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Electric Mobility in Portugal: 2 Case Studies

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Summary

In 2010, Portuguese legislation defined an electric mobility network model which differs from the traditional approach of integrating this activity as part of the electricity sector. The present paper describes this model and presents two case studies to illustrate developments in greater detail.

The first case study describes the conclusions of a demonstration program of electric mobility carried out by the Ministry of Environment and Energy between May14 and July15.

In the second case study, we summarize the implementation, and identify the difficulties, of one of the elements established by the national legislation, private charging points with private access.

Keywords: electric mobility, Portugal, case study.

1 The Portuguese Electric Mobility Model

In Portugal, the Electric Mobility Network framework was established between 2010 and 2014 (Decree-Law 39/2010 of April 26, reviewed by Decree-Law 90/2014 of June 11). The main goal was to create a regime enabling electric vehicle (EV) users to access charging point infrastructure within an electricity retail model promoting competition.

This Electric Mobility Network, although delivering electricity to EV users, is totally dissociated from the public electricity distribution network and from the agents and commercial relationships involved in this environment.

In the Portuguese model, the mobility sector was separated explicitly from the electricity sector. As a growing sector, the EV mobility sector depends largely on public funds, and it is important to avoid cross-subsidization from the electricity sector.

The Portuguese legislation establishing the mobility framework defines the following main activities:

1. CEME, electricity retailers for electric mobility;

The CEME activity consists in contracting electricity from a retailer of the electricity sector or from organized markets and selling it to EV users. This selling price is liberalized.

2. OPC, the Charging Point Operators of the electric mobility network;

The OPC activity consists in installing, exploiting and maintaining charging points and making them available to EV users. The OPC price is liberalized. OPC may provide other services. OPC are clients of the electricity sector.

3. EGME, the entity managing the electric mobility network

The EGME activity, performed by the entity MOBI.E, is a monopoly and, as a consequence, is subject to regulation. This activity consists mainly in:

a) establishing and developing the information and communication systems for the integration of the electric mobility network, adapted to their characteristics and management needs, ensuring the operation of the charging points in conjunction with the charging point operators;

b) managing all the data related to energy and financial information of CEMEs, OPCs, electricity distribution system operators (DSO) and, where appropriate, other service providers, including the provision of measurement and reading services for the energy consumption associated with the use of EVs at the charging points; and

c) monitoring the growth of electric mobility in accordance with the guidelines defined by the Office for Electric Mobility in Portugal (GAMEP).

In this model, EV users establish contracts with one (or more) CEMEs in order to have the possibility to charge EVs at OPC charging points. This is a post-paid scheme and it is expected that payment systems will also include pre-paid and ad-hoc solutions. All OPC perform roaming, i.e. grant access to all EVs regardless of the specific CEME contracted by the EV user. This roaming scheme also applies in the islands of Madeira and Azores, which are autonomous regions from an institutional point of view.

To charge EVs, the authentication methods in use include RFID card and mobile app based authentication. Smart meters are required by law.

This model is based on a fully interoperable scheme managed by the EGME that handles all the data involved in terms of metering (as well as invoicing and billing, if required) in the mobility sector. The EGME also exchanges metering data with the DSO.

The following diagram describes the entities involved and the data exchanges needed to support the activities mentioned:

