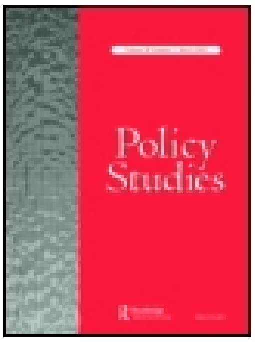

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Are only demand-based policy incentives enough to deploy electromobility?

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ABSTRACT
European Union (EU)'s energy and policy targets necessitate the penetration of new propulsion systems in the automotive industry. In this direction, the deployment of electric vehicles (EVs) and plug-in hybrid electric vehicles that rely on low greenhouse gas emission electricity generation has great potential to significantly alleviate the dependence on fossil fuel consumption in the transport sector. In this study, the policy incentives that different countries have implemented for stimulating the market of EVs are presented. Different policy instruments are examined, in order to support the deployment of EVs in Greece. Based on data from previous study, where total costs of ownership have been calculated, three alternative policy support incentives have been developed and analysed to promote the use of EVs until 2030 in Greece. Results indicate the direct subsidy scheme is more favourable over a carbon taxation system. It is suggested that EV will be competitive with ICE in the year 2022/2023, if no additional policies are implemented in Greece. This study fills the gap in the literature by offering a policy view of the main measures as well of actions that need to be taken in Greece, in order to promote electromobility.

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Electric vehicle; total cost of ownership; scenario analysis; policy instruments

1. Introduction

Global CO_2 emissions caused by fossil fuel combustion are expected to increase from 31.2 Gt in 2011 to 37.0 Gt in 2035, reaching a peak at 32.4 Gt before 2020 and decline steadily to 30.5 Gt in 2035 (IEA 2012). The majority of CO_2 emissions are coming from the burning of fossil fuels in both energy and transport sector. The transport sector is responsible for 22.43% of the world's total CO_2 emissions (IEA 2013). As far as European Union (EU) is concerned, 98% of the transportation depends on fossil fuels; whereas 21% of the greenhouse gas (GHG) emissions are attributed to transportation sector (European Commission 2010a). The EU addressed the abovementioned issues by introducing EU Directive (2009/33/EC), which promoted clean and energy-efficient road transport vehicles, in an attempt to decarbonize the transportation sector and to reduce the oil dependency.

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In this direction, fleet electrification has been proposed as a strategy for reducing air pollutant emissions and improving air quality in urban areas. Several new propulsion systems such as plug-in hybrid electric vehicles (PHEVs), range extenders as well as electric vehicles (EVs) have emerged and entered the market or are ready to enter the market in the near future (Schmid, Mock, and Friedrich 2010). As a matter of fact, many countries are planning to have more than 1 million EVs on the road before 2020; whereas EVs on the road are estimated to reach nearly 20 million around the world by 2020 (IEA 2013). However, the cost disadvantages of the newly emerging propulsion systems, as well as their limited driving range, have to be overcome in order to achieve a shift in the transportation sector. In this context, finding effective policy measurements for the promotion of the use of EVs is of great significance for a sustainable transportation system.

In recognition of the aforementioned issues, the "European Strategy for Competitive, Sustainable and Secure Energy 2020" (European Commission 2010b) states that the creation of market conditions which stimulate more low carbon investments into key technologies for electromobility is needed. Moreover, the Roadmap on Regulation and Standards for Electric Cars and the respective follow-up activities aim at creating the necessary conditions for a market deployment of EVs in Europe (European Commission 2013). Furthermore, Clean Power for Transport initiative (EU Insight 2009), the European Commission aims at the development of the comprehensive mix of alternative fuels in different transport modes.

Current research on effective policy mechanisms for the promotion of EVs include inter alias the studies of Jenn, Azevedo, and Ferreira (2013), regarding the effectiveness of the Energy Policy Act of 2005; of Thiel, Perujo, and Mercier (2010), regarding adequate policy instruments necessary to overcome the current cost disadvantages of EVs; of Ahman (2006), regarding the effect of government policy on building the market for EVs; of Ogden, Williams, and Larson (2004) on the societal lifecycle cost of transportation including the purchase price, fuel costs, externality costs of securing oil supply and damage costs for emissions of air pollutants and greenhouse gases; as well as of Cohen and Naor (2013), regarding policy entrepreneurship activities used, so as to promote the introduction of EVs in Israel. Further analysis on the relationship between the mechanisms of incentives and the market outcome for EVs is of great interest as this will improve EVs acceptance. Based on the above mentioned, it is obvious that different policy instruments are necessary to be developed and evaluated in order to convince consumers that EVs are not only environmentally friendly, but also economical.

The deployment of EVs in urban areas is not only beneficial in regard to the reduction in CO_2 and greenhouse emissions, but also as they can work as energy storing device able to absorb renewable energy (i.e. wind and solar power), they can contribute to solving the problem of intermittency and non-dispatch ability of this power (Bellekom et al. 2012). Moreover, EVs can utilize their storage capacity (vehicle to grid) in order to balance the electricity demand of various locations in the network, or to ease the integration of intermittent renewable energy sources to the grid (Vandael et al. 2011; Battistelli, Baringo, and Conejo 2012).

Nonetheless, the number of EVs in use is still very limited. In 2013, there were 123,188 EVs registered, which stands for 1.1% of the total number of vehicles registered that year in EU28, which was a total of 10,801,973 vehicles (Eurostat 2016). The limited share of EVs is also present in the USA (Carley et al. 2013) as well as in China and Japan (Lam et al. 2018).

