Technological and economical context of renewable and non-renewable energy in electric mobility in Slovakia and Hungary

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**Abstract.** Authors have investigated battery electric road vehicles and their possible impacts on the environment and on the Hungarian and Slovakian energy sector. In this article authors investigated the effect of electric market on the emission of electric cars. After analyzing the tendencies of electric market the tendencies of plug.in electric vehicles were analyzed. As a conclusion authors have showed the significant drop of emission caused by electric vehicles in Hungary and Slovakia. The main finding are from this article that battery electric cars could significantly decrease the emission of transport sector only and if only that the appropriate energy sector support this.

**Keywords:** Plug.in electric road vehicles, electric sector, transport sector

1. Introduction

Nowadays, on number of places it can be seen that the market penetration of electric road vehicles (Battery Electric Road Vehicle) are increasing. Nowadays this has been proven in The European Union by several statistical analysis, for instance one made by EUROSTAT [1] (see Fig. 1.).

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| **Fig. 1.** Market penetration of road electric vehicles in EU  *(source: own compilation from EUROSTAT [2])* |

European Commission has a plan to cut transport emissions and boost use of electric vehicles. The deadline for reaching this objective is the year 2030. The Commission has a plan to reduce the average emissions level of newly manufactured vehicles by 30% in 2030 compared to the reference levels for 2021 [3]. These represent 95 grams of CO2 per kilometer for passenger vehicles and 147 grams for light commercial vehicles. For reaching this ambitious objective synergy of different strategies should be used [3]. Some of the effects were analyzed in researches [4-6].

As demonstrate sources [7-10] for an electric vehicle the source of the electricity used during its operation plays a large role in the overall environmental impacts. There are different electric energy supported technologies used in road transport sector (hybrids, plug-in hybrids, battery electric) that have also significant effect on transport sector [11], but in this paper only battery electric vehicles are investigated. Electric vehicles are usually powered by an electrical power bank. These energy storage units (power banks) are charged from the existing electrical network.

Battery electric vehicles are brought to the market by a number of manufacturers. Slovakia is in many cases referenced as a „superpower“ of the automotive industry. The 127,000 automotive industry workers that are currently working in this country manufacture around 1 million vehicles annually. It is representing approximately 12% of the country’s GDP. Three big international automotive companies have built factories in the country (Kia Motors Slovakia, [PSA Peugeot Citroën Slovakia](https://sk.wikipedia.org/wiki/PSA_Peugeot_Citro%C3%ABn_Slovakia) and [Volkswagen Slovakia](https://sk.wikipedia.org/wiki/Volkswagen_Slovakia)). The fourth, Jaguar Land Rover, is under construction. Slovakia is currently the only European country that is manufacturing Volkswagen’s electric car. So there exists an expectation that use of low-emission vehicles in this region will increase. Research question of the authors is: Does the electric market influences the emission of electric cars? In the second chapter authors investigate the electric market and related short-term tendencies in Hungary and Slovakia. In the third chapter battery electric road vehicles development was analyzed. In the fourth concluding chapter authors quantitatively show the effect of market changes on the pollution of battery electric road vehicles in Hungary and Slovakia.

1. Electric power generation and network

Generating electricity for the battery electric road vehicles are created in power plants, where different energy sources (fossil – coal, oil, nuclear, renewable – solar, wind, etc.) are converted to electric energy. The increasing number of vehicles would give an increasing demand for electricity [12]. In Hungary and also in Slovakia the main energy source is the nuclear energy (see Fig. 2) and in both countries the total primary energy supply is less than the demand, therefore net import is necessary. One could easily understand that source of power converted to electricity has significant effect on emission factor of battery electric road vehicles.

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| **Fig. 2.** Electricity generation in Hungary (left) and Slovakia (right) in 2016  *(source: EEA report)* | |

Due to the changes in price of electricity in Hungary and Slovakia there were closed some old and polluting power plants. Nowadays it is rather feasible to buy cheap electricity that has lower environmental load than to produce it in old coal and gas power plants. During the period covering 2005 to 2015, there was an overall reduction of 2.6 % in the level of EU-28 net electricity generation (see Fig. 3). This pattern was repeated in 16 of the 28 EU Member States.

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| **Fig. 3.** Overall change in net electricity generation, 2005-2015  *(source: own compilation from [13])* |

It should be noted that changes in electricity generation do not directly reflect changes in electricity consumption as they are also affected by changes in the different energy products used for energy production and by changes in electricity imports and exports. Total net electricity generation in the EU-28 was 3.07 million gigawatt hours (GWh) in 2015 — which was 1.3 % higher than a year before, ending a period of four consecutive reductions in output.

