

Benefits of Reducing Air Emissions: Replacing Conventional with Electric Passenger Vehicles

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ABSTRACT

The study estimated the cost of local and global air emissions, and to compare the differences between electric passenger vehicles (EV) and conventional, internal combustion engine (ICE) vehicles. The air emissions were estimated for the year 2020, for Denmark, France and Israel, because of their significantly different fuel mixes to produce electricity—a high percentage of renewable energy, mainly nuclear energy and high fossil fuels, respectively. Air emissions from electricity production and conventional traffic were calculated for each country and then multiplied by the specific country's cost of emissions. Subtracting the total cost of electricity production from the total cost of conventional transportation yields the total benefit for each of the economies studied. The environmental benefit, depending on EV penetration rates, was found to be in the range of 7.8 to 133 MEUR/year for Denmark, 94 to 1948 MEUR/year for France and only 4 to 82 MEUR/year for Israel, whose energy mix is the most polluting. Our analysis also shows higher potential benefits when replacing passenger car fleets comprising a high percentage of diesel cars with EVs, as well as in highly populated areas. In addition, we quantified the differences between EVs with fixed batteries and the new switchable battery concept (EASYBAT), as part of the EU 7th Framework Program. The additional electricity demands for the EASYBAT concept are negligible, and therefore, do not change the overall conclusion that the cleaner the electricity energy mix and the higher the penetration of EVs, the higher the environmental benefits achieved.

Keywords: Air Emissions; Electric Vehicles; Passenger Car Externalities; Power Generation Externalities; Battery-Switch EASYBAT EU FP7

1. Introduction

Two major forces are driving the world to find alternative fuels for conventional transportation. The first is the increasing concern about local and global air emissions and their effects on areas such as human health, agricultural crops and property value. The second force is the need to reduce the world's dependency on oil, and will not be discussed in this paper.

Gasoline- and diesel-powered passenger vehicles are major contributors of many noxious emissions, on the local level, including carbon monoxide (CO), nitrogen oxides (NO_x) and fine particulate matter (PM_{2.5}) [1]. [2,3] showed that, although PM_{2.5} is directly related to vehicle exhaust emissions, PM₁₀ emissions originate from non-exhaust emissions. Since our analysis is based on tank-to-wheel emissions as will be described shortly, we may

regard transportation as the sole contributor of PM_{2.5}. Within urban areas, the contribution by passenger cars is particularly high [4]. The effect of traffic on urban air quality in Israel can be most accurately assessed on Yom Kippur (the Day of Atonement—the holiest day in the Jewish calendar), when the streets are practically empty of traffic for the entire day, whereas heavy industry (including power plants and oil refineries) reduces its capacity only slightly [5]. The data show that pollutant concentrations in the large urban centers are reduced nearly to zero.

Growing evidence links vehicle pollutants to severe health effects such as respiratory, cardio-pulmonary diseases and lung cancer [6]. According to the World Health Organization (WHO), car-exhaust emissions are responsible, worldwide, for more deaths than road accidents [1].

Numerous studies have shown that introduction of electric vehicles (EV) can contribute to pollution abatement, mainly CO₂, from gasoline- and diesel-powered

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vehicles (e.g., [7-10]). All these studies concluded that introduction of EVs will be beneficial, especially where the power for charging the vehicles will be generated from alternative, low emissions, sources (renewable or nuclear).

The economic benefits of improving air emissions by replacing internal combustion engine (ICE) vehicles with EVs are country-specific, as they not only depend on specific meteorology [11], synoptic patterns [12,13] and geographic variation [14]. They are also a function of population density [15,16] and of the type of vehicles replaced (for example, NO_x and CO₂ emissions from diesel cars are higher than from gasoline cars, therefore, one may expect that replacing diesel cars will be more beneficial than replacing gasoline cars).

These economic benefits should be assessed according to various inputs, such as the specific energy mix required to produce the electricity, the specific cost of air emissions (or benefits gained by improving it) and the population affected by the pollution.