Poor penetration rates can be attributed to a number of different factors that dissuade potential buyers (Coffman, Bernstein, and Wee 2017). These factors are associated with legally binding, national and local governments, who are deploying sets of incentives to EV adoption, including purchase grants, tax exemptions, non-monetary incentives such as free parking and access to restricted lanes, and financial support for the development of extensive charging infrastructure (IEA 2013a; Lutsey 2015). Incentives are necessary to overcome the substantial cost gap currently existing between EVs and conventional internal combustion engine vehicles (ICEVs).

In this direction, the objective of this study is to identify a future use of alternative vehicle technology, taking into consideration the policy objectives it aims to achieve, particularly in regard to the creation of a low carbon energy system. This is done by analysing different policy alternatives by assessing the total cost of ownership (TCO) of different EV and ICEVs in Greece. Based on the results of previous study – where TCO for different vehicle types was calculated (Nanaki, Xydis, and Koroneos 2015) – three different policy scenarios are developed and assessed. A business as usual (BAU) scenario considering currently implemented taxes and subsidies for ICE and EV for the period 2015–2030 is build. The results of this study can be used by policymakers as a basis for discussion of key features and possible implications of current EV policy and to identify opportunities for making it more robust under uncertainty. This study is structured as follows. Sections 2 and 3 provide an overview of available policy support mechanism for the promotion of EVs as well as of the current EV market. Section 4 presents the data and methodology. An analysis on different policy support instruments to equalize the TCO of EV and ICE in Greece is presented in Section 5, whereas Section 6 concludes.

2. Policy mechanisms for the promotion of EVs

During the past decades, it has been suggested that the use of EVs not only can be considered as a promising solution to the problems of environmental degradation and energy depletion but also it can be conducive to adjusting the energy structure through increasing the proportion of non-fossil fuel energy (Muneer et al. 2015; Nanaki and Koroneos 2016; Yu and Stuart 2017).

Taken into consideration the recent advances in technical performance and improvements in cost, much attention has shifted beyond the technical and economic dimensions of EVs to issues of policies, policy mechanisms, and policy mixes (Rogge, Kern, and Howlett 2017). For instance, it has been demonstrated that political factors such as city, state, and national policies for EVs can play a determining role in EV diffusion and acceptance (Stokes and Breetz 2018). Similarly, the necessity of strong, consistent, and stable policies for Chinese promotion of EVs has been demonstrated (Huang and Ji 2018). In turn, it has been supported that the strength of EV policies interacts with consumer preferences and purchasing patterns (Berkeley et al. 2017; Wolbertus et al. 2018; Hardman et al. 2017). The design, implementation, scope, and interactions of EV policy have therefore become central in discussions about widespread EV transitions. In this direction, many countries consider the deployment of electromobility as one of their strategic targets in achieving a sustainable transportation system, whereas they set their targets to promote large-scale adoption of EVs.

To be more specific, in the *United States*, the federal government provides EV incentives in the form of income tax credits. The value of the tax credit starts at $2500, increasing based on battery capacity; EVs with a battery capacity of 17 kWh or greater are eligible for the maximum $7500 incentive. The federal income tax credit incentive is available for each manufacturer's vehicles until 200,000 qualifying vehicles are sold (US Internal Revenue Service 2016). In addition to this national subsidy, many states, such as California, Connecticut, Maryland, and Massachusetts, offer additional rebates, which typically range from $1000 to $3000 per battery electric vehicle (BEV) and are about half that for PHEVs.

Many states provide EVs free access to high occupancy vehicle (HOV) lanes. Others exempt EVs from various taxes, registration fees, or inspection requirements. Certain states define and tax electricity used for electric cars at a lower rate. Thirteen states currently allow EVs to use HOV lanes without restrictions. Similarly, Arizona, Hawaii, and Nevada also provide special parking privileges to EVs. It should be highlighted, that in 2016, California was the state, which accounted for 50% of EVs sold in the USA, with Los Angeles representing as much as 20% US EV Sales. California has been promoting EVs since the 1990s, with its "Zero-emission vehicles" programme (Clean Air, US), which requires manufacturers to sell increasing EV quotas year after year. On top of national subsidies, which amount to $7500 per vehicle for the first 200,000 EVs sold in the USA by a single manufacturer, California has introduced a purchase grant programme to help low income in acquiring an EV.

As far as China is concerned, the *Chinese* central government adopted deployment targets for new energy vehicles. A deployment target for new energy vehicles (NEVs) – defined as hybrid electric vehicles (HEVs), PHEVs, BEVs, and fuel cell electric vehicles (FCEVs) (Gong, Wang, and Wang 2013) – announced in January 2009 included a sales target for passenger vehicles of 5% between 2009 and 2011. The State Council announced an additional deployment target, with a sales goal of 10% by 2012, 500,000 and 5 million of electric vehicles by 2015 and 2020, respectively. The financial incentives to promote EVs in the market are separated into two parts, namely government purchase and private purchase.

South Korea planned to increase the market share of the EVs through battery life and storage capacity improvements and establishment of a network of charging stations in July 2016 (Lim 2016). A one-time purchase subsidy of 14 million South Korean Won is given to EV buyers. In addition, the EV owners can also benefit from reductions in tax surcharges, insurance premiums, expressway tolls, and parking fee.

