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Environmental benefits analysis of electric vehicles in the Czech Republic

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ABSTRACT

The article evaluates the environmental benefits of electric vehicles using well-to-wheel analysis in the Czech Republic. The power consumption per kilometer is determined from the combined cycle of the New European Driving Cycle. Using information from the integrated registry of polluters and mandatory disclosures of the CEZ company the specific harmful emissions production per 1 kW h of electricity is determined. The combination of electricity consumed and the production of harmful emissions per 1 kW h of electricity determine the indirect harmful emissions of an electric vehicle per kilometer. Computer simulation of the indirect production of harmful emissions is performed on the Mitsubishi MiEV engine, typical for an electric vehicle.

1. Introduction

Between 1990 and 2007 there was a significant reduction of transport-related emission of particulate matter, acidifying substances and ozone precursors across the 32 European Environmental Agency (EEA) member countries. These reductions can largely be attributed to advances in exhaust gas after-treatment devices together with improved fuel quality. Nevertheless, road transport is the largest contributor to NO_X emissions in member countries, and the second largest contributor to pollutants forming particulate matter (PM) (European Environmental Agency, 2009). NO_X emissions and particular matters (PM_{10}, $PM_{2.5}$) are associated with health problems. Small concentration of NO_X emissions cause inflammation in the respiratory track, while high concentrations can cause bronchitis, bronchopneumonia or even acute lung oedema (Public Health Institute, 2008). Particular matters, especially $PM_{2.5}$ cause a number of ailments affecting the cardiovascular system and lungs.

The other major pollution problem connected with transport is that of carbon dioxide production that contributes to climate change effects. Greenhouse gas emissions from the sector continue to grow in contrast to other activities such as industrial activities, housing and energy production. In the EEA-32, emissions of greenhouse gases from transport, excluding international aviation and maritime transport, increased by 28% between 1990 and 2007 and now account for just under 20% of all production (European Environmental Agency, 2010). Production of carbon dioxide is directly proportional to the burning of fossil fuels.

The "White Paper", *European Transport Policy for 2010: Time to Decide* was the first significant report on emissions by the European Union (European Commission, 2001). In argues that emission from transport are a serious problem and the main source of pollution of air in urban agglomerations and argues for a reduction of transport generated CO_2 by reducing dependence on carbon based fuels (European Commission, 2001). This paper focuses on the implications of adopting alternatives to conventional gasoline based transport in the Czech Republic, taking a full life-cycle approach. In particular, we adopt the well-to-wheel approach developed by the Joint Research Centre (JRC) in co-operation with the European Commission (EUCAR, CONCAVE, JRC 2008) to consider the merits of electric vehicles.

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Table 1
Production of harmful emissions for the most common methods of electricity production.

Production of selected emissions [t/rok]			
CO_2	NO_X	SO_X	PM_{10}
34069000	56964	54486	1961.3
Amount of electricity produced [GW h/rok]			
Coal power station	Nuclear power station	Renewables	Water power – pumping
32709.02	26549.81	1309.82	353.35
Specific emissions in the energy mix [g/kW h]			
CO_2	NO_X	SO_X	PM_{10}
559.22	0.94	0.89	0032
Specific emissions for electricity generation only from coal [g/kW h]			
CO_2	NO_X	SO_X	PM_{10}
1041.58	1.74	1.67	0.06

2. Methodology

First we determine the power consumption for one driving kilometer in the same mode as in JRC analysis to determine the combined power consumption in the homologation cycle, New European Driving Cycle (NEDC). This cycle consists of an urban element (UDC) and extra-urban part (EUDC) with the combined energy consumption based on a weighting of the two components; UDC part being 36.8% and EUDC part, 63.2%.

The second step involves establishing the electricity consumption used in the production on pollutants based on information taken from the integrated registry of polluters, maintained by the Ministry of the Environment (Integrated Pollution Register, 2010). Information on the amount of electricity produced and the individual methods of production comes from the CEZ Group (2010) that has to disclose the following information under the law Energy Act No. 458/2000 Coll. ČEZ is the dominant electricity producer in the Czech Republic with a market share exceeding 60%. Production of harmful emissions for the most common methods of producing electricity is shown in Table 1.

3. Results

Determination of the energy consumption per kilometer is done using virtual simulation of the driving cycle. The information inputted represents the speeds in the NEDC cycle and vehicle parameters that affect its dynamic behavior. The Mitsubishi In-wheel Motor Electric Vehicle (MiEV) was selected for the simulation: its basic features are seen in vehicle Table 2.[1]

The first step is to estimate the resistance of the electric vehicle driving cycle NEDC and using Eq. (1) the instantaneous driving performance is determined. Integrating the instantaneous driving resistance gives the cumulative value of energy consumption, Eq. (2).

$$P(i) := F_c(i) \cdot \frac{v_D(i)}{3.6} \tag{1}$$

where $P(i)$ [W] je is the immediate driving power defined in every second of the cycle, $F_c(i)$ [N] is the driving resistance of the vehicle, $v_D(i)$ [km h^{-1}] is the speed of the vehicle

$$E(i) := \sum_{i=0}^{i} P(i), \quad E(195) = 1.893 \times 10^5 \tag{2}$$

where $E(i)$ [J] is the cumulated energy in the cycle ECE 15, which lasts 195 s.

The instantaneous power and cumulated energy consumption are shown in Fig. 1.

The cumulative primary energy consumption in the urban cycle ECE 15 is 189.300 kJ and the accumulated energy, determined in a similar way in EUDC part of the cycle, is 2.919 MJ. To determine the well-to-wheel analysis, it is necessary to use the calculated electric energy in estimating energy consumption by distance travelled in units of kWh/km. The average energy consumption per kilometer of the UDC cycle is determined from Eq. (3). Eq. (4) determines the same value for the EUDC part of the cycle.

$$E_U := \frac{E(195)}{1.013 \cdot 3600000}, \quad E_U = 0.0519 \tag{3}$$

where E_U [kW h/km] is the average energy consumption in the urban cycle, E [J] is the cumulated energy consumption in the cycle ECE 15.

[1] More details of the simulations are in Hromádko (2009).