The current study assessed the benefits of introducing EVs in Denmark, France and Israel, as these benefits have not been previously evaluated and these countries are characterized by very different fuel mixes to produce electricity and by different car fleet compositions. In addition, the study enables calculation of the benefits of improved air quality in urban areas.

It is important to note that these countries were the first to introduce the EV developed by Renault, as part of the EASYBATEU FP7 project [17]¹.

2. Methodology

The study was conducted in several stages:

1) Energy mix for electricity production and related air emissions. Assessment of anticipated air emissions from the projected electricity production mix (tons pollutant/kWh) for the different countries under study, for the year 2020.

2) Passenger car stock and related emissions. According to the national assessments of passenger car stock in 2020, we estimated air emissions from ICE vehicles according to Euro 6 standards and real-world emissions, under different scenarios of EV penetration to the market.

3) Electricity needs for charging EV cars. Calculation of the electricity needs for charging EV cars and the share of the additional needs in the overall electricity consumption was analysed for every country.

4) Air emission costs. Calculation of the externalities²

¹Easybat is an FP7 STREP (Specific Targeted Research) project. In the field of transport, the project addresses the topic of smart storage integration. The project mission is to develop models and generic interfaces for easy and safe battery insertion and removal in electric vehicles.

resulting from the electricity production needed for charging the EV cars compared to the air emissions from the same number of ICE vehicles.

5) Life cycle differences between the proposed switchable battery (SB) and the conventional FB (fixed battery, e.g., Nissan Leaf). The only difference found was the amount of electricity needed at the battery switch stations for battery temperature control. Therefore, this electricity consumption and the related environmental externalities will be subtracted from the benefits found in the next stage.

6) Quantification of benefits from reducing emissions by replacing conventional cars with EVs. For Denmark and France, the analysis was performed according to the Extern E Methodology developed by the European Commission [16,19]. For the analysis in Israel, we used the environmental quantification produced by [20,21]. It is noteworthy that the Israeli figures were obtained using the benefit-transfer approach³.

3. Assumptions

3.1. Anticipated Energy Mix for Electricity Production

The projected fuel mixes for electricity production in Denmark, France and Israel are presented in **Table 1**, according to national policy papers and energy outlooks [22-24].

As much effort is invested today in reducing the specific emissions resulting from electricity production, it is reasonable to assume that by 2020, they will be lower than at present. Yet, we calculated primary air pollutants and CO₂ emissions from electricity production according to present data. Therefore, the use of current limits, regardless of the techniques used to achieve them, is a stringent assumption with respect to the present research. For

Table 1. Projected share of fuel mix for electricity production for 2020.

	Denmark	France	Israel
Fossil energy			
Coal and lignite	27%		25%
Gas	22%		65%
Thermal		8.7%	
Oil	1%		
Non-fossil and RE			
Wind & other renewables	50%	4%	10%
Nuclear		73.7%	
Hydro		13.6%	

²Externalities are costs or benefits arising from an economic activity that affects someone other than the people engaged in the economic activity and are not reflected fully in prices [18]. Benefits are obtained by decrease in social costs, e.g., by reducing air emissions.

³The benefit-transfer approach enables evaluation of externality values found in various studies in specific countries and their adaptation to other countries using econometric methods.

the purpose of the analyses presented in this study, we shall refer to this mix as BAU (Business As Usual).

Given the BAU energy mix in **Table 1** and each country's anticipated emission limits, we calculated the total emissions from 1 kWh of electricity produced. The figures are provided in **Table 2**.

3.2. Anticipated Passenger Car Stock and Emissions from ICE Vehicles

The projected car fleet composition in the countries under study is presented in **Table 3**, calculated according to [25-27].