In regard to *Japan*, it is noted that the Japanese Government set deployment targets across new vehicle technologies, with an FCEV target of 1% of vehicles on the road by 2020, and 3% by 2030. For BEV and PHEVs, the target was 15–20% of vehicles on the road by 2020, and 20–30% by 2030. An additional deployment target was announced in 2015, envisioning that NGVs should represent 5–7% of new vehicle sales by 2030 (GOJ 2015). The inclusion of BEVs, PHEVs, and FCEVs shows the government adopted a technology-neutral approach to new vehicle technologies. The central government provides subsidies to manufacturers, targeting BEV and FCEV, as well as diesel, technologies. The largest sum was allocated to BEVs, with 5.6 billion Yen (US$50 million) provided for battery development, against 4 billion Yen (US$36 million) for FCEVs.

3. Current status of electric vehicle market in EU

The market for EVs has increased between 2010 and 2014 in most EU countries, but most profoundly in Norway, which currently is the European leader in EV adoption. As per European's vehicle market statistics [17], HEVs were 1.4% of new car sales in 2014, but in some Member States, their market share was significantly higher – 3.7% in the Netherlands, for example, and 2.3% in France. PHEVs and BEVs accounted for 13.8% of all new car sales in Norway in 2014, and in the first quarter of 2015, their market share further increased to 22.9%. As a matter of fact, Norway can be considered as a frontrunner in Europe with EVs (in terms of market share, not absolute number of vehicles) adding up to 6.2% of total car sales in 2013. Despite the fact that Norway is not a member of EU, its EV uptake is of great interest, given that the share of EVs in new sales reached 13.8% of new vehicle registrations in 2014, and in the first quarter of 2015, their market share further increased to 22.9%. The Netherlands is the European runner-up with more than 4% of new car sales falling into the EV category in 2013. France, Germany, and the UK are showing high EV sales growth rates of approximately 50%, but EVs have a smaller share of overall market (Figure 1).

Regarding Greece's passenger vehicle's market share, it is mentioned that between 2009 and 2014 in Greece, the share of mini and small vehicles increased, while sales in other segments declined considerably – as illustrated in Figure 2. The greatest impact can be seen on the medium segment, which diminished from 14% in 2009 to a mere 3% in 2014. Additionally, the percentages of upper-medium, luxury, and sport segments were almost completely wiped out by 2014. In general, new vehicle sales also fell considerably; they were 67% lower in 2014 than in 2009, and 76% lower compared to 2001. It is noted that the percentage of EVs in 2014 reached 0.7% of new car sales in 2014 (European Vehicle Market Statistics Pocketbook 2015/16, 2015).

3.1. Policy instruments implemented for passenger cars in EU

EU is addressing the challenges of road transport decarbonization by the introduction of policy packages aiming to accelerate the deployment of advanced automotive technologies, such as EVs in the market place. Aligned to the abovementioned, EU member states

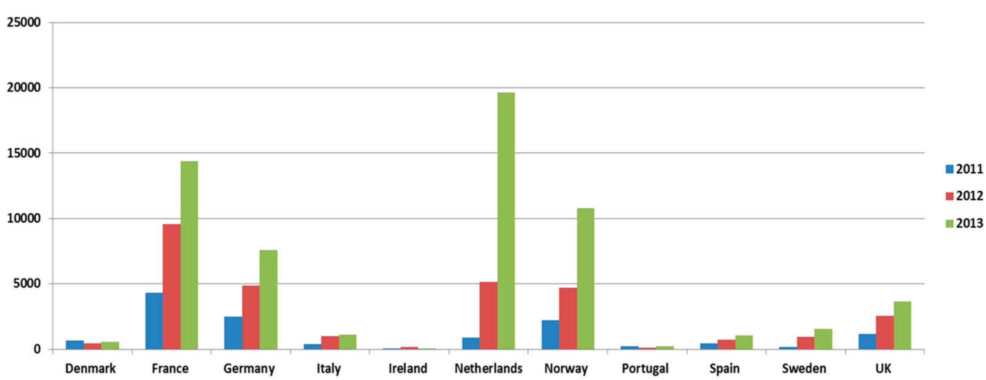

Figure 1. Uptake of EVs in different EU member states (Database of Eurostat 2015).

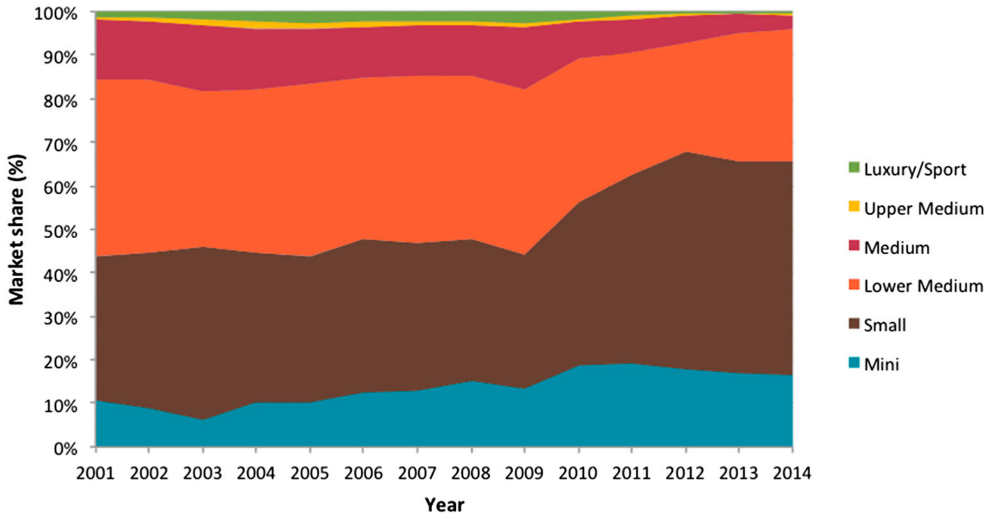

Figure 2. Greece's market share by vehicle segment from 2001 to 2014 (European Vehicle Market Statistics Pocketbook 2015/16, 2015).