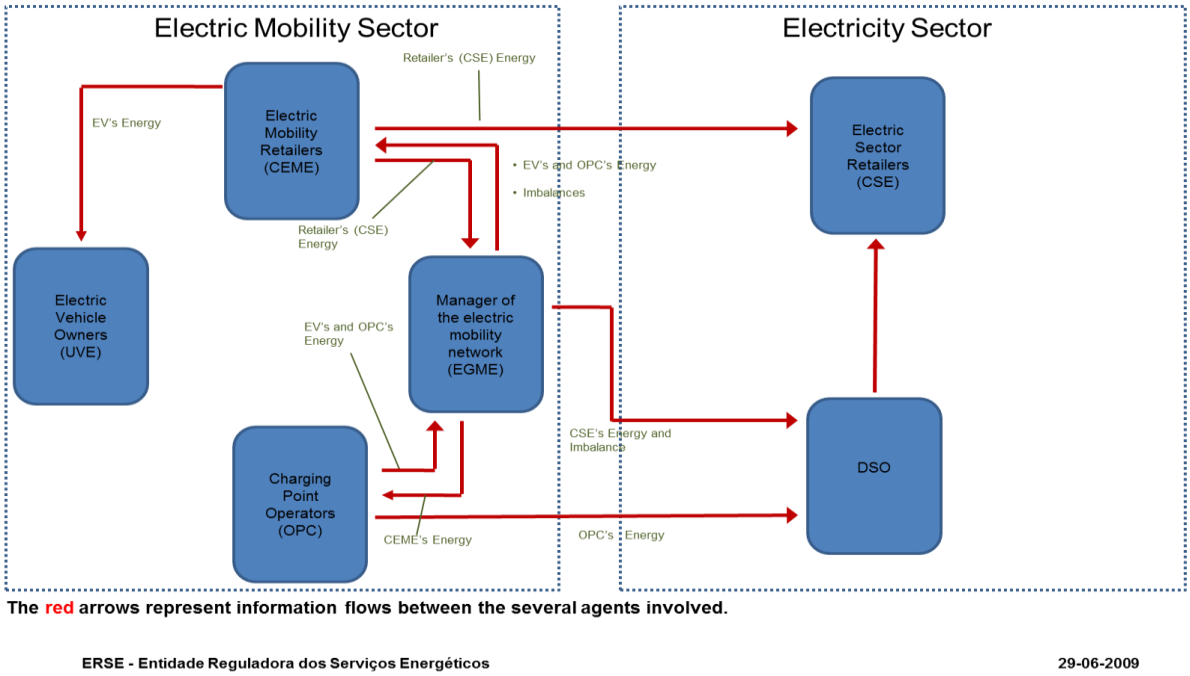

Figure 1: Information flows between the several entities involved

As may be seen from Figure 1, the EGME is responsible for the data flow necessary for CEMEs' to function, e.g. weekly or monthly, invoicing and billing associated with charging operations by an EV user, and with all the contracts (with CEMEs) the user has established.

Another important example is the exchange of information from the EGME to the DSO that is needed in

order to map the demand from CEMEs in the mobility sector to the retail suppliers from the electricity sector (CSE).

As explained above, the EGME's monopoly nature renders it subject to regulation. In Portugal, the Government attributed to ERSE (the Energy Services Regulatory Authority for gas and electricity) this role. To fulfill this role, on 28 December 2015 ERSE published the Regulation on Electric Mobility. This Regulation deals with matters subject to regulation in the electric mobility sector, the relationship between this sector and the electricity sector and the protection of the rights and interests of electric vehicle users in relation to prices and quality of service.

The EGME is responsible for registering and controlling the relationships between the EV users, CEMEs and CSEs, in order to guarantee that any consumption of electricity for the purposes of electric mobility is allocated to an agent of the electricity sector (CSE or the organized market). This allocation of energy to the specific agents of the electricity sector must be communicated to the DSOs of the corresponding charging points, in order to apply the procedures (metering, calculation) defined in the electricity sector regulations, namely discounting the EV charging values (energy and power) from the OPC's local electricity supply. The energy allocated to the agents of the electricity sector is settled by the application of network access tariffs and incorporation in the retailers' portfolios.

In order to perform this function, the EGME must be aware of the contractual relations between CEMEs and the EV users and between CEMEs and CSEs. Any new contracts, changes and terminations of contracts have to be communicated to the EGME.

In the event that the EGME cannot allocate in a charge operation a given load in the mobility sector to a CEME and to any CSE, the charging operation in the mobility network of that EV will be prevented.

As regards what EV users have to pay, the bill includes three components, one related to the energy used, one tariff defined by ERSE corresponding to the EGME revenues and also one element related to the service provided by the OPC. For this model to be sustainable and have reasonable costs, the number of users needs to increase significantly. For the moment, these costs are supported by public funds.

2 Electric mobility demonstration program in the Ministry of the Environment, Land Use Management and Energy

2.1. Objectives and operation

From May 2014 to July 2015, a demonstration program of electric mobility was carried out in the Portuguese Ministry of Environment, Land Use Management and Energy (MAOTE), involving four members of the Government. The main objectives of the demonstration program were to:

- Give a public example of the feasibility of electric mobility, reinforcing the credibility of this modality / transportation technology; and
- Obtain data and experience that would contribute to the design of a sustainable mobility program within the wider scope of Public Administration.

The Program was the result of a partnership between the Association of Portuguese Electric Vehicles (APVE) and the Office of the Minister for Environment, Land Use Management and Energy, with the collaboration of 13 brands, almost all brands of cars with electric vehicles available on the market at the time. Plug-in and hybrid plug-in vehicles were used.

The program was managed by a Monitoring Committee composed of members of: Portuguese Environment Agency, General Directorate of Energy and Geology, Shared Services of Public Administration (public entity responsible for the public procurement), Cabinet of the Secretary of State for the Treasury, Cabinet of Secretary of State for Energy and Cabinet of the Minister for the Environment, Land Use Management and Energy (chair).

The Monitoring Committee was responsible for the implementation of the demonstration program (including infrastructure issues), the elaboration of the monitoring model and publication of five preliminary reports as well as the final report.

For ten months, the four members of the government (minister and three secretaries of state – energy, environment and land management) carried out urban trips mostly in electric vehicles (plug-in). For the longest journeys, a hybrid plug-in vehicle was used. In total, 16 different vehicles were used, which allowed a significant diversity of information and experiences.

