

A Work Project, presented as part of the requirements for the Award of a Master's degree in Finance from the Nova School of Business and Economics.

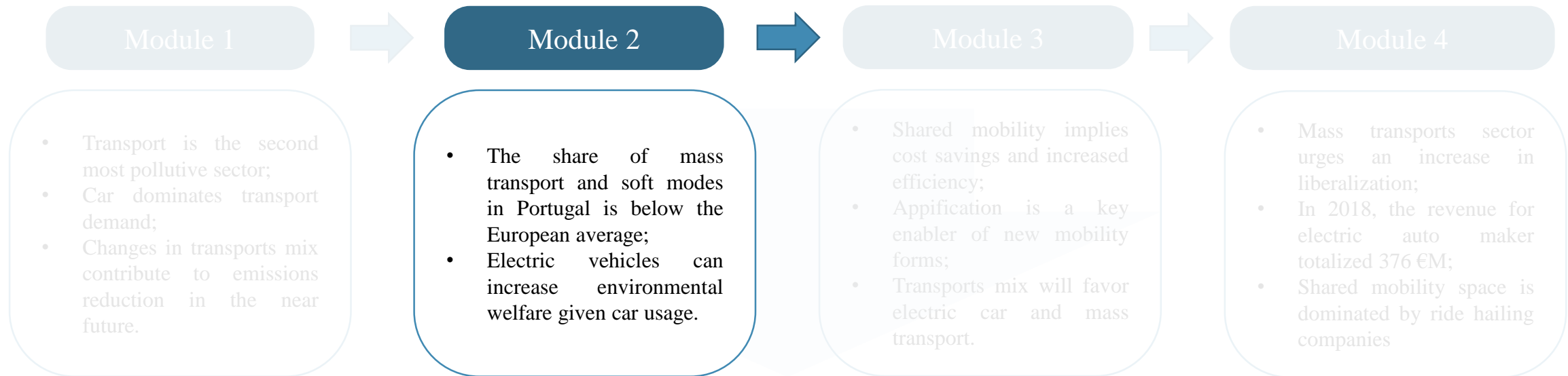
Shaping the future of urban mobility - potentiating car alternatives, increasing environmental and socioeconomic welfare given car usage and the rise of electric vehicles

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Shaping the future of urban mobility - potentiating car alternatives, increasing environmental and socioeconomic welfare given car usage and the rise of electric vehicles

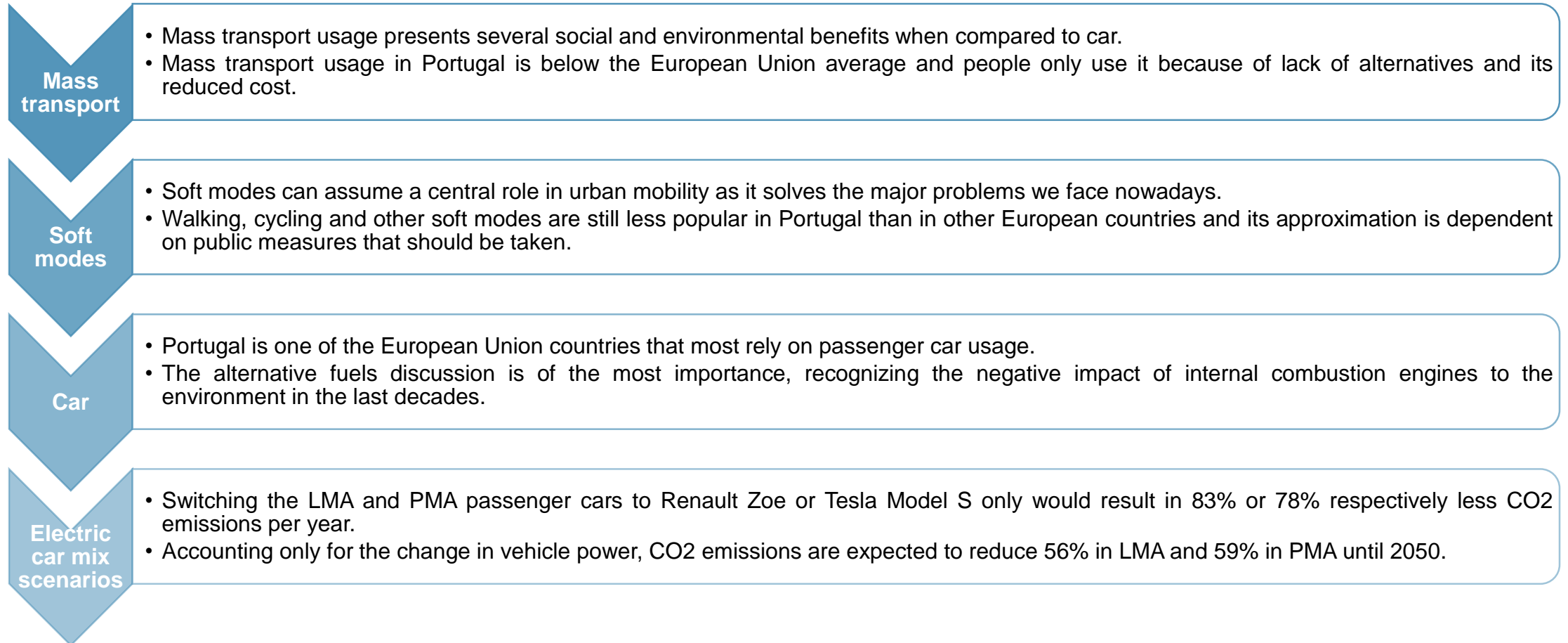


Abstract

Mass transport and soft modes play a critical role in solving the majority of urban mobility problems that emerged in the last decades. Despite the benefits of these transportation types, their usage in Portugal is still below its European peers and further below the desired levels. The car usage reduction, particularly in city centers, should be a main concern of decision-makers as it interferes in social welfare. Having to deal with the car, alternatively-powered vehicles appear as a solution to face the environmental problems raised by the excessive GHG emissions to the atmosphere.

Keywords: CO2 emissions, Electric vehicles, Mass transport, Soft modes.

Shaping the future of urban mobility - potentiating car alternatives, increasing environmental and socioeconomic welfare given car usage and the rise of electric vehicles



Mass transport present several benefits when compared to car

Less pollutant

Higher energy
usage efficiency

Reduces traffic

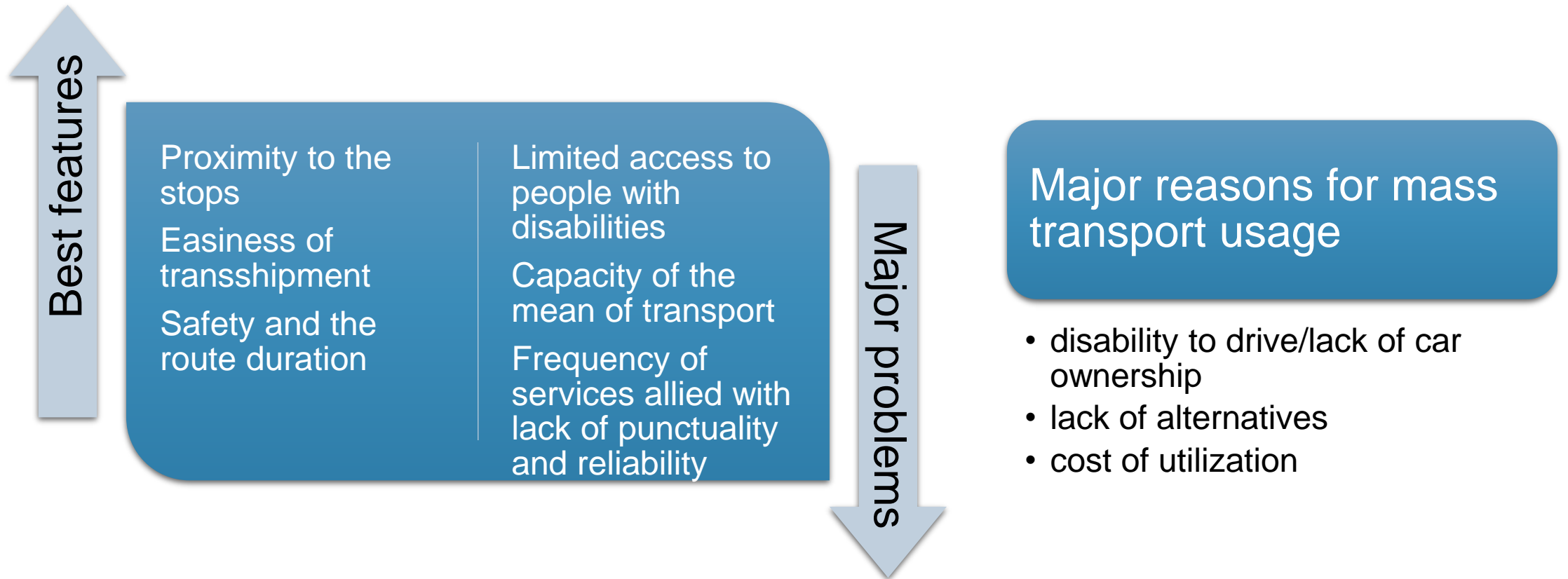
Cheaper

More inclusive

Enhances
productivity

Safer

Mass transport systems in LMA and PMA fail to please people needs and expectations as the major users those forced to rely on this solution