introduced national targets for the EV driving stock as well as the expansion of charging infrastructure production (Kley, Wietschel, and Dallinger 2010). It should be mentioned that EU does not only provide incentives for the use of EVs, but also focuses on punishments for the use of high emission vehicles. For instance, it offers credits to carmakers that produce vehicles with less than 50 g of CO_2 per kilometre and provides additional incentives for the introduction of EVs (Wilde and Kroon 2013). For instance, Norway offers a package of subsidies amounting to approximately EUR 17,000 when compared with the purchase of a compact class ICEV car; UK pays back to buyers a one-time premium of GPB 4000–7000 (based on purchasing price) for all vehicles emitting less than 75 g/km.

To be more specific, in the new Ultra Low Emission Discount, the UK government gives a discount to EVs that emit 75 g/km or less of CO_2 and provides a 100% discount from the Congestion Charge for qualified vehicles (www.greencarcongress.com). In addition, the UK created a subsidy programme in 2011 called the *Plug-In Car Grant* (www.gov.uk) for consumers to enable the purchase of ultra-low carbon vehicles. Under the programme, qualified ultra-low emission cars will receive a grant towards their cost. This is 25% off the cost of a new electric car, but not to exceed £5000. Furthermore, the UK proposed a vehicle scrappage scheme (www.bbc.co.uk), in order to stimulate consumers to buy lower-emissions vehicles. Italy, Germany, and France also have put forward similar policies, as well. France adopts the *bonus-malus* system as the financial incentive (ACEA 2014). *Bonus* is a discount in the premium, and *malus* is an increase in the premium. For example, vehicles that emit 20 g/km could benefit from a premium of €6300, and for vehicles that emit between 20 and 60 g/km, the premium is €4000 (www.ec.europa,eu). This system is designed to reward the purchase of a new car emitting less CO_2 via giving the *bonus* to consumers and punishing those who opt for a more polluting model. On the other hand, countries, such as Germany, Denmark, and Norway, do not have policies depending on CO_2 emissions.

Germany uses the ownership tax by which it establishes a fiscal incentive for EV with a 10-year exemption. It must also be stated that, together with the Netherlands, Germany is one of the few EU member states that favours the use of EVs for commercial purposes since it includes the emission volume in the invoice calculation for the ownership tax. In this regard, it must be highlighted that both counties incorporate incentives for a personal income tax that favours the acquisition of EVs. In the case of incentives implemented through infrastructure measures, France appears to be the first country that expanded charging stations and delimited low emissions zones using infrastructure incentives. In regard to Norway, it should be mentioned that not only proposes tax credits and direct subsidies, but also supplies free parking and bus lane access. Additionally, the government of Norway supplied 3200 free charging stations (namely, free electricity) for consumers (AVERE 2012), which is attractive to most Norwegians, because of the high petrol price.

Based on the abovementioned, the policy instruments that are currently implemented in EU member states, so as to accelerate the deployment of alternative propulsion systems can be categorized to the following (AEA Energy & Environment 2008): (i) registration or purchase taxes; (ii) circulation or motor taxes; and (iii) fuel taxes. Registration duties (value added tax – VAT, registration tax and registration fee) are payable in all EU countries.

The circulation tax is usually associated with the engine power, cylinder capacity or fuel consumption and is a monthly or annual paid tax. The impact of this policy instrument in the promotion of EVs is rather low as the cost range of such measures is limited (JRC 2008). As per Joint Research Center's study (JRC 2008), fuel tax is considered to be a successful instrument that can be used in order to reduce energy consumption in road transport as well as to incentivize consumers to buy more energy-efficient cars. Fuel price (gasoline and diesel) in EU countries, related Excise Duties, as well as Fuel Tax in May 2016 are presented in Table 1. Italy, Greece, The Netherlands, Denmark, UK, Sweden, Ireland, Germany, and France have higher fuel price, fuel tax percentage, and fuel tax cost, than other EU countries, during May 2016. Average gasoline price in 27 countries is 1203 €/l; average excise duties on gasoline reach 0.546 €/l and average tax is 0.213€/l; average diesel price is 1070 €/l, average excise duties on diesel reach 0.429 €/l, and average tax is 0.189 €/l. It is indicated that in 14 countries, the average prices for both fuel types are below the average prices; whereas in 13 countries, the average prices are above the average prices. It is obvious that in most of the EU countries, tax on gasoline is higher than diesel, thus vehicles with gasoline engine have to pay more fuel tax than diesel engine vehicles.

In Greece, all new passenger are imported – given that no passenger vehicles are produced or assembled in Greece. New vehicles (EURO 5) are subjected to import taxes ranging from 5 to 50% depending on the cylinder capacity of the engine and 24% VAT. Used vehicles are subjected to heavier import taxation depending on their EURO emission classification. Circulation tax applies to all vehicles with Greek licence plates, which are registered at the tax office as active. Also after 2014, all vehicles registered after 2002 with an engine capacity over 1929 cc are assessed a special levy (luxury goods tax). Vehicles with engine capacity of 1929–2500 cc pay 5%; and those 2501 cc and above pay 10%. Passenger cars registered for the first time in Greece on or after 1 November 2010 are also assessed a "green fee", according to grams of carbon emissions (CO_2) per

Table 1. Fuel price, excise duties, as well as fuel tax in EU member states (Europe's Energy Portal 2016).

