Improvement on Environment by Using EV's
The Portuguese Perspective

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Abstract

The growing necessity to evaluate mobility alternatives, in Portugal, came with the substantial increase of the car fleet and its negative effects, during the last decade.

Nowadays, the environmental pollution associated to the energy sub-sector of transport, in Portugal, are affecting not only the population quality of life, but also putting in danger the conservation of cities historic centres. The inversion of this tendency depends on the use of environmental friendly vehicles, in which electric vehicles perform an important role.

The road electric vehicle, powered from the mains, presents the clear advantage of not polluting locally. However, it should not be considered a zero emission vehicle, in a global perspective, once, depending on how the electricity is produced, it may or may not have originated pollutant emissions. From this perspective, depending on the structure of the electricity production system, each country would have more or less advantages regarding the use of these vehicles.

This paper aims to study the environmental impacts of introducing electric vehicles in urban public transport fleets, in Portugal. For this, it will be considered the use of two electric mini-buses "Gulliver", on the ongoing demonstration action "Introduction of Electric Buses in Public Transportation Fleets in Portugal", sponsored by the Portuguese Directorate-General for Inland Transport and deployed by the Portuguese Electric Vehicle Association.

Keywords: "Demonstration", "Electric Vehicle", "Emissions", "Energy Consumption", "Public Transportation".

1 Introduction

The questions surrounding the themes of pollutant emissions and greenhouse effects are no longer approached as future problems, and are now considered urgent.

According to the Portuguese Program for Climatic Changes (PNAC – Programa Nacional para as Alterações Climáticas) "the subject of climatic changes constitutes a priority regarding the definition of a national strategy of sustainable development and it is one of its most important components".

Since 1990, the energy sector represents the greater contribution of greenhouse effect gases. In 2000 this contribution was of 70%, of which 38% were due to the sub-sector of energy offer and 33% due to the sub-sector of transport. Figure 1 illustrates the evolution of the several sub-sectors that constitute the energy sector, during the last decade. As can be observed, the sub-sector of transport presents the most relevant increase during this period (67%).

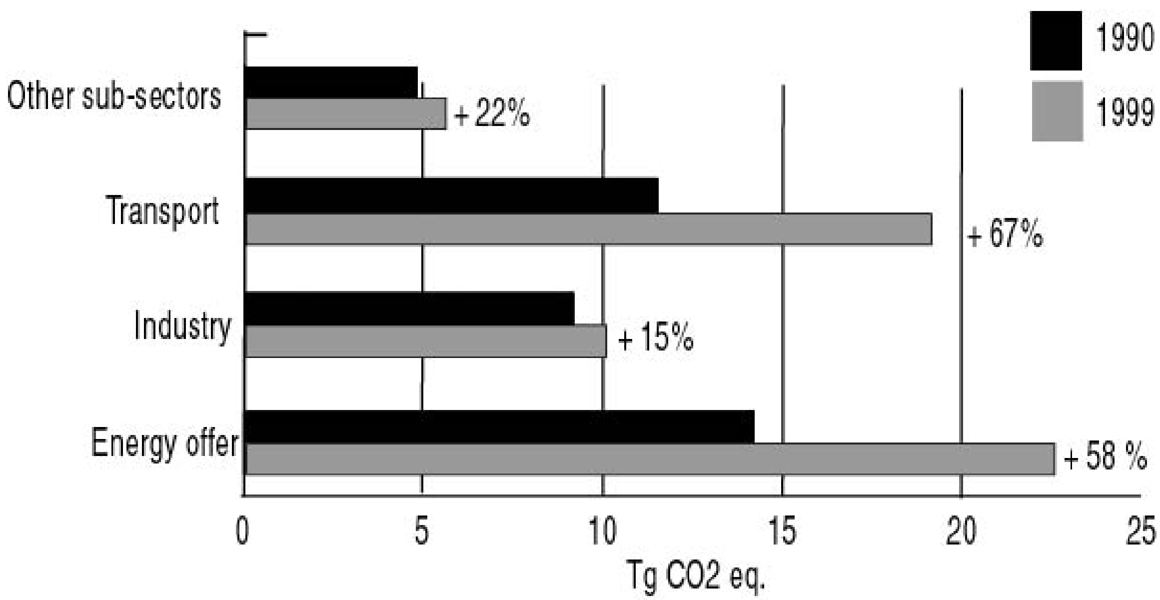

Figure 1 Evolution of Energy sector sub-sectors [1]

Being the sub-sector of transport one major contributor for the emissions of greenhouse effect gases, the applications of measures, to contain the negative impacts associated to this emissions, is considered urgent. Several measures to reverse this tendency were proposed, in the Portuguese program for climatic changes, in which the increase of efficiency on road transportation is considered.