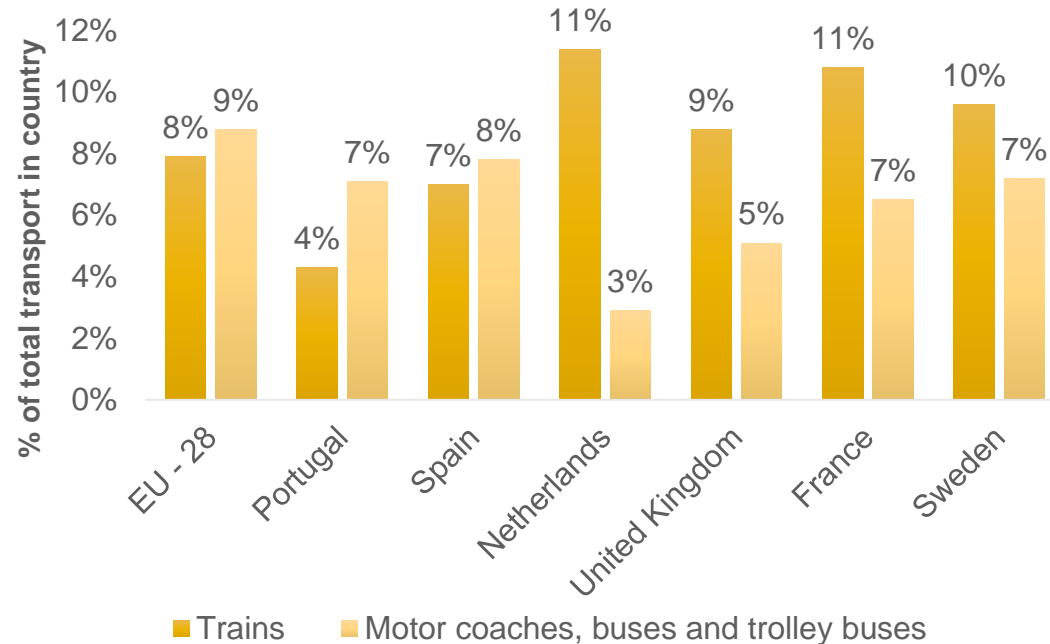


Portugal needs to improve the capacity and quality of mass means of transport and implement measures to promote its usage to levels closer to its peers

Mass transport utilization in Portugal is behind the European Union average. The train usage is further from the Community average and below every peer analyzed.

More than price reduction, it is necessary to improve mass transport quality in Portugal. There is a long way to go to reach a desirable level of mass transport usage.

Graph 30: 2017 Mass transport usage



Source: made by the authors based on [Reference list 31](#)

Measures recently adopted in Portugal

- Price reduction of the mensal mass transport pass.
- Family pass creation.

State Budget 2020

- Benefit companies that pay social passes to their employees
- Rolling stock acquisition financing to the railroad sector.
- Allow retirees with experience in rolling stock maintenance in the railroad sector to work to state companies.

Source: made by the authors based on [Reference list 32\) to 34\)](#)

Mass transport usage depends on its quality perception, easiness of interchange and advantages to cars

Quality

- Ensure high levels of predictability and punctuality in transport, as well as comfort and safety improvements.

Interchange

- Provide a connected network with easy and quick transshipment between transport modes or lines.

Advantages to cars

- Increase the amount of bus lanes and give mass transport priority in traffic signals.

Soft modes present several benefits when compared to car

Healthier

Cheaper

Safer

Less pollutant

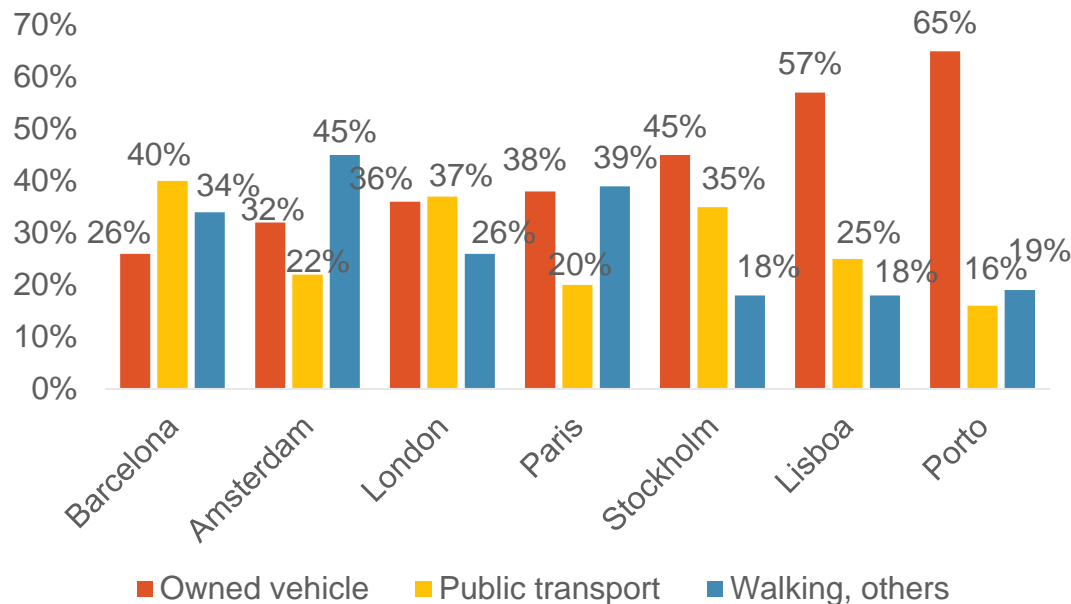
Reduces traffic

Soft modes are a viable alternative to car in LMA and PMA, but we are still behind other comparable cities and the European average

The use of soft modes in Lisbon and Porto is less significant than in the majority of its peers cities. The graph also stresses the massive car usage in the two Portuguese cities.

In Portugal, more than 50% of car trips are made in distances below 5 km, and more than 80% in distances until 10km. This signals the huge potential of soft modes as a viable mode of transportation, especially in city centers.

Graph 31: Type of transportation in European city centers



Source: made by the authors based on [Reference list 30](#)) and [37](#))

Measures adopted in Portugal: Bicycle

- Bicycle path predicted expansion from the actual 2.000km to 10.000km in 2030.
- Appearance of shared and pay-as-you go bicycles in city centers.

Measures adopted in Portugal: Scooter

- Appearance of pay-as-you-go shared vehicles in city centers.

Source: made by the authors based on [Reference list 38](#)) to [40](#))

Measures to increase soft modes usage

The reduction of road hazard is a key factor to encourage citizens to give soft modes a stronger importance in their everyday movements.

Wider walks

Bicycle lanes

Safer
crosswalks

Reduction of
automobiles

Reduction of
velocity limits

Urban design
oriented to
nonmotorists

Bicycle
parking
facilities

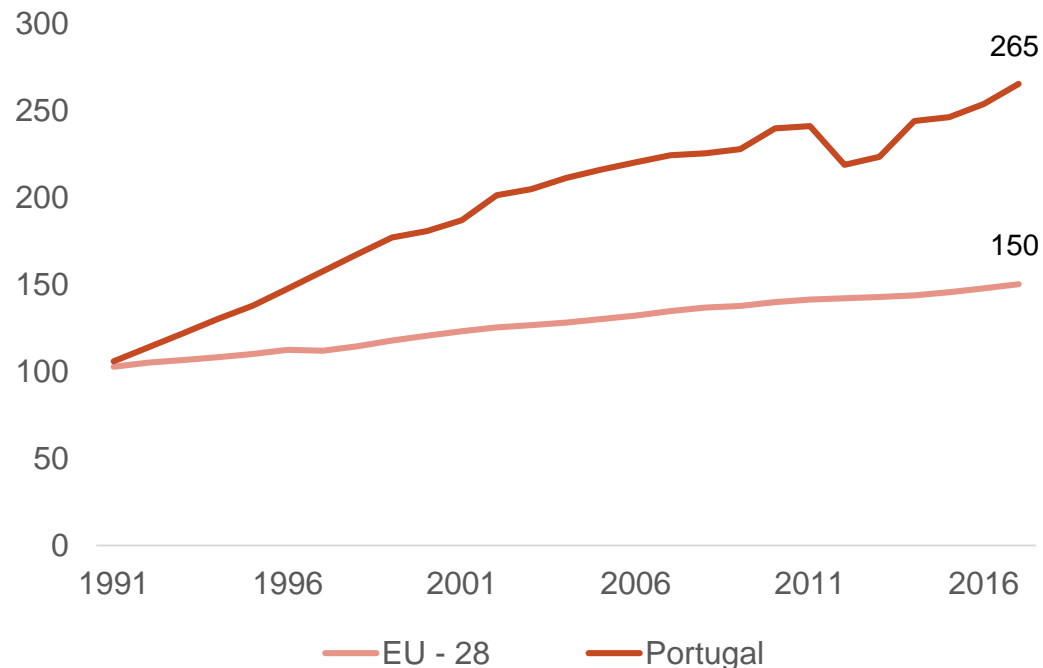
The public
bicycle

Although the trend is to reduce car usage, we will continue to have to deal with it and Portugal is one of the most car dependent countries in the European Union

Since 1991, car ownership in Portugal increased significantly more than the European Union average. This trend evidence the growing importance car was given in Portugal in the last decades.