[28] sets two emission standards for the registration and sale of new passenger vehicles, vans and commercial vehicles intended for the transport of passengers or goods (Euro 5 standard came into force on January 1st 2011 and Euro 6 standard will come into force on the January 1st 2015). Vehicles that do not comply with the limits set in the Euro 5 and 6 standards must be refused registration in the member state [28]. Actions targeting the reduction of CO₂ emissions in the transport sector have been discussed since the early 1990s. In 2007, a new objective target for emissions was proposed at a level of 120 g CO₂/km by 2012. Later, however, this target was set to a level of 130 g/km [29].

This study considers Euro 6 emissions for ICE vehicles which, according to different penetration scenarios, will be replaced by EV.

Nevertheless, several studies have indicated that, in

particular, on-road (real-world) NO_x emissions from light-duty diesel vehicles might substantially exceed the emission levels identified during emissions testing in the laboratory. [30] showed that Portable Emission Measurement Systems indicate that average NO_x emissions of Euro 5 diesel vehicles are 0.62 ± 0.19 g/km (grams NO_x per kilometer), which substantially exceed the Euro emission limits.

On-road NO_x emissions of gasoline vehicles, as well as CO and THC (total hydrocarbon) emissions of both diesel and gasoline vehicles generally stay within Euro emission limits.

During on-road testing, the average emissions from light-duty diesel and gasoline vehicles are 189 ± 51 g CO₂/km and 162 ± 29 g CO₂/km, respectively, thereby exceeding the CO₂ emissions as specified during laboratory testing by $21\% \pm 9\%$. The magnitude of on-road emissions varies depending on vehicle type, operation mode, route characteristics and ambient conditions; the higher the emission from ICE vehicles, the greater the benefits from replacing these vehicles. To conduct a conservative analysis in this study, we used the following real-world emissions: NO_x emissions from diesel cars—0.6 g/km instead of 0.08 g/km [28] and CO₂ emissions—160 g/km instead of 130 g/km for both gasoline- and diesel-powered vehicles [28]. In all other parameters and with respect to gasoline cars, we used the Euro 6 standards.

Table 4 presents the emission limits of Euro 6 and real-world emissions used in this study.

Table 2. Calculated air emissions from 1 kWh electricity production for year 2020.

Average Emissions (g/1kWh)	Denmark	France	Israel
CO ₂	149.9	33.2	498
SO ₂	0.05	0.08	0.18
NO _x	0.25	0.07	0.35
NMVOG	0.003	0.009	0.01
PM ₁₀	0.003	0.005	0.03
As	1.46E-06	9.4E-07	
Cd	2.8E-07	1.4E-07	Total Heavy metals (excluding Hg)
Cr	1.96E-06	2.1E-06	
Ni	1.5E-05	1.2E-05	7.50E-05
Pb	4.4E-06	2.3E-06	
Hg	1.6E-06	1.9E-07	1.5E-06
Dioxin	1.2E-11	1.4E-12	1.21E-12

Table 3. Projected passenger cars (in millions) and average kilometers traveled for year 2020*.

	Denmark	France	Israel
Gasoline	1.72 (79.3%)	15.5 (45.1%)	2.6 (96.3%)
Diesel	0.45 (20.7%)	18.9 (54.9%)	0.1 (3.7%)
Total	2.17	34.4	2.7
Annual Average Kilometers Travelled (Km)	19,000	12,800	16,800
Annual Average Kilometers Travelled (Km) diesel	NA	16,000	NA
Annual Average Kilometers Travelled(Km) gasoline	NA	9,000	NA
Annual Average Kilometers Travelled	Urban (35%), Rural (46%), Highways (19%)	Urban (27.9%), Rural (44.5%), Highways (27.6%)	Urban (84.3%), Non-Urban (15.7%)

*We assume that future figures will not change significantly from current national figures.

Table 4. Emission limits of Euro 6 and real-world emissions (gr/km).