2.2. Monitoring

The monitoring carried out included the following parameters: distance (km), consumption (electricity - kWh with time discrimination and petrol - liters), trip made (urban, out of town), opinion of drivers and passengers.

The parameters "distance" and "type of trip" were monitored by manual registration carried out by the drivers. For this purpose, a logbook was prepared where the drivers registered each trip (initial km, final km, urban / non-urban trip and other incidents).

The opinion of the users was obtained through a survey completed by the driver and by one of the passengers.

The electricity consumption at the electric chargers was metered using the EGME's platform, which metered the charges made at public places and the charges made at the six charging points installed in the garage of MAOTE. Each vehicle was assigned an authentication card which allowed identification of the vehicle, the start and end of the charge and the energy consumed.

For hybrid plug-in vehicles, the consumption of fossil fuel (petrol) was monitored by a logbook recording, and the values were checked controlling the expense incurred.

2.3. Results

The demonstration program carried out by the MAOTE led to a set of results which can be merged in the following items [2]:

- Comparison with the previous fleet used in the four ministerial cabinets (diesel vehicles);
- Extrapolation of the results to other cases, namely private use, business use and use in public administration from total cost of ownership (TCO).

2.3.1. Government members' fleet

Demonstration vehicles (electric vehicles) travelled a total of 69 269 km, with exclusive-electric vehicles (BEV) being used mainly for urban travel (37% of the total distance traveled).

On average, the following consumption was obtained:

- Plug-in vehicles (exclusive electric - BEV) - 19.3 kWh / 100 km
- Plug-in hybrid vehicles (electricity and petrol) - 73.6 kWh / 100 km

The following table sets out the information obtained for each two-month period (replacement of models).

Table 1: Bimonthly information

		Jun - Aug 2014	Sep - Oct 2014	Nov - Dec 2014	Jan - Feb 2015	Mar - Apr 2015	Jun 2014 Apr 2015
Total distance							
Plug-in (a)	km	(1)	(1)	(1)	(1)	(1)	25581
Hybrid plug-in (b)	km	(1)	(1)	(1)	(1)	(1)	43688
Total (a+b)		9911	14516	16729	12364	15749	69269
Energy consumption							
Eletricity	kWh	1305	1930	1658	974	1140	7007
Petrol (for hybrid)	liter	305	525	1306	745	780	3661
Average consumption (plug-in)	kWh/100km	19,1	17,8	24,0	18,7	19,5	19,3
Average consumption (hybrid plug-in)	kWh/100km	(1)	(1)	(1)	(1)	(1)	73,6
Average consumption	kWh/100km	41,3	46,4	66,3	63,0	40,7	52,6

(1) Not available for confidentiality reasons

A similar analysis can be made comparing the operational costs of the EVs used in the program. For this

purpose, the cost of electricity and the cost of petrol were taken into account, including the following assumptions:

- Price of petrol: average value of the retail price in each period (source: General Directorate of Energy and Geology)
- 1 liter of petrol corresponds to 9.14 kWh (source: General Directorate of Energy and Geology)
- The MAOTE building is connected to a medium voltage grid, so the price of the transitional tariff at medium voltage published by the regulator applies (peak hours because charging was mainly done during the day)

The following figure outlines the operational cost (€/km) for each type of vehicle, for the total fleet (four exclusive electric vehicles and one hybrid plug-in) and compares costs with the costs of the previous diesel vehicle fleet (which has been replaced) and with the best in class vehicle from that fleet.