Country name	Gasoline: Without taxes (€)	Gasoline: Excise duties (€)	Gasoline: VAT (€)	Gasoline: Retail price (€)	Diesel: Without taxes (€)	Diesel: Excise duties (€)	Diesel: VAT (€)	Diesel: Retail price (€)
Austria	0.400	0.482	0.176	1.058	0.364	0.425	0.158	0.947
Belgium	0.496	0.615	0.233	1.344	0.513	0.444	0.201	1.158
Bulgaria	0.407	0.363	0.154	0.924	0.411	0.330	0.148	0.889
Croatia	0.442	0.505	0.237	1.184	0.454	0.400	0.214	1.068
Cyprus	0.428	0.479	0.172	1.079	0.436	0.450	0.168	1.054
Czech Republic	0.380	0.467	0.178	1.025	0.397	0.398	0.167	0.962
Denmark	0.589	0.608	0.299	1.496	0.564	0.414	0.244	1.222
Estonia	0.506	0.423	0.186	1.115	0.478	0.393	0.174	1.045
Finland	0.408	0.681	0.261	1.350	0.413	0.506	0.220	1.139
France	0.434	0.624	0.212	1.270	0.450	0.468	0.184	1.102
Germany	0.368	0.670	0.197	1.235	0.391	0.486	0.167	1.044
Greece	0.396	0.670	0.245	1.311	0.491	0.330	0.189	1.010
Hungary	0.443	0.397	0.227	1.067	0.435	0.366	0.216	1.017
Ireland	0.428	0.588	0.234	1.250	0.403	0.479	0.203	1.085
Italy	0.470	0.728	0.264	1.462	0.418	0.617	0.228	1.263
Latvia	0.468	0.411	0.185	1.064	0.406	0.333	0.155	0.894
Lithuania	0.401	0.434	0.175	1.010	0.356	0.330	0.144	0.830
Luxembourg	0.467	0.465	0.159	1.091	0.428	0.338	0.130	0.896
Malta	0.566	0.519	0.195	1.280	0.558	0.442	0.180	1.180
The Netherlands	0.465	0.766	0.259	1.490	0.488	0.482	0.204	1.174
Poland	0.263	0.487	0.173	0.923	0.335	0.349	0.157	0.841
Portugal	0.465	0.618	0.249	1.332	0.553	0.402	0.220	1.175
Romania	0.455	0.462	0.183	1.100	0.446	0.430	0.175	1.051
Slovakia	0.427	0.551	0.196	1.173	0.457	0.386	0.169	1.012
Slovenia	0.440	0.528	0.213	1.181	0.394	0.455	0.187	1.036
Spain	0.520	0.425	0.198	1.143	0.509	0.331	0.176	1.016
Sweden	0.452	0.643	0.274	1.369	0.624	0.555	0.295	1.474
UK	0.475	0.674	0.230	1.379	0.475	0.674	0.230	1.379

kilometre. Rates vary from €0.90 per gram of CO_2 emitted (101–120 g/km) to €3.40 per gram (above 250 g/km). Cars with emissions up to 100 g/km are exempt. The vehicle circulation tax is calculated on the basis of engine capacity and vehicle CO_2 emissions. For instance, new cars emitting 120 g/km are subject to an annual tax of 108€, while vehicles emitting 140 g/km have to pay about 42% more annual tax.

As far as electric and hybrid cars are concerned, these are exempted from the special consumption tax and from the yearly circulation taxes as well as from registration tax. In addition, EVs and hybrid cars are excluded from circulation restriction in metropolitan areas, where these are applied. At present, only BEVs type models are classified as EVs by Ministry of Environment and Energy. As a result, PHEV (plug-in hybrid electric cars) and EREV (extended range electric vehicles) have been left out of the category and, consequently, are subject to the luxury goods tax. The tax adds between 10,000 euros and 20,000 euros to the market price of each vehicle. Lawmakers have agreed that the aforementioned categories will need to be exempted from the luxury goods tax to spur growth in EV market, despite an objective set by PPC to play an active role in the sector, and the intention of auto manufacturers to supply electric cars to the Greek market.

4. Data and methodology

TCO takes into consideration all costs arising with the ownership of a vehicle (i.e. purchasing, operating, maintaining, charges and taxes as well as recycling and disposal costs) over a specified timeframe under consideration of opportunity costs. Based on the results of a previous study where the TCO has been calculated for three different vehicle options for Greece – based on data of technical specifications and costs (Nanaki, Xydis, and Koroneos 2015), three different fiscal scenarios standing for three different policy approached are analysed.

Scenario analysis is performed for a pair of a small city car, a pair of mid-size car, and a pair of large family car. The small car segment includes vehicle of two doors city cars to larger 2/4 doors car, up to 1.4 l engine with a length up to 3 m; the mid-size car segment includes saloon vehicles, from 1.3 to 2.8 l with a length up to 4.5 m. The large car segment includes executive, luxury, and sport cars as well as dual and multipurpose vehicles; these come in a variety of body shapes and lengths with largest vehicles and engines.