	CO	THC	THC + NO _x	NO _x	PM	CO ₂
Diesel						
Euro 6	0.50	-	0.17	0.08	0.005	130
Real world		-				
Gasoline						
Euro 6	1.0	0.10	-	0.06	0.005	130
Real world						

3.3. Electricity Needs for Charging EV Cars

According to different EV penetration rates (3%, 20%, 40%), it was found that in Denmark, the electricity demand will grow by 0.65%, 4.34% and 8.68%, respectively. For the same respective rates in France, we anticipate an increase of 0.53%, 3.55% and 7.11%, and in Israel, of 0.42%, 2.8% and 5.59%. These electricity demands include the negligible needs of the EASYBAT concept that will be introduced in Section 3.5.

We assume that no increase in electricity production will be necessary, as existing power plants will be used.

3.4. Air Emission Costs

Air pollution costs are caused by the emission of air pollutants such as particulate matter (PM), NO_x, SO₂ and VOC (volatile organic compounds). They include health costs, building and material damages and crop losses, as well as costs of further damage to the ecosystem (biosphere, soil, water). Health costs (mainly caused by PM from exhaust emissions or from transformation of other pollutants) are by far the most important cost category (e.g., [31]). The state of research on these costs is far more advanced than for the other components, mainly based on estimations carried out by the Extern E model, funded by several EU-research projects ([16,19]).

In this study, we addressed tank-to-wheel air emissions; that is to say, we refer only to primary air emissions associated with the vehicle's actual operation (and not secondary pollutants such as Ozone).

Externalities for Denmark and France were calculated according to data provided by [16,19]. The data provided by [20,21] were used to calculate the relevant assessments for Israel.

Table 5 presents the different costs (in 2000 EUR) of air pollutants from transportation and electricity production in the countries under study.

Using the Extern E data, the external costs of all air pollutants in France were found to be significantly higher than in Denmark. The possible explanation for this includes different meteorological conditions and different population densities residing in urban areas. The urban population in Denmark is 24.5% [32], whereas in France,

34% of the population resides in cities with more than 500,000 inhabitants [33]. The denser the population in the cities, the higher the environmental costs associated with air pollution generated in the cities.

The Israeli studies assessing the air pollution costs were based on the Extern E project, but, as discussed above, several amendments and benefit-transfer techniques were used to fit the Israeli economy, meteorological conditions and the fact that Israel is a densely populated country (according to [34], 6,808,000 out of 7,419,000 inhabitants live in metropolitan areas with an average of 361 inhabitants per km²). Hence, no distinction is made in Israel between urban and rural areas.

One may argue about the accuracy of the official Israeli figures provided by [20,21], but we use them in this study because, to the best of our knowledge, no better data prevail.

Although the aforementioned pollutants impose different costs on the countries under study, the same damage costs of CO₂, heavy metals and dioxins were used in each country, as shown in **Table 6**, (following [16,19]).

It is noteworthy that the transportation sector in Europe was responsible for 20.2% of total greenhouse gas emissions in 2009 [35]. The price that we assumed for CO₂ in our analysis (40 EUR/ton) is relatively conservative, as according to the United States Environmental Protection Agency [36], the price could be higher than 50 EUR/ton.

Table 5. Air emission costs in 2000 EUR/ton of substance emitted.

Substance	Costs of Air Emissions (2000 EUR/ton)			
	Denmark	France	Israel	
NO _x	Road Transport	4400	7700	14,147
	Electricity production	4400	7700	3853
NMVOC	Road Transport	700	1400	4022
	Electricity production	700	1400	513
SO ₂	Road Transport	5200	8000	8367
	Electricity production	5200	8000	6653
PM _{2.5}	Road Transport	185,768	216,706	27,328
PM ₁₀	Electricity production	5475	11,486	9496
CO	Road Transport	500	500	1224

Table 6. Air emission costs in 2000 EUR/ton of substance emitted.