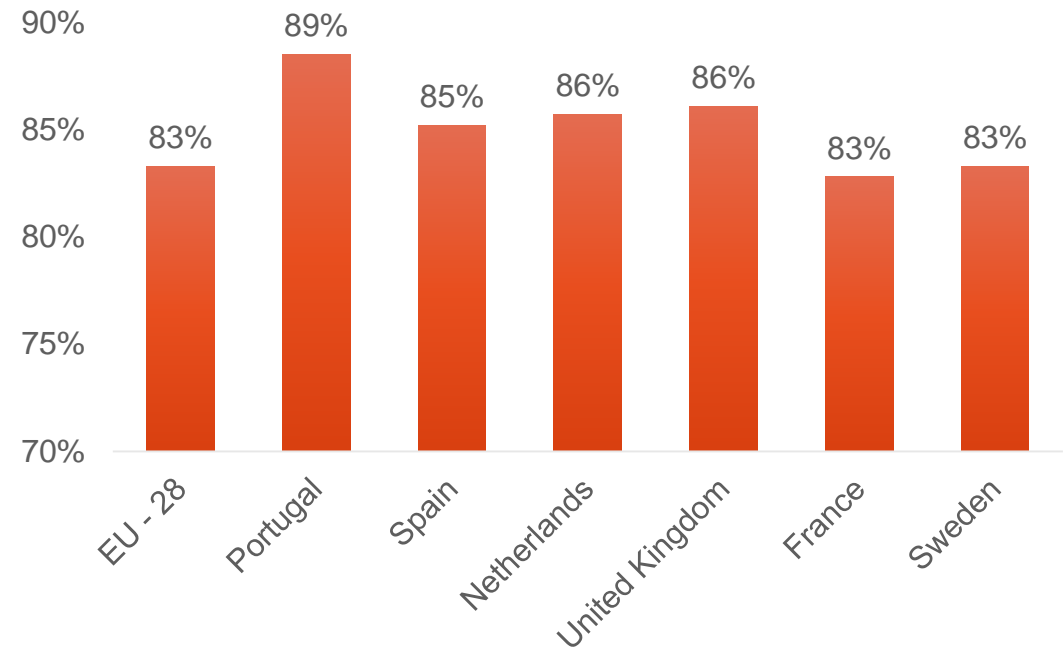
The car usage in Portugal is substantially higher than in its comparable countries and in the European Union average. This stresses a structural reliability on car by the Portuguese population.

Graph 32: Passenger car ownership growth (1991=100)



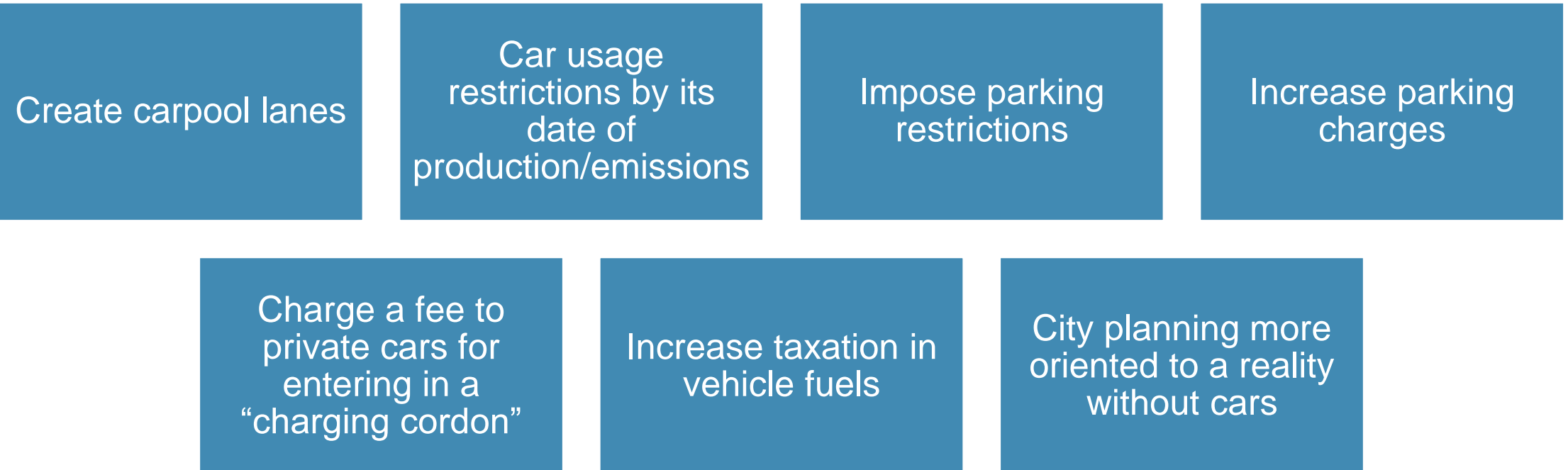
Source: made by the authors based on [Reference list 43](#)

Graph 33: 2017 passenger car usage (% of total transport in country)



Source: made by the authors based on [Reference list 44](#)

To reduce car usage, people must be given viable alternatives in terms of accessibility, costs and comfort - although no other single mode of transport can offer the same level of flexibility as car, it may be possible using a mix of modes

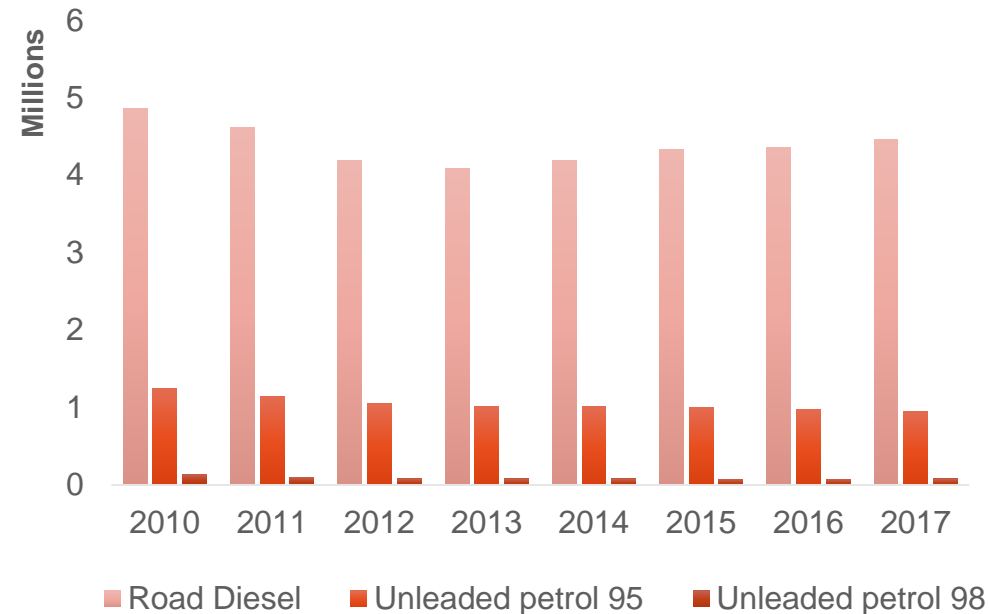


The transport sector in Portugal is still highly dependent on fossil fuels and have been increasing the GHG emissions

Fossil fuel, namely road diesel consumption has been increasing since 2013. This trend is expected to invert in the following years, due to the rising of alternative powered vehicles.