In this context, given the efficiency of the electric motor and the absence of local emissions, the electric vehicle represents an interesting alternative. The objective of this document consists on the analysis of a real application of electric vehicles in Portugal, and the benefits that are associated to the use of this type of technology.

2 Demonstration Action “Introduction of Electric Buses in Public Transportation Fleets in Portugal”

2.1 Background

The Directorate-General for Inland Transport and the Portuguese Electric Vehicle Association, developed the demonstration action “Introduction of Electric Buses in Public Transportation Fleets in Portugal” not only to present alternative types of technologies in public transports, available today, but also to let know new mobility concepts.

So far, this ongoing action as travelled over sixteen Portuguese cities, allowing several municipalities, transports operators and all types of users to experiment what this type of vehicles has to offer.

This demonstration action is divided in two phases, the first one, that included all the preparatory activities and preliminary tests, occurred from September to February, 2002. In this first phase the “OREOS 55H” hybrid mini-bus, from Gépebus was used.

Figure 2 – Hybrid Electric mini-bus OREOS 55 H

For the ongoing second phase of this demonstration action, two electric mini-buses “GULLIVER”, from Tecnobus, were acquired.

Figure 3 – Electric mini-bus GULLIVER

So far, during the demonstration action second phase, the two electric mini-buses “Gulliver” have visited twenty Portuguese cities and travelled over 50.000 kilometres.

2.2 Statistical Analysis of Energy Consumption

During the demonstration action two monitoring procedures were developed, which allowed the determination of the daily mean consumption of the two electric minibuses. One of this consisted in the monitoring of the battery recharging process and permitted the calculation of the efficiency of the recharging process, Figure 4.

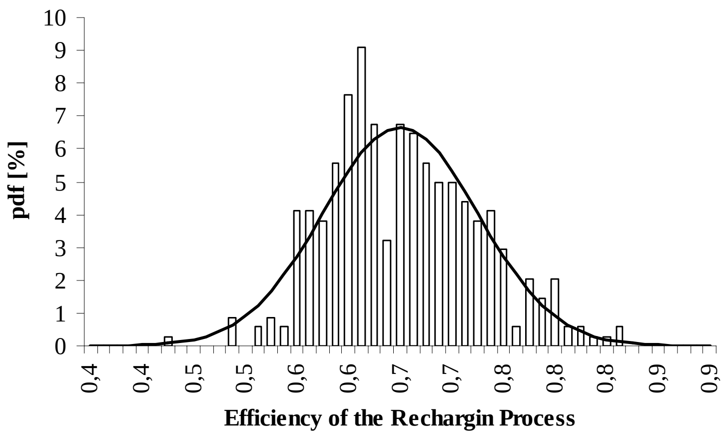

Figure 4 – Probability Density Function of the efficiency corresponding to the batteries recharging process.

The values given in the previous figure represent a random variable and where submitted both to the “random test” [] and to the “goodness of fit test” [], which allows one to test whether a random sample corresponds to a specified, or partially specified, probability function. In this case, the group of values fit the normal distribution with a mean of 66% and a standard deviation of 6,7% meaning a coefficient of variability of 10%.

The same tests were performed in the total sample (corresponding to 20 cities) of daily energy consumption, however, these didn’t fit the normal distribution, Figure 5.

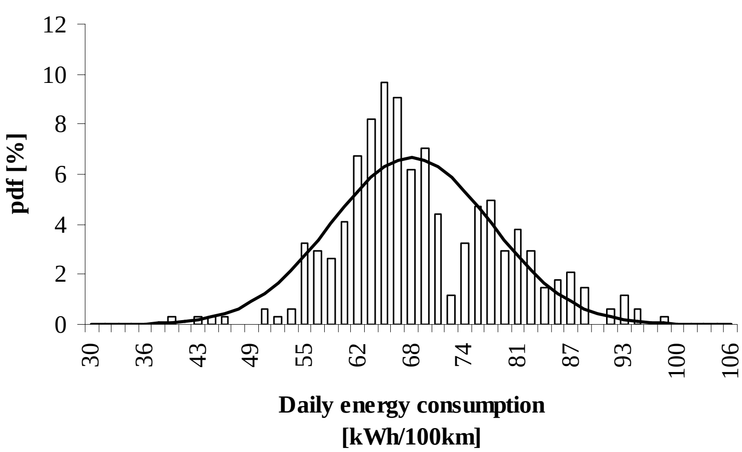

Figure 5 – Probability Density Function of the daily energy consumption.