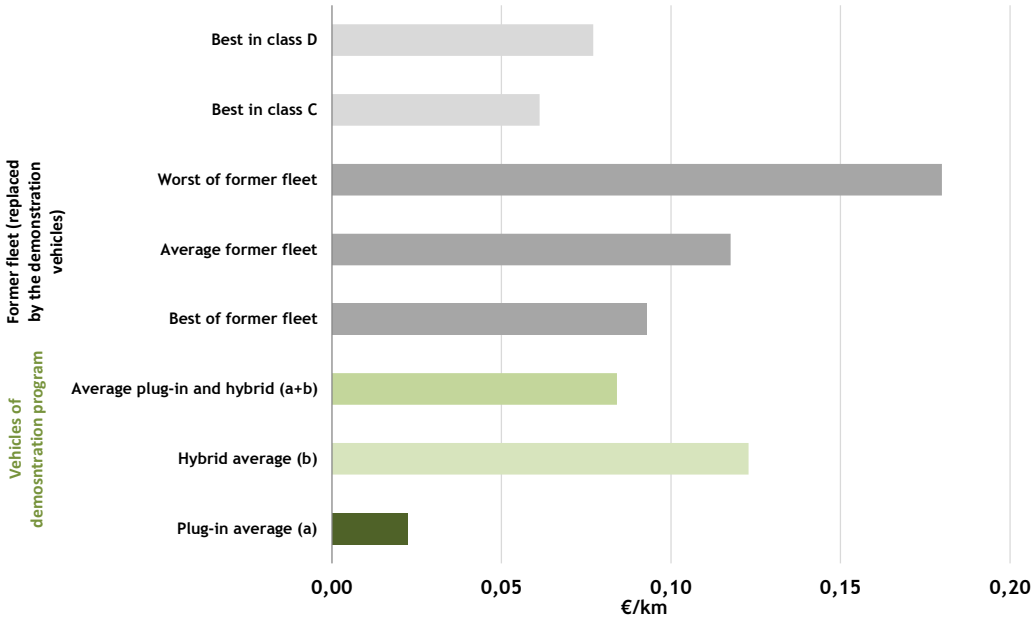

Figure 2: Operational costs of demonstration program and former fleet

The analysis of the information results in the following conclusions:

- The average cost of using electric vehicles, considering only energy, are close to 0.02 EUR / km;
- The average cost of the electric fleet represents a reduction of around 81% compared to the average of the fleet replaced under the pilot project and a reduction of around 64% and 71% when compared to the best-in-class diesel vehicles of the segments C and D.

The values obtained for the hybrid vehicles are considered high and close to the average of the replaced diesel vehicles. It should be stressed that the values obtained are difficult to extrapolate to other situations for the following reasons:

- The use of hybrid electric vehicles was essentially restricted to medium and long-distance travel outside Lisboa. This is not the optimal use for a hybrid vehicle, since the "electric weight" is reduced when compared to the "weight of the combustion engine";
- The vehicles were driven in high regimes, which reduced the performance of vehicles in terms of consumption.

2.3.2. Extrapolation to other uses of electric vehicles

Taking into account the results obtained with the fleet of the demonstration program, the aim was to extrapolate these findings for other types of use. Thus, scenarios were created for three different uses:

- Use by an individual (household)
- Use by a company
- Use by a public entity

For each scenario, it became necessary to further define:

- The form of acquisition / use of the vehicle (purchas or rental)
- The total annual distance covered
- The type of vehicle to be used, having chosen to carry out simulations for three segments within each scenario (city, utility and family vehicles)

For the calculations, the following assumptions were considered:

- Lifetime - 5 years
- Residual value of the vehicle at the end of the project's lifetime (5 years) - market values obtained from rental companies
- Rate of return: 9.0%
- Inflation rate: 1.5%
- The current fiscal situation in 2015 was considered, which includes several fiscal incentives for electric mobility, namely [3]:
    - Increasing the maximum amount of depreciation acceptable the tax expenses
    - Reduction of separate tax rates on individuals 'and companies' income taxes
    - Tax incentives in the form of vehicle tax (ISV) return or by the assignment of an Allowance, by purchasing a new electric or plug-in hybrid vehicle (electric vehicles: €4 500; Plug-in hybrid vehicles - €3 250)
    - Exemption from vehicle tax and road tax for electric vehicles
    - Recovery of VAT up to a maximum purchase cost of the vehicle (€ 62 500 for vehicles powered exclusively by electricity and € 50 000 for plug-in hybrid vehicles).

For the reasons already mentioned, the results obtained in the use of the hybrid vehicles are not considered as representative and were not used for extrapolations. As a result, only fully electric vehicles were considered.

The following table presents a systematization of the evaluated scenarios.

Table 2: Evaluated scenarios

	Scenarios		
Assumption	Household	Company	Public entity
Lifetime	5 years		
Km/year	15 000		
Property type	Ownership	Renting	Renting
Taxes	Taxes in force during 2015		
Vehicles segment	City	Utility	Family

The total cost of ownership (TCO) is the sum of three costs: acquisition, operation and taxation. TCO presented are for the total lifetime (5 years) and €/km values are the average of the lifetime.

For all scenarios and vehicle options, a comparison was made with the equivalent traditional combustion vehicle.

2.3.2.1. Household case study

This first scenario is intended to represent the use of an electric vehicle by a particular individual (household), with the above-mentioned assumptions. The following results were obtained for the total cost of ownership

(TCO) and a comparison was made between the electric option and the combustion option. The following figure presents the average TCO, the minimum and the maximum for each kind of vehicle (a set of vehicles was used for each segment and the average is presented).