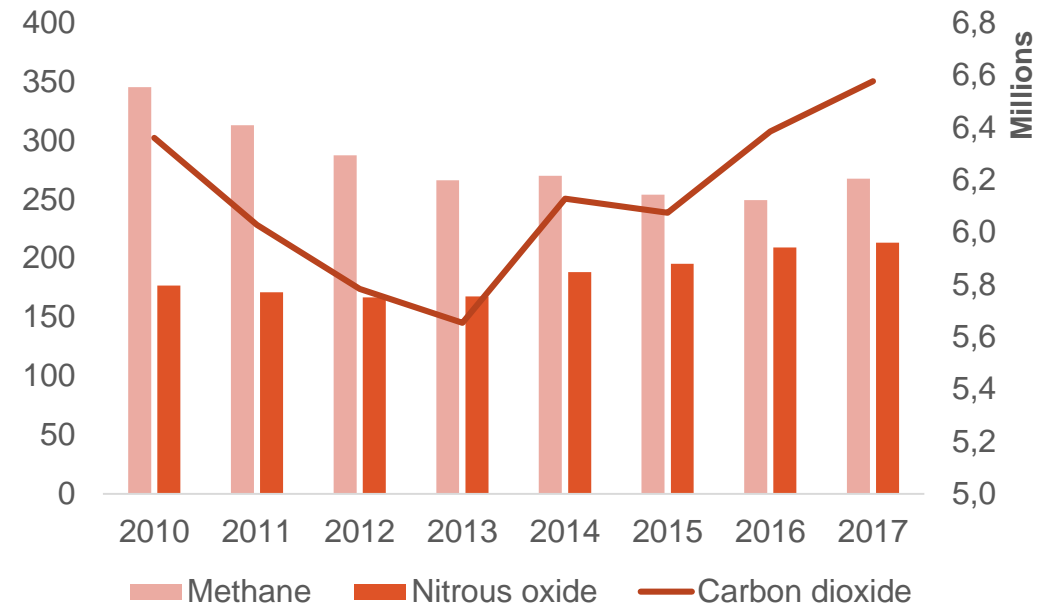
The carbon dioxide and nitrous oxide emissions in transport have been increasing since 2013. In an era of increasing environmental concern and decarbonization plans, this trend must be inverted.

Graph 34: Tonnes of fossil fuel consumption in Portugal



Source: made by the authors based on [Reference list 46](#)

Graph 35: Tonnes of GHG emissions in transport in Portugal (carbon dioxide on the right scale)



Source: made by the authors based on [Reference list 47](#)

Several sources of energy can be used as alternatives to traditional internal combustion engine (ICE) vehicles in order to reduce GHG emissions in transport

Ethanol

Natural gas

Electricity

Hydrogen

Propane

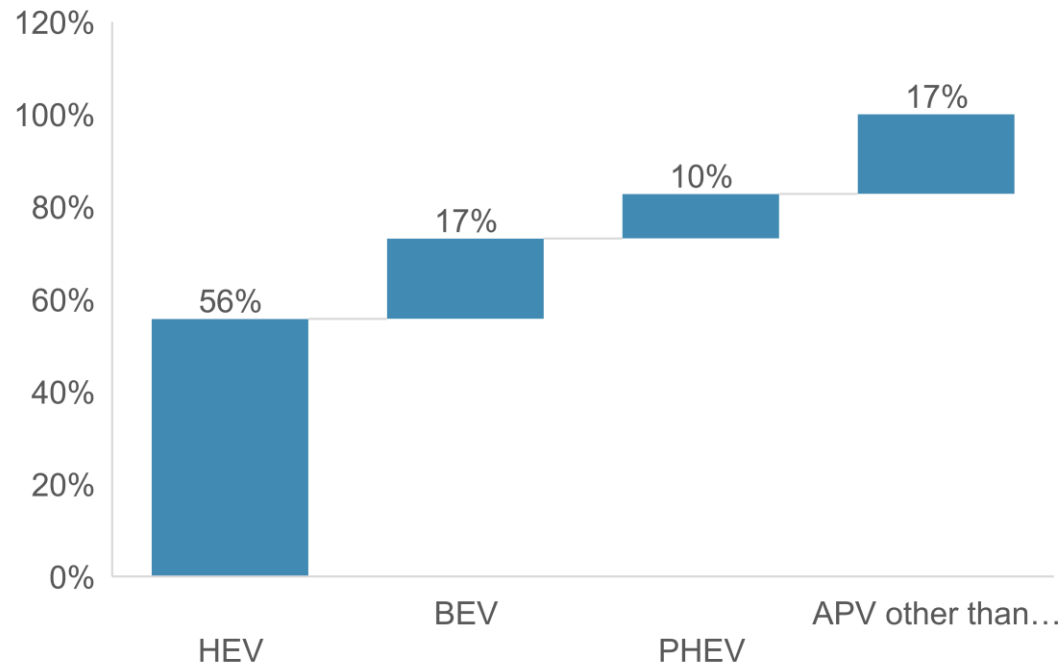
Biodiesel

Methanol

The winner alternative power until today is electricity, in the form of battery electric vehicles, plug-in hybrid electric vehicles and hybrid electric vehicles

The number of electric passenger cars registrations represents 83% of the total alternatively-powered passenger cars registrations in the first three quarters of 2019, establishing the electric car as the major alternative to ICE vehicles. The hybrid electric vehicle has the higher share of new registrations, with 56% of the total alternative power passenger car registrations.

Graph 36: Alternative power passenger car registrations in European Union Q1-Q3 2019



Source: made by the authors based on [Reference list 49](#)

APV – Alternately-powered vehicles

- Vehicles powered by some fuel/energy other than traditional petroleum fuels.

HEV – Hybrid electric vehicles

- Vehicles powered both by electric batteries and petrol.

BEV – Battery electric vehicles

- Fully-electric vehicles with rechargeable batteries and no fossil fuel engine.

PHEV – Plug-in hybrid electric vehicles

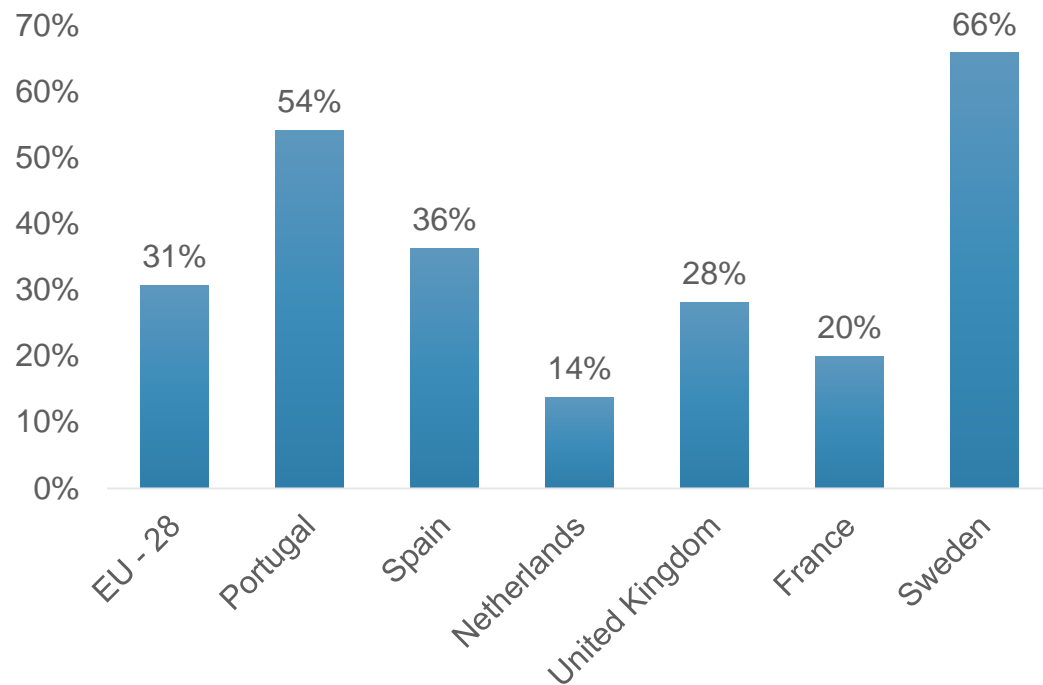
- Vehicles that can recharge the battery through both regenerative braking and “plugging in” to an external source of electrical power.

Source: made by the authors based on [Reference list 50](#)

The high share of renewable sources in electricity production in Portugal can be an opportunity to reduce emissions in the electric vehicle transition

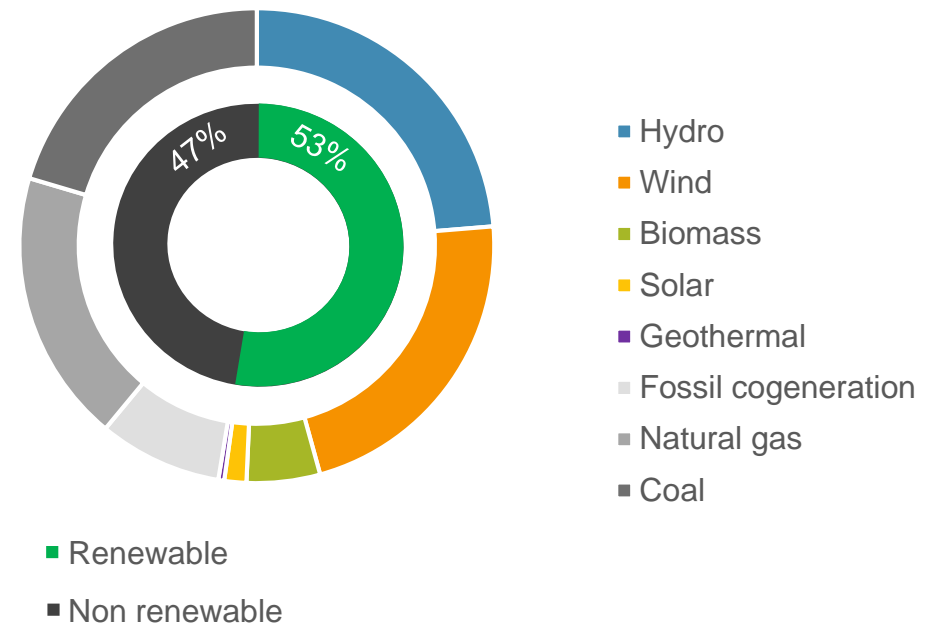
53% of the electricity produced in Portugal in 2018 was generated based on renewable sources, which is a better share of renewables in electricity production than the European Union average. According to PNEC (*Plano Nacional de Energia e Clima*), the goal for 2030 is that 80% of the electricity come from renewable sources.