Careful observation of the previous figure indicates that exist two distinct normal distribution functions, corresponding each to the two groups of cities with higher and lower consumption values. This can also be observed in Figure 6.

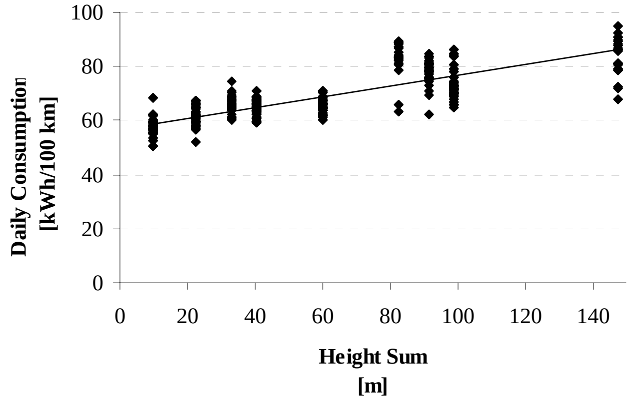

Figure 6 –Daily energy consumption in each city, related to their itinerary's elevation.

Figure 6 represents the daily consumption of each city related to the height sum of the itinerary. As expected, the highest consumptions correspond to the higher elevations. Also, in this figure, the two distinct groups of cities, mentioned previously, can be observed.

Separating the lower and the higher consumption cities and performing, the following probability distribution and cumulative distribution function were obtained.

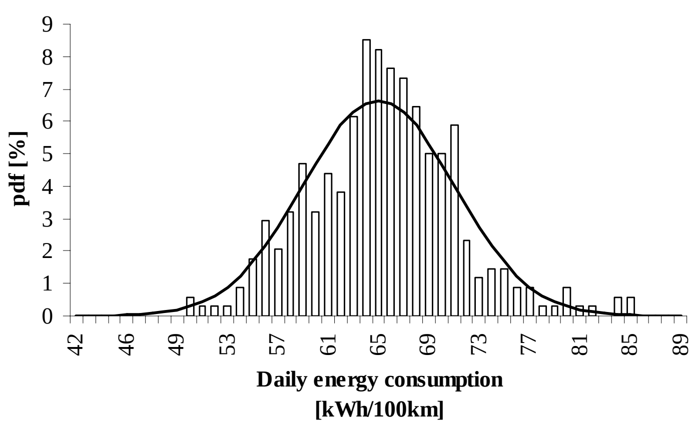

Figure 7 – Probability Density Function of the daily energy consumption of the lower consumption cities.

Applying now the random and the goodness of fit tests, to these new values, the normal distribution fits with a mean of 65 kWh/100 km and a standard deviation of 6 kWh/100 km, which imply a coefficient of variability of 9%.

In Figure 8, the normal distribution fit can be easily observed.

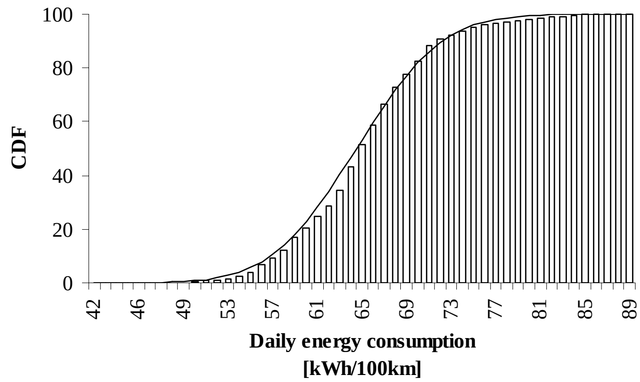

Figure 8 – Cumulative Distribution Function of the daily energy consumption of the lower consumption cities.

The same process was applied to the higher consumption cities, which confirmed the normal distribution fit with a mean of 80 kWh/100 km and a standard deviation of 6 kWh/100 km, which imply a coefficient of variability of 7,5%. These set of values can be observed in Figure 8and Figure 9.

