again as in 2010.

In order to achieve this aim, this report will investigate various possible scenarios in which the introduction of electric vehicles will be analysed in detail for various reasons, including how many vehicles are expected to be introduced into the current vehicle fleet. These electric vehicles will mainly substitute diesel vehicles, which, as can be seen in the following pages, are the main cause of these high levels as they produce up to 20 times more nitrogen oxide than petrol. The approximate number of charging stations required to meet the needs of the introduction of these electric vehicles will also be investigated.

³ Data obtained from Ecologistas en acción.

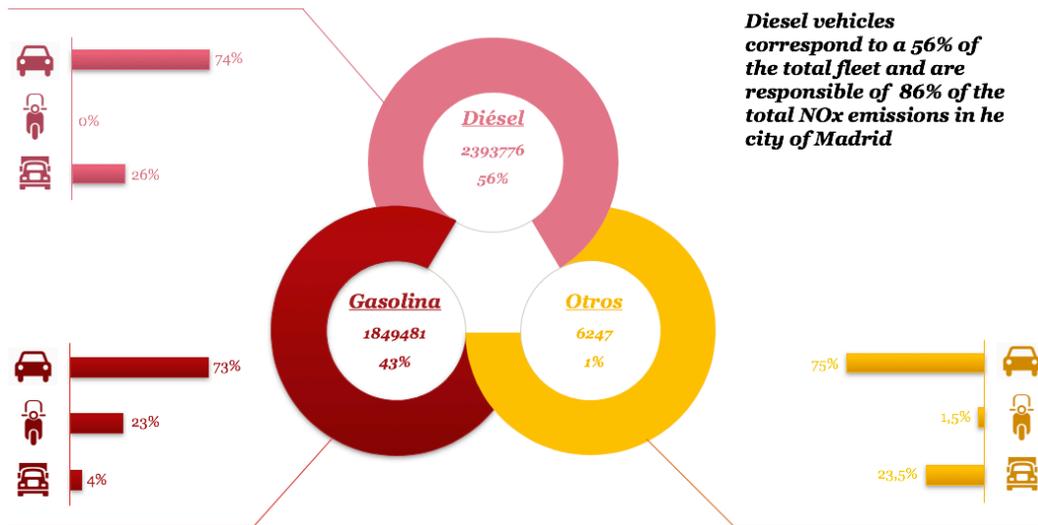
⁴ Data obtained from the legislation of the Community of Madrid. (Comunidad de Madrid, 2015)

Currently, the vehicle fleet in the Community of Madrid has approximately 4,800,000 vehicles, of which 56% are diesel, 43% are petrol and the remaining 1% are other fuels such as LPG and electric vehicles. This shows that there is a great dependency on fossil fuels, which are imported, non-renewable energy sources and their combustion is the main source of greenhouse gases.

As it can be seen, 99% of the energy consumed in the transport sectors is covered with fossil fuels, which means that there is a big dependence on imported, non-renewable energy sources and such combustion is one of the main sources of GHG. Furthermore, this causes a significant increase in the air pollution of urban areas, where vehicle traffic is the main source of pollution.

Furthermore, it is important to differentiate by vehicle registration year as the efficiency of vehicles has improved over the years and, therefore, in this report, vehicles will be split into two categories: those registered before 2006 and those registered after 2006, which relate to approximately 40% and 60% of the entire fleet, respectively. The following figure shows an overview of the main vehicles in the fleet in the Community of Madrid, which are private cars, motorbikes and lorries/vans.⁵

figure 5. Breakdown of the fleet of the city of Madrid

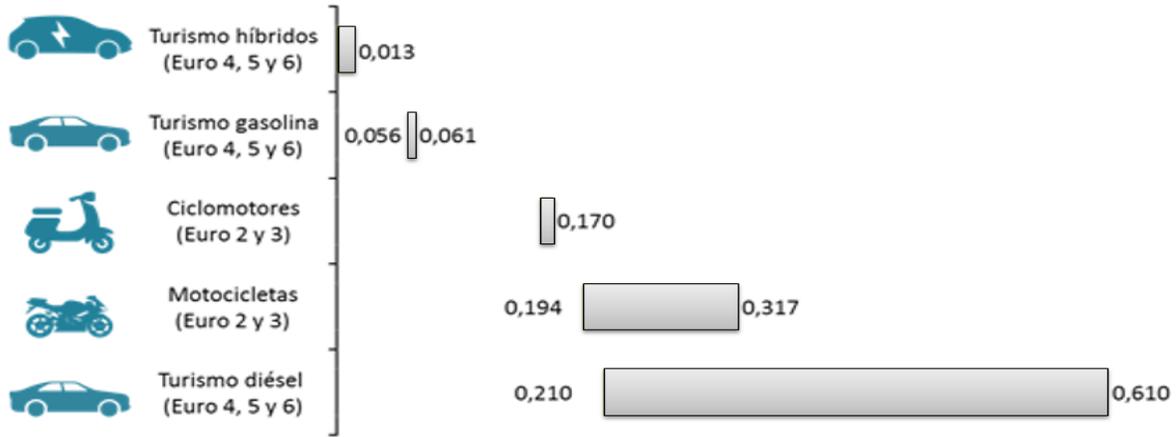


- (1) Values have been rounded to the closest value.
- (2) Approximately 4,2% of the fleet are hybrids and electric cars.

⁵ Data obtained from the Dirección general de tráfico (DGT)

There are many debates regarding which type of fuel is the most contaminating and the answer lies in the pollutant that this report focuses on. Petrol vehicles contribute most to the production of CO₂, accounting for approximately 14% of the total gases that vehicles emit, compared to diesel vehicles, which emit 12%. In terms of NO_x, diesel vehicles produce up to thirty times more emissions than petrol vehicles, as shown in the following figure.⁶

figure 6. NO_x emissions per type of vehicle (expressed in g/Km)



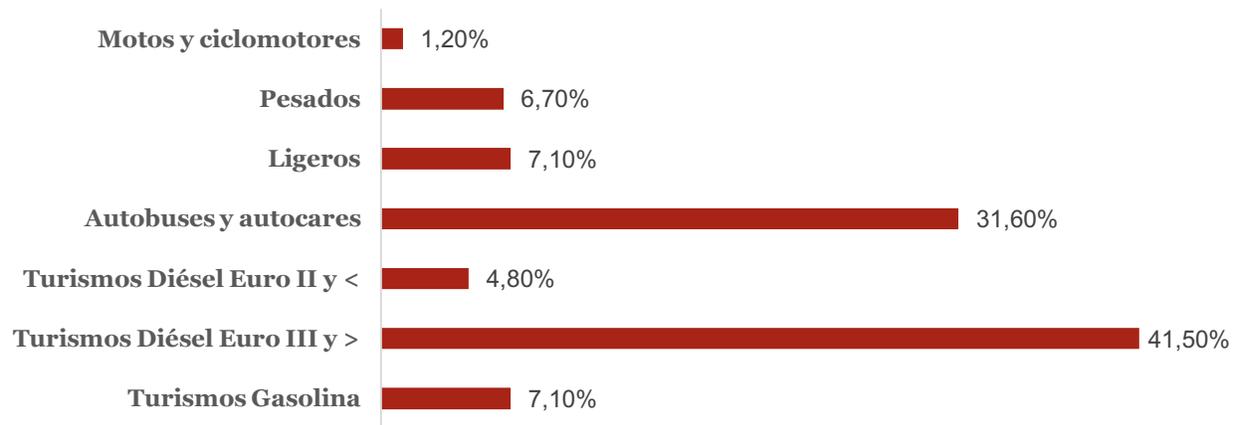
If we join the high number of diesel vehicles in the vehicle fleet in the Community Madrid with their high levels of nitrogen oxide emissions, it can be concluded that this type of vehicle is the main cause of the high levels of NO_x (approximately 86%). Therefore, it is the vehicle that should be replaced in order to combat Madrid's problems with NO_x.

To comply with the measures related to air quality, this report will propose various scenarios with the aim of reducing the levels of these pollutants. The following graph breaks down the contribution of the main NO_x vehicles⁷.

⁶ Data obtained from Energía y Sociedad.

⁷ Data obtained from the report of NO_x reduction measures. Community of Madrid, January 2010 (Dirección general de calidad, control y evaluación ambiental, 2010)

figure 7. NO_x emissions breakdown per type of vehicle in the city of Madrid.



Scenario 1.

To promote a change of modality across the collaborative economy or "Carpooling", use of the public transport ...



The term carpooling is used to describe sharing a car with other people for both repeated and one-off journeys. This concept has been used in several countries, such as the USA, Canada and Mexico, for many years with the aim of reducing congestion at rush hour, which is when people must get to/from work, and reducing CO₂ emissions.

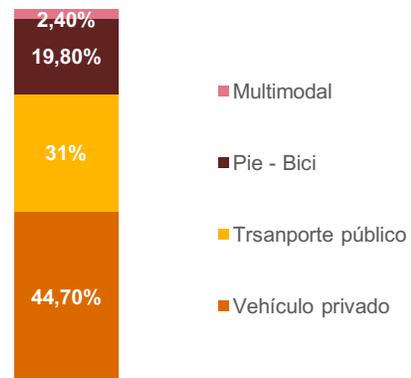
In these countries, these initiatives mainly come from companies in order to encourage comradeship in the company as well as reducing the stress that can come from being alone on the road. This initiative could help to increase the occupation rate of vehicles in Madrid, which currently has an average of 1.35 passengers per car⁸.

Furthermore, as shown in figure 8, the use of private vehicles would reduce significantly, above all in the “zona interna y radial”, which account for 45% and 28% of total journeys to work, respectively. Achieving values of 44,7% leaving a small percentage to the public transport of 31%⁹

.figure 8. Trips to work breakdown

	Viajes	%
Interna Madrid	2179973	45%
Radial con Madrid	1335989	28%
Interna Municipios	614333	13%
Transversal	575232	12%
Externa	114055	2%
TOTAL	4819582	100%

figure 9. Modal distribution in the city of Madrid



⁸ Plan de Movilidad Urbana Sostenible de la ciudad de Madrid. Resumen Diagnóstico

⁹ Movilidad al trabajo. CONAMA 2016, Congreso nacional del medio ambiente.

Moreover, the reduction of the cost per journey based on the number of passengers in the car is an obvious benefit of carpooling, resulting in a considerable monthly saving per person.

Therefore, encouraging companies to promote this initiative between employees, through the use of existing platforms such as BlaBlacar, Car2Go and Emov or the introduction of buses to work, could be one of the possible initiatives for achieving a reduction of both emissions and daily congestion in the city. This leads to the first scenario that is discussed in this report.

Given that the aim is to reduce NO_x emissions by 15%, the decrease required to reach the adequate levels in Madrid as shown in figure 3, it is clear that, by applying only the initiative of the sharing economy, the occupation rate would need to be increased significantly. In order to estimate the required increase, it has been considered that practically 45% of daily transport is carried out in private vehicles and that 55% of the vehicle fleet is diesel as seen in the breakdown of the vehicle fleet in Madrid. According to this data, the vehicle occupation rate would then have to be increased to a rate of 2.3 passengers per vehicle.

In economic terms, it is an initiative that does not suppose much effort. As aforementioned, it is an initiative that has already emerged in other countries as companies have tried to encourage comradeship between their employees. Therefore, from the Government's point of view, it is an initiative that, if companies are supported and provided with some kind of benefit, should be achieved without any major problems.

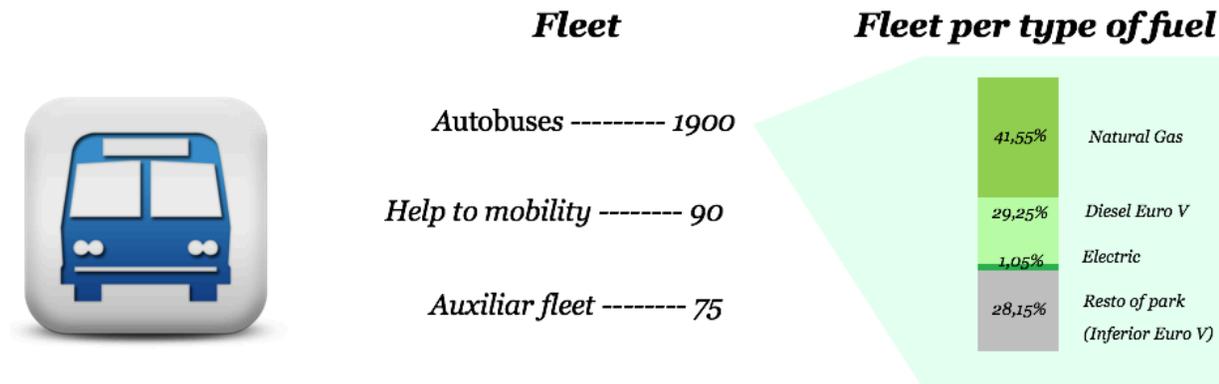
The main negative aspect of this initiative is that changing the habits of a population is a complicated task if adequate incentives are not given. Therefore, a significant amount of time would be needed to make people aware that these initiatives are the right step towards a future with low emissions.

Consequently, the role of the government in supporting companies is essential, since if the right incentives are given to them, the responsibility for implementing these initiatives is passed to the companies as they have more direct contact with their workers and they can make a greater effort with their employees to encourage regular use of these initiatives with the aim of achieving a more sustainable city.

Scenario 2.

The second scenario focuses on public transport, with the aim of substituting part of the current fleet because, as shown below, approximately 60% of the fleet are still diesel.

figure 10. EMT fleet and breakdown per type of fuel



The change of vehicles in EMT's fleet has advanced greatly during recent years. Since 2010, the Community of Madrid has not acquired any diesel vehicles and has instead progressively substituted them with more efficient vehicles, achieving one of the most modern fleets in Europe with an average age of 8.8 years¹⁰. Even so, as aforementioned, approximately 60% of the fleet is still diesel and only 1.05% is electric, even though EMT is committed to making a progressive change to its fleet.

Analysing the viability of substituting these diesel vehicles with pure electric vehicles (in terms of distance covered), considering that the daily distance covered by diesel buses is approximately 200-250km and the batteries for electric vehicles that are currently available in the market reach 300km, a change from one type of fuel to another is feasible. If this viability is analysed in terms of emissions, with a reference of around 1100 diesel buses, removing this part of the fleet would result in a decrease of approximately 17% in total nitrogen oxide emissions, which are only produced by these buses (equivalent to around 1200 tons of NO_x)¹¹.

¹⁰ Data obtained from the Empresa Municipal de Transporte of the city of Madrid.

¹¹ Information obtained from Movilidad eléctrica.

The conclusion that should be taken from this is that it is the council's responsibility to ensure that the Community of Madrid does not have to pay any more fines imposed by the European Commission for exceeding the established levels of emissions. By substituting the entire EMT diesel fleet with electric vehicles, achieving the 15% reduction would be possible.