Graph 37: Share of energy from renewable sources 2017



Source: made by the authors based on [Reference list 51](#)) and [52](#))

Graph 38: Portugal electricity production by source in 2018



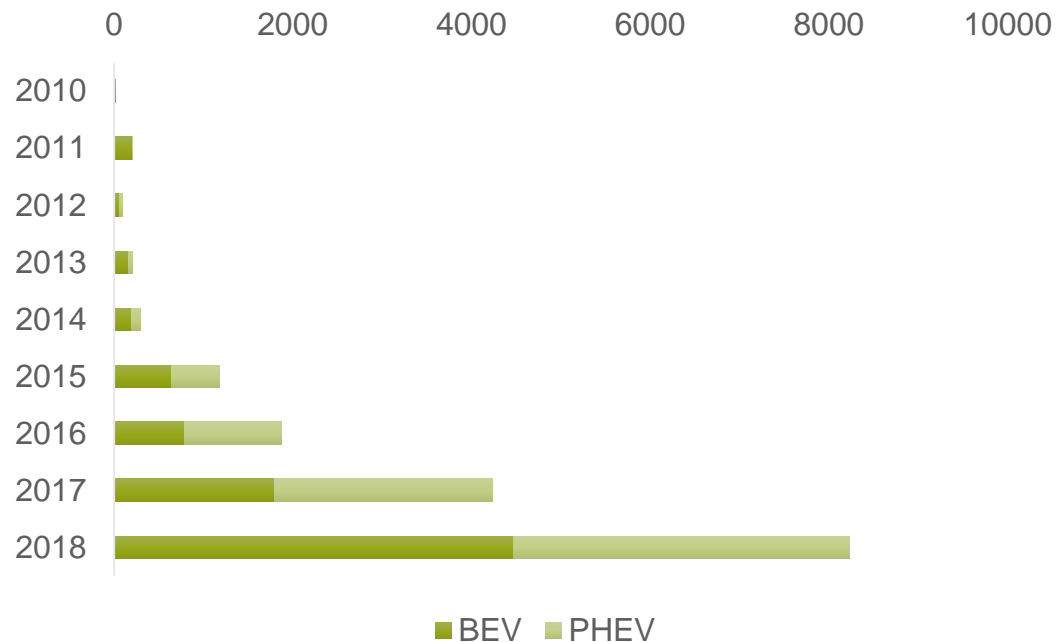
Source: made by the authors based on [Reference list 53](#)) and [54](#))

The electric passenger car evolution in Portugal has been substantial in last years, with a CAGR of 121% in the electric cars fleet from 2010 to 2018

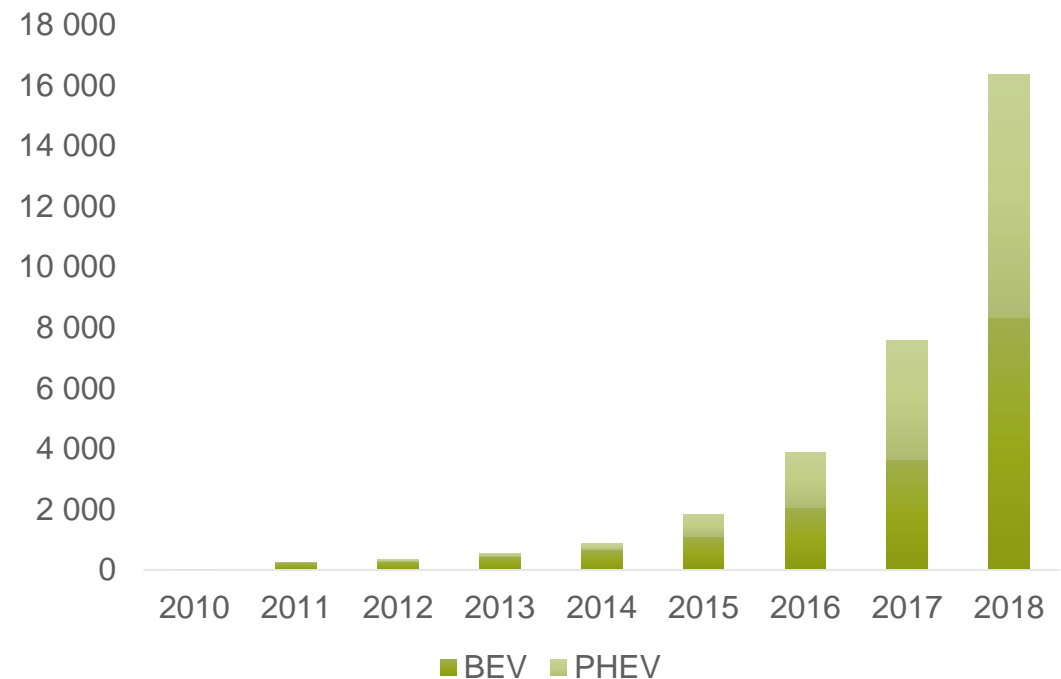
Since 2010, the number of electric passenger cars new registrations in Portugal only decreased in 2012, explained by the state incentives withdrawn. The incentives were reintroduced in 2015, keeping up to date.

With a CAGR of 121% between 2010 and 2018, the electric passenger cars fleet in Portugal is following a notorious growth. At the end of 2018, there were more than 16.000 electric cars in the Portuguese roads.

Graph 39: Electric passenger cars new registrations in Portugal



Graph 40: Electric passenger cars fleet in Portugal

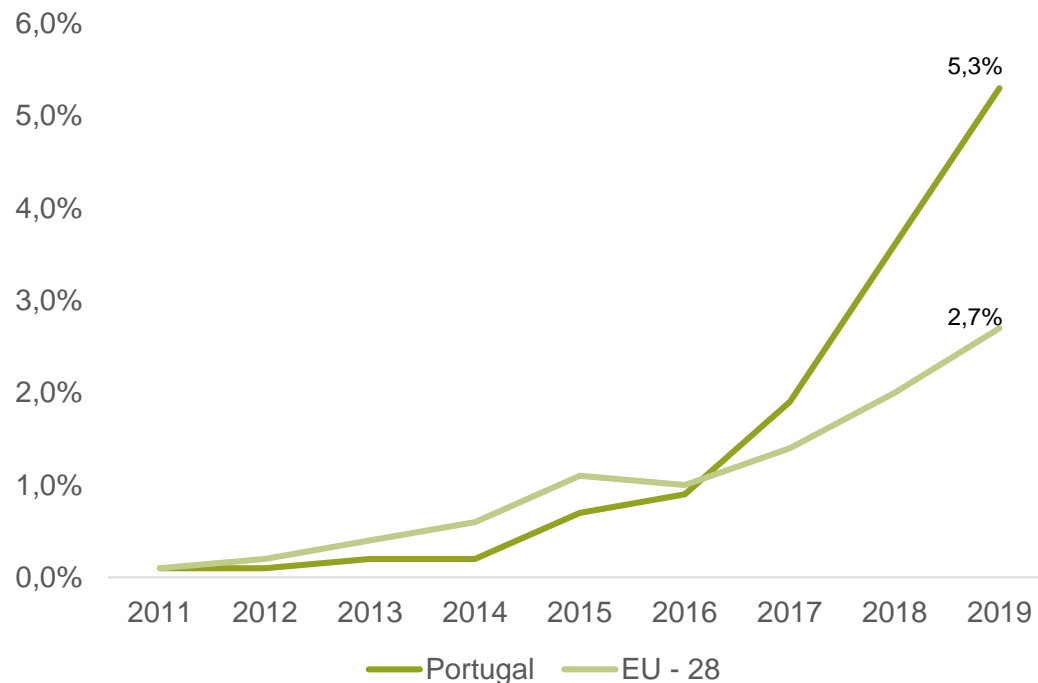


The electric passenger cars market in Portugal is developing faster than its European peers average