Substance	Costs of pollutant (2000 Euro/ton)
CO ₂	40
Arsenic (As)	80,000
Cadmium (Cd)	39,000
Chrome (Cr)	31,500
Nickel (Ni)	4000
Lead (Pb)	600,000
Mercury (Hg)	8,000,000
Dioxin	37,000,000

In this study, we did not present any other benefits of replacing ICE vehicles with EV, such as noise reduction, water and soil pollution reduction, etc.

3.5. Specific Electricity Demands for the EASYBAT Concept

To assess the environmental benefits of the EASYBAT concept, we compared the proposed SB with the conventional FB. According to current literature, the driving range of these cars is the same, 160 km [37], and the life span and the degradation of the battery are also considered equal—160,000 km over 10 years (EASYBAT, personal communication). The SB and FB in their second life and end of life are treated the same, and therefore, no differences exist.

Our basic assumption is that the energy consumption of any EV is 0.2 kWh/km [38]. In addition, the weight of the SB infrastructure and the electricity consumption of the additional cars is negligible (EASYBAT personal communication).

Nonetheless, to facilitate the SB concept, it is necessary to construct battery switch stations (BSS). The battery's life span is significantly influenced by the charging and storage temperature, therefore, it is crucial to cool (or heat) the battery at the BSS. On arrival, the battery should be connected to a cooling/heating system to achieve the temperature of $20^{\circ}\text{C} \pm 2^{\circ}\text{C}$ (EASYBAT personal communication). In addition, the EASYBAT inventory model assumes a requirement for an extra battery inventory of 2% for the car fleet in each country where the concept is applied (TUM model, EASYBAT personal communication). These batteries need to be kept at a controlled temperature also when stored at the BSS. According to our analysis, each battery required 1.5 kWh to maintain the required temperature. Therefore, the total electricity demand for the temperature regulation was calculated as 58 GWh (per 1000 batteries in 100 BSS, needed for 50,000 vehicles and 160,000 km travelled for 10 years). Given this electricity consumption, we applied the same methodology as described in Section 3.4.

4. Results and Discussion

4.1. Projected Emissions and Costs from Electricity Production

Given the total emissions from 1 kWh of electricity produced (Table 2), it can be seen that, due to the fact that the French fuel mix for producing electricity includes 91.3% of alternative energy (nuclear and renewable energy), France has the lowest emission of each specific pollutant per kWh. Denmark is next, as its fuel mix includes an anticipated 50% of renewable energy. Israel has the highest percentage of fossil fuel energy, and shows the highest levels of pollution per kWh. By multiplying

the cost of air pollutants presented in Tables 5 and 6 with the emissions from electricity production, we can calculate the emissions external costs per kWh produced.

The cost of producing 1 kWh in Denmark is 0.00506 EUR, in France the cost is 0.003 EUR and in Israel it is 0.0331 EUR.

4.2. Benefits of Replacing ICE Vehicles with EV

Our study included various penetration rates (3%, 20% and 40%) of EVs, whose batteries were charged with the projected energy mix given in Table 1. The emissions from ICE vehicles were evaluated for Euro 6 and real-world emissions, as discussed in Section 3.2 above.

It should be noted that the original EASYBAT FP7 project estimated a larger scope of scenarios, but we present the most likely electricity production estimates. The results are shown in Table 7. The replacement of conventional cars with EVs was calculated for each country according to the specific distribution between diesel and gasoline vehicles.

It can be seen that the higher the EV penetration rate, the larger the reduction in the social cost of emissions. Since real-world ICE vehicle emissions are higher than Euro 6 limits, the benefits of replacing them with EVs will yield even higher benefits.

Since France has the least polluting fuel mix for producing electricity, the option of replacing ICE vehicles in France will yield the highest benefits. We conclude, therefore, that the cleaner the electric energy production used for charging the EVs, the higher the environmental benefits that are achieved.

Most of the environmental benefits, (approximately 70%) are due to the reduction of CO₂ emissions, with a common global price of 40 EUR/ton. As for the other pollutants, the higher the external costs, the higher the environmental benefits of EV in comparison to the ICE vehicles.