The ICE have been chosen to be of similar size and technical specifications. They represent the most often sold cars in their vehicle class. Two of the vehicles under examination are BEVs (Mitsubishi MiEV and Nissan Leaf), whereas the third (Opel Ampera REV) is an EV with range extender (Mitsubishi Motor Company 2015; Nissan Motor Company 2015; Opel Motor Company 2015). The Mitsubishi MiEV is a five door, four seat all EV powered by a 47 kW permanent magnet synchronous motor. Electricity is stored in a 16 kWh Lithium-ion battery pack. The Nissan Leaf is a five door, four seat all EV powered by an 80 kW motor. Electricity is stored in a 24 kWh Lithium-ion battery pack. The Opel Ampera is an EREV, which for 25–50 miles, its lithium-ion battery pack powers the electric drive unit, which provides full vehicle speed and acceleration. For longer trips, the car's "range-extending" engine sustains the battery. The range extender, powered by a 1.4 l petrol-driven generator, can create electricity to power the car for 310 miles more.

The analysis takes into consideration (i) further technical improvements for ICE as well as (ii) cost reductions of EV through battery performance. The fuel consumption rate of ICE is continuously improving in order to meet the market demand for more fuel-efficient vehicles and with respect to the EU's average emission target of passenger cars of 95 g/km in 2021 (phased in from 2020). It is assumed that ICE-powered vehicle would have 7% better energy efficiency in the period 2015–2020 (Kloess and Müller 2011). For the EVs, no further efficiency improvements were considered for 2030 versus 2020 and for 2020 versus 2015 as these vehicles probably feature all near-term conceivable advanced efficiency measures. Further technology improvements will lead to cost reductions.

The key assumptions of the vehicle model developed for this study include:

- ICEVs have a 7% better energy efficiency in 2020 than in 2015.
- EVs in regard of energy efficiency improvements remains the same – given (Thiel, Perujo, and Mercier 2010) as EV already feature all near-term conceivable efficiency advances.
- Distance weighted average of ECE-15 and EUDC cycles.
- The expected service life of vehicles is about 15 years.

- Cost reductions in terms of battery performance have been taken into consideration. The assumed learning rate for battery cost reductions reaches 9% per annum (The Boston Consulting Group 2012). Battery costs amount to approximately 600 EUR/kWh (Thiel, Perujo, and Mercier 2010) and are expected to decline to approximately 210 EUR/kWh in 2020. Nonetheless as battery costs range between EUR 500 and EUR 800 in 2010 and between EUR 180 and EUR 300 in the period 2011–2020. It represents an average cost reduction of approximately 60% over the period 2011–2020 which results in an annual learning rate of about 9% (Thiel, Perujo, and Mercier 2010; Kloess and Müller 2011). Projected production volumes are reflected in the assumed learning rate and have not been separately calculated. Consequently, price reductions resulting from an increase in production volume are already reflected in the calculation of the TCO.
- The fuel price cost (gasoline) in Greece is equal to 1.60 EUR/l including upcoming taxes and charges, which are going to be implemented as of June 2016. The gasoline prices are assumed to be consistent with the projected oil prices in the Annual Energy Outlook 2012 (28. US Energy Information Administration 2012) representing a compound annual growth rate of approximately 4.2% per year. The cost of electric energy is considered equal to EUR 0.12 per kWh (Nanaki, Xydis, and Koroneos 2015). These conservative estimates have been utilized to simplify the economic calculations in the study. The energy prices may fluctuate significantly over the next 35 years and if anything, higher oil prices will likely lead to increased EV purchase. Table 2 summarizes the technical characteristics as well as the TCO for each of the abovementioned vehicle categories.

5. Results

Three fiscal policy scenarios take into consideration some of the key attributes that affect the purchase of EVs. These include vehicle price and running costs, brand and segment supply, access to charging facilities, driving range, and charging time as well as the consumers' receptiveness to plug-in vehicles. With the exception of running costs (which are reduced), the scenarios assess current situation (reference scenario), a financial

Table 2. Technical characteristics and TCO for the vehicles under study (Nanaki, Xydis, and Koroneos 2015).

	Mitsubishi i – gasoline fuelled	Mitsubishi i-MiEV – (BEV)	Nissan Note – gasoline fuelled	Nissan Leaf – BEV	Opel Meriva – gasoline fuelled	Opel Ampera EREV
Fuel consumption/100 km	6.4 lt	11.35 kWh	6.8 lt	12.06 kWh	6.7 lt	11.88 kWh
Annual registration fees and maintenance cost (EUR)	450	370	600	500	800	820
Purchase Price (EUR)	9770	36,700	17,800	40,700	15,700	43,000
TCO 5 years (EUR)	23,068	38,589	33,071	42,660	31,785	47,192
Annual CO_2 exhaust emissions (tons)	3.14	0	3.33	0	3.28	0
Annual CO_2 emissions from the electric generation system (tons)	0	2.15	0	2.28	0	2.25

support policy scenario, as well as a carbon tax scenario. The minimum level of incentive to make EV competitive from 2015 onwards is considered for each policy instrument.

5.1. Reference scenario

In reference scenario, no policy instruments are implemented, the ICEVs and EVs in Greece – as per calculated TCOs – are cost-competitive by the year 2022/2023 (Nissan Note & Nissan LEAF) as indicated in Figure 3. The TCO of ICE is increasing over time mainly due to rising fuel costs. TCO of EVs decrease slightly, due to battery improvements. The reference scenario implies that EVs will be competitive by the year 2022/2023. Nonetheless, it should be mentioned that competitiveness could be effected only if projected volumes are produced to realize the necessary economies of scales. In this context, subsidies may be necessary.