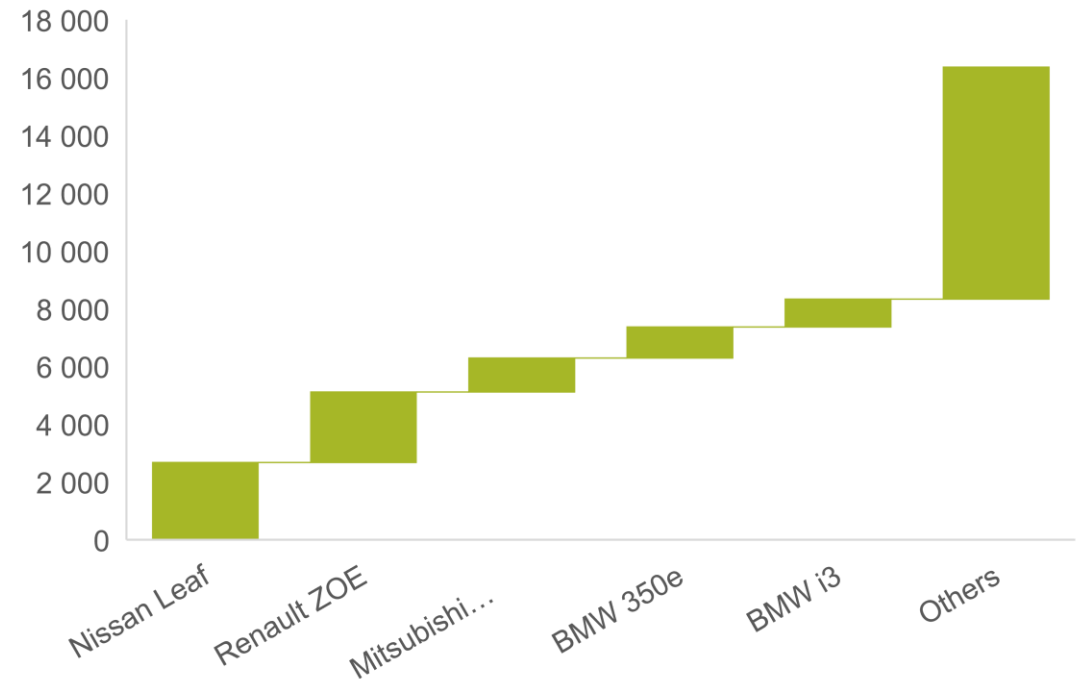
If until 2016 the share of electric vehicles in Portugal was below expectations, since then it has been above the European average, almost doubling the Community average share in 2019.

The 100% electric proposals of Nissan and Renault dominate the market in Portugal, being the two responsible for 31% of the electric passenger cars fleet in Portugal. The Mitsubishi Outlander PHEV surges in the last place of the podium.

Graph 41: Electric vehicles share in new registrations



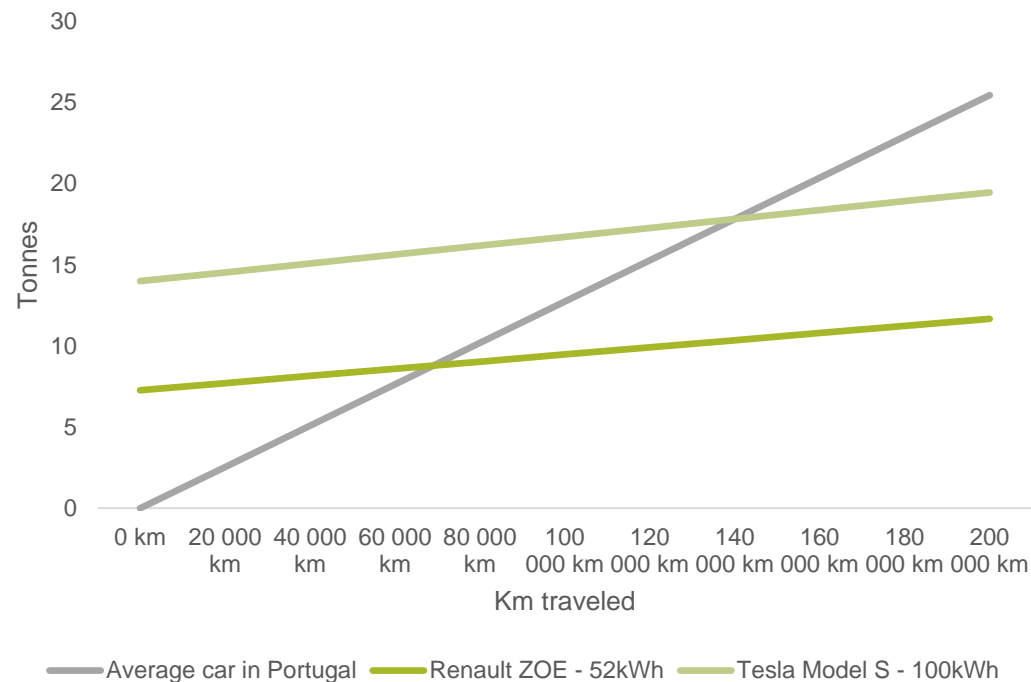
Graph 42: Top electric passenger cars models in Portuguese fleet



It takes 69 000km for Renault ZOE and 140 000km for Tesla Model S to environmentally breakeven in Portugal

The results of this study yield that it takes 69 000km for Renault ZOE and 140 000km for Tesla Model S to environmentally breakeven. This means that, currently, the total CO2 emissions of a Renault ZOE and a Tesla Model S are higher than an average car in Portugal ones until each breakeven point.

Graph 43: CO2 marginal emissions per vehicle in Portugal



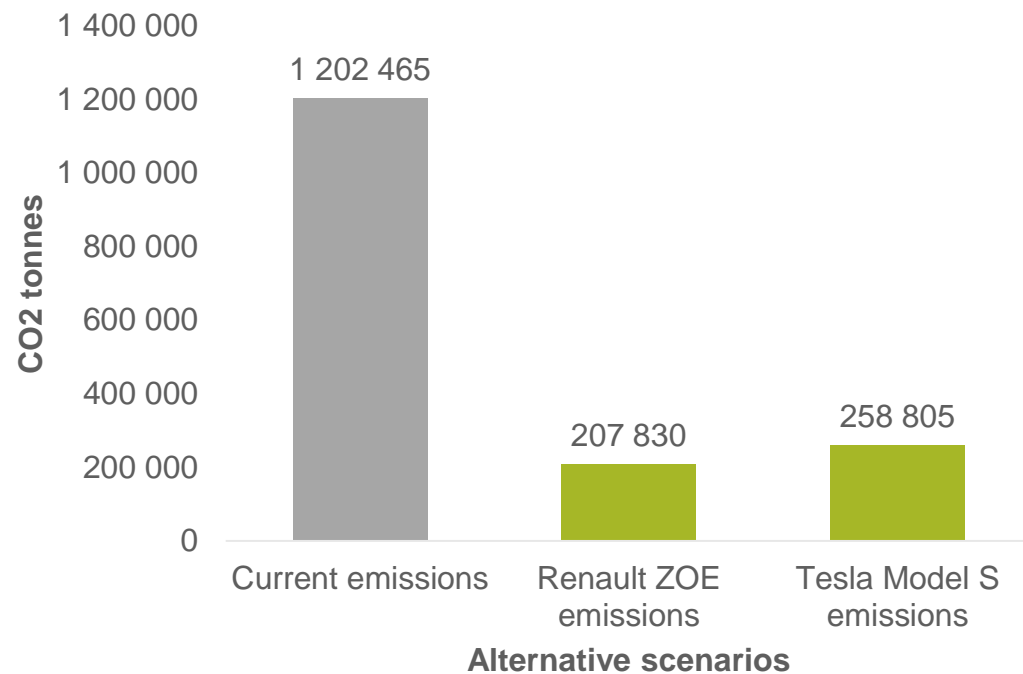
Assumptions

- A comparison of similar cars was made, one boosted by fossil fuels and two others by electric batteries. It was assumed that the CO2 emissions required for production of the two types of cars were the same, excluding the emissions of the battery production. Thus, the electric cars emissions also account for the battery production emissions. The average car represents the Portuguese current car fleet and the emissions in electricity production the current situation in Portugal.

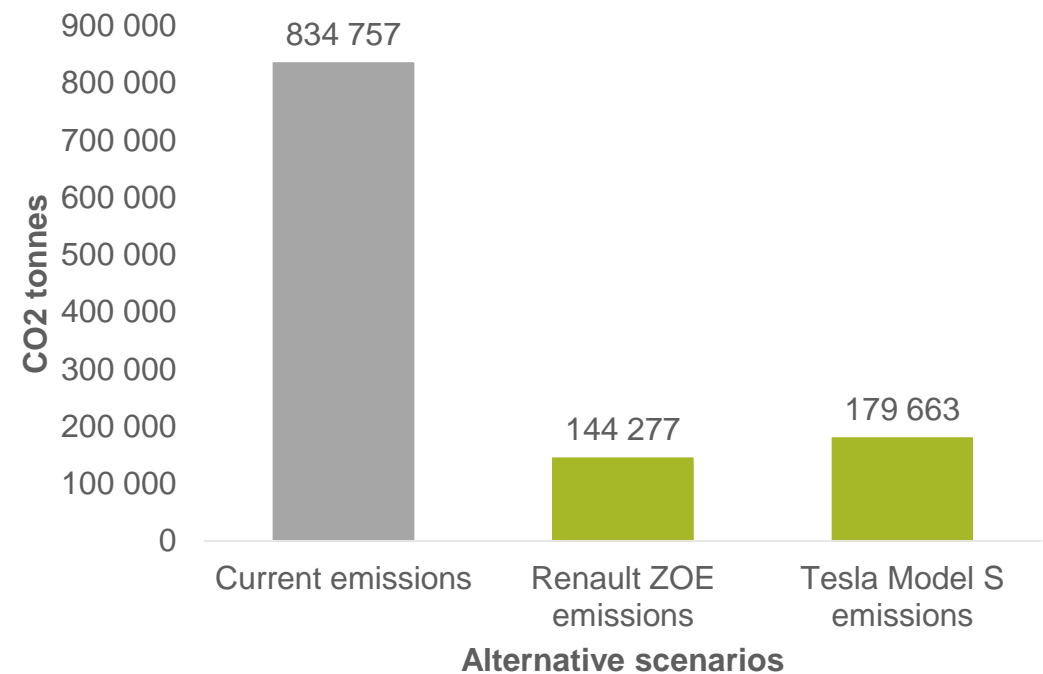
Emissions in LMA and PMA could reduce up to 83% if the Portuguese passenger cars fleet was electric