In addition, France has the largest share of diesel ICE vehicles (54.9%). Therefore, their replacement with EV will further increase environmental benefits due to their higher externalities as compared to gasoline vehicles.

4.3. The Net Benefits of Replacing ICE Vehicles with EVs

The benefit per car and per 10,000 km driven is subject to the available electricity source. The comparison is made by replacing ICE vehicles emitting pollutants according to Euro 6 standards or real-world measurements.

To calculate the net benefits of the replacement, we calculated the electricity demand to control the temperature of the SB concept. The external costs of this consumed electricity (58 GWh) were subtracted from the external benefits found for the Euro 6 or real-world ICE

vehicle replaced by EV. The net benefits are presented in **Table 8**.

It can be seen that in all real-world cases, the replacement of ICE vehicles yields higher benefits compared to the expected Euro 6 emissions. The highest net benefits are obtained for France, since its electricity production is the cleanest and its transportation fleet is comprised of a relatively high number of diesel cars, which are more polluting and therefore, impose higher externalities as compared to gasoline vehicles.

As electricity production in Israel is based on a relatively high percentage of polluting coal, the benefits from the replacement of ICE vehicles with EV will be 50% of those achieved in Denmark and 60% than those in France.

4.4. Prediction of Benefits of Reduced Air Emissions by Replacing ICE Vehicles with EVs

Our analysis enabled prediction of the anticipated benefits,

given the specific conditions of each country facing the introduction of EVs. As already demonstrated, the higher the pollution related to electricity production, the lower are the benefits of replacing ICE vehicles with EVs. On the other hand, if energy used for charging EVs is obtained by renewable, non-polluting resources, the cleaner the electricity production, the greater will be the benefits from the replacement.

In 2020, the share of energy mix for electricity production used in our study in Demark, France and Israel will consist of 30%, 91.3% and 10% of alternative energy, respectively. If all electricity is produced by alternative resources (either renewable or nuclear), the benefits for real-world car fleet emissions will increase by 19.7%, 5.4% and 254% for Demark, France and Israel, respectively.

Another factor influencing the change in benefits depends on car fleet composition.

The higher the percentage of diesel cars replaced, the

Table 7. Annual benefits (MEUR) from ICE replacement with EV at different penetration rates.

Scenario	Country	Share of EV (% of Total presented in Table 3)	Share of Renewable Energy (%)	ICE emissions Euro 6 or Real World	Annual benefit (MEUR/year)
1		3		Euro 6	7.8
2				RW	10.0
3	Denmark	20	50	Euro 6	52.0
4				RW	66.8
5		40		Euro 6	103.9
6				RW	133.6
7		3		Euro 6	94.2
8				RW	146.1
9	France	20	91.3	Euro 6	628.1
10				RW	974.3
11		40		Euro 6	1256.2
12				RW	1948.5
13		3		Euro 6	4.1
14				RW	6.2
15	Israel	20	10	Euro 6	27.2
16				RW	41.2
17		40		Euro 6	54.4
18				RW	82.4

Table 8. Net benefits (EUR/vehicle*10,000 km) achieved by replacing ICE transportation with EV.

Country	ICE emissions Euro 6/Real World	Scenario	External Benefits (EUR/vehicle*10,000 km)	External costs of SB maintenance (EUR/vehicle*10,000 km)	Net Benefits (EUR/vehicle*10,000 km)
Denmark	Euro 6	1, 3, 5	63	0.36	62.64
	RW	2, 4, 6	81	0.36	80.64
France	Euro 6	7, 9, 11	71	0.21	70.79
	RW	8, 10, 12	111	0.21	110.79
Israel	Euro 6	13, 15, 17	31	1.66	29.34
	RW	14, 16, 18	46	1.66	44.34