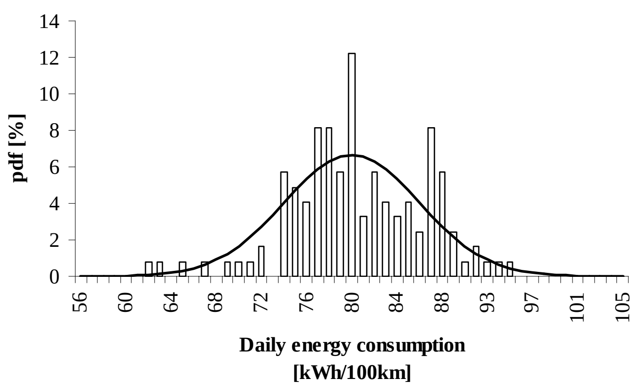

Figure 9 – Probability Density Function of the daily energy consumption of the higher consumption cities.

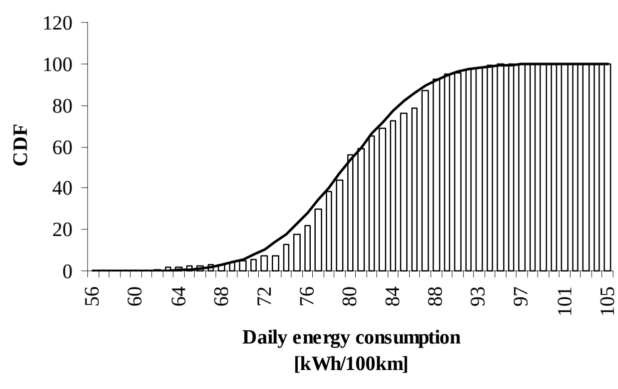

Figure 10 – Cumulative Distribution Function of the daily energy consumption of the higher consumption cities.

3 Portuguese Electricity Production System

3.1 Evolution

From a general point of view, the positive contribution of using electric vehicles depends strongly on the processes of electricity production. Figure 11 shows the installed capacity evolution of the Portuguese Electricity System (SEN) during the last twenty years.

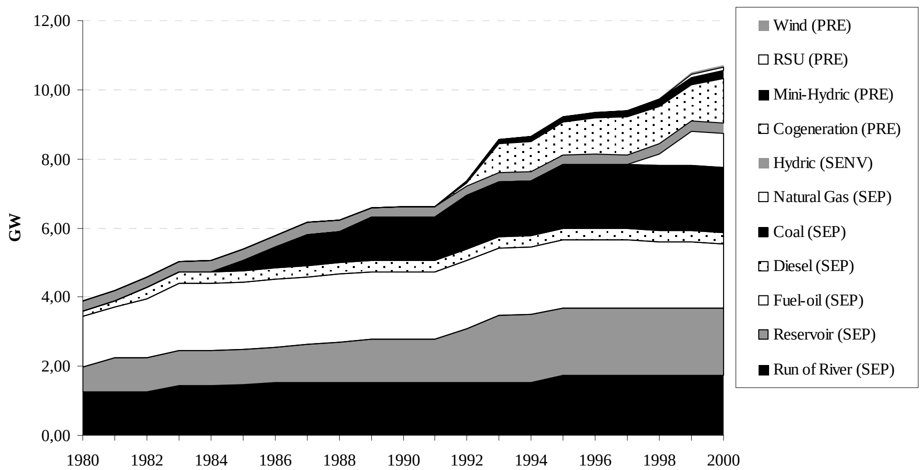

Figure 11: Evolution of the installed capacity of the SEN [2]

PRE – Special Regime Generation
SENV – Non – Binding Electricity System
RSU – Biomass Power Station
SEP – Public Service Electricity System

Hydroelectricity has been a tradition in Portugal. Electricity production from renewable energies - cogeneration and biomass - emerged only in the nineties and represents presently nearly 15% of the total installed capacity of the SEN.

On the other hand, in 1999, a natural gas combined-cycle power-plant at Tapada do Outeiro has started operation. This power station, characterized by an efficiency of 54% and very low emission levels, seems to be the right approach concerning thermal production options.

For the most important pollutants, Figure 11 to Figure 14 show the evolution of the specific emissions (g/kWh) arising from the Portuguese thermal power-stations.