5.2. Financial support

A package of measures including innovative ownership models would be necessary, for the promotion of electromobility till 2030 (taking into consideration the evolution of EV costs as well as consumer attitudes). New leasing and ownership models have been suggested as an effective way to address capital cost premiums of EVs (and the high discounting rates of consumers) with the added benefit of removing consumer concerns regarding component degradation and residual values (Element Energy Limited 2013). In this direction, vehicle ownership and financing models for EVs should be supported as consumers emphasize more on the purchase price of a vehicle than on the resulting maintenance and operating costs. In this scenario, possible financial support measures, such as capital subsidies, are investigated. These are €10,000 in 2016, €5,000 in 2018, €2000 in 2020, €1000 in 2022, and €500 in 2024. The subsidy programme allows consumers to buy an eligible car discounted at the point of purchase with the subsidy claimed back by the manufacturer afterwards.

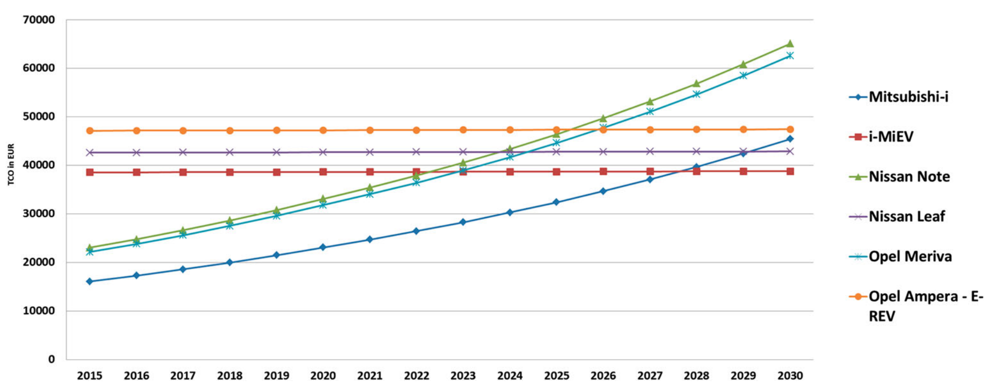

Figure 3. TCO for the vehicles under study for the period 2015–2030 without the implementation of any policy instruments.

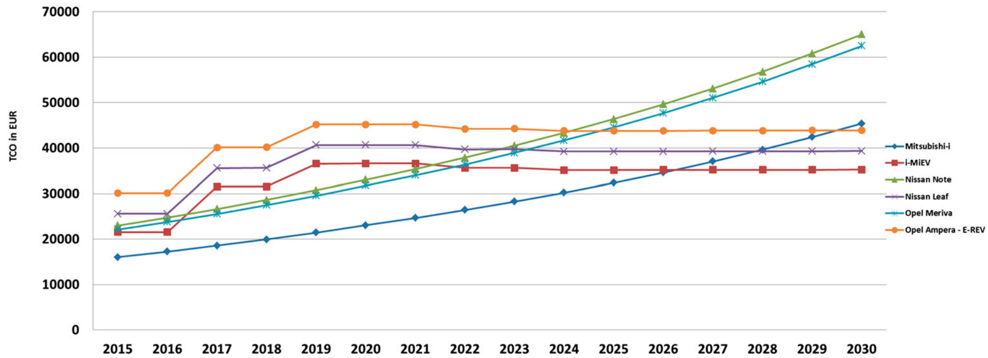

Figure 4. TCO for the vehicles under study for the period 2015–2030 with financial support.

Figure 4 indicates that with the implementation of a financial support mechanism such as capital subsidies over a period of 8 years ICEV and EVs can be cost-competitive by the year 2016/2017.

5.3. Carbon tax

The implementation of a carbon tax and especially CO_2 tax for the transportation sector in order to promote the deployment of EVs in urban areas is being examined in this scenario. As per Giblin and McNabola (2009), a CO_2 tax is an effective policy instrument not only from an environmental point of view, but also from an economic point of view as it can reduce other external costs of ICEVs (changing driving habits, reducing traffic congestion, etc.).

A CO_2 tax can be achieved by imposing taxes to gasoline's carbon content – resulting in increased price. The implementation of a CO_2 tax becomes effective, when CO_2 price is

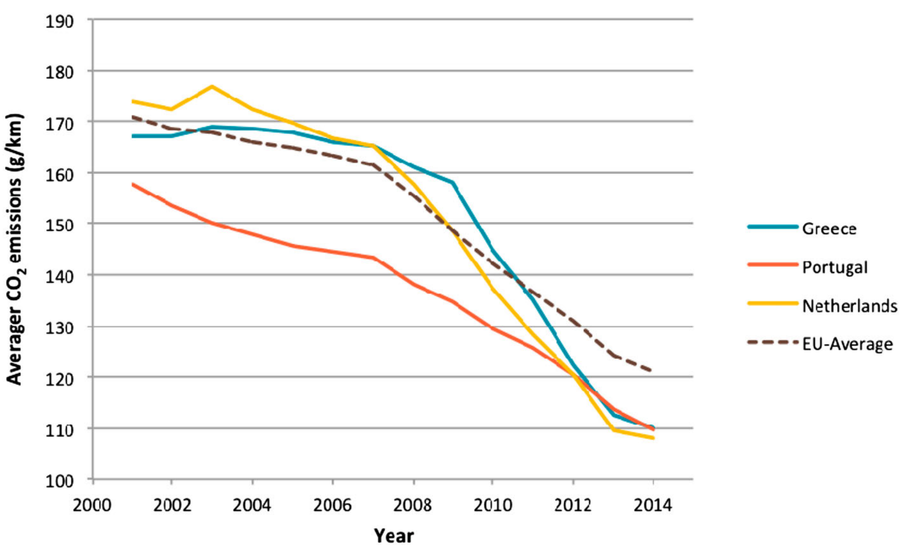

Figure 5. Average CO_2 emissions of EU member states from 2001 to 2014 (Database of Eurostat, 2016).