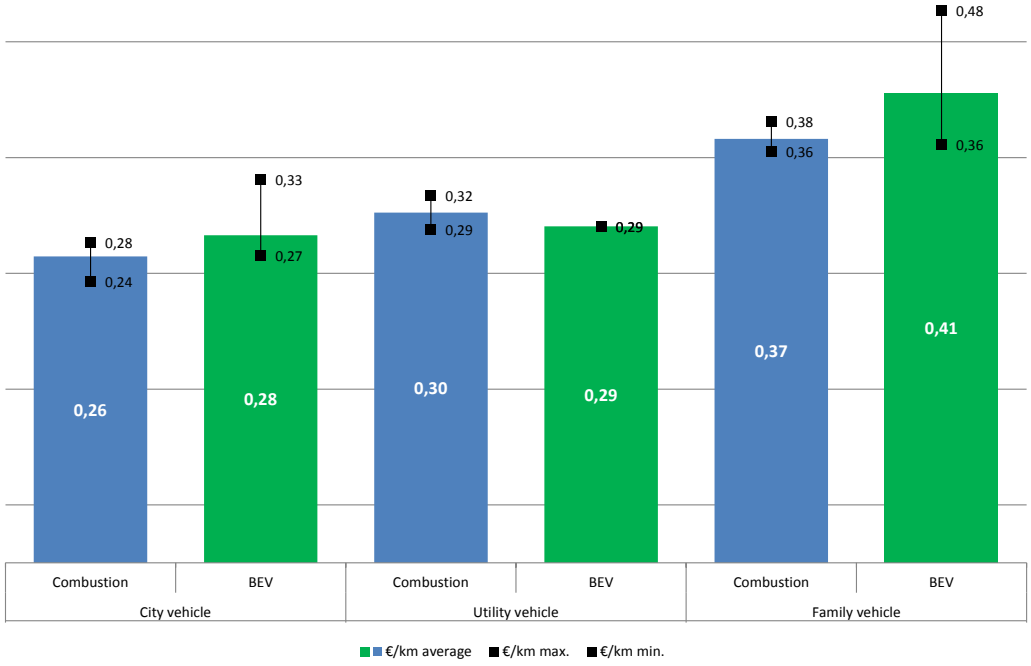

Figure 3: Household TCO (€) for a Combustion engine and BEV

In order to be able to analyze the various components of the TCO, the TCO is broken down for the city vehicle.

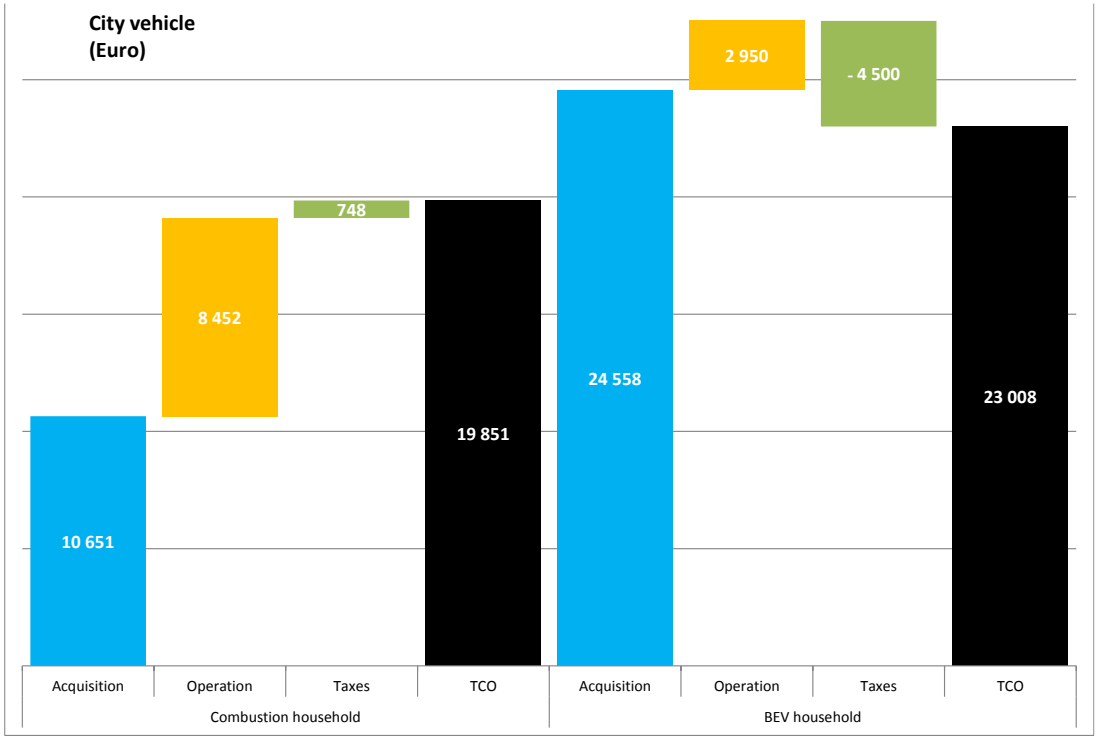

Figure 3: Household TCO components (€) for a combustion engine and BEV

The main conclusions are:

- Compared to conventional vehicles (combustion), electric vehicles (BEV) have lower TCO in the utility vehicle segment (-4%) and higher TCO in other cases (+ 16%); and
- Taxation is the most important factor in the advantage of electric vehicles.

2.3.2.2. Company case study

This scenario aims to calculate the TCO for the use of electric vehicles in a company, and compare it with the equivalent of combustion vehicles, thus applying taxation to companies.