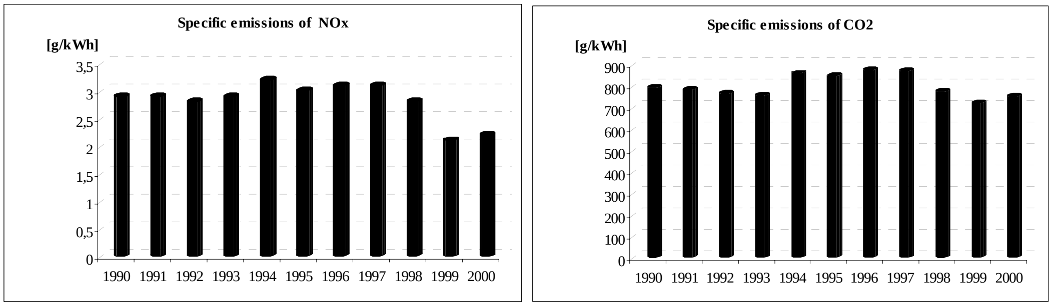

Figure 4

Figure 12 and 13: Evolution of the specific emissions of CO_2 and NO_x of the SEN [2]

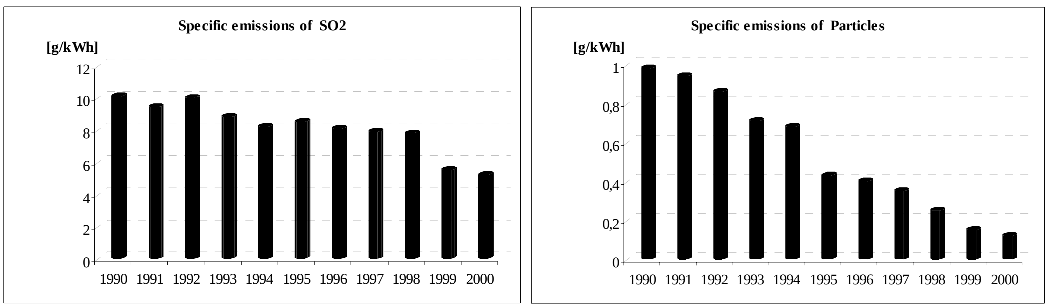

Figure 14 and Figure 15: Evolution of the specific emissions of SO_2 and Particles of the SEN [2]

3.2 Pollutant Emissions

A clear dependence of annual pollutant emission levels is related to the ratio between electricity production in thermal and hydroelectric power plants. Rain precipitation and other factors are essential for the definition of the electricity production annual “mix” and, consequently, for the emissions level definition of the Portuguese electricity production system.

Although electric vehicles are locally zero-emission, the electricity production to power them, has environmental impacts. Those environmental issues are associated to all types of electricity production, for even the power-stations with renewable resorts cause disturbances in the surrounding ecosystems.

A thermal power-station produces pollutant emissions of sulphur oxide (SO_x), essentially sulphur dioxide (SO_2), carbon dioxide (CO_2), carbon monoxide (CO), and Particles (PM). These pollutant emissions have several consequences as acidification incidents, mainly produced by the two mentioned oxides, the increase greenhouse effect caused by the emissions of CO_2, and as the health damage associated to disturbances at the local ecosystems due to emissions of particles.

When an EV is recharging, it is not possible to determine which specific power-station is supplying the electricity, being possible to assume several recharging scenarios. In this paper we considered the worst case and assumed that the vehicle is being fed by a combination of all power-stations of the Portuguese Electricity System. For that, the production “mix” of electricity needs to be calculated. For this research the year 2000 “mix” represented in Figure 8 was used.

Production by Type of Power-Station of the SEN, 2000

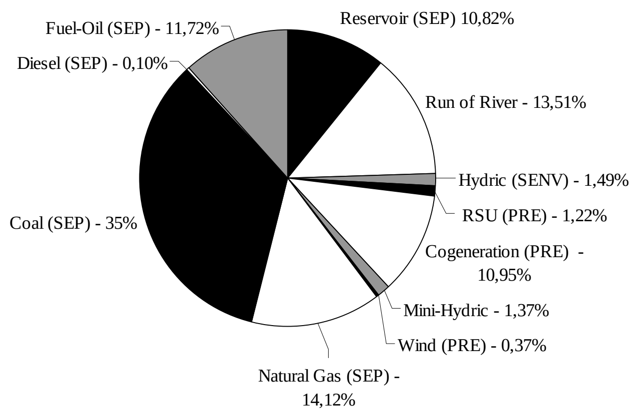

Figure 8: Production of Electricity of the SEN, 2000 [2]

From the knowledge of the specific emissions [3] [4] [5] for each power-station, and considering the previous "mix", the pollutant emissions for an EV in Portugal can be determined (Table 1).