Three different scenarios were assumed in this analysis: the current situation, an utopic situation where all cars in Portugal were Renault ZOE and a similar situation with Tesla Model S. Since Renault ZOE is a more efficient car than Tesla Model S in terms of autonomy per battery kWh, it would allow a greater reduction in CO2 emissions. Nonetheless, the emissions evolution in the Tesla Model S scenario is also quite impressive, yielding a 78% reduction compared to the current scenario.

Graph 44: Yearly emissions of passenger cars in LMA



Graph 45: Yearly emissions of passenger cars in PMA

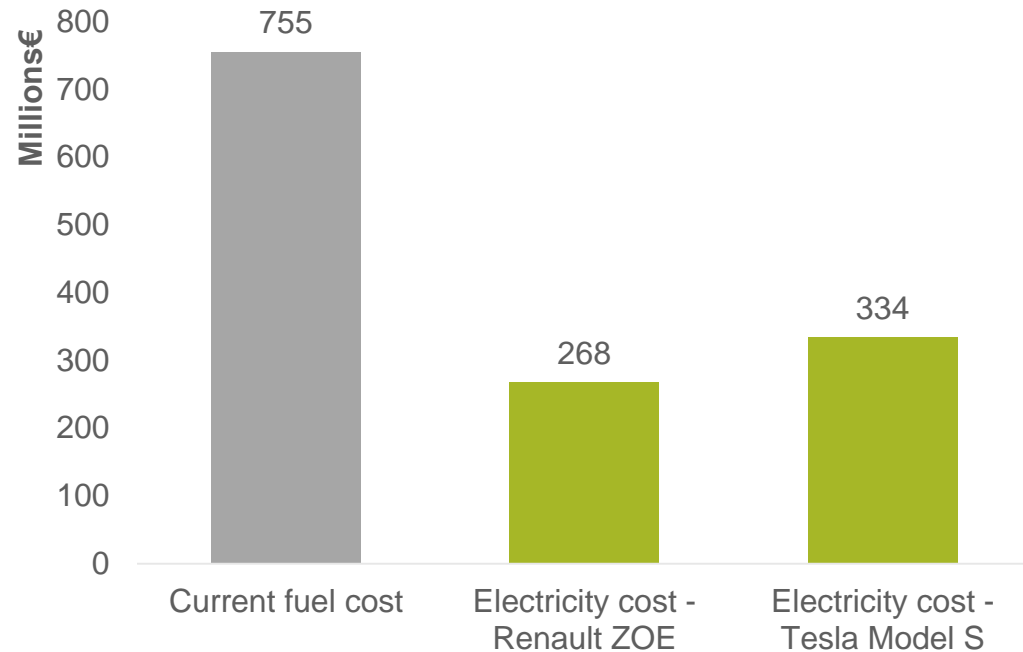


Source: made by the authors based on [Reference list 30](#) and [60](#) and [Appendix 7](#)

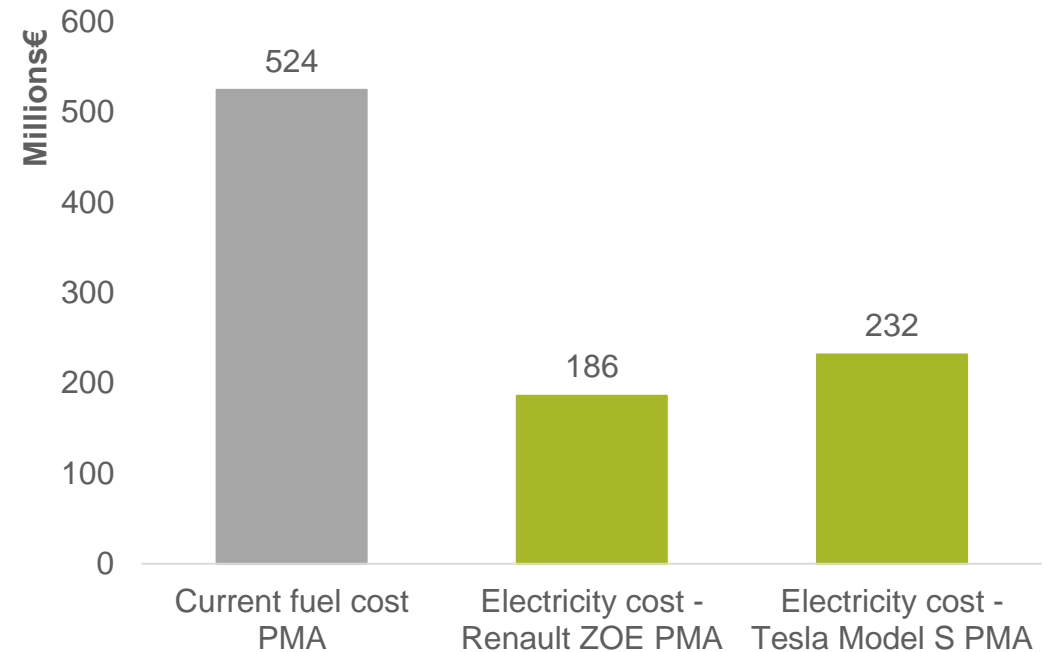
Fuel/electricity costs in LMA and PMA could reduce up to 65% if the Portuguese passenger cars fleet was electric

Expanding the analysis to an economic level, the passenger car fleet shift to Renault ZOE would allow a 65% reduction in fuel/electricity costs in urban mobility transport in Portugal, from 755 M€ to 268 M€ in LMA and from 524 M€ to 186 M€ in PMA. A similar situation for Tesla Model S would enable a 56% yearly save in this type of costs.

Graph 46: Actual and estimated yearly fuel/electricity costs in LMA



Graph 47: Actual and estimated yearly fuel/electricity costs in PMA

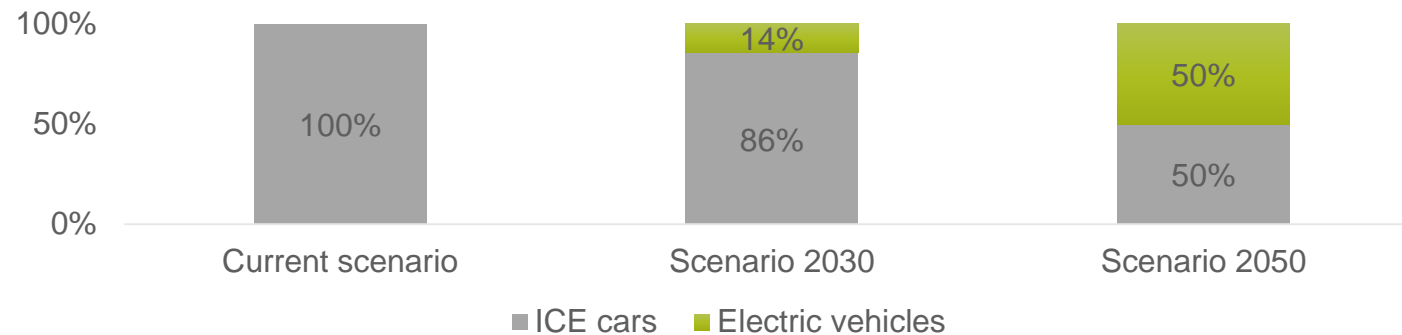


Source: made by the authors based on [Reference list 63\) to 66\)](#) and [Appendix 7](#)

Accounting only for the change in vehicle power, the CO2 emissions are expected to reduce 22% until 2030 and 56% until 2050 in LMA

