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Energy Sources Management and Future Automotive Technologies: Environmental Impact

Florin Mariasiu
Technical University of Cluj-Napoca, Automotive & Transportation Department,
Bdul. Muncii 103-105, RO-400641, Cluj-Napoca, Romania.
Email: florin.mariasiu@arma.utcluj.ro

ABSTRACT: The paper presents the environmental impact created through the introduction of introducing new technologies in transportation domain. New electric vehicles are considered zero-emission vehicles (ZEV). However, electricity produced in power plants is still predominantly based on fossil fuel usage (required for recharge electric vehicle batteries) and thus directly affects the quantity of pollutant emissions and greenhouse gases (CO_2, NO_x and SO_x). Given the structure of EU-wide energy sources used for electricity generation, the potential pollutant emissions stemming from these energy sources, related to energy consumption of an electric vehicle, was determined under the projected environmental impact of specific market penetration of electric vehicles. In addition to the overall impact at the EU level, were identified the countries for which the use of electric vehicles is (or not) feasible in terms of reaching the lower values of future emissions compared to the present and future European standards.

Keywords: Energy sources; Electric vehicles; Pollutant emission; Environment
JEL Classifications: L91; O32; Q43; Q53; Q56

1. Introduction

Throughout human history, development of different civilizations was directly related to increasing energy consumption. This link between sustainable energy consumption and economic development of countries or regions was highlighted by the work of Stern (1993), Kaplan et al. ,(2011) and Farhan and Ben Rejeb (2012). However, historically, energy required in modern industrial technology was (and still is) typically produced using mainly fossil fuels (coal, oil and natural gas), with very few renewable energy sources (wind, solar, nuclear, biomass). This dependence and overuse of fossil fuels has, over time, given rise to serious problems, including environmental pollution and adverse global climate changes, stemming from greenhouse gas emissions (GHG). In this context, Soytas and Sari (2009), Ozturk and Acaravci (2010) examine the long-term causal relationship between the economic growth issues, energy consumption and the related carbon emissions.

To limit these negative effects, for each economic sector, both groups of authors have proposed a specifics series of technological, political, and administrative measures.

In the Energy production sector, technologies that allow increased efficiency and effectiveness (fluidize bed sheet-burning process, co-generation of heat and power), combined with methods of reducing pollution, are developed (Myszczyk and Darowicki, 2002; Rozpondek and Siudek, 2009).

Similarly, in Residential, Commercial and Institutional sector, measures aimed at increasing the thermal efficiency of buildings—including building materials that must have a reduced CO_2 life cycle—are proposed and prototyped (Taygun and Balanli, 2007).

For the Agriculture, Forestry and Fishery sector, the authors proposed increasing the surfaces used for production of industrial crops and products, and have advised that related technologies (production and use of biogas and biomass) should be modified in order to yield crops with high renewable potential (Gavrilescu, 2008).

In Transport domain, to reduce the massive use of fossil fuels, policies and directives at European level (for short term) were adopted, emphasizing the need for using greater proportion of biofuels, thus reducing the need for conventional fuels (McCormick, 2007). Compared to fossil fuels, biofuels offer several advantages, including lower greenhouse emissions, mainly due to characteristics of the renewable characteristics of raw material used for their production (industrial crops and agricultural wastes).

However, if the carbon monoxide (CO), unburned hydrocarbons (HC) and particulate matter (PM) emissions respectively decline by 15-28%, 12-40.2%, 5.7-17.8% when using biodiesel, the nitrogen oxide (NO_x) emissions will correspondingly increase (+11.3-43%), compared to the levels emitted when using fossil fuels (Ng et al., 2009; Burnete et al., 2011; Mariasiu et al. 2011).

To eliminate this drawback, when implementing new technologies in automotive industry, it is recommended to use hybrid automotive powertrain, hydrogen fueled engine, fuel cell and electric vehicle (EV) as main energy sources powering road vehicles (Thomas, 2009).

Electric vehicles have the greatest potential to reduce air pollution, as they are considered to be zero-emission vehicles (ZEV), due to absence of internal combustion (IC) engine fueled by fossil fuel in powertrain structure. However, due to some engineering and structural design specifications (the existence of a battery that powered the electric motor), at present, the EV batteries and rechargeable accumulators are charged by external electric power source. Thus, even if EVs are considered ZEV vehicles, they can still pollute the environment indirectly, due to pollutant emissions stemming from electricity production process in power plants in.

The following factors are considered main barriers to increasing the car market share for EVs:

- The median EV purchase price is almost 100% greater that for a new IC engine car;
- Significant limitations regarding the autonomy and charging time of most EVs (average value for autonomy is considered to be 130 km and mostly EVs need 6 hours for a complete charging cycle);
- Battery capacity is relatively low, the usable energy depending directly on ambient temperature, car usage (driving style and traffic conditions) and charging technology.