Table 1: Specific pollutant emissions of an EV concerning the production "mix" of 2000

	Specific Pollutant Emissions [g/kWh]
SO_2	3,14
NO_x	1,32
CO_2	442
CO	0,01
Particles	0,1

3.3 Future Perspectives

A permanent effort to reduce the particles emission (reduction to one tenth in the last ten years period) and a diminution of SO_2 and NO_x associated to initiation of electricity production at the Tapada do Outeiro power station was verified.

This trend is expected to improve with the foreseen investment in renewable energies and with the construction of a new natural gas combined-cycle power-station which is characterized by a higher efficiency and installed capability compared to Tapada do Outeiro. Simultaneously, old power-stations of Tapada do Outeiro and Barreiro, both using fuel-oil (and rather pollutant), will be shut down.

The progress of the electricity production system, associated to the fact that pollutant emissions originated by thermal production are confined to a specific location (making it easier to intervene), enhances the EV as an interesting alternative to its internal combustion alternative. Not only by the effective reduction of pollutant emissions but also by its removal from city centers.

4 Comparison of Pollutant Emissions

With the consumption and the production "mix" referred to previously, the pollutant emissions for an electric mini-bus can be determined and compared to the standard limits for its internal combustion correspondent (Figure 17).

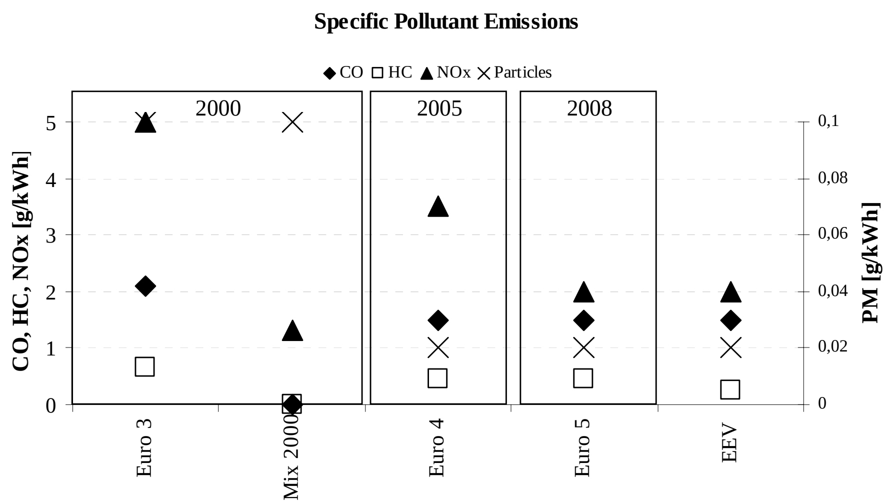

Figure 17: Comparison of specific emissions related to electric and internal combustion mini buses

The use of electric vehicles causes a significant reduction of pollutant emissions, with exception for the particles. The value of particles pollutant emissions correspondent to a mini bus electric vehicle circulating in Portugal, considering the production "mix" of 2000, is respecting the limits for EURO 3 (2000), being superior to the values referred on EURO 4 (2005) and EURO 5 (2008). However, the values of the other pollutant gases are bellow all the restrictions mentioned, being even lower than the values corresponding to an Enhanced Environmentally Friendly Vehicle.

The values calculated for particles emission are expected to be considerably reduced by the foreseen evolution of the Portuguese Electricity System, since the natural gas combined-cycle power-stations do not release this type of emissions. As can be observed in Figure 7, the evolution of particles emissions in the nineties was highly reduced, due to a particular effort in reducing this type of pollutant.

5 Conclusions

The use of electric vehicles, in Portugal, allows a meaningful reduction not only of pollutant emissions that are harmful to the human health, but also their deviation from city centers.

The investments that have occurred and are predicted point out to a positive evolution in the level of specific pollutant emissions by the thermal installations of the Portuguese Electricity System.

Thus we predict that the electric vehicle will be in conditions to fulfill the limits set for its internal combustion correspondent for the year 2008 before this date. This fact of a zero pollution effect at a local level, allied to the absence of noise emissions, places the EV in an important position when analyzing sustainable mobility alternatives in Portugal.

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7 Authors

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