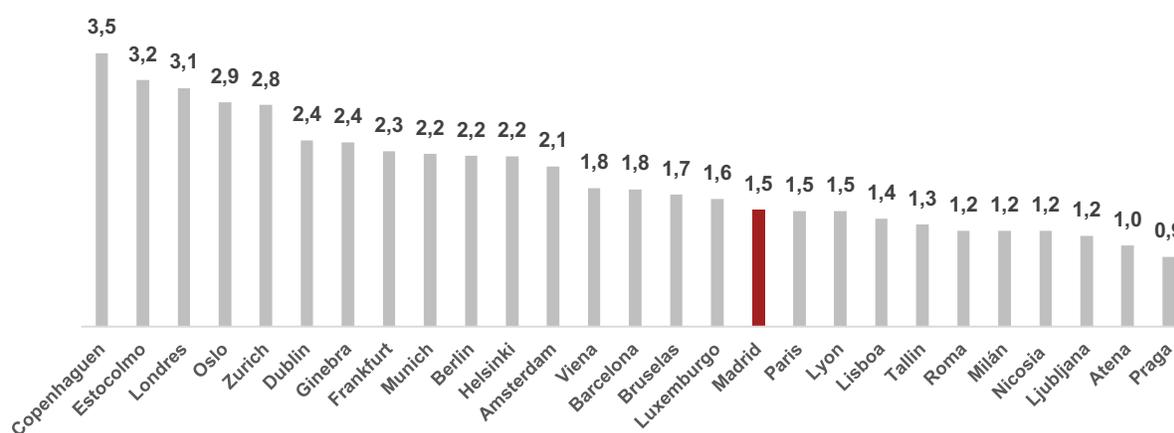
Similarly to the first scenario, the investment that this initiative would require from the Madrid City Council is too high considering the low average age of the fleet and, therefore, it is not considered as the best option or an adequate step.

It is preferable to keep the fleet of diesel buses and encourage the use of public transport through incentives and discourage the use of private petrol vehicles, however this type of initiative will be discussed further on in this report.



Although this initiative solves the problem, an intense incentive program would be required in order to try to ensure that residents in the city of Madrid use public transport more frequently. However, as with the first scenario, changing people’s habits is not an easy task. The other extreme would be to increase ticket prices, due to the economic impact of substituting the bus fleet. If the prices in Madrid are compared with various European capitals, it can be seen that Madrid is much cheaper than many cities. Therefore, as for being the capital of the third most visited country in the world and tenth most visited city in Europe, it would be a good consideration to increase the prices of the tickets in order to obtain more income.¹²

figure 11. Breakdown of average bus and train ticket prices in different European cities.



A possible option is to combine the first and second scenario as, if they are both viable, albeit difficult to achieve, the combination of the two would be plausible. Consequently, the incentives required to encourage the sharing economy would be halved – i.e. the occupation rate would need to increase from 1.35 to 1.8 passengers per vehicle instead of 2.3, as proposed in the first scenario.

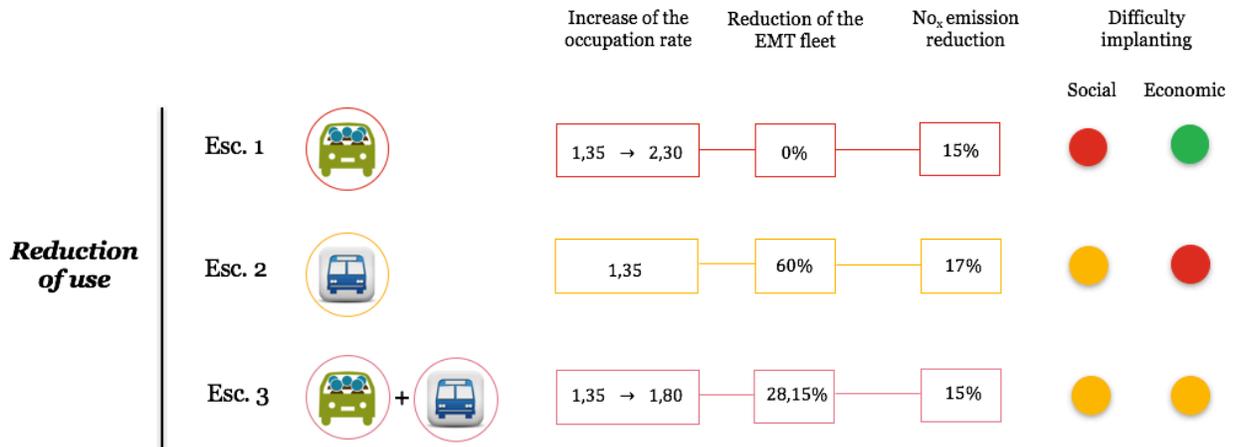
Regarding EMT’s diesel fleet, substituting the buses categorised as below Euro V would be sufficient, as they account for approximately 9.5% of total emissions.

The three scenarios mentioned up until now only focus on reducing daily vehicle consumption and, although they would solve the problem, the implementation would be

¹² (Vanguardia, 2015)

very costly, both economically and socially. To summarise, the following diagram collates the three scenarios and their main characteristics.

figure 12.. sum up of first three scenarios



Up to now, we have presented several scenarios related to the reduction of consumption, change of habits of the people, substitution of buses for electric buses, but we see that only one of them is very difficult to implant in economic and social terms.

That is why, the following block will analyse another set of scenarios in which we will study whether removing private diesel cars would be a suitable idea in the both terms considered before, social and economic. Afterwards, we will carry out a deeper economic analysis to understand all the factors which affect the prices and the evolution of costs of what we will consider the life of the vehicles concluding then if the scenario proposed is considered a suitable idea to implant.

Scenario 3.



Apart from the large number of private cars travelling on the busiest roads, one of the main reasons why Madrid suffers from these high levels of pollutants is the high presence of diesel light goods vehicles, which transport goods on a daily basis in the most urbanised areas. Due to the high number of kilometres covered daily, these vehicles contribute 7% of total emissions, as shown in Figure 7.

For that reason, this is a possible scenario to be considered as technology upgrade measures in the light goods vehicles sector are usually more efficient than upgrading the entire vehicle fleet in terms of the ease of implementation. However, combining both measures would produce the best results.

As aforementioned, the high number of light goods vehicles that travel throughout the most urbanised areas of Madrid daily contribute 7% of total NO_x emissions. The Community of Madrid has launched a series of measures to combat these problems, directed at self-employed professionals and SMEs for the acquisition of efficient light goods vehicles. If we look at the regulatory bases established by Order 1384/2016 of 18

July 2016, the total amount of the call reaches €1,000,000, subject to the following conditions:

- Section I: €6,000 per vehicle. Vehicles with emissions below or equal to 80g of CO₂ per km and 60mg of NO_x per km.

- Section II: €3,000 per vehicle. Vehicles not included in Section I with emissions below or equal to:
 - 160g of CO₂ per km
 - 80, 105 or 125mg of NO_x per km based on whether they are classified as class I, class II or class III N1 vehicles, respectively.

- Section III: €2,000 per vehicle. Vehicles not included in the previous sections with emissions below:
 - 200g of CO₂ per km
 - 80, 105 or 125mg of NO_x per km based on whether they are classified as class I, class II or class III N1 vehicles, respectively.

This amount is too low to result in a reduction of emissions. The incentives that are given to a company to substitute its current fleet are not sufficient enough to benefit them. From what can be concluded, although a lot is being done in the transport sector to combat pollution from GHGs, there is still a lot that can be done. The following tables summarise the main quantities financed by the European Union and the Spanish Ministry of Finance and Public Administration (MINHAFP).

In the following tables, we can check the low levels of financing that transport projects are being given in comparison to what renewable sources or energy efficiency are obtaining.

3.1 Public EU funding

The regulations governing the community funds for 2014-2020 give prime importance to “Objetivo Temático 4: Economía baja en Carbono (OT₄) al incluirle entre los objetivos de concentración temática” and placing priority on it.

Table 2¹³ shows the funding provided by the EU for energy efficiency aims through the European Energy Efficiency Fund, 2020 horizon, and other related initiatives.

Table 1. Presupuestos del OT₄ de los PO regionales y de los POCS del FEDER para el periodo 2014-2020 en €

CCAA	POCS				PO Regionales				Total OT ₄
	Renovab.	Eficiencia	Transporte sostenible	Total	Renovab.	Eficiencia	Transporte sostenible	Total	
Andalucía	112.612.046	562.695.723	68.143.451	743.451.220	87.082.339	150.687.353	101.368.634	339.138.326	1.082.589.546
Aragón	3.780.451	18.534.557	1.745.258	24.060.266	4.500.000	11.111.962	0	15.611.962	39.672.228
Asturias	5.453.203	21.752.904	4.999.172	32.205.279	2.128.468	12.991.787	0	15.120.255	47.325.534
Canarias	137.141.158	33.487.872	13.969.642	184.598.672	9.365.797	14.048.696	0	23.414.493	208.013.165
Cantabria	1.609.823	7.597.982	744.354	9.952.159	0	6.538.023	0	6.538.023	16.490.182
Castilla y León	12.200.519	74.326.849	7.580.218	94.107.586	10.614.757	19.031.532	0	29.646.289	123.753.875
Castilla-La Mancha	19.795.729	103.333.845	12.616.985	135.746.559	3.600.000	38.920.000	0	42.520.000	178.266.559
Cataluña	18.964.839	110.515.668	9.356.207	138.836.714	14.027.703	70.080.681	42.330.713	126.439.097	265.275.811
Extremadura	14.633.645	54.199.370	14.459.933	83.292.948	16.517.356	17.706.344	0	34.223.700	117.516.648
Galicia	30.758.217	192.914.693	22.717.984	246.390.894	27.700.000	67.700.000	57.507.438	152.907.438	399.298.332
Islas Baleares	2.262.970	4.964.566	2.492.796	9.720.332	3.746.010	37.688.441	900.000	42.334.451	52.054.783
La Rioja	644.985	4.446.663	388.591	5.480.239	0	3.742.501	0	3.742.501	9.222.740
Madrid	12.989.841	79.362.279	6.662.352	99.014.472	14.500.000	20.500.000	34.500.000	69.500.000	168.514.472
Murcia	10.834.091	59.757.027	7.748.463	78.339.581	9.034.058	13.550.000	0	22.584.058	100.923.639
Navarra	1.452.749	5.883.677	526.554	7.862.980	0	4.173.589	0	4.173.589	12.036.569
País Vasco	3.494.539	21.573.188	1.837.888	26.905.615	19.208.906	11.918.122	14.583.091	45.710.119	72.615.734
Valencia	25.003.737	165.877.315	20.463.118	211.344.170	8.280.000	27.500.000	32.720.000	68.500.000	279.844.170
Ceuta	491.049	856.436	214.110	1.561.595	0	3.012.541	0	3.012.541	4.574.136
Melilla	1.101.839	2.131.611	232.404	3.465.854	4.130.289	2.199.990	2.774.680	9.104.959	12.570.813
Total nacional	415.225.430	1.524.212.223	196.899.480	2.136.337.133	234.435.683	533.101.562	286.684.556	1.054.221.801	3.190.558.934

¹³ Data obtained from REBECA (Red de Economía Baja en Carbono). Elaboración propia

3.2 Call from the autonomous communities published in the grant platform of the MINHAFP

The MINHAFP provides a platform with all of the grants published by each public organisation, through which 88 credit facilities have been identified for projects related to an economy low in carbon in the 15 autonomous communities (Ceuta and Melilla do not have published credit facilities), which are currently able to receive applications. The value of these credit facilities is €74,055,374. Furthermore, an additional facility from the Public Administration is included, related to the MOVELE and PIMA Aire plans (for electric vehicles), amounting to €33,200,000.

Table 2. Volumen de convocatorias de ayudas para las CC.AA.

CC.AA.	Finalidad de la Convocatoria de ayudas						Total
	General	Edificación	Biomasa	Alumbrado	Transporte	Otros	
Andalucía	672.259	0	0	43.016	200.000	40.845	956.120
Aragón	400.000	1.800.000	0	0	0	0	2.200.000
Asturias	49.900	947.500	0	0	0	0	997.400
Canarias	0	3.000.000	71.000	0	0	0	3.071.000
Cantabria	1.750.000	0	0	0	0	50.000	1.800.000
Castilla y León	3.708.701	2.941.589	0	0	0	0	6.650.290
Castilla-La Mancha	40.000	0	0	0	0	0	40.000
Cataluña	18.000	94.700	0	50.000	0	0	162.700
Comunidad de Madrid	0	25.068.000	0	0	0	0	25.068.000
C.F Navarra	1.020.000	538.000	0	0	0	0	1.558.000
Comunidad Valenciana	3.610.000	200.000	1.600.000	1.600.000	0	0	7.010.000
Extremadura	3.920.000	4.291.171	3.332.882	900.000	0	0	12.444.053
Galicia	0	500.000	0	0	0	2.000.000	2.500.000
Islas Baleares	124.828	2.555.000	231.631	0	0	0	2.911.460
La Rioja	3.455.000	0	700.000	0	0	0	4.155.000
País Vasco	30.000	160.860	0	0	0	0	190.860
Región de Murcia	1.434.707	0	905.784	0	0	0	2.340.491
Ceuta	0	0	0	0	0	0	0
Melilla	0	0	0	0	0	0	0
Total CC.AA.	20.233.395	42.096.820	6.841.297	2.593.016	200.000	2.090.845	74.055.374
Estado*	0	0	0	0	258.200.000	0	33.200.000
Total CC.AA.	20.233.395	42.096.820	6.841.297	2.593.016	258.400.000	2.090.845	332.255.374

*Volumen de ayudas del plan MOVELE, PIMA Aire Y PIVE-8.

The open calls for the autonomous communities can be classified by the area to which the grants are allocated¹⁴. In this way, the current open budgets, which are used for EE/ER actions, building sector, street lighting, sustainable transport or other areas that are not included in the objectives set out for this study (e.g. grants for aquatic companies), have been identified.

As can be seen, the majority of funding for improving transport comes from the MOVELE, PIMA Aire and PIVE – 8 plans, with funding amounting to €258,400,000.

In 2016, the first two plans merged into one under the name of the MOVEA Plan (Plan de impulso de a la Movilidad con Vehículos de Energías Alternativas) with the aim of encouraging the use of alternative energy vehicles in Spain until 2020. In 2017, this will be funded by €16.6m, of which €12m will be used for electric transportation, divided in the following manner¹⁵:

- €7m for private cars
- €4m for light goods vehicles
- €1 for charging stations

This leads to the next scenario: “The substitution of diesel vehicles for electric vehicles in the private sector”. In this section, as we briefly introduced a couple of pages before, we will analyse the number of diesel vehicles that should be substituted for pure electric vehicles and we will carry out the economic analysis in which we will include all the factors that we consider relevant at the time this paper is written and will be key to decide whether the electric vehicles are up to now, a viable idea or if instead we should wither wait or give incentives to the people if we really want to make the transition.

¹⁴ Data obtained from the grant platform published in the MINHAFP.

¹⁵ Plan MOVEA approved for year 2017

Scenario 4.



All of the scenarios considered until now are possible measures for achieving the elimination of the high levels of pollution from particles such as NO_x, PM_{2.5} and PM₁₀. However, if total decarbonisation is to be achieved by 2050, what is really needed is the progressive introduction of electric vehicles so that, even though other vehicles continue to emit particles, they do so in smaller amounts.

So, what impacts do electric vehicles have on the system? One of the impacts that would provoke the introduction of electric vehicles is the increase in electric energy demand. What is likely to happen in Spain will be evaluated in order to qualitatively analyse the impacts on the demand curve. For this we will use a simulator called “Simulador de recarga del Vehículo Eléctrico de Red Eléctrica de España” and which we can access thank to Red Eléctrica de España (REE), which is the Spanish transmission system Operator (TSO).

Two extreme cases will be analysed with the aim of analysing the effects of a high penetration of electric vehicles in Spain.