higher the benefits. The anticipated car fleet in 2020 will be based on 20.7%, 54.9% and 3.7% of diesel cars in Denmark, France and Israel, respectively. If EVs replace only diesel cars (and not according to the specific distribution between diesel and gasoline vehicles as presented in **Table 3**), in the case of real-world emissions and BAU energy mix, the benefits per car replaced in Denmark, France and Israel will increase by 37%, 55% and 291%, respectively, as compared with replacing only gasoline cars with EVs. This is a very important policy input. If policy makers wish to promote replacement of conventional vehicles with EVs and to maximize the benefits from this replacement, the policy should be oriented toward replacing the diesel vehicles rather than the gasoline cars.

Densely populated urban areas are likely to benefit from improved air quality, due to the change in car fleet from ICE to electric vehicles. BAU conditions in Denmark and France represent 23.3% and 34% of the population living in urban areas, respectively. If the entire population in these countries will live in urban areas, the benefits of replacing ICE vehicles in the car fleet with electric vehicles, in “real life” conditions and using a BAU energy mix for producing electricity, the benefit for Denmark and France will increase by 16.4% and 15.2%, respectively. As mentioned earlier, this calculation is not relevant for Israel, where no distinction is made in the evaluation between urban and rural areas due to the density of the country.

5. Conclusions

The aim of this study was to estimate the differences between electric vehicles (EV) and internal combustion engine (ICE) vehicles in terms of air emissions and to analyze and estimate the differences between the EV with fixed battery and the new switch able battery concept (EASYBAT), as part of the FP7 project.

The environmental impact was estimated for three countries—Denmark, France and Israel—for different scenarios of charging mix to produce electricity and different ratios of EV to ICE vehicles. The annual environmental benefits found were in the range of 7.8 to 133 MEUR for Denmark, 94 to 1948 MEUR for France and 4.1 to 82 MEUR for Israel, given that Israel has the most polluting fuel mix for producing electricity.

By taking into account the electricity demand for temperature control of the switch able battery concept, the net annual benefits obtained for Denmark were 63 EUR/vehicle*10,000 km and 28% higher if the real-world scenario was considered. The benefits found for France were 71 EUR/vehicle*10,000 km and 56% higher when real-world was estimated, due to the high percentage of diesel cars in the French fleet. Israel would gain the least benefit from the replacement of ICE vehicles with EV, with benefits of 29 EUR/vehicle*10,000 km obtained and

48% higher when real-world was evaluated.

It is agreed that practically all countries are facing high social costs associated with transportation. Policies and budgets are allocated to reduce dependency on private transportation; this notwithstanding, all the figures show that the kilometrage driven in private cars is constantly on the increase.

Given that the main source of pollution in dense cities and more than 20% of greenhouse gas emissions are attributed to transportation, vehicle manufacturers and policy makers should adopt strategies that will promote clean, environmentally-friendly technologies to reduce these costly influences.

In addition, the production of electricity in power plants is a point source of pollution that is continuously monitored and regulated. The foreseen improvements in electricity production, the anticipated efficiency increase and the growing share of renewable energy will further contribute to the environmental benefits described in the present study. These advances will be achieved without the need to replace the electric car fleet.

Our study showed that replacing ICE vehicles with EVs is a significant step for a greater nexus between the social goals and the automotive industry’s objectives.

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Abbreviations

BAU, Business As Usual;
CO, Carbon Monoxide;
CO₂, Carbon Dioxide;
NMVOC, non-methane volatile organic compounds;
NOX, Nitrogen Oxides;
PM₁₀, Inhalable Particulate Matter (smaller than 10 micrometers);
PM_{2.5}, Fine particular matter (smaller than 2.5 micrometers);

ters);
SO₂, Sulfur dioxide;
CAFÉ, Cleaner Air for Europe;
EV, electric vehicle;
ICE vehicle, internal combustion engine;
MoEP, Ministry of Environmental Protection;
WHO, World Health Organization;
SB, Switch Battery;
FB, Fix Battery.