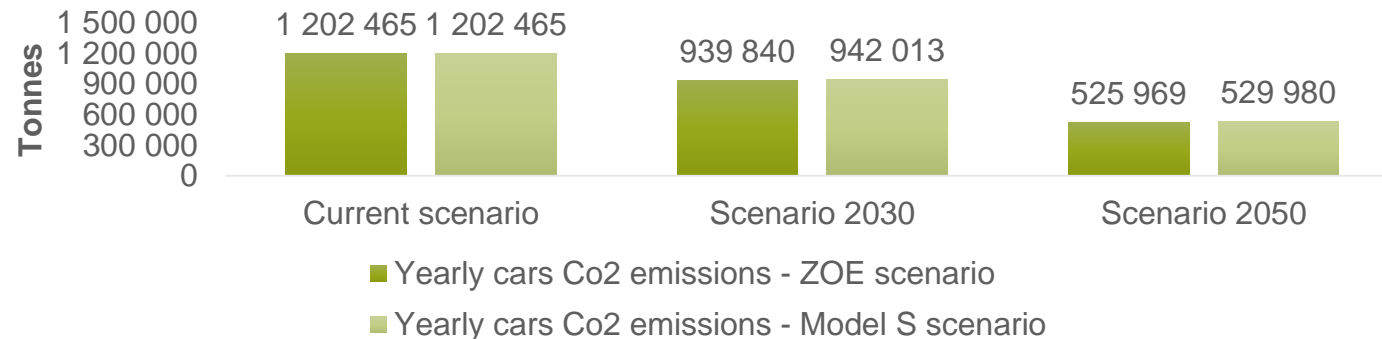


Graph 48: Possible scenarios for electric vehicles mixes



Two possible scenarios were created, one for 2030 and other for 2050 with the expected electric passenger car share in total cars. This scenarios include an estimation of the number of cars, the emissions in electricity production and the emissions by ICE vehicles for the respective years. It is expected that the share of electric passenger cars in Portugal will be 14% in 2030 and 50% in 2050.

Graph 49: LMA yearly cars CO2 emissions



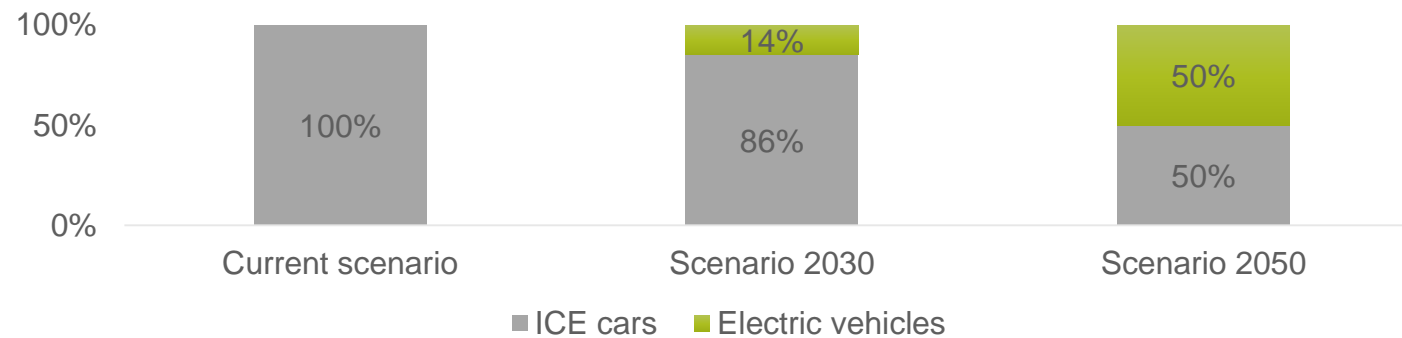
Accounting only for the change in vehicle power (ignoring transport mix evolution for 2030 and 2050), the CO2 emissions are expected to reduce 22% until 2030 and 56% until 2050 in LMA.

Source: made by the authors based on Reference list 51), 52) and 67) to 72) and Appendix 8

Accounting only for the change in vehicle power the CO2 emissions are expected to reduce 27% until 2030 and 59% until 2050 in PMA

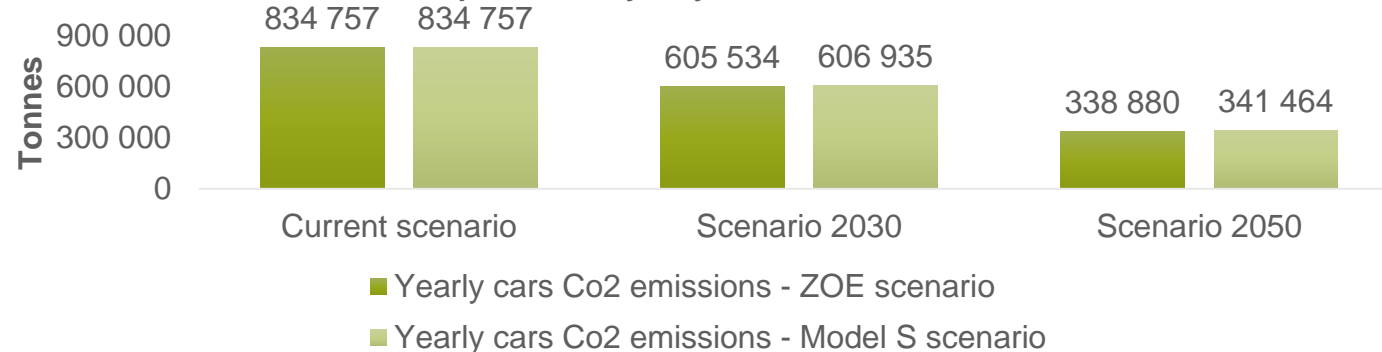


Graph 50: Possible scenarios for electric vehicles mixes



Two possible scenarios were created, one for 2030 and other for 2050 with the expected electric passenger car share in total cars. This scenarios include an estimation of the number of cars, the emissions in electricity production and the emissions by ICE vehicles for the respective years. It is expected that the share of electric passenger cars in Portugal will be 14% in 2030 and 50% in 2050.

Graph 51: PMA yearly cars CO2 emissions



Accounting only for the change in vehicle power (ignoring transport mix evolution for 2030 and 2050), the CO2 emissions are expected to reduce 27% until 2030 and 59% until 2050 in PMA.

Source: made by the authors based on [Reference list 51\), 52\) and 67\) to 72\)](#) and [Appendix 8](#)

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Appendix 7 - Electric case study

Table 34: Renault ZOE and Tesla Model S battery power and autonomy

| | Battery power | Autonomy (WLTP) |
|----------------------|---------------|-----------------|
| Renault ZOE | 52 kWh | 395 km |
| Tesla Model S | 100 kWh | 610 km |

This table resumes the key features of Renault ZOE and Tesla Model S cars used in analysis.

Table 36: Fuel and energy costs and consumptions

| | |
|---|--------|
| Price per diesel liter | 1,37 € |
| Price per petrol liter | 1,54 € |
| Price per electricity kWh | 0,22 € |
| Average consumption diesel car (l/100km) | 5,05 |
| Average consumption petrol car (l/100km) | 6,55 |

This table contains data used in analysis, namely energy costs and average consumptions.

Table 35: CO2 emissions of both ICE and electrical vehicles

| | Average Co2 emission |
|------------------------------------|----------------------|
| Battery production/kWh | 0,13977 tonnes |
| ICE car/km | 0,00013 tonnes |
| kWh of electricity produced | 0,00017 tonnes |

This table contains information about the average CO2 emissions of battery production, ICE cars and electricity production.

Table 37: Cars and km in LMA and PMA

| | LMA | PMA |
|--|---------|--------|
| Total amount of cars | 1291019 | 842959 |
| Total number of km per year per car | 7322 | 7785 |

This table resumes the total amount of cars and the total number of km per year per car estimated for LMA and PMA in 2017.

Appendix 8 – Electric vehicles scenarios and respective CO2 emissions

Table 38: Cars and km in LMA and PMA

| | 2018 | 2030 estimated | 2050 estimated |
|------------------------------|--------|----------------|----------------|
| Portuguese population | 10,284 | 9,845 | 9,216 |
| LMA population | 2,84 | 2,719 | 2,545 |
| PMA population | 1,721 | 1,648 | 1,542 |

Values in millions

This table contains estimations of Portugal, LMA and PMA population estimations for 2030 and 2050.

Table 41: Estimated renewable share and emissions in electricity

| | 2030 | 2050 |
|---|----------|----------|
| Estimated % of electricity from renewable sources in Portugal | 86% | 92% |
| Estimated average emission (tonnes) by kWh of electricity produced | 0,000051 | 0,000029 |

This table summarizes both the estimated % of electricity from renewable sources and its emissions per kWh for 2030 and 2050.

Table 39: Cars and electric vehicles estimations

| | 2030 | 2050 |
|------------------------------------|-------|-------|
| Cars estimation - Portugal | 4,519 | 4,230 |
| Cars estimation - LMA | 1,248 | 1,168 |
| Cars estimation - PMA | 0,756 | 0,708 |
| Electric vehicles -Portugal | 0,655 | 2,115 |
| Electric vehicles LMA | 0,181 | 0,584 |
| Electric vehicles PMA | 0,110 | 0,354 |

Values in millions

Table 40: % of electric cars

| | 2030 | 2050 |
|------------|------|------|
| LMA | 14% | 50% |
| PMA | 14% | 50% |

Tables 39 and 40 presents the estimations of electric cars for both LMA and PMA in 2030 and 2050.