Given that REE's estimates confirm that the current network is capable of taking over up to 5 million electric vehicles with the need for new investments, an electric vehicle penetration rate of 12% has been used for this simulation, which is approximately the number of vehicles that the current network would be able to support.

figure 13. Demand curve when rational recharging

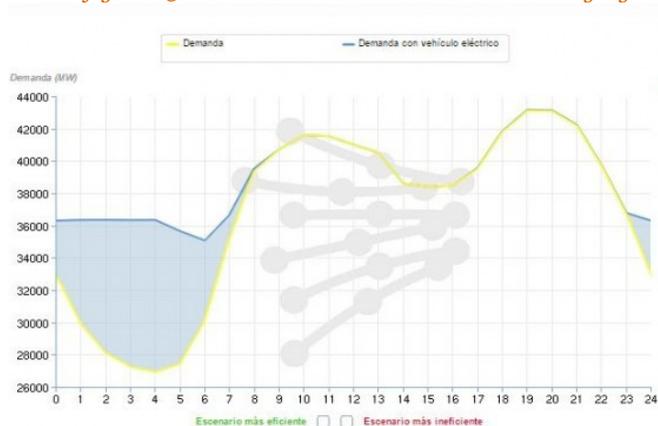
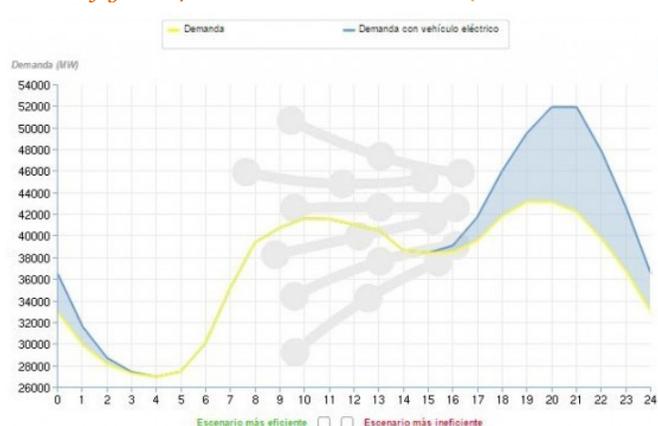


figure 14. Demand curve when not (Red Eléctrica de



The first graph shows the demand curve if electric vehicles are charged in a rational way, for example at night when demand is lower. As aforementioned, one of the benefits of efficiently charging vehicles is levelling out the demand curve, thus achieving a better use of renewable energy as there are certain times at night when wind energy is wasted. Furthermore, the maximum power does not increase, meaning that more time can be taken to make the necessary investments in the network.

On the other hand, if the vehicles are not charged in a rational way, the effects are the opposite to those just mentioned. The maximum power increases notably and, therefore, early investments in the network would be needed. Moreover, one effect of an increase in the maximum power is that primary energy sources, mainly fossil fuels, are introduced into the daily energy mix.

It could be thought as a good idea that giving the maximum priority to the introduction of the electric vehicles since, if we look at the annex and we look the NO_x emissions according to each SNAP group, we can check that 51.4% of the total emissions come from the transport sector, nevertheless we would be lying to ourselves if the origin of that electricity with which we would charge the batteries were being generated by energy sources that use fossil fuels as input.

It would not be fair to clean the air in Madrid but continue polluting other areas and contributing to the fundamental problem that affects the entire planet. Therefore, it is essential that the development of electric is linked recharging vehicles with clean energy, i.e. with renewable energy.

These percentages contribute significantly to total emissions, however knowing that Madrid's main problem is due to the concentration in the most urbanised areas and that the few power plants in Madrid are located in areas that are not heavily populated, efficient emission distribution can be achieved, freeing Madrid from the current high level of pollution.

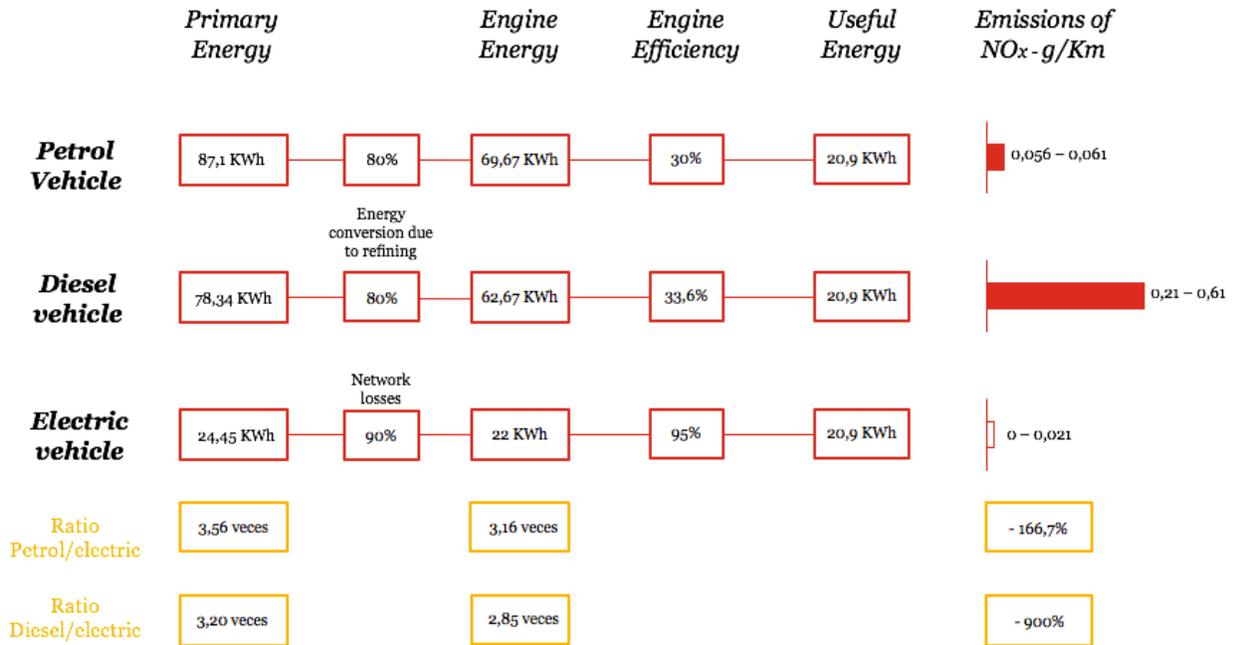
Furthermore, Renewable Energy Sources (RES) penetration levels, both solar and wind, are increasing considerably. This means that these sources are being used more and more to charge batteries.

If the primary energy required by an electric, petrol and diesel vehicles is analysed, it can be seen that electric cars save between 3 and 4 times more primary energy ¹⁶.

In order to compare what are the different energy sources, the levels of pollutants each type of vehicles contributes, next figure will help us understand.

¹⁶ Information obtained from Motorpasión. "Hablemos de eficiencia: coches de combustión vs eléctricos"

figure 15. Comparison between different type of fuel



In order to make a comparison in this study, the Renault Fluence, has been used as the more similar performance is, the more precise calculations and conclusions will be.

As shown in the Figure 14, the percentages by which an electric car reduces emissions compared to other types of fuel are relatively high, particularly with petrol vehicles, which achieve a reduction of 900% and a use of energy 3.2 times lower.

Therefore, the idea of substituting diesel cars as an initiative to solve pollution problems in the city of Madrid would result in the most changes. The question is, how many vehicles would need to be removed from the current vehicle fleet in order to achieve the aim of a 15% reduction of NO_x?

The study carried out by PwC Spain showed that substituting 175,000 petrol vehicles for completely electric vehicles would solve the problem, helping Madrid to become a city that complies with the permitted levels established by the WHO¹⁷.

¹⁷ Número obtenido de análisis PwC España.

In order to achieve an effective implementation of electric vehicles, a large amount of both public and private charging stations is required. In this report, an economic analysis will be carried out based on the following two scenarios:

- If all charging stations were private.
- If all charging stations were public.

As expected, the number of stations for the first of the two scenarios will be much lower, therefore we will utilise the least favourable ratio of 1:1. For the second scenario, we will use a ratio of 1:10, i.e. one charging station for every ten vehicles, as proposed by the Ministry of Industry, Energy and Tourism in the RD 1053/2014, and I quote:

“A título indicativo, el número adecuado de puntos de recarga deberá ser equivalente, al menos, a un punto de recarga cada 10 vehículos, teniendo asimismo en cuenta el tipo de vehículos, la tecnología de carga y los puntos de recarga privados disponibles”

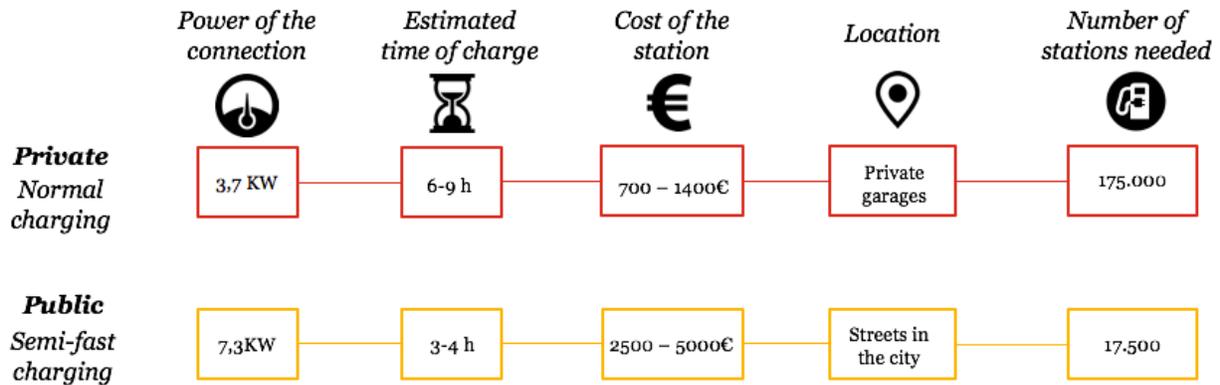
Therefore, if approximately 175,000 electric vehicles are needed then the number of charging stations would be 175,000 for private areas and 17,500 for public areas. Given that the most common are the normal and the semi-fast, only these two types of charging stations will be considered in this study as it can be assumed that fast and super-fast stations will be subject to study when penetration level are higher as their initial investment costs are too high to be economically viable at the moment.

Normal charging stations are the most common to be installed in private garages and semi-quick charging stations tend to be the most common on public roads. Therefore, for ease, it is assumed that all charging stations required for each facility will be distributed in this way.

To summarise, the following figure distinguishes between the charging stations required for private and public vehicles ¹⁸.

¹⁸ Information obtained from Endesa. “Vehículos eléctricos”.

figure 16. Type of charging stations according to location, type, and number of stations needed



Currently in Madrid there are around 300 stations in which we can recharge our electric vehicles, out of which 85 are located in the city of Madrid, spread out in hotels, cinemas, commercial centres, public parking's, Street...etc. This is then a big difference between the 17.500 that this paper proposes. If we calculate the investment that should be done, we can easily find out that we would need approximately 44 to 90 million euros, depending on what is the cost of the station we have considered.

On the other hand, if we consider how much expenditure it would mean installing the charging posts in private houses, the investment needed to cover would be approximately 123 to 245 million euros depending on the actual cost of the station.

However, this would only mean the resolution of one of the barriers, which according to the report elaborated by Cetelem, 63% of the respondents see as the main drawback the lack of infrastructure in the roads to enable them to charge their electric vehicles.¹⁹

figure 17. Main drawbacks when purchasing an electric vehicle



¹⁹ Information obtained from the “observatorio mensual de Cetelem 2015. Los españoles y el vehículo eléctrico.”

However, the prices of the electric vehicles are still very expensive in comparison to the conventional cars (up to 30-40% more expensive²⁰) and as we can see in the previous figure is the second drawback with a 54%. This maybe suggests there must be an incentive in parallel to the individual to purchase an electric vehicle.

So apart of both scenarios presented above, we have to add the idea of what could cost to incentivise the purchase of an electric vehicle to an individual in case we do wasn't to consider it as a possible idea to take by the town hall of Madrid. To calculate the extra amount of money we only need to subtract the average price an electric vehicle is over its homologue car (petrol/diesel)

This means then, considering that an electric vehicle is around 5.000€ more expensive, the amount of extra money needed would raise up to 950M€²¹.

Some of the measures that are already in use, not only in Madrid, but also in many other European cities that suffer the same problem of pollution in the urban areas is to incentivise the purchase of an electric vehicle not only with economic helps, but de incentivising old cars that have as fuel diesel or that are old.

The community of Madrid is adopting several measures to encourage the efficient cars in terms of date of purchase, type of fuel, etc. As an example, here are some of the most recent actions taken by the city hall.

- ✓ In January 2017 the city of Madrid activated for the first the high pollution protocol in which it stated that no cars were allowed to circulate inside what is commonly known in Madrid as the almond, besides electric or hybrid vehicles, taxis and motorbikes.
- ✓ Speed limited to 70 Km/h in the M-30 and 90 Km/h in the M-40, M-50 and some radial roads.
- ✓ Penalties when parking your car in the streets if the vehicle is considered to be a high pollutant vehicle.

²⁰ Datos obtenidos del marco de acciona nacional de energías alternativas en el transporte.

²¹ Este valor incluye el incentivo para los vehículos eléctricos y los puntos de recarga.

As Madrid, some of the measures taken by other European cities like Paris, Brussel, London, etc, who are suffering the same problems of high pollution are presented below²²:

- In Paris, speed reduction measures have also been adopted, public transport has been reorganized, campaigns have been launched to make more rational use of the car and the use of public transport
- In Brussels, the main problem is with high levels of CO₂ and to combat this problem speed-reduction measures have been adopted on motorways throughout the country, programs to raise awareness of people that by reducing one degree Celsius their homes can achieve total savings of 8% and therefore a considerable reduction of CO₂ emissions. As in the Netherlands, Belgians have a long tradition of cycling, so parking has been facilitated in many of the Streets and subway entrances.
- In London, licenses have been revoked for taxis over the age of 15, promotion of electric cars and the imposition of stricter limits for the emission of pickups and minibuses in the low emission zone.
- In Athens, the problems are similar to those of the Community of Madrid as the levels of NO₂ and SO₂ have been very high in recent years. Among the measures adopted, we can find, elimination of the car park those who don't have a catalyst, and the most drastic measure they have adopted is that the city center can only access those cars with even plates on even days and vehicles with odd number plates on odd days.
- In Lisbon, given the serious pollution problems in the most central area of the city suffer, the European Commission has issued a notice for failure to meet the established levels, since they exceeded the upper limit by 135 days. For this reason, measures are being used to regulate access to the vehicles that pollute the historic area of La Baixa.

²² Data obtained from the newspaper ABC. Así combaten la contaminación atmosférica las grandes ciudades europeas”

- In Berlin, despite the lack of use of the vehicles on a daily basis as the use of public transport is the most used means of transportation, parking has been partially or totally limited in some areas of the city center. As has now been done in Madrid, vehicles are required to wear a sticker confirming the quality of the fumes emitted by the exhaust pipe.

It is true that a strong disincentive program is necessary and the measures that have been adopted are appropriate, but to make the transit are also necessary programs campaigns with the aim of making people more and more aware of the environment in The living.

The following table represents some of the incentives that European cities such as Amsterdam, Paris, London or Oslo are adopting as measures to encourage the entry of electric vehicles²³.

Table 3. Incentives in different European citie.