Source of energy has a significant contribution on CO2 intensity of power generation [gCO2eq/kWh] (see Fig. 4.). Renewable or CO2 neutral energy sources are more favorable.

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| **Fig. 4.** CO2 emission intensity of power generation  *(source: EEA report)* |

In 2018, due to the increasing import and closure of national old power plants the CO2 intensities of power generation are 197 gCO2eq/kWh on average in Slovakia and in Hungary the average is196 gCO2eq/kWh. With these not only environmental effect of electricity production has been lowered but also related external costs as well (see Fig. 5.):

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| **Fig. 5.** External costs of electricity production in the EU, 1990 and 2005  *(source: EEA report)* |

The external costs in the above figures is based upon the sum of below components of electricity production:

* climate change related costs (CO2 emission),
* costs of local pollutants (impacts on health, plants and animals, etc.).

The external costs from nuclear have to be treated with caution, as only parts of the externalities are included by EEA. Differences of production cost of electricity are noted

1. Electric power generation effect on environmental pollution of electric vehicles

It is unquestionable that emission during production of electricity has significant contribution on environmental pollution of electric vehicles and it should be to be comparable with internal combustion engines [14]. Due to the changes of price in electricity and the market changes significant improvement was noticed in CO2 intensity of electricity production that could have significant effect on health conditions [15].

Authors collected several battery electric road vehicles’ data (see Table 1.):

**Table 1.** Efficiency of plug.in electric vehicles

*(source: own edition)*

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| Name of vehicle | Capacity related distance [km/kWh] |
| 2016 Ford Focus Electric | 6.5 |
| 2016 Nissan Leaf (24 kWh) | 6.7 |
| 2016 Volkswagen e-Golf | 7.9 |
| 2017 BMW i3 (60 Ah) | 7.8 |
| 2017 BMW i3 (94 Ah) | 7.9 |
| 2017 BMW i3 (94 Ah) | 7.6 |
| 2017 Chevrolet Bolt EV | 6.9 |
| 2017 Ford Focus Electric | 6.1 |
| 2017 Hyundai IONIQ Electric | 8.7 |
| 2017 Kia Soul EV | 6.8 |
| 2017 Mercedes-Benz B 250 E | 6.0 |
| 2017 Nissan Leaf (30 kWh) | 6.7 |
| 2017 Volkswagen e-Golf | 7.9 |
| 2018 Kia Soul EV | 7.0 |
| Citroen C-Zero (14,5 kWh) | 7.9 |
| Citroen C-Zero (16 kWh) | 7.4 |
| Mitsubishi i-MiEV (after 2015) | 8.0 |
| Mitsubishi i-MiEV (before 2015) | 7.4 |
| Peugeot iOn (14,5 kWh) | 7.9 |
| Peugeot iOn (16 kWh) | 7.4 |
| Renault Zoe Q210 (22 kWh) | 6.8 |
| Renault Zoe Q210 (22 kWh) | 6.4 |
| Renault Zoe Q90 (41 kWh) | 6.8 |
| Renault Zoe Q90 (41 kWh) | 6.5 |
| Renault Zoe R240 (23,3 kWh) | 7.5 |
| Renault Zoe R240 (23,3 kWh) | 7.0 |
| Renault Zoe R90 (41 kWh) | 7.5 |
| Renault Zoe R90 (41 kWh) | 6.8 |
| Volkswagen e-up! | 8.5 |

As it can be seen from Table 1. the average efficiency of investigated vehicles is 13.9 kWh/100 km in 2018. The average efficiency was 19.3 kWh/100 km in 2013 and 22.4 kWh/100 km in 2010. As it can be noticed a significant improvement has been reached meanwhile the CO2 intensity of energy production also significantly dropped from 343 gCO2eq/kWh to 197 gCO2eq/kWh in case of Hungary and to 195 gCO2eq/kWh in case of Slovakia in the last decade.

1. Conclusion

From the market change it can be easily derived that the CO2 intensity of used energy in battery electric road vehicles has been dramatically dropped, nearly halved. Meanwhile energy efficiency of battery electric road vehicles also significantly improved by 40 %. Altogether battery electric road vehicles emission rate improved from 2010 66.2 gCO2eq/km to 27.4 gCO2eq/km in case of Hungary and to 27.1 gCO2eq/km in case of Slovakia in the last decade.

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