The following chart presents the results for the TCO in the different vehicle segments.

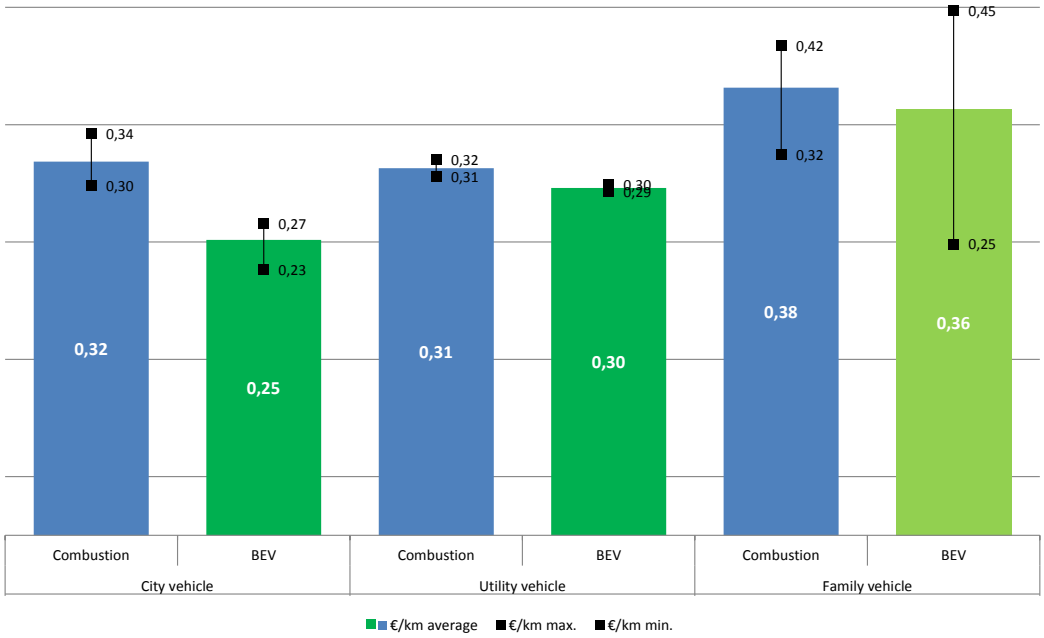

Figure 4: Company TCO (€) for a Combustion engine and BEV

As before, a TCO breakdown for the "city vehicle" segment is presented.

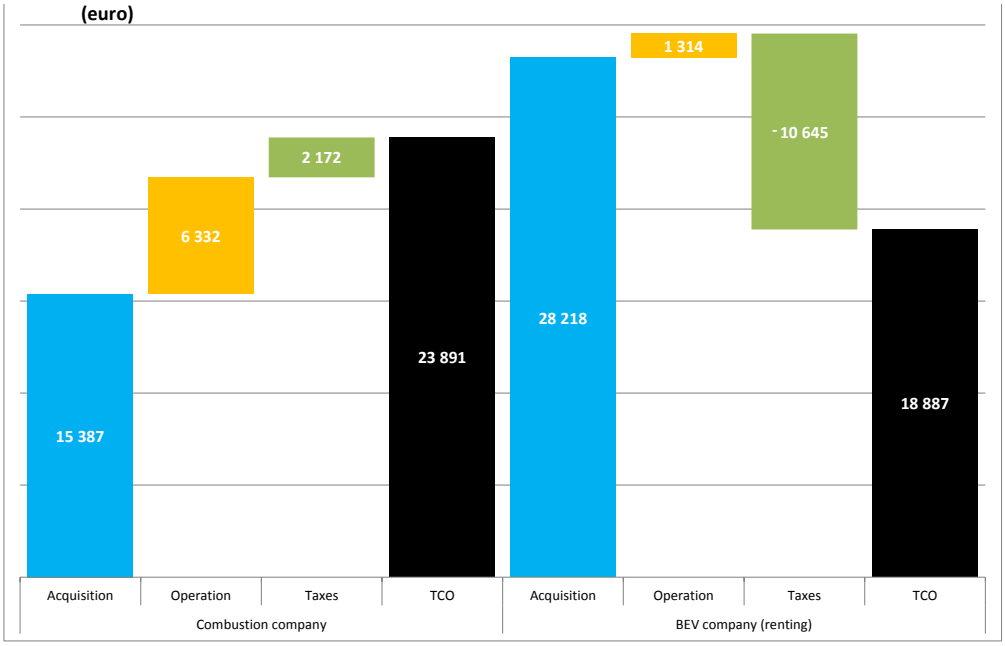

Figure 5: TCO breakdown (€) for the "city vehicle"

The main conclusions are:

- Compared to conventional vehicles (combustion), electric vehicles (BEV) have generally more favorable TCOs, -21% for city residents, -5% for utilities and -18% for family members; and
- Taxation is the factor that is most important in the advantage of electric vehicles.