	Amsterdam	Paris	London	Oslo
Subsidy for EV on purchase price	<ul style="list-style-type: none"> • EUR 5.000 / 10.000 / 40.000 for passenger / car / truck 	<ul style="list-style-type: none"> • EUR 4.000 – 7.000 premium (one time grant) 	<ul style="list-style-type: none"> • 25% off (up to GBP 5.000 off) 	<ul style="list-style-type: none"> • Exempt from 25% VAT and purchase Tax.
EV Benefits	<ul style="list-style-type: none"> • No waiting list for parking permits • 4 parking garages with free charging • Exempt from registration tax and annual circulation tax 	<ul style="list-style-type: none"> • Reduced toll and parking fees • For Autolib: free parking exempt from road and registration tax. • Access to bus lanes 	<ul style="list-style-type: none"> • Exempt from congestion charge and registration tax 	<ul style="list-style-type: none"> • Exempt from all non-recurring vehicle fees, including road tax • No parking fees or toll payments • Access to bus and taxi lanes
EV car sharing service	<ul style="list-style-type: none"> • Launched Car2Go in 2011, 300 vehicles (135 Km range) 	<ul style="list-style-type: none"> • Launched Autolib in 2011, 2,000 vehicles (200 Km range) • E-scooter sharing service (2011) 	<ul style="list-style-type: none"> • Launched E-car club in 2013 (145-200 Km range) 	<ul style="list-style-type: none"> • Launched Move in 2009

²³ Information extracted from the report elaborated by McKinsey&Company. Evolution. Electric vehicles in Europe. Gearing up for a new phase.

The entrance of the electric vehicle is ceasing to be a dream and is slowly becoming a reality. In the municipality of Madrid already there are services of ecological mobility by companies like Car2Go, emov, ecootra ... each with a fleet of 500 electric vehicles, that any registered user can rent and use to make the trip that needs. This type of business will not be the only ones in recent years, for example DriveNow, a joint venture of the BMW group and the rental company Sixt, is expected to launch a new fleet of 500 cars with its range of electric vehicles i3 by the end of this Year 2017.

The perception of users when asked about the electric vehicle is very satisfactory in terms of comfort, accessibility, experience... but the vast majority do not see feasible today the idea of acquiring one at a particular level because the prices of these types of vehicles are more expensive than a conventional car as was presented a couple of pages before.

However, there are many factors that we must take into account, since apart from the initial investment that a private individual must make to acquire the car, we must add fuel, maintenance, recharging points, taxes, repairs, etc.

In order to take into account all these factors, we have developed a model in which we try to cover as many as possible in order to obtain more accurate and realistic conclusions.

The following tables then compare what are the factors that should be included when considering analyzing the costs of one of these type of vehicles.

Table 4. Input data for electric and diesel/petrol vehicles

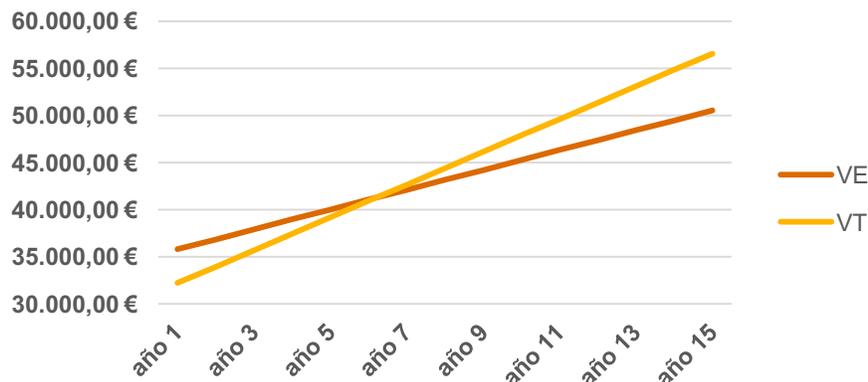
Electric Vehicle input data		Petrol/Diesel input data	
Price (without grants) (€)	33250	Price (€)	25000
Consumption (KWh/100km)	22	Consumption (L/100km)	7
Rental of battery (if its proceeds) (€)	0	Estimated Price of fuel (€/L)	1,15
Installation of the charging station (€)	1500	Daily kilometres	50
Estimated price of electricity (€/KWh)	0,08	Days of use	365
Daily Kilometres	50	Life of vehicle (in years)	15
Days of use	365	Annual parking expenditure in city (€)	200
Life of vehicle (in years)	15	Circulation tax (€)	70
Annual parking expenditure in city (€)	0	Maintenance (€)	420
Circulation tax (€)	0		
Maintenance (€)	255		

Table 5. Breakdown of maintenance cost per type of vehicle²⁴

	Térmico	Eléctrico
Mantenimiento	420	255
Aceite Motor	<input checked="" type="checkbox"/>	X
Aceite Caja de cambios	<input checked="" type="checkbox"/>	X
Filtro de Aceite	<input checked="" type="checkbox"/>	X
Filtro habitáculo	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Filtro de aire	<input checked="" type="checkbox"/>	X
Filtro carburante	<input checked="" type="checkbox"/>	X
Líquido de frenos	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
líquidos de refrigeración	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Correa de distribución	<input checked="" type="checkbox"/>	X
Correa de accesorios	<input checked="" type="checkbox"/>	X
Comprobación controladores	X	<input checked="" type="checkbox"/>
Batería	En Uso	En Uso
Control y nivel de refrigerante	<input checked="" type="checkbox"/>	Cada 6 años
Control de sistema de frenos	<input checked="" type="checkbox"/>	X

As you can see, the initial cost of acquiring an electric vehicle is greater than that of a thermal car. However, as it can be seen in the previous tables, there are many elements in which the thermal vehicle is more expensive than the electric vehicle. Without going any further, it can be seen from table 5 that the maintenance costs are reduced to around 40%, since many of the mechanical parts are totally obsolete. Therefore, if we analyze how long it takes to generate profits, the following graph shows how costs are evolving to what has been considered to be the life cycle of one of these vehicles.

figure 18. Evolution of electric and thermal vehicles costs.



²⁴ Note that this table has been presented in Spanish for simplicity of the author.

As you can see, it is about the sixth year when the electric vehicle generates benefits. If we therefore calculate the amount of money an individual can then save over the 15 years of life, we see the value as being around 18,500€.²⁵

Table 6. Evolution of electric and fossil fuels vehicle costs (price considered: 0,08 €/KWh – 1,15 €/L)

	0,08 €/KWh - 1,15 €/L		
	EV	TV	Difference
year 1	35.801,20 €	32.214,13 €	3.587,08 €
Year 2	36.852,40 €	33.953,25 €	2.899,15 €
Year 3	37.903,60 €	35.692,38 €	2.211,23 €
Year 4	38.954,80 €	37.431,50 €	1.523,30 €
Year 5	40.006,00 €	39.170,63 €	835,38 €
Year 6	41.057,20 €	40.909,75 €	147,45 €
Year 7	42.108,40 €	42.648,88 €	-540,47 €
Year 8	43.159,60 €	44.388,00 €	-1.228,40 €
Year 9	44.210,80 €	46.127,13 €	-1.916,33 €
Year 10	45.262,00 €	47.866,25 €	-2.604,25 €
Year 11	46.313,20 €	49.605,38 €	-3.292,18 €
Year 12	47.364,40 €	51.344,50 €	-3.980,10 €
Year 13	48.415,60 €	53.083,63 €	-4.668,03 €
Year 14	49.466,80 €	54.822,75 €	-5.355,95 €
Year 15	50.518,00 €	56.561,88 €	-6.043,88 €
	TOTAL		18.426,00 €

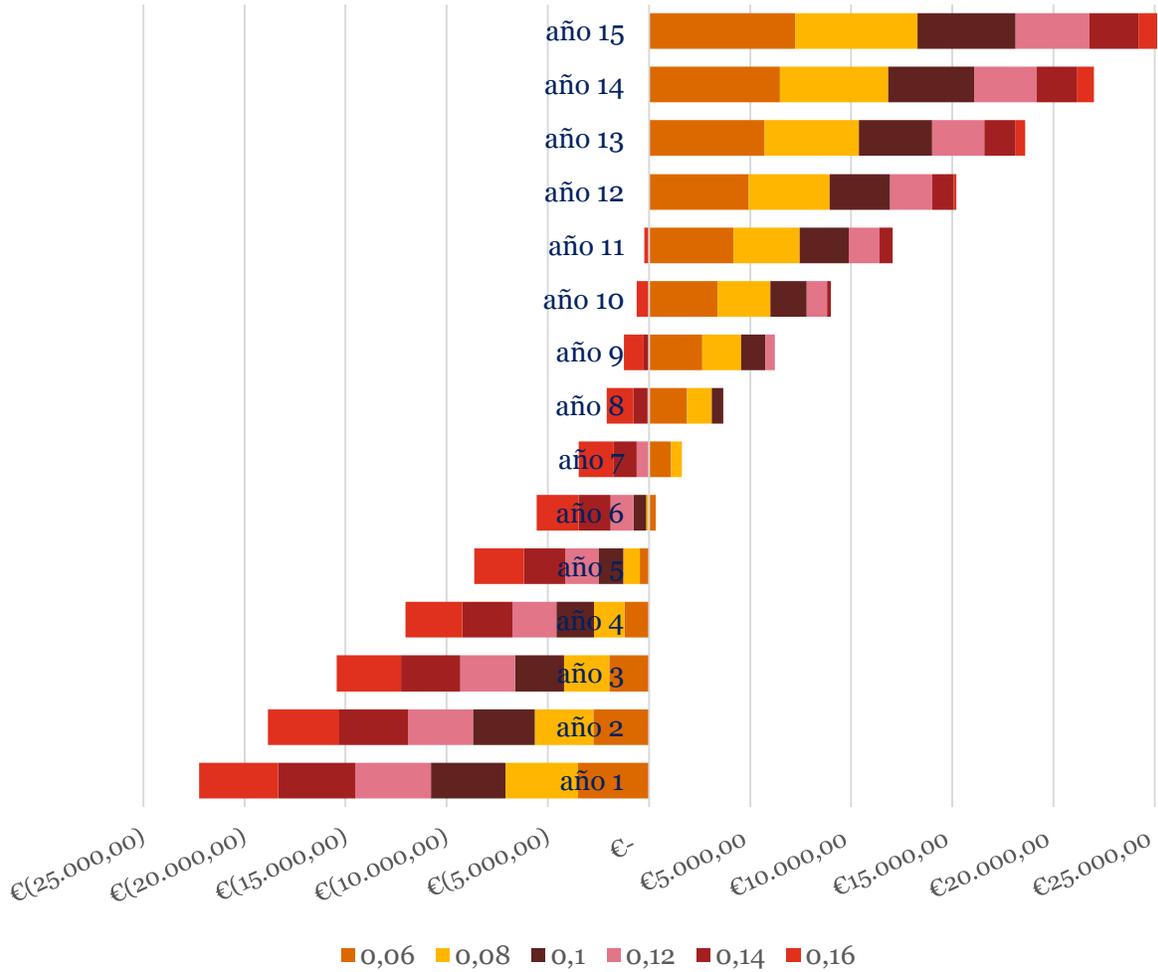
Now, this table has been constructed assuming that all the parameters set in tables four and five remain constant. Therefore, the question one should ask is, How does the profitability of an electric vehicle change if we change the price of electricity? What if we change the number of miles traveled annually?

Next, a sensitivity analysis will be done analyzing the parameters that most affect the profitability of the electric vehicle. This will serve as a precedent to conclude whether an incentive should be given to individuals when purchasing such vehicles or not.

²⁵ We have assumed the prices of electricity are 0,10 €/KWh and 1,15 €/L for fossil fuels. Elaborated by PwC Spain.

The first analysis we will do is assume that the price of fossil fuel remains on average at 1.15 €/L and that the price of recharging the electric vehicle varies between 0.06 and 0.16 €/KWh.

figure 19. Evolution of the electric vehicle costs considering fossil fuel price remains constant.



As can be seen from the above graph, the price of recharge is a factor that generates a very large variability, because if we manage to recharge the electric vehicle at prices of 0.06 €/KWh, which is equivalent to a rational recharge, the electric vehicle begins to generate income from the fifth year. However, if the recharge is not efficient, which would be equivalent to recharging electricity prices of 0.14 or 0.16 € / KWh, we see that it takes approximately 9 to 11 years respectively to generate income.

The following table presents, as presented in table 6, what are the results we would obtain if the recharging was not efficient.

Table 7. sumup of electric and thermal vehicle costs (Price considered: 0,14 y 0,16 €/KWh – 1,15 €/L)

	0,14 €/KWh - 1,15 €/L				0,16 €/KWh - 1,15 €/L		
	VE	VT	Difference		VE	VT	Difference
year 1	36.042,10 €	32.214,13 €	3.827,98 €	año 1	36.122,40 €	32.214,13 €	3.908,28 €
Year 2	37.334,20 €	33.953,25 €	3.380,95 €	year 1	37.494,80 €	33.953,25 €	3.541,55 €
Year 3	38.626,30 €	35.692,38 €	2.933,93 €	Year 2	38.867,20 €	35.692,38 €	3.174,83 €
Year 4	39.918,40 €	37.431,50 €	2.486,90 €	Year 3	40.239,60 €	37.431,50 €	2.808,10 €
Year 5	41.210,50 €	39.170,63 €	2.039,88 €	Year 4	41.612,00 €	39.170,63 €	2.441,38 €
Year 6	42.502,60 €	40.909,75 €	1.592,85 €	Year 5	42.984,40 €	40.909,75 €	2.074,65 €
Year 7	43.794,70 €	42.648,88 €	1.145,83 €	Year 6	44.356,80 €	42.648,88 €	1.707,93 €
Year 8	45.086,80 €	44.388,00 €	698,80 €	Year 7	45.729,20 €	44.388,00 €	1.341,20 €
Year 9	46.378,90 €	46.127,13 €	251,78 €	Year 8	47.101,60 €	46.127,13 €	974,47 €
Year 10	47.671,00 €	47.866,25 €	-195,25 €	Year 9	48.474,00 €	47.866,25 €	607,75 €
Year 11	48.963,10 €	49.605,38 €	-642,28 €	Year 10	49.846,40 €	49.605,38 €	241,03 €
Year 12	50.255,20 €	51.344,50 €	-1.089,30 €	Year 11	51.218,80 €	51.344,50 €	-125,70 €
Year 13	51.547,30 €	53.083,63 €	-1.536,33 €	Year 12	52.591,20 €	53.083,63 €	-492,43 €
Year 14	52.839,40 €	54.822,75 €	-1.983,35 €	Year 13	53.963,60 €	54.822,75 €	-859,15 €
Year 15	54.131,50 €	56.561,88 €	-2.430,38 €	Year 14	55.336,00 €	56.561,88 €	-1.225,88 €
		TOTAL	-10.482,00 €			TOTAL	-20.118,00 €

As it can be seen in Table 7, if the individual does not perform an efficient management of recharging the electric vehicle, despite the fact that it generates profits after nine to eleven years, electric vehicles do not represent a profitable investment, requiring an additional 10,500€ if the recharge prices during the life of the vehicle were 0.14 €/KWh and an additional 9,500€ if the price amounts to 0.16 €/KWh.

In the following table, you can see how the electric vehicle costs vary, keeping the price of fossil fuel fixed by varying electricity prices from 0.06 to 0.16 €/KWh.

It can be seen that with prices of 0.12 €/KWh, which can still be considered very high with respect to what is considered efficient recharging, the electric vehicle is an investment very similar to that of a combustion vehicle.