approximately 500 EUR/t (Gass, Schmidt, and Schmid 2014). As the CO_2 price on the EU Emission Allowances spot market trades at 5.8EUR/t (European Emission Allowances 2016), it is obvious that the introduction of a carbon tax as a policy instrument, in order to increase the penetration of EVs in the market is not viable.

Moreover, this measure would not be feasible in Greece due to economic crisis. In regard to CO_2 emissions from passenger cars, it is noticed that Greece is among the countries (along with the Netherlands and Portugal) with the lowest average CO_2 emission level of new passenger cars in the EU (Figure 5). Whereas the reduction in CO_2 emissions in the Netherlands was achieved by the implementation of fiscal incentives (regarding plug-in and full BEVs); the reduction in Greece is attributed to the economic crisis. In fact – as illustrated in Figure 2 – low CO_2 segments are the ones that customers prefer through the economic crisis, as they require less fuel to circulate and are more economical to both acquire and maintain. The fact that during the past 5 years, a shift towards lower vehicle segments and increased dieselization in larger ones (since 2011, the ban on diesel vehicles in Athens and Thessaloniki was lifted) has led Greece to have one of the lowest-CO_2 car fleets in the EU.

6. Conclusions

The positive impact of EV roll-out over several aspects concerning citizen lives and technological progress are out of any doubt. During the past years, a big effort has been realized, so as to facilitate the entrance of EVs into the mobility arena as a growing alternative.

Results indicate that EVs can be cost-competitive with ICEVs by the year 2017, if financial support, through a direct subsidy scheme is provided. TCO has been calculated for different EV and ICEVs for the period of 2015–2030. According to the reference scenario, EV will be competitive with ICE in the year 2022/2023, if no additional policies are implemented in Greece. The adaptation and implementation of financial support mechanism indicate that ICEV and EVs can be cost-competitive by the year 2016/2017. This study indicates that imposing CO_2 taxes is not viable for a successful market uptake and expansion of EVs. The analysis suggests that the most important policy instruments to promote the use of EVs in Greece for the period of 2015–2030 is mainly financial incentives for purchasing of EVs.

The cost of EV's battery packs is still a major reason that TCO for EVs is significantly higher than it is for ICEs. It is clear that the short-term adoption of EVs is dependent on both demand incentives (subsidies, tax breaks) and consumer willingness to pay extra to bridge the gap. For longer-term mass market adoption, lower battery prices will be an important driver. On the other hand, providing financial incentives such as some direct subsidies (defined here as a one-time bonus upon purchase of an EV) seems to be favourable rather than taxation. Lowering up-front costs for EV will as well have a greater effect on the consumer decision-making process.

The findings of this study offer the opportunity to craft strong arguments to the policymakers that might better influence the uptake of EVs and to target certain types of potential users in a more strategic way. In addition, the results can be used, so as to offer to policymakers as well as to stakeholders the possibility to use a wide range of policy instruments to promote electromobility in the context of 2020 strategy. It must also be stated that policy instruments to promote the use of EVs are largely used in EU28, in order to facilitate decisions similarly to those used to promote the usage of renewable energy systems (RES).

Another key conclusion of the paper is the significance of EV incentives in influencing positive outcomes for the deployment of EVs in Greece. The subsidization of EVs in Greece during the period of 2016–2024 is of great importance, in order to meet the strategic targets of 2020. This finding can be used, in order to strengthen the hand of policymakers and governments in the short to medium term, while EV market penetration is gaining momentum. Additionally, car dealerships or energy/environment government agencies will need to consider particular contracts for EV users, whereby the car purchaser will pay only a part of the vehicle cost.

It is noted that the results of this study are in accordance with the literature (AEA Energy & Environment 2008; Kloess and Müller 2011; Gass, Schmidt, and Schmid 2014). Despite the fact that cost disadvantages may be addressed with policy instruments, technical barriers such as limited range and relatively long charging times remain an issue. Finally, although the results of this analysis, in regard to the promotion of the use of EVs, are in line with the available literature, some policy recommendations might be considered.

For instance, the vehicle age could be included as an additional parameter to calculate the ownership tax. This could facilitate the replacement of older and higher polluting vehicles by newer and less contaminating EVs. Also, communication programmes could help to disseminate correct knowledge about the basic cost and operating features of EVs. Furthermore, measures to support EVs could be seen as a part of the effort required to meet the delivery services offered by e-retailers. EVs could also become part of future smart electricity systems by using their batteries as a disperse storage system for better management of demand peaks.

Based on the abovementioned, it is deducted that the adoption of relevant policy actions and effective policy mechanisms to spur the market for EVs is of great significance for the implementation of Greece's obligations to EU.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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