Given the barriers noted above, the EU countries and authorities are presently taking several political and economic measures aimed at increasing the penetration of EVs in the car market. Free parking, right to use bus lanes, free entry to city centers, financial subsidies and incentives, as well as exemptions from registration tax, VAT, annual car tax and congestion charges, are some of the measures aimed at promoting the acquisition of EVs, with the target of 4,752,100 units at EU level for the end of 2015 (Reiner et al., 2010; Nemry and Brous, 2010).

All these measures are taken in order to increase electric vehicle car market penetration and thus achieve a more favorable share of these vehicles in the total number of registered cars (Table 1).

Table 1. Number of electric vehicles announced to be integrated in car market

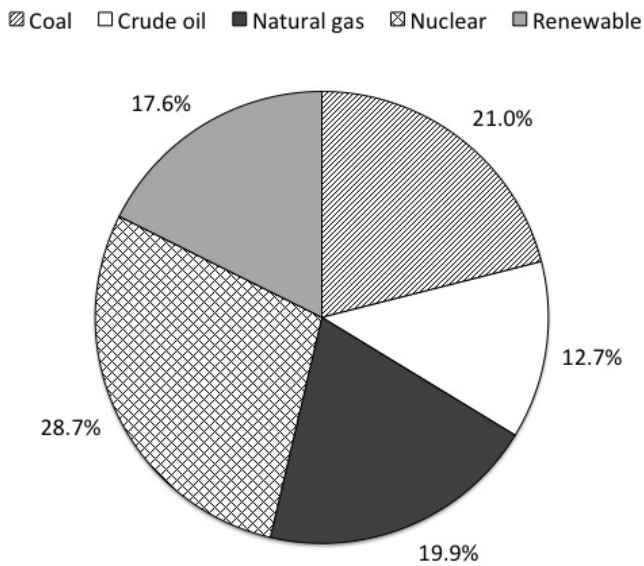
Country	Number of electric cars	Year
Denmark	100,000	2011
France	2,000,000	2020
Germany	1,000,000	2020
Spain	1,000,000	2014
Ireland	250,000	2020
United Kingdom	200,000	2015
Netherlands	200,000	2020
EU-27	4,752,100	2020

Source: Grunig et al., (2011)

The growth of electric vehicle participation in the total auto car market production/utilization has immediate implications as lowering pollution and improving quality of life in major urban areas. However, the automotive industry faces many challenges in raising powertrain and transmission efficiency, increasing battery life and reducing production cost, as well as achieving lower costs of production and sale. All these processes need to be optimized in order to increase the availability and usability of this new and emerging technology in transport.

At European level, the structure and management of energy sources used for electricity production is presented in Figure 1.

Figure 1. Structure of energy sources used for electricity production - EU-27 (EC, 2011)



Note that, in the European Union, fossil fuels (coal, crude oil and natural gas) are used in 53.6% of the electric energy production. Consequently, in order for European countries that already have programs in place that are aimed at introducing greater number of electric vehicles in car market, the required structure of energy sources used for electricity production must change (as presented in Table 2).

Table 2. Structure of energy sources used for electricity production in the EU countries that have programs aimed at introducing a greater number of electric vehicles (EC, 2011)

Country	Share of primary energy total production (%)				
	Coal	Crude oil	Natural gas	Nuclear	Renewable
Denmark	0	54.1	34.0	0	11.9
France	0	0.8	0.6	84	14.7
Germany	37.8	2.3	8.5	28.9	22.4
Spain	13.9	0.4	0.1	50.3	35.4
Ireland	42.4	0	23.3	0	34.3
United Kingdom	6.4	44.4	38.1	8.2	2.9
Netherlands	0	3.3	90.3	1.6	4.7
EU-27	21	12.7	19.9	28.7	17.6

2. Experimental Procedures

To evaluate the effect of the electric vehicle introduction into the car market, based on the increased usage of transportation in general, the following algorithm was developed.

Step 1. The necessary data on the structure of energy sources used for electricity production was gathered and was presented in previous sections, both at European level as well as the countries that have programs and policies supporting the electric vehicle penetration in the car market.

Step 2. Table 3 presents the quantities of CO_2 emissions for each source of energy used to produce 1 kWh electricity.

Table 3. CO_2 emissions related to a particular energy source characteristics (POST, 2006)

Electrical generation source	Coal	Crude oil	Natural gas	Nuclear	Renewable
Grams of CO_2 emissivity (g/kWh)	1000	650	500	5	15

Step 3. An average energy consumption of 0.163 kWh / km for a compact electric vehicle was chosen for use in the algorithm. The average energy consumption was determined using data from the

work of Perujo and Ciuffo (2009), pertaining to the technical characteristics of the electric vehicles currently available in the car market.

Step 4. The specific CO_2 emissions for each electric vehicle were calculated using Equation (1).

$$EV_{CO2(g/km)} = P_{egl} \cdot \sum_{i=1}^{n} EV_{ec} \cdot S_{es\_i} \tag{1}$$

were $EV_{CO2/km}$ is the amount of CO_2 emitted by electric vehicle energy consumption (g/km), EV_{ec} is electric vehicle energy consumption (kWh/km), S_{es_i} is the CO_2 emissivity (gCO2/kWh) of each energy source considered (as a share of the total) to produce electricity, and the $P_{egl} = 1.15$ is the coefficient that takes into account the losses caused by electric distribution grid and internal EVs electrical circuits (Tesla motors, 2010).