Table 8. Evolution of electric vehicles costs varying the prices of electricity

	0,06	0,08	0,1	0,12	0,14	0,16
año 1	-3.506,78 €	-3.587,08 €	-3.667,38 €	-3.747,68 €	-3.827,98 €	-3.908,28 €
año 2	-2.738,55 €	-2.899,15 €	-3.059,75 €	-3.220,35 €	-3.380,95 €	-3.541,55 €
año 3	-1.970,33 €	-2.211,23 €	-2.452,13 €	-2.693,03 €	-2.933,93 €	-3.174,83 €
año 4	-1.202,10 €	-1.523,30 €	-1.844,50 €	-2.165,70 €	-2.486,90 €	-2.808,10 €
año 5	-433,88 €	-835,38 €	-1.236,88 €	-1.638,38 €	-2.039,88 €	-2.441,38 €
año 6	334,35 €	-147,45 €	-629,25 €	-1.111,05 €	-1.592,85 €	-2.074,65 €
año 7	1.102,58 €	540,47 €	-21,63 €	-583,72 €	-1.145,83 €	-1.707,93 €
año 8	1.870,80 €	1.228,40 €	586,00 €	-56,40 €	-698,80 €	-1.341,20 €
año 9	2.639,03 €	1.916,33 €	1.193,63 €	470,93 €	-251,78 €	-974,47 €
año 10	3.407,25 €	2.604,25 €	1.801,25 €	998,25 €	195,25 €	-607,75 €
año 11	4.175,48 €	3.292,18 €	2.408,88 €	1.525,58 €	642,28 €	-241,03 €
año 12	4.943,70 €	3.980,10 €	3.016,50 €	2.052,90 €	1.089,30 €	125,70 €
año 13	5.711,93 €	4.668,03 €	3.624,13 €	2.580,23 €	1.536,33 €	492,43 €
año 14	6.480,15 €	5.355,95 €	4.231,75 €	3.107,55 €	1.983,35 €	859,15 €
año 15	7.248,38 €	6.043,88 €	4.839,38 €	3.634,88 €	2.430,38 €	1.225,88 €
TOTAL	28.062,00 €	18.426,00 €	8.790,00 €	-846,00 €	-10.482,00 €	-20.118,00 €

However, in these tables presented above we are considering not only that the price of fuel is 1.15 €/L, but we are considering that we are traveling approximately 15,000 kilometers.

Since fuel is one of the variables that affects the most to the evolution of the costs of both, the electric vehicle and the combustion vehicle, it is logical to think that depending on the number of annual kilometers the individual travels, costs will vary significantly.

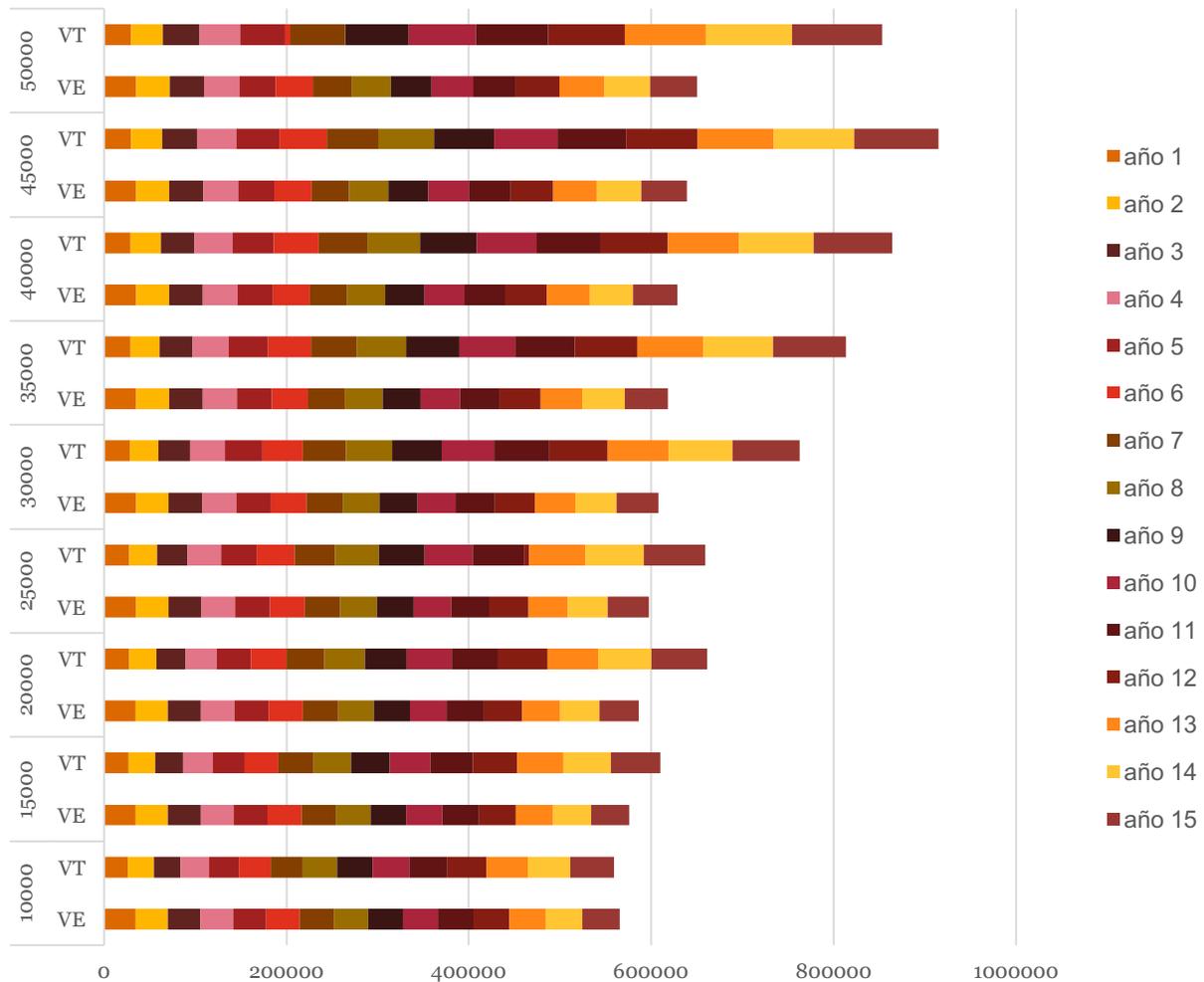
This is what the following graph reflects, the costs from the acquisition of the until reaching the end of the life of the vehicle.

To fill the table, three input data is needed:

- Price of electricity (€/KWh)
- Price of the fossil fuels (€/L)

Following the flow of prices used so far, remember 0.08 €/KWh and 1.15 €/L, the following graph will compare how costs vary according to the number of kilometers per year.

figure 20. Evolutions of costs depending on the annual number of kilometres.



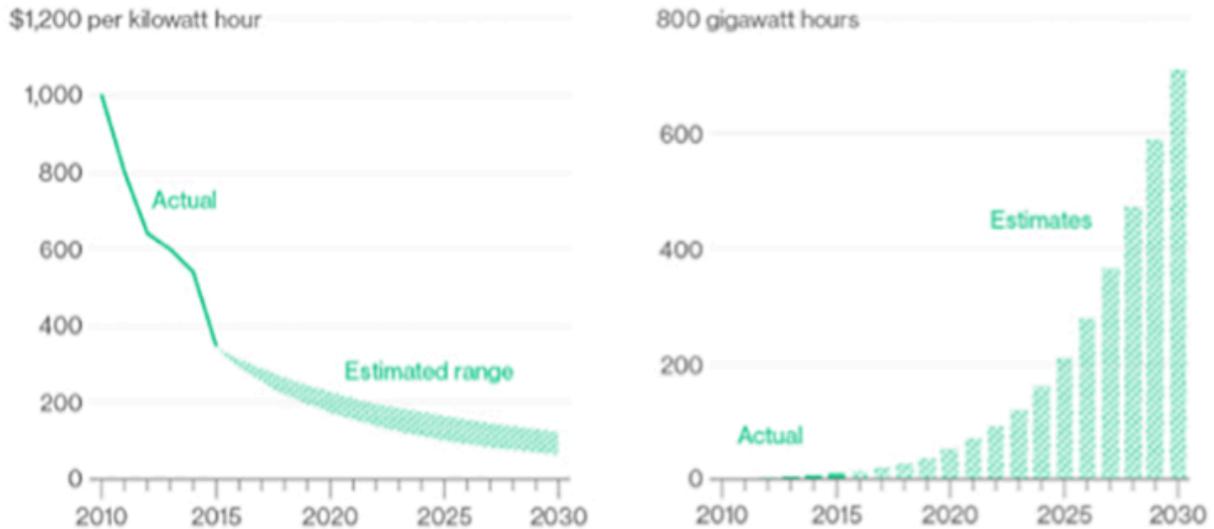
As you can see from the previous graph, as the annual kilometers increase the difference between both vehicles is increasing reaching differences of up to 75,000€ over the life of the vehicle if you travel 20,000 kilometers per year, which is approximately the kilometers that an individual travels in a year.

An important thing to note is that even traveling a distance of 10.000 km per year the investment is very similar, which indicates that if we add the tendency for electric vehicle prices to decline over the years, as it is expected a reduction in prices of batteries, which is what mainly increases the price of electric vehicles²⁶, would amortize the acquisition up to two years earlier than the previous tables indicate. And I quote from the report

²⁶ Information obtained from Bloomberg new energy finance.

published by Bloomberg for the year 2022: “Batteries make up a third of an electric vehicle. As battery costs continue to fall, demand for EVs will continue to rise”. In addition, the increasing measures that are being taken to prevent combustion vehicles from circulating through the busiest areas of the city, as already seen in previous pages, is also a key factor why prices will also decrease within years.

figure 21. Costs of batteries and yearly demand for EVs battery power.



As a conclusion of all these analyzes that have been made in the previous pages, being an investment that is amortized over the years, this document proposes that it would not be necessary to give many incentives to the purchase of the electric vehicle, but to focus the efforts in installing more public stations as it is seen in figure 17 the main barrier to purchase an electric vehicle.

To remember which were the investments that were obtained to install all the infrastructure proposed, public and private, and acquisition of electric vehicles, the following image breaks down the amounts to us schematically²⁷.

²⁷ Remember the prices obtained are based in assumptions presented previously in the document.

figure 22. Funds needed for electric vehicles and charging infrastructure.

Incentives VE and infrastructure

***Electric
Vehicle***



950 M€

Individual



123 - 245 M€

Streets



44 - 88 M€

Therefore, by dedicating the smallest of the investments, which is effectively and efficiently deploying the recharging infrastructure stations all around the city of Madrid, not only it can be saved over 1.000 million euros in incentives for the Madrid city council, but it will also mean a broader entrance of the electric vehicle with a greater speed because this type of measures tells the consumer that the city is prepared for its incorporation to the day to day. However, these investments only cover what is the recharging point and not the reinforcements that would have to be made in new management and measurement centers, expansion of the distribution network, additional and more specific software, ways of charging the customer Connects ... etc.

All these are costs that will have to be faced by the distributors and therefore an additional cost that had not been mentioned, but thanks to the report published by the IIT, we can get an idea of how much these values go for a penetration of 9.24%, which is what they estimate to be the penetration of the electric vehicle in the year 2030 for what they consider their scenario III.²⁸

- Medium and low voltage transformers: 390 €/VE.
- Medium voltage network: 270 €/VE.
- Low voltage network: 275 €/VE.
- Management and control equipment € 75 per meter.
- 70.000 € for new software.

²⁸ Information obtained from report published by the IIT “cost-benefit analysis of plug in electric vehicles penetration.”

4. Conclusions

This project presents a strategic plan with the objective of reducing the pollutant elements (NO_x , $\text{PM}_{2.5}$ or PM_{10}) that the city of Madrid is suffering being then one of the reasons why the European Commission has opened a file. Therefore, the beginning of the project was to analyse the origins of these high levels and quantify which of the main sectors is the main contributor to these high emissions.

After carefully analysing the data obtained from the annual report the town hall of Madrid published related to the air quality of the city, it was discovered that the origins of the high levels are mainly due to the transport sector, specially diesel vehicles covering a high percentage of the total amount of emissions.

Therefore, this paper has focused on analysing what are some of the measures that could be done to correct this situation, concluding that the substitution of certain amount of diesel cars for electric vehicles would be most suitable measure to adopt. This paper shows that the investments that would have to be held by Madrid's town hall would be very high and not affordable with just public investment. The reason behind is due to the fact that covering all the costs involved in building new charging infrastructure (Private and Public) and the current differences in prices between conventional and electric vehicles reach very high amounts. Nevertheless, after building the model in which we compare the evolution of costs for a combustion and an electric vehicle, we can see the last one has a return on investment within years. Additionally, the fact that cost of batteries is intended to decrease, a substantial reduction in prices of the electric vehicles is also expected to occur the following years, reducing then the return of investment of the purchase.

Note that all the returns of investments calculated are subject to a big uncertainty since prices of electricity and fossil fuels are very volatile, therefore, a sensitivity analysis was carried out to understand how can the prices affect the years in which the electric vehicle starts generating a positive cash flow.

Using what we have considered the most likely situation to happen, this paper then proposes the reduction/elimination of subsidies for the acquisition of electric vehicles since it is an investment that amortises with time, enhancing Madrid's town hall to focus efforts in building public infrastructure all around the city.

Finally, some improvements can still be done to the model and the input data in order to obtain more realistic results. This paper suggests the need of a broader analysis of the costs that would incur installing new public recharging infrastructure since this report only covers the main costs distribution companies would have to use to reinforce the actual measurement systems, software, feeders, network, etc.

5. Appendix

Stations	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Average.
Arturo Soria	46	41	36	33	30	30	28	27	41	43	51	51	38
Av. Ramon y Cajal	44	37	39	37	37	39	41	34	52	57	52	58	44
Barajas	43	34	36	31	29	28	28	31	42	48	45	51	37
Barrio del Pilar	43	36	34	32	30	29	32	30	45	53	51	61	40
C/ Farolillo	42	36	37	32	31	28	28	28	44	52	50	59	39
Casa de Campo	24	18	17	16	14	12	15	15	24	31	31	39	21
Cuatro Caminos	45	39	38	35	33	34	36	28	46	56	55	67	43
El Pardo	21	15	15	15	13	13	16	14	22	23	24	25	18
Ensanche Vallecas	41	32	34	32	30	25	25	24	38	47	49	57	36
Escuelas Aguirre	56	54	54	49	50	53	52	46	65	70	66	71	57
Mendez Alvaro	44	37	36	30	27	25	26	26	42	54	53	61	38
Moratalaz	44	37	37	32	31	31	29	28	44	47	48	63	39
Parque Juan Carlos I	23	18	20	17	17	15	17	16	26	30	24	26	21
Pº Castellana	43	36	37	34	32	31	30	25	43	46	46	51	38
Pza Castilla	48	42	43	40	38	38	37	31	47	51	51	56	43
Pza de España	43	37	40	38	37	40	42	37	57	60	54	61	46
Pza. del Carmen	46	43	46	42	39	37	47	42	49	55	52	57	46
Pza. Fdez. Ladreda	52	47	49	47	47	48	52	49	65	66	68	78	56
Retiro	38	31	32	26	24	23	22	18	33	43	44	49	32
Sanchinarro	41	32	32	29	26	23	25	22	36	42	46	53	34
Tres Olivos	41	34	34	29	27	25	25	23	37	45	50	55	36
Urb. Embajada (Barajas)	49	40	41	36	34	32	33	35	47	53	52	57	42
Vallecas	45	37	38	32	31	29	30	29	43	52	54	59	40
Villaverde Alto	47	40	40	33	32	31	29	30	49	54	55	73	43
Total	42	35	36	32	31	30	31	29	43	49	49	55	39
Upper limit	40	40	40	40	40	40	40	40	40	40	40	40	40

NO_x data extracted from the town hall of the city of Madrid – 2016.

Data analysed with excel. Self-prepared.

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- AUTOBUSES Y AUTOCARES (3,0%)
- MOTOS y CICLOMOTORES (6,0%)
- PESADOS (1,0%)

La distribución del parque circulante en este escenario central es la que se presenta en el Anexo A.IV, distinguiendo por categoría de vehículo, combustible, uso del vehículo y normativa aplicable.