2.3.2.4. Public administration case study

In this scenario, the extrapolation was made for use by a Public Administration entity. The following chart presents the results for the TCO in the different vehicle segments.

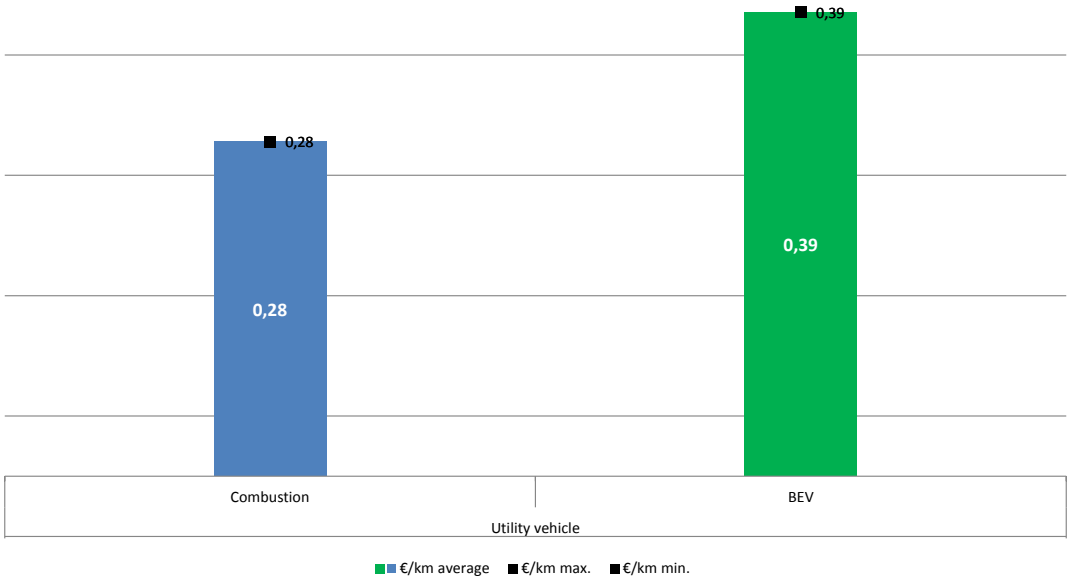

Figure 5: TCO components (€) in different vehicle segments

The taxation applicable to Public Administration is similar to a private individual.

Thus, the TCO of electric vehicles is higher than that of combustion vehicles. However, it is important to analyze these results with caution, given the characteristics of the State Vehicle Fleet, namely the average age of vehicles, which increases the operating costs compared to the standard values used [4].

2.3.2.5. Summary and conclusions

The following table summarizes the comparison between the TCO of conventional vehicles (combustion) and the TCO of the electric vehicles (BEV), taking into account the tax benefits applicable in 2015. It is worth highlighting those situations in which electric vehicles have a lower TCO than combustion equivalents.

Table 3: TCO comparison: Combustion vehicles versus BEV

	Household		Company		Public Administration	
	Euro	%	Euro	%	Euro	%
City vehicle	3 158	16%	-5 004	-21%	-	-
Utility vehicle	-886	-4%	-1 258	-5%	8 067	39%
Familiar vehicle	4 287	16%	-5 959	-18%	-	-

Some sensitivity analyzes were tested, namely in terms of the price of fuels, the distance traveled and the price of electric vehicles. Main conclusions are:

- Lowering the price of electric vehicles is the key to making TCO for electric vehicles more competitive when compared to combustion vehicles; and

- Taxation in 2015 played an important role in making electric vehicles more competitive, especially for companies.

3 Eco.mob – Public Administration Sustainability projet

In July 2015, the Portuguese Government approved a sustainable mobility project. ECO.mob is a €41.5 million project with a component of fleet management, a component of electric vehicle use in the state fleet and behavioral actions (eg. eco.driving) [1]. The estimated savings are €50 million until 2020.

Eco.mob was designed with the support of the Monitoring Committee of the demonstration program analyzed in the previous section. As a result, Eco.mob benefited significantly from the experience and results obtained in that program.

It should be noted that the state vehicle fleet consists of about 26 000 vehicles, about 80% belonging directly to the state's administration. The fleet is characterized by vehicles with a high average age (15.2 years, 60% of vehicles are over 13 years old) and, of course, high mileage (46% of vehicles are over 200 000 km). The average age has increased in recent years, from 12 years in 2010 [4]. This is a fleet in which the replacement of vehicles by environmentally more suitable vehicles leads to significant environmental gains and a significant reduction in costs maintenance.

The first results issued for the "electric vehicle use in the state fleet" are related to the use of 30 city vehicles for six months. The information gathered allowed to confirm that the consumption obtained with electric vehicles (kWh / km) is in line with those measured in the demonstration in the Ministry and used in the extrapolations presented above, which reinforces their validity and conclusions.