Step 5. The data obtained were compared to the values of pollution emitted by a compact vehicle with internal combustion engine.

Step 6. Analysis and discussion of the environmental impact of the electrical vehicle usage, which indicated that the amount of CO_2 emissions would be at the EU level that stipulates increased usage of electric vehicles.

3. Results and Discussion

Applying the calculation algorithm presented in previous sections, results obtained on the quantity of CO_2 emitted, depending on the structure of each country's energy sources considered (Table 4).

Table 4. Indirect CO_2 emissions stemming from electric vehicle use and the corresponding European emission regulations

Country	Electric vehicle emission (gCO_2/km)	Differences relative to future European emission regulations (2020) - %	
		Internal combustion emission vehicle (ICEV) - 95 gCO_2/km	Low emission vehicle (LEV) - 50 gCO_2/km
Denmark	98.11	+3.27	+96.22
France	2.73	-97.12	-94.54
Germany	82.52	-13.13	+65.04
Spain	28.10	-70.42	-43.80
Ireland	102.28	+7.66	+104.56
United Kingdom	101.96	+7.32	+103.92
Netherlands	88.80	-6.52	+77.60
EU-27	74.37	-21.71	+48.74

Note that, in terms of compliance with European standards of pollution emissions (compared to ICEV emissions), several EU countries, namely France, Germany, Spain and Netherlands, currently comply with the limits. In contrast, Denmark, UK and Ireland failed to achieve these limits by using EV in transportation. If comparison is made with acceptable pollution limits for LEV, it is evident that only France and Spain reach (and even exceed) the acceptable value of these norms, due to the greater share of electricity produced in nuclear plants in these countries.

Consequently, in France and Spain, the introduction of greater number of electric vehicles into the car market, and the future substantial investments needed to develop necessary charging infrastructure, are justifiable in terms of positive effects in reducing CO_2 emissions.

Thus, other countries that also aim to introduce electric vehicles into the car market and transport system and have already adopted relevant economic policies should introduce measures that enable proper management of energy sources used in electricity production. This can be achieved by increasing the share of total renewable energy sources and / or nuclear into their energy production infrastructure.

The recent policy and decisions of German government are also important in this context, as they are aimed at replacing the nuclear component of the country's energy source structure (because of the effects of nuclear accident in Fukushima, Japan). The aim is to compensate the loss of nuclear power by investing in renewable energy. For Germany, such a move could result in meeting the necessary targets required for compliance with future pollution rules.

Two other European countries, Poland and Greece, both of which use substantial amount of coal for electricity production are also worth consideration. Coal accounts for 85.9% and 83.3% of total energy sources, in Poland and Greece respectively. Thus, the introduction of electric vehicles into the transport infrastructure of these countries will achieve CO_2 emissions values 167.45 g CO_2/km for Poland, and 157.41 g CO_2/km for Greece, under the conditions presented in this paper. Relative to the future standards adopted by European Commission for ICEV vehicles, these values are 76.26% and 65.69% higher for Poland and Greece, respectively.

In sum, for these two countries, the introduction and use of electric vehicles in a country's transport infrastructure will not bring substantial benefits in lowering CO_2 emissions. Thus, it is more appropriate to encourage car market penetration by hybrid or fuel cell vehicles. Outside towns, these vehicles run on biofuel blend (which have a CO_2 emissivity less than coal) and use the electric motor in the urban areas.

It can be said that, before introducing new technology (electric vehicles), economic policies and management of energy sources used for electricity production must take into account the indirect environmental effects that may occur because of this initiative. Prior to make major investments in recharging infrastructure of electric vehicle batteries, it is necessary to invest in modernization of power plants (increasing efficiency, reducing emissions, using renewable resources, etc.), and the structure of energy sources used.

4. Conclusion

The paper presented the environmental impact of significantly increased use of electric vehicles in transportation. Although considered zero-emission vehicles, by using electricity produced by power plants, electric vehicles "pollute" the environment indirectly. The use of electric vehicles certainly leads to lower pollution and increase quality of life in big cities. However, globally, owing to the nature and structure of power plant emissions, a present threat of acid rain (by more emissions of sulfur and nitrogen oxides emitted by coal burning process) is still not fully mitigated.

Some EU countries could benefit from the introduction of electric vehicles, due to the structure of energy sources used in their electricity production processes, as they can meet the conditions necessary for sustainable development in transport. European countries that cannot achieve significant reductions in emissions through the introduction of electric vehicles should initiate programs of introduction, development and management of renewable energy sources (wind, solar and hydro), as this move would help mitigate the effects of currently predominant use of solid fossil fuels.

To obtain global results in terms of future sustainable development in transport, need a new vision of management of energy sources used to produce electricity. The renewable component of energy sources mix structure must increase in the future to decrease the amount of pollutants that are currently emitted into the atmosphere. This can assure sustainable car market penetration and the prevalent use of electric vehicles in transportation domain.

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