4.2 EMISIONES POR CATEGORÍAS DEL VEHÍCULO TIPO.

La contribución a las emisiones del parque circulante por categoría de vehículo teniendo en cuenta sus recorridos, y ordenadas las categorías en orden descendente, es la siguiente (véanse más abajo tablas y gráfico del escenario “escenario central”):

En términos de NO_x

- TURISMOS (53,4%) , de los cuales, sobre el parque total de vehículos, son de :

GASÓLEO: 46,3% (porcentaje relativo a turismos: 86,6%)

GASÓLEO “EURO III y +” : 41,5%

GASÓLEO “EURO II y -” : 4,8%

GASOLINA: 7,1% (porcentaje relativo a turismos: 13,4%)

- AUTOBUSES Y AUTOCARES (31,6%)
- LIGEROS (7,1%)
- PESADOS (6,7%)
- MOTOS y CICLOMOTORES (1,2%)

En términos de NO₂ primario

- TURISMOS (70,9) , de los cuales, sobre el parque total de vehículos, son de :

GASÓLEO: 69,8% (porcentaje relativo a turismos: 98,5%)

GASÓLEO EURO III y +: 67,7%

GASÓLEO EURO II y -: 2,1%

GASOLINA: 1,1% (porcentaje relativo a turismos: 1,5%)

- AUTOBUSES Y AUTOCARES (16,4%)
- LIGEROS (9,0%)
- PESADOS (3,5%)
- MOTOS y CICLOMOTORES (0,2%)

MUESTREOS CON CÁMARAS VEHÍCULO TIPO						
CATEGORÍA DE VEHÍCULO				NO_x		
				P	FE (g/km)	%EE TOTAL
AUTOBUSES			2,27%	10,4911	26,91%	12,81%
	EMT		1,57%	11,3546	20,15%	12,79%
		BIODIÉSEL	1,05%	13,6269	16,08%	13,12%
		GASÓLEO	0,35%	8,5519	3,35%	12,88%
		GNC	0,18%	3,5682	0,73%	5,00%
	RESTO	GASÓLEO	0,70%	8,5519	6,76%	12,88%
LIGEROS			5,91%	1,0970	7,31%	33,24%
MOTOCICLETAS			3,16%	0,1521	0,54%	3,07%
PESADOS			0,63%	5,5391	3,95%	13,07%
TURISMOS			88,01%	0,6176	61,30%	35,46%
	GLP		0,00%	0,1044	0,00%	5,00%
	GASOLINA		23,62%	0,2392	6,37%	3,76%
	GASÓLEO		64,39%	0,7564	54,93%	39,14%
		EURO II y ANTERIORES	4,97%	0,8198	4,59%	11,00%
		EURO III y POSTERIORES	59,42%	0,7511	50,33%	41,71%
TOTAL				0,8867		

MUESTREOS CON CÁMARAS VEHÍCULO TIPO						
CATEGORÍA DE VEHÍCULO				NO		
				P	FE (g/km)	%EE TOTAL
AUTOBUSES			2,27%	9,1469	32,65%	87,19%
	EMT		1,57%	9,9025	24,45%	87,21%
		BIODIÉSEL	1,05%	11,8390	19,44%	86,88%
		GASÓLEO	0,35%	7,4501	4,06%	87,12%
		GNC	0,18%	3,3898	0,96%	95,00%
	RESTO	GASÓLEO	0,70%	7,4501	8,19%	87,12%
LIGEROS			5,91%	0,7323	6,79%	66,76%
MOTOCICLETAS			3,16%	0,1474	0,73%	96,93%
PESADOS			0,63%	4,8153	4,78%	86,93%
TURISMOS			88,01%	0,3986	55,06%	64,54%
	GLP		0,00%	0,0992	0,00%	95,00%
	GASOLINA		23,62%	0,2302	8,53%	96,24%
	GASÓLEO		64,39%	0,4603	46,52%	60,86%
		EURO II y ANTERIORES	4,97%	0,7296	5,69%	89,00%
		EURO III y POSTERIORES	59,42%	0,4378	40,83%	58,29%
TOTAL				0,6372		

0,10 €/KWh - 1,15 €/L	10.000 €		15.000 €		20.000 €		25.000 €	
	VE	VT	VE	VT	VE	VT	VE	VT
1	34.681 €	26.537 €	34.769 €	26.961 €	34.857 €	27.384 €	34.945 €	27.808 €
2	35.112 €	28.074 €	35.288 €	28.921 €	35.464 €	29.768 €	35.640 €	30.615 €
3	35.543 €	29.611 €	35.807 €	30.882 €	36.071 €	32.152 €	36.335 €	33.423 €
4	35.974 €	31.148 €	36.326 €	32.842 €	36.678 €	34.536 €	37.030 €	36.230 €
5	36.405 €	32.685 €	36.845 €	34.803 €	37.285 €	36.920 €	37.725 €	39.038 €
6	36.836 €	34.222 €	37.364 €	36.763 €	37.892 €	39.304 €	38.420 €	41.845 €
7	37.267 €	35.759 €	37.883 €	38.724 €	38.499 €	41.688 €	39.115 €	44.653 €
8	37.698 €	37.296 €	38.402 €	40.684 €	39.106 €	44.072 €	39.810 €	47.460 €
9	38.129 €	38.833 €	38.921 €	42.645 €	39.713 €	46.456 €	40.505 €	50.268 €
10	38.560 €	40.370 €	39.440 €	44.605 €	40.320 €	48.840 €	41.200 €	53.075 €
11	38.991 €	41.907 €	39.959 €	46.566 €	40.927 €	51.224 €	41.895 €	55.883 €
12	39.422 €	43.444 €	40.478 €	48.526 €	41.534 €	53.608 €	42.590 €	58.690 €
13	39.853 €	44.981 €	40.997 €	50.487 €	42.141 €	55.992 €	43.285 €	61.498 €
14	40.284 €	46.518 €	41.516 €	52.447 €	42.748 €	58.376 €	43.980 €	64.305 €
15	40.715 €	48.055 €	42.035 €	54.408 €	43.355 €	60.760 €	44.675 €	67.113 €

0,10 €/KWh - 1,15 €/L	30000		35000		40000		45000	
	VE	VT	VE	VT	VE	VT	VE	VT
1	35.033 €	28.231 €	35.121 €	28.655 €	35.209 €	29.078 €	35.297 €	29.502 €
2	35.816 €	31.462 €	35.992 €	32.309 €	36.168 €	33.156 €	36.344 €	34.003 €
3	36.599 €	34.693 €	36.863 €	35.964 €	37.127 €	37.234 €	37.391 €	38.505 €
4	37.382 €	37.924 €	37.734 €	39.618 €	38.086 €	41.312 €	38.438 €	43.006 €
5	38.165 €	41.155 €	38.605 €	43.273 €	39.045 €	45.390 €	39.485 €	47.508 €
6	38.948 €	44.386 €	39.476 €	46.927 €	40.004 €	49.468 €	40.532 €	52.009 €
7	39.731 €	47.617 €	40.347 €	50.582 €	40.963 €	53.546 €	41.579 €	56.511 €
8	40.514 €	50.848 €	41.218 €	54.236 €	41.922 €	57.624 €	42.626 €	61.012 €
9	41.297 €	54.079 €	42.089 €	57.891 €	42.881 €	61.702 €	43.673 €	65.514 €
10	42.080 €	57.310 €	42.960 €	61.545 €	43.840 €	65.780 €	44.720 €	70.015 €
11	42.863 €	60.541 €	43.831 €	65.200 €	44.799 €	69.858 €	45.767 €	74.517 €
12	43.646 €	63.772 €	44.702 €	68.854 €	45.758 €	73.936 €	46.814 €	79.018 €
13	44.429 €	67.003 €	45.573 €	72.509 €	46.717 €	78.014 €	47.861 €	83.520 €
14	45.212 €	70.234 €	46.444 €	76.163 €	47.676 €	82.092 €	48.908 €	88.021 €
15	45.995 €	73.465 €	47.315 €	79.818 €	48.635 €	86.170 €	49.955 €	92.523 €

Numbers obtained from the input data shown in tables 5 and 6 in the paper. Self-prepared

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	RESUMEN AÑO ANTERIOR DE LA RCE (1) 2015						ESTIMACION Diciembre 2015		VARIACIONES TEMPORALES DE TRAFICO (%) (3)						CUADRO ORIGEN	
	Longitud	IMD (Veh/Día)	Vh-Km	Crec. 15/14	Porc. Porc.(4)	E (2)	IMD (Veh/Día)	Vh-Km (7)	MENSUAL		ANUAL		INTERANUAL			
									2015 / 2014	2014 / 2013	2015 / 2014	2014 / 2013	2015 / 2014	2014 / 2013		
TOTAL RCE (1)																
Motos	26.311,57	81	773.110.251		100,0	0,6	D									
Ligeros	26.311,57	10.716	102.914.132.331	3,7	100,0	85,3	D	9.569	7.804.758.602	2,8	(3,2)	3,7	(1,1)	3,7	(1,1)	Cuadro 1
Pesados	26.311,57	1.648	15.824.589.703	5,6	100,0	14,0	D	1.568	1.278.689.294	11,6	(4,5)	5,6	(3,0)	5,6	(3,0)	
Total(8)	26.311,57	12.444	119.511.832.285	4,0	100,0	100,0	D	11.213	9.145.860.328	4,0	(3,4)	4,0	(1,3)	4,0	(1,3)	
1.TOTAL RCE SIN AUTOPISTAS DE PEAJE																
Ligeros	23.761,47	10.266	89.032.537.203	3,3	86,5	85,4	D	9.168	6.753.022.767	2,6	(3,1)	3,3	(1,1)	3,3	(1,1)	Cuadro 1a
Pesados	23.761,47	1.564	13.560.720.804	5,2	85,4	13,8	D	1.483	1.092.499.384	11,0	(4,0)	5,2	(2,5)	5,2	(2,5)	
Total(8)	23.761,47	11.913	103.323.154.419	3,6	86,4	100,0	D	10.731	7.904.660.491	3,8	(3,2)	3,6	(1,3)	3,6	(1,3)	
1.1 AUTOVIA y AUT.LIBRE (5)																
Ligeros	9.402,33	20.687	70.994.736.004	3,7	70,1	85,2	D	18.766	5.469.772.450	2,0	(3,6)	3,7	(1,3)	3,7	(1,3)	Cuadro 2
Pesados	9.402,33	3.138	10.769.615.131	5,6	70,2	14,0	D	3.078	897.108.208	12,4	(3,6)	5,6	(3,0)	5,6	(3,0)	
Total(8)	9.402,33	23.975	82.278.362.091	4,0	70,2	100,0	D	22.024	6.419.479.530	3,7	(3,7)	4,0	(1,6)	4,0	(1,6)	
1.2 CONVENCIONAL																
Ligeros	14.359,13	3.442	18.037.801.199	1,7	16,4	86,4	D	2.883	1.283.250.317	-3,2	(1,3)	1,7	(0,1)	1,7	(0,1)	Cuadro 5
Pesados	14.359,13	533	2.791.105.673	3,6	15,3	13,2	D	439	195.391.176	-3,0	(3,5)	3,6	(0,8)	3,6	(0,8)	
Total(8)	14.359,13	4.015	21.044.792.328	1,9	16,2	100,0	D	3.336	1.485.180.962	-3,8	(2,1)	1,9	(0,1)	1,9	(0,1)	
2.AUTOPISTAS DE PEAJE (9)																
Ligeros	2.550,14	14.914	13.881.595.128	6,1	13,5	84,7	D	13.304	1.051.735.835	6,3	(5,1)	6,1	(1,7)	6,1	(1,7)	Cuadro 3
Pesados	2.550,14	2.432	2.263.868.899	8,1	14,6	15,0	D	2.355	186.189.909	6,4	(11,2)	8,1	(6,8)	8,1	(6,8)	
Total(8)	2.550,14	17.392	16.188.677.866	6,4	13,6	100,0	D	15.701	1.241.199.836	6,3	(6,0)	6,4	(2,4)	6,4	(2,4)	
INTERURBANO (6)																
Ligeros	20.086,97	7.148	52.405.491.067	3,7	48,2	82,2	D	6.041	3.761.443.738	-0,9	(3,4)	3,7	(1,3)	3,7	(1,3)	Cuadro 6
Pesados	20.086,97	1.376	10.087.168.354	5,5	62,8	17,5	D	1.289	802.925.489	11,8	(3,5)	5,5	(2,8)	5,5	(2,8)	
Total(8)	20.086,97	8.564	62.790.773.840	4,0	50,1	100,0	D	7.352	4.578.356.516	1,0	(3,4)	4,0	(1,6)	4,0	(1,6)	
PERIURBANO																
Ligeros	6.224,60	22.231	50.508.641.264	3,7	51,8	88,5	D	20.954	4.043.314.864	3,9	(2,9)	3,7	(0,8)	3,7	(0,8)	Cuadro 7
Pesados	6.224,60	2.525	5.737.421.349	5,8	37,2	10,4	D	2.466	475.763.804	9,8	(8,1)	5,8	(3,3)	5,8	(3,3)	
Total(8)	6.224,60	24.966	56.721.058.445	3,9	49,9	100,0	D	23.670	4.567.503.812	4,7	(3,5)	3,9	(1,1)	3,9	(1,1)	

(2) P - Provisional: Año base 2014 con datos provisionales de estaciones Permanentes y Semipermanentes en 2015

E - Estimado: Año base 2014 con datos estimados de estaciones Permanentes y Semipermanentes de los años siguientes: 2015

D - Definitivo: Año base 2014 con datos definitivos del tráfico registrado en la RCE. Año 2014 obtenido a partir del comportamiento de las estaciones Perm y Semiperm una vez validados los datos de cada mes..

(3) Variación mensual, anual (desde enero hasta el mes en estudio) o interanual (12 meses hasta el mes de estudio) del tráfico en el periodo estimado en relación al valor obtenido durante el mismo periodo en idéntico mes del año anterior. Entre paréntesis figura el valor del crecimiento registrado en el mismo mes del año anterior y en idéntico periodo.

(4) La primera cifra es el porcentaje de Lig, Pes y Total de ese tipo de vía o ámbito respecto al tráfico total de la RCE de ese tipo de vehículo (L, P y T) mientras que el segundo indica el porcentaje del tipo de vehículo (L, P y T) respecto al tráfico total de la red en ese mismo grupo

(5) A efectos de esta estimación, las carreteras de Doble calzada están incluidas en este tipo.

(6) A efectos de esta estimación las autopistas de peaje se incluyen en el ámbito interurbano.

(7) La estimación (IMD v Vh/Km) corresponde al mes indicado. En los cuadros 1 a 7 figuran las series mensuales de los 3 años v sus valores.

(8) El TOTAL 2014 comprende realmente al resumen del año base v es la suma de ligeros, pesados v motos.

(9) La longitud de autopistas de peaje según inventario es 2538.15 km pero a efectos de tráfico según el servicio de concesiones de autopistas con datos completos comparables en 3 años es el que aparece en este informe (Punto 2 v Cuadro 3).

ELABORACION: Subdirección General Explotación y Gestión de Red (DGC) con datos de las estaciones de aforos permanentes, semipermanentes y autopistas de peaje.