4 Installation of a charging point linked to the electric mobility network in a condominium

The practical experience of the MAOTE demonstration program has shown that a pilot project is a very interesting learning field. Having this in mind, ERSE purchased an electric vehicle, essentially for urban travel.

The car was purchased and in the negotiation a charging point of 22 kW was included. ERSE is located in a collective building (condominium) with a common garage. The first challenge was to install the charging point. It was necessary to ensure the following conditions:

- Compliance with legislation, technical requirements and safety regulations
- Guarantee that the consumption for charging the car is measured and discounted from the consumption of the condominium, including the cost relative to the power (kW)
- Use of the charging point included in the commercial offer of the vehicle which did not include metering or any type of communication

A solution was chosen that combined metering equipment available in the market (with memory discrimination of 15 minutes) associated with a module of communications with the electric mobility network. The EGME manages all the information, ensuring that the consumption of electric mobility (connected to the network) is measured and the information transmitted to the respective electric mobility supplier for billing the customer. The management entity also gives information to the distribution system operator that deducts the electric mobility consumption (Energy/kWh, Power/kW) from the total consumption of the condominium.

With this solution it was not necessary, in our case, to create a new electrical infrastructure to connect to the electricity grid, instead the electrical installation of the building (condominium) was used, without the need for a new project, works and licensing. The solution found will improve the regulation of the electric mobility sector, facilitating the installation of charging points in collective garages of condominiums. It is important to stress that electric mobility has special preponderance in cities where many people live in condominiums. The experience in finding this approach showed that there are still no solutions available in the market that can fulfill the objectives and make the interconnection with the EGME, who is responsible for the data flows between the agents. Besides the benefits to regulation policy, this project has developed a new technological

solution that may become a standard in the future.

The electrical infrastructure of buildings will be stressed in the future with the installation of charging points namely, fast charging points. The industry will have the opportunity to minimize this problem. To solve this, intelligent automated chargers will be a must in order to optimize the available infrastructure able to satisfy EV charging (declared) needs.

5 Development of electric mobility in Portugal

Portugal has an electric mobility infrastructure prepared for future developments. Despite a significant growth in recent years, which was motivated by fiscal incentives for vehicle acquisition and by evolutions in the market, the number of electric vehicles is small, representing a sub-utilization of the existing infrastructure.

Given the experience gained in the policy area and regulation, some clues and proposals are presented to develop electric mobility:

- It is vital to promote electric mobility and invest in transport in general and in public local transport in particular. We can expect multiple gains in that area (fuel savings, reduced dependence on fuel, lower CO_2 emissions, economies of scale, etc.). With private vehicles, there are still several entry barriers to overcome, e.g. behavioral and overall TCO. There are also technical difficulties in the installation of charging stations which leads to a lack of charging points compared to petrol stations.
- Given the existence of several environmental advantages, Governments may have to define ambitious targets and adequate frameworks including appropriate incentive systems in terms of the number of EV to reach and the electrical infrastructure for charging points. In parallel to private transport, support should also be given to electric mobility for commercial vehicles (e.g. urban delivery vehicles, local public transport) and two-wheeled vehicles (particularly given the potential TCO advantages identified above). It is important to incentive fleets.
- Electric mobility will be an important tool to create new forms of urban mobility, e.g. car-sharing, with impacts on development planning.
- The social acceptance of the climate and economic policy goals to implement in the years to come need social approval and it is essential to involve people, ensuring transparency and providing information on the implementation of development plans.
- The development of electric mobility goals should be subject to periodic monitoring and reevaluation while the most recent developments have to be considered. Technological solutions evolve quite quickly and if the planning is executed too soon or too rigidly, obsolete solutions and sunk costs will occur.
- Electric fleets with good management (e.g. car sharing, commercial transport, mass local transport) leads to significant savings once the vehicle use is higher compared to private standard use. The social responsibility associated with the environment will lead people to consider values other than external image when using transport and will increase the acceptance of electric mobility versus vehicle performance.
- Air pollution is already a problem in several cities. The tourism industry requires high standards in this aspect since it represents for people a value to look for. Electric mobility in tourist cities like Lisboa has this relevant added value.

Acknowledgements:
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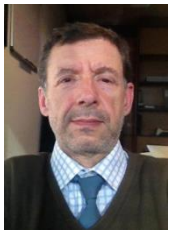

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Alexandre Santos is a member of the Board of Directors of ERSE - Energy Services Regulatory Authority since June 2013 with the supervisory roles of the electricity and natural gas sectors. In 2016, he was elected President of MEDREG - Association of Mediterranean Energy Regulators. He chairs the Working Group on Consumers at ARIAE - Ibero-American Association of Energy Regulators. Prior to joining ERSE, Alexandre was a member of the Board of Directors of the Fundo de Inovação e Eficiência Energética. Alexandre holds a Master's Degree in Organizational Behavior from ISPA, and a degree in Economics from Católica-Lisbon Business & Economics.