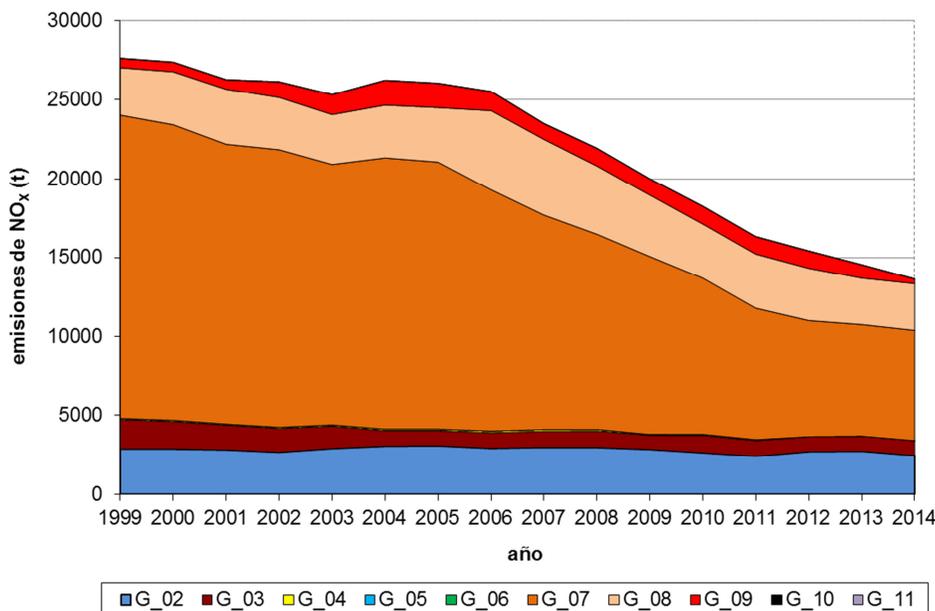


Figura 6. Evolución de las emisiones de NO_x por grupo SNAP (t)

En la Tabla 10 y Figura 7 se muestra de forma numérica y gráfica la evolución de la contribución porcentual de cada grupo SNAP a las emisiones totales de NO_x. El grupo más relevante es el SNAP 07, que representa entre el 70% y el 48% de las emisiones a lo largo del periodo inventariado. Los siguientes grupos con mayor contribución al total son los SNAP 02 y 08, que en 2014, aportaron, respectivamente, el 18% y 21%, del total. Los grupos SNAP 03 y 09 participan de forma menos relevante pero significativa (7% y 2% en 2014, respectivamente), mientras que el resto de grupos de forma conjunta apenas suponen el 0,14% de las emisiones.

Tabla 10. Contribución a las emisiones de NO_x por grupo SNAP (%)¹

Año	G_02	G_03	G_04	G_05	G_06	G_07	G_08	G_09	G_10	G_11	TOTAL
1999	10,4	6,7	0,26	0,0	0,0	69,5	10,9	2,1	0,02	0,06	100
2000	10,4	6,3	0,30	0,0	0,0	68,4	12,2	2,2	0,01	0,06	100
2001	10,7	5,9	0,27	0,0	0,0	67,5	13,2	2,3	0,01	0,06	100
2002	10,2	5,7	0,28	0,0	0,0	67,3	12,6	3,8	0,01	0,06	100
2003	11,4	5,6	0,32	0,0	0,0	65,3	12,4	5,0	0,01	0,07	100
2004	11,6	3,7	0,34	0,0	0,0	65,6	12,7	6,0	0,01	0,06	100
2005	11,8	3,7	0,34	0,0	0,0	65,1	13,2	5,9	0,01	0,06	100
2006	11,4	3,8	0,43	0,0	0,0	60,0	19,5	4,7	0,01	0,07	100
2007	12,6	4,3	0,46	0,0	0,0	57,9	20,4	4,2	0,01	0,07	100
2008	13,5	4,7	0,45	0,0	0,0	56,4	19,8	5,1	0,00	0,07	100
2009	14,2	4,5	0,26	0,0	0,0	56,3	19,5	5,2	0,00	0,08	100
2010	14,3	6,0	0,41	0,0	0,0	54,1	18,9	6,2	0,01	0,09	100
2011	14,7	6,0	0,37	0,0	0,0	51,1	21,0	6,8	0,01	0,10	100
2012	17,5	6,1	0,00	0,0	0,0	47,8	21,4	7,1	0,01	0,11	100
2013	18,7	6,6	0,00	0,0	0,0	48,7	20,0	5,9	0,01	0,11	100
2014	18,0	6,9	0,00	0,0	0,0	51,4	21,5	2,1	0,01	0,13	100

1) G_02: Combustión no industrial; G_03: Combustión industrial; G_04: Procesos industriales sin combustión; G_05: Extracción y distribución de combustibles; G_06: Uso de disolventes; G_07: Transporte por carretera; G_08: Otros modos de transporte; G_09: Tratamiento de residuos; G_10: Agricultura; G_11: Naturaleza.

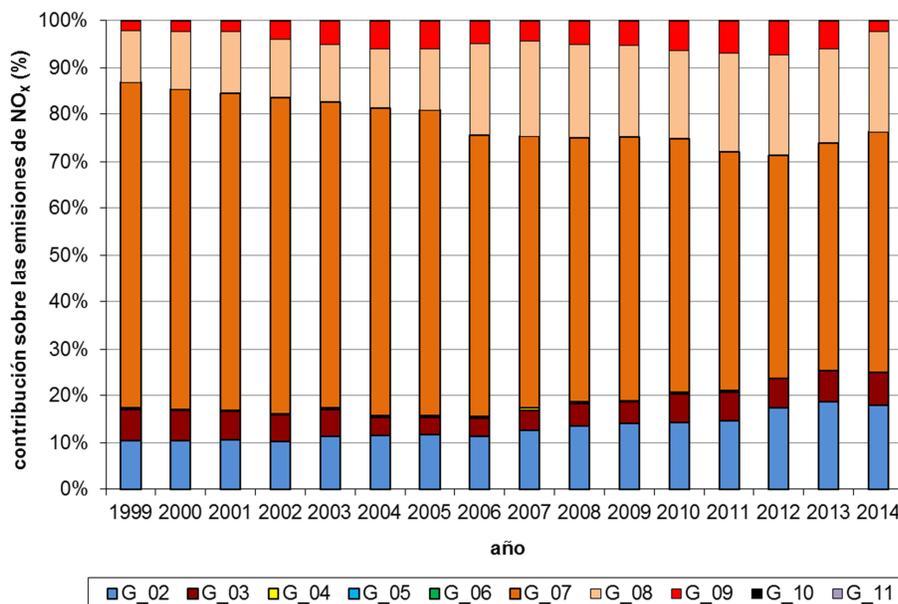


Figura 7. Contribución por grupo SNAP al total de emisiones de NO_x (%)

La Tabla 11 y la Figura 8 muestran la evolución de las emisiones de cada sector a lo largo del periodo inventariado, tomando como base el año 1999.

A excepción del grupo SNAP 11, que apenas varía, se observa que las emisiones de NO_x son menores en 2014 que en 1999. Las emisiones de NO_x del grupo SNAP 08 se han estabilizado en los dos últimos años, tras una tendencia descendente desde 2006.

El importante aumento de las emisiones del grupo SNAP 09 en el periodo 2002-2013 se produce por la utilización de gas natural en el secado de lodos durante esos años.

Tabla 11. Evolución de las emisiones de NO_x por grupo SNAP (Año 1999 = 100)¹

Año	G_02	G_03	G_04	G_05	G_06	G_07	G_08	G_09	G_10	G_11
1999	100	100	100	-	-	100	100	100	100	100
2000	100	94	115	-	-	97	111	102	69	100
2001	98	84	100	-	-	92	115	101	44	99
2002	93	81	105	-	-	92	109	168	44	101
2003	101	76	113	-	-	86	104	212	48	103
2004	106	53	127	-	-	90	110	266	39	100
2005	107	52	126	-	-	88	114	261	32	102
2006	101	53	154	-	-	80	166	204	32	106
2007	103	55	153	-	-	71	159	168	29	99
2008	103	56	140	-	-	64	144	188	20	101
2009	99	48	74	-	-	59	130	175	21	101
2010	91	59	106	-	-	51	114	191	31	99
2011	84	53	86	-	-	43	114	187	23	104
2012	94	51	0	-	-	38	109	185	24	103
2013	95	51	0	-	-	37	97	144	26	101
2014	85	51	0	-	-	36	97	49	26	107

1) G_02: Combustión no industrial; G_03: Combustión industrial; G_04: Procesos industriales sin combustión; G_05: Extracción y distribución de combustibles; G_06: Uso de disolventes; G_07: Transporte por carretera; G_08: Otros modos de transporte; G_09: Tratamiento de residuos; G_10: Agricultura; G_11: Naturaleza.

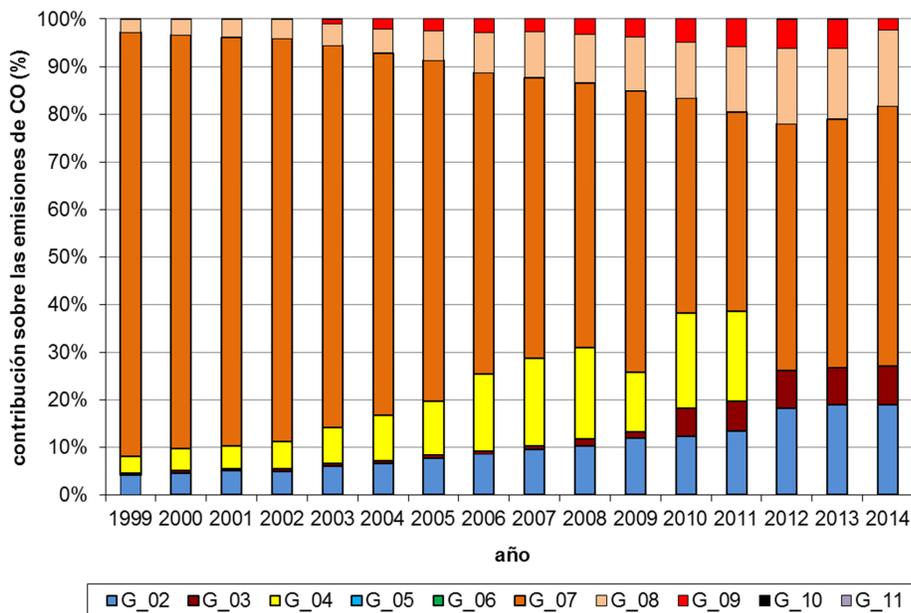


Figura 16. Contribución por grupo SNAP al total de emisiones de CO (%)

3.2.4 Emisiones de material particulado

En la Tabla 20, Tabla 21 y Tabla 22 y en la Figura 17, Figura 18 y Figura 19 se muestran de forma numérica y gráfica las emisiones de PM_{2,5}, PM₁₀ y PST del municipio de Madrid.

Las emisiones totales de partículas han descendido, de forma evidente, en el periodo 1999–2014. Concretamente, la reducción estimada para PM_{2,5} se sitúa en el 58% y para las PST en el 51%. Además, se observa que son los grupos SNAP 07 y 02 los que presentan una mayor contribución al total.

Tabla 20. Emisiones de PM_{2,5} por grupo SNAP (t)¹

Año	G_02	G_03	G_04	G_05	G_06	G_07	G_08	G_09	G_10	G_11	TOTAL
1999	597	60	7	0	0	1.133	49	26	0,8	0	1.872
2000	534	54	9	0	0	1.111	51	33	0,8	0	1.793
2001	465	47	7	0	0	1.054	52	11	0,8	0	1.637
2002	407	44	8	0	0	1.050	51	10	0,8	0	1.571
2003	392	39	8	0	0	997	50	20	0,9	0	1.506
2004	379	24	9	0	0	1.011	50	41	0,7	0	1.514
2005	369	23	9	0	0	969	49	33	0,7	0	1.452
2006	358	26	11	0	0	892	141	25	0,7	0	1.454
2007	346	25	11	0	0	801	110	25	0,7	0	1.319
2008	325	18	10	0	0	744	87	22	0,7	0	1.207
2009	313	16	5	0	0	688	72	20	0,7	0	1.115
2010	304	12	8	0	0	590	46	21	0,7	0	980
2011	293	9	6	0	0	496	45	22	0,7	0	873
2012	294	7	0	0	0	450	51	16	0,7	0	818
2013	290	5	0	0	0	433	42	26	0,6	0	796
2014	283	5	0	0	0	428	38	23	0,6	0	777

1) G_02: Combustión no industrial; G_03: Combustión industrial; G_04: Procesos industriales sin combustión; G_05: Extracción y distribución de combustibles; G_06: Uso de disolventes; G_07: Transporte por carretera; G_08: Otros modos de transporte; G_09: Tratamiento de residuos; G_10: Agricultura; G_11: Naturaleza.

Tabla 21. Emisiones de PM₁₀ por grupo SNAP (t)¹

Año	G_02	G_03	G_04	G_05	G_06	G_07	G_08	G_09	G_10	G_11	TOTAL
1999	622	63	9	0	0	1.297	49	26	4,4	0	2.070
2000	557	58	10	0	0	1.278	52	33	4,3	0	1.991
2001	485	50	8	0	0	1.225	52	11	4,3	0	1.835
2002	425	47	9	0	0	1.230	51	10	4,3	0	1.776
2003	407	41	10	0	0	1.175	50	20	4,5	0	1.707
2004	394	24	11	0	0	1.196	50	41	4,3	0	1.719
2005	383	23	11	0	0	1.155	49	33	4,1	0	1.658
2006	372	26	13	0	0	1.073	141	25	4,1	0	1.655
2007	359	25	13	0	0	973	110	25	4,1	0	1.509
2008	337	18	12	0	0	910	87	22	4,1	0	1.391
2009	323	16	6	0	0	849	72	20	4,1	0	1.291
2010	313	12	9	0	0	752	46	21	4,1	0	1.157
2011	302	9	7	0	0	653	45	22	4,1	0	1.043
2012	303	7	0	0	0	601	51	16	4,1	0	982
2013	299	5	0	0	0	577	42	26	4,1	0	952
2014	291	5	0	0	0	572	38	23	4,1	0	934

1) G_02: Combustión no industrial; G_03: Combustión industrial; G_04: Procesos industriales sin combustión; G_05: Extracción y distribución de combustibles; G_06: Uso de disolventes; G_07: Transporte por carretera; G_08: Otros modos de transporte; G_09: Tratamiento de residuos; G_10: Agricultura; G_11: Naturaleza.

Tabla 22. Emisiones de PST por grupo SNAP (t)¹

Año	G_02	G_03	G_04	G_05	G_06	G_07	G_08	G_09	G_10	G_11	TOTAL
1999	642	71	11	0	0	1.509	50	26	9	0	2.318
2000	575	64	12	0	0	1.495	53	33	8	0	2.242
2001	501	55	11	0	0	1.445	53	11	8	0	2.084
2002	438	52	11	0	0	1.464	52	10	8	0	2.035
2003	420	45	12	0	0	1.405	51	20	8	0	1.961
2004	406	24	14	0	0	1.435	51	41	8	0	1.978
2005	394	23	13	0	0	1.399	50	33	7	0	1.919
2006	383	26	16	0	0	1.308	142	26	7	0	1.907
2007	369	25	16	0	0	1.194	111	25	7	0	1.747
2008	346	18	15	0	0	1.124	88	22	6	0	1.620
2009	332	16	8	0	0	1.056	73	20	6	0	1.512
2010	321	12	11	0	0	956	47	21	7	0	1.375
2011	310	9	9	0	0	848	46	22	6	0	1.251
2012	310	7	0	0	0	789	52	17	6	0	1.181
2013	307	5	0	0	0	757	42	26	6	0	1.144
2014	299	5	0	0	0	754	39	23	6	0	1.126

1) G_02: Combustión no industrial; G_03: Combustión industrial; G_04: Procesos industriales sin combustión; G_05: Extracción y distribución de combustibles; G_06: Uso de disolventes; G_07: Transporte por carretera; G_08: Otros modos de transporte; G_09: Tratamiento de residuos; G_10: Agricultura; G_11: Naturaleza.

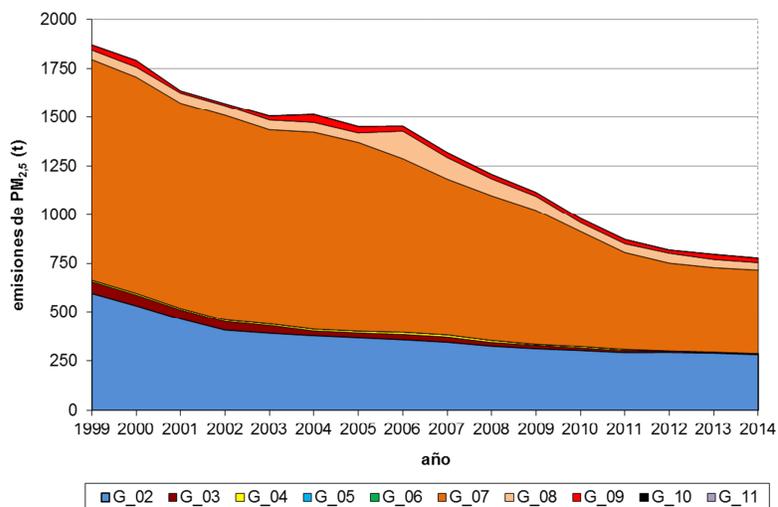


Figura 17. Evolución de las emisiones de PM_{2,5} por grupo SNAP (t)

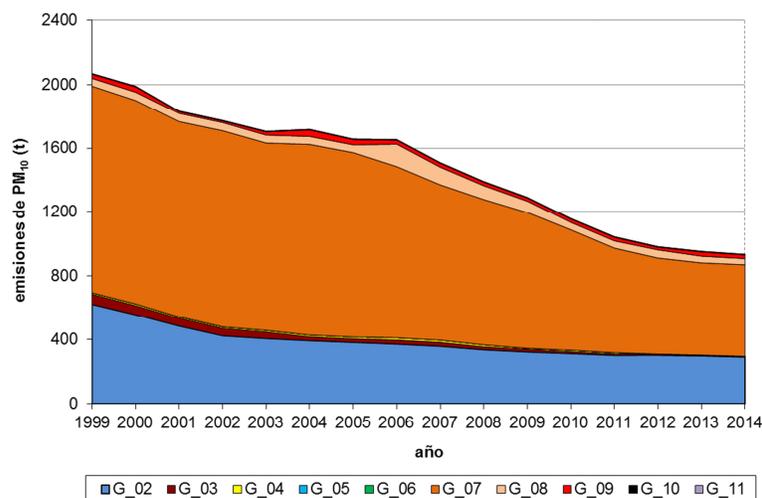


Figura 18. Evolución de las emisiones de PM₁₀ por grupo SNAP (t)

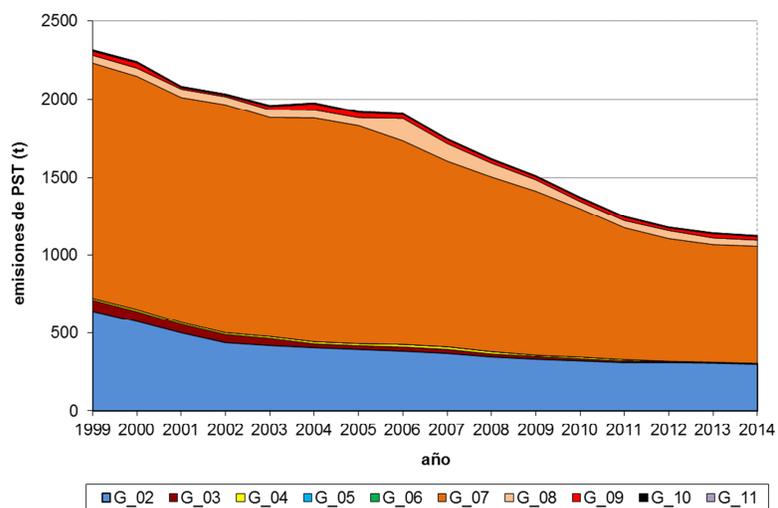


Figura 19. Evolución de las emisiones de PST por grupo SNAP (t)

Centrando el análisis en las emisiones de PM_{2,5} debido a su mayor impacto sobre la salud, en la Tabla 23 y Figura 20 se muestra la contribución relativa de cada grupo SNAP al total de emisiones.

Tabla 23. Contribución a las emisiones de PM_{2,5} por grupo SNAP (%)¹

Año	G_02	G_03	G_04	G_05	G_06	G_07	G_08	G_09	G_10	G_11	TOTAL
1999	31,9	3,2	0,4	0,0	0,0	60,5	2,6	1,4	0,04	0,0	100
2000	29,8	3,0	0,5	0,0	0,0	62,0	2,9	1,8	0,04	0,0	100
2001	28,4	2,9	0,5	0,0	0,0	64,4	3,2	0,7	0,05	0,0	100
2002	25,9	2,8	0,5	0,0	0,0	66,9	3,2	0,6	0,05	0,0	100
2003	26,0	2,6	0,6	0,0	0,0	66,2	3,3	1,3	0,06	0,0	100
2004	25,0	1,6	0,6	0,0	0,0	66,8	3,3	2,7	0,05	0,0	100
2005	25,4	1,6	0,6	0,0	0,0	66,7	3,4	2,2	0,05	0,0	100
2006	24,6	1,8	0,8	0,0	0,0	61,3	9,7	1,7	0,05	0,0	100
2007	26,2	1,9	0,9	0,0	0,0	60,7	8,4	1,9	0,05	0,0	100
2008	27,0	1,5	0,9	0,0	0,0	61,6	7,2	1,8	0,06	0,0	100
2009	28,0	1,5	0,5	0,0	0,0	61,7	6,5	1,8	0,06	0,0	100
2010	31,0	1,2	0,8	0,0	0,0	60,1	4,7	2,1	0,07	0,0	100
2011	33,6	1,1	0,7	0,0	0,0	56,9	5,1	2,5	0,07	0,0	100
2012	35,9	0,9	0,0	0,0	0,0	55,0	6,2	2,0	0,08	0,0	100
2013	36,4	0,6	0,0	0,0	0,0	54,4	5,2	3,3	0,08	0,0	100
2014	36,4	0,6	0,0	0,0	0,0	55,1	4,9	2,9	0,08	0,0	100

1) G_02: Combustión no industrial; G_03: Combustión industrial; G_04: Procesos industriales sin combustión; G_05: Extracción y distribución de combustibles; G_06: Uso de disolventes; G_07: Transporte por carretera; G_08: Otros modos de transporte; G_09: Tratamiento de residuos; G_10: Agricultura; G_11: Naturaleza.

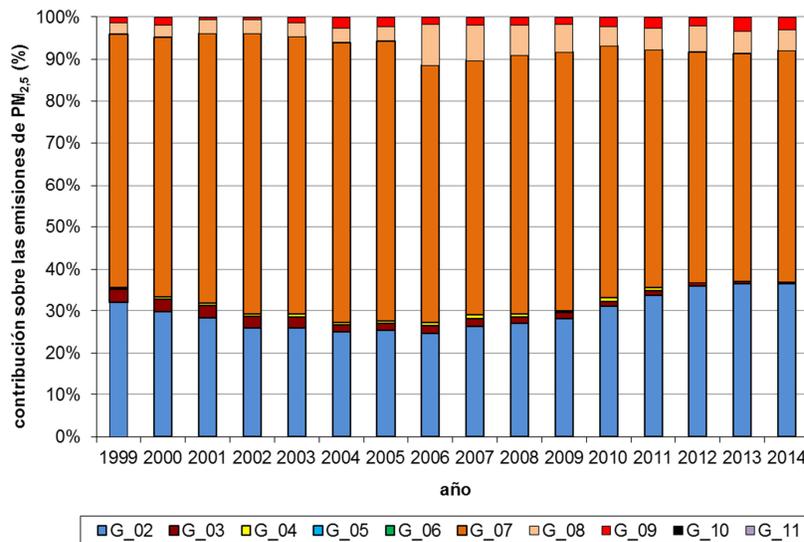


Figura 20. Contribución por grupo SNAP al total de emisiones de PM_{2,5} (%)

Es el grupo SNAP 07 el que contribuye de forma mayoritaria, siendo su aportación en 2014 igual al 55% (alcanzando valores del 67% a lo largo de la serie histórica). El siguiente grupo en importancia es el SNAP 02, que supone el 36% de las emisiones en 2014. Las emisiones de PM_{2,5} en este grupo siguen una tendencia decreciente en todo el periodo inventariado. Sin embargo, la contribución del SNAP 02 sobre este tipo de material particulado es mayor en los últimos años debido a que las emisiones del grupo SNAP 07 han disminuido de una forma más evidente, lo que se traduce en una menor contribución del transporte por carretera en las emisiones totales. En relación al resto de grupos SNAP, el grupo SNAP 08 contribuye con un 5% del total en 2014, siendo la contribución del resto de grupos poco significativa.

3.3.5 Emisiones de NO_x por sectores

Tabla 29. Emisiones de NO_x por sector (t)

ANO	RCI	Industria	Transporte rodado	Otros modos de transporte	Tratamiento de residuos	Otros	TOTAL
Emisiones							
1999	2.874	1.925	19.226	3.015	592	20	27.651
2000	2.863	1.820	18.740	3.353	606	19	27.401
2001	2.810	1.632	17.752	3.475	600	18	26.287
2002	2.659	1.578	17.612	3.293	995	18	26.155
2003	2.894	1.495	16.535	3.142	1.255	19	25.339
2004	3.042	1.071	17.221	3.325	1.572	18	26.249
2005	3.067	1.049	16.954	3.429	1.543	18	26.060
2006	2.909	1.088	15.319	4.991	1.208	18	25.533
2007	2.970	1.120	13.614	4.792	992	17	23.504
2008	2.959	1.141	12.388	4.336	1.110	17	21.952
2009	2.838	947	11.279	3.908	1.038	17	20.027
2010	2.622	1.174	9.887	3.450	1.129	17	18.278
2011	2.403	1.048	8.344	3.425	1.106	18	16.343
2012	2.697	945	7.380	3.296	1.095	18	15.430
2013	2.723	954	7.093	2.913	853	17	14.553
2014	2.451	940	7.012	2.933	290	18	13.644
Contribución porcentual al total (%)							
1999	10,4	7,0	69,5	10,9	2,1	0,1	100
2000	10,4	6,6	68,4	12,2	2,2	0,1	100
2001	10,7	6,2	67,5	13,2	2,3	0,1	100
2002	10,2	6,0	67,3	12,6	3,8	0,1	100
2003	11,4	5,9	65,3	12,4	5,0	0,1	100
2004	11,6	4,1	65,6	12,7	6,0	0,1	100
2005	11,8	4,0	65,1	13,2	5,9	0,1	100
2006	11,4	4,3	60,0	19,5	4,7	0,1	100
2007	12,6	4,8	57,9	20,4	4,2	0,1	100
2008	13,5	5,2	56,4	19,8	5,1	0,1	100
2009	14,2	4,7	56,3	19,5	5,2	0,1	100
2010	14,3	6,4	54,1	18,9	6,2	0,1	100
2011	14,7	6,4	51,1	21,0	6,8	0,1	100
2012	17,5	6,1	47,8	21,4	7,1	0,1	100
2013	18,7	6,6	48,7	20,0	5,9	0,1	100
2014	18,0	6,9	51,4	21,5	2,1	0,1	100

3.3.10 Emisiones de PM_{2,5} por sectores

Tabla 34. Emisiones de PM_{2,5} por sector (t)

ANO	RCI	Industria	Transporte rodado	Otros modos de transporte	Tratamiento de residuos	Otros	TOTAL
Emisiones							
1999	597	67	1.133	49	26	1	1.872
2000	534	63	1.111	51	33	1	1.793
2001	465	54	1.054	52	11	1	1.637
2002	407	52	1.050	51	10	1	1.571
2003	392	47	997	50	20	1	1.506
2004	379	33	1.011	50	41	1	1.514
2005	369	32	969	49	33	1	1.452
2006	358	37	892	141	25	1	1.454
2007	346	36	801	110	25	1	1.319
2008	325	29	744	87	22	1	1.207
2009	313	22	688	72	20	1	1.115
2010	304	20	590	46	21	1	980
2011	293	16	496	45	22	1	873
2012	294	7	450	51	16	1	818
2013	290	5	433	42	26	1	796
2014	283	5	428	38	23	1	777
Contribución porcentual al total (%)							
1999	31,9	3,6	60,5	2,6	1,4	0,0	100
2000	29,8	3,5	62,0	2,9	1,8	0,0	100
2001	28,4	3,3	64,4	3,2	0,7	0,0	100
2002	25,9	3,3	66,9	3,2	0,6	0,0	100
2003	26,0	3,1	66,2	3,3	1,3	0,1	100
2004	25,0	2,2	66,8	3,3	2,7	0,0	100
2005	25,4	2,2	66,7	3,4	2,2	0,0	100
2006	24,6	2,6	61,3	9,7	1,7	0,0	100
2007	26,2	2,8	60,7	8,4	1,9	0,1	100
2008	27,0	2,4	61,6	7,2	1,8	0,1	100
2009	28,0	2,0	61,7	6,5	1,8	0,1	100
2010	31,0	2,0	60,1	4,7	2,1	0,1	100
2011	33,6	1,8	56,9	5,1	2,5	0,1	100
2012	35,9	0,9	55,0	6,2	2,0	0,1	100
2013	36,4	0,6	54,4	5,2	3,3	0,1	100
2014	36,4	0,6	55,1	4,9	2,9	0,1	100

3.3.11 Emisiones de PM₁₀ por sectores

Tabla 35. Emisiones de PM₁₀ por sector (t)

ANO	RCI	Industria	Transporte rodado	Otros modos de transporte	Tratamiento de residuos	Otros	TOTAL
Emisiones							
1999	622	72	1.297	49	26	4	2.070
2000	557	68	1.278	52	33	4	1.991
2001	485	58	1.225	52	11	4	1.835
2002	425	56	1.230	51	10	4	1.776
2003	407	51	1.175	50	20	5	1.707
2004	394	35	1.196	50	41	4	1.719
2005	383	34	1.155	49	33	4	1.658
2006	372	39	1.073	141	25	4	1.655
2007	359	38	973	110	25	4	1.509
2008	337	30	910	87	22	4	1.391
2009	323	23	849	72	20	4	1.291
2010	313	21	752	46	21	4	1.157
2011	302	17	653	45	22	4	1.043
2012	303	7	601	51	16	4	982
2013	299	5	577	42	26	4	952
2014	291	5	572	38	23	4	934
Contribución porcentual al total (%)							
1999	30,1	3,5	62,7	2,4	1,3	0,2	100
2000	28,0	3,4	64,2	2,6	1,7	0,2	100
2001	26,4	3,2	66,7	2,8	0,6	0,2	100
2002	23,9	3,1	69,3	2,9	0,6	0,2	100
2003	23,9	3,0	68,8	2,9	1,2	0,3	100
2004	22,9	2,0	69,5	2,9	2,4	0,2	100
2005	23,1	2,0	69,7	3,0	2,0	0,2	100
2006	22,5	2,4	64,9	8,5	1,5	0,2	100
2007	23,8	2,5	64,5	7,3	1,6	0,3	100
2008	24,2	2,2	65,5	6,2	1,6	0,3	100
2009	25,0	1,8	65,8	5,6	1,5	0,3	100
2010	27,1	1,8	65,0	4,0	1,8	0,4	100
2011	29,0	1,6	62,6	4,3	2,1	0,4	100
2012	30,8	0,7	61,2	5,2	1,7	0,4	100
2013	31,4	0,5	60,5	4,4	2,8	0,4	100
2014	31,2	0,5	61,3	4,1	2,4	0,4	100

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