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# Health and environmental benefits related to electric vehicle introduction in EU countries

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ABSTRACT

Introduction of electric vehicles (EV) can help to reduce $CO_2$-emissions and the dependence on petroleum products. However, sometimes relatively larger air pollutant emissions from certain power plants can offset the benefits of replacing internal combustion engine (ICE) cars with EV. The goal of this study was to compare the societal impact (climate change & health effects) of EV introduction in the EU-27 under different scenarios for electricity production. The analysis shows that countries that rely on low air pollutant emitting fuel mixes may gain millions of Euro/annum in terms of avoided external costs. Benefits extend across the EU, especially for emissions in small countries. Transport pollution affects the local scale, while electricity pollution has a regional reach. Other European countries, that depend on more polluting fuel mixes, may not benefit at all from introducing EV. Data on the present fuel mix were available for Belgium, France, Portugal, Denmark and the UK on a detailed time scale (5–30′ basis) and show that the time dependent variation of external cost for charging EV is dwarfed compared to the overall gain for introducing EV. The largest benefit is found in not driving an ICE car and avoiding local combustion related emissions. Data on the present fuel mix were also available for Romania on a detailed time scale (10′) and show that the variation in external costs is relatively larger than for the other countries and at some moments it may be worth the effort, at least in theory, to reschedule EV loading schemes taking into account social impact analysis.



## Introduction

Conventional cars with internal combustion engines (ICE) are still a major source of air pollutants such as carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), black carbon (BC) and fine particulate matter ($PM_{2.5}$; particles with an aerodynamic diameter <2.5 μm) (Hausberger, 2010). Some of the emitted pollutants cause severe health effects, including premature mortality (Dockery et al., 1993; Pope et al., 2004; WHO, 2005; Brook et al., 2010). The World Health Organisation WHO presently considers $PM_{2.5}$ mass as the most relevant indicator for assessing the impact of air pollution on human health (HEI, 2013). Although ultrafine particles are often blamed for causing health effects (Seaton et al., 1995), coarse particles from tire and brake wear could be implicated as well (Riediker et al., 2008; Gasser et al., 2009). In urban areas the contribution of conventional transport to $PM_{2.5}$ concentrations is relatively large (Keuken et al., 2013). Direct emissions of ICE cars have an effect on public health as well as on crops, buildings and the natural environment. From an environmental point of view, the replacement of ICE cars with electric vehicles (EV) may be beneficial for the climate because of the possible reduction of greenhouse

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gas emissions, particularly $CO_2$ (Thiel et al., 2010; Van Vliet et al., 2011). On the other hand EV are also not 100% clean. When EV are charged, the electricity required is produced by a wide range of different power plants (e.g. nuclear, gas, coal, ...), which may also be sources of air pollution.

It's a generally accepted strategy to find a common denominator to express different public health and environmental impacts in order to compare them. A standardized methodology is to convert emissions into monetary values proportionally to the damage of the externalities they cause (Bickel and Friedrich, 2005; Maibach et al., 2008). This approach has been used to compare the impacts of different fuels and engine technologies for cars (Int Panis et al., 2001, 2002, 2004). External costs for electricity production are mainly determined by health effects and greenhouse gas emissions (Nijs et al., 2011). Other categories considered are impacts on agriculture and on materials and buildings, biodiversity loss due to acidification and eutrophication, impacts of the emissions to air of heavy metals, of emissions of radioactive substances and risks of waste disposal, of biodiversity loss due to land use, accidents and noise and visual impact. In terms of external costs related to electricity generation these categories are relatively less important than the effects on health and climate. Health effects are driven by particulate matter pollution.

When EV are introduced in the car market and replace ICE cars, the emissions of air pollutants will increase at the site of the power plants while the emissions of local road pollutants, often urban, will decrease. These differences in the type, size and location of emissions need to be weighted in order to give an overall picture of environmental and health impacts and related external costs. This study was set up to answer the following major research question: What are the differences in health and environmental impacts of air pollution for each EU country when 5% of the ICE vehicle fleet is replaced by EV in the years 2010 and 2030? Additionally we study the maximum within-country difference in health and environmental impact of air pollution related to the annual variability in electricity generation.

The latter analysis requires detailed time specific information on the country's electricity fuel mix which is prone to high fluctuations. This detailed information was only publicly available and found for Belgium,[1] France,[2] Portugal,[3] Denmark,[4] the U.K.[5] and Romania.[6]

Electric vehicles considered in this study are entirely battery powered electric vehicles (BPEV). The impact is expressed in external costs for each of the EU-27 member states. Data were not yet available for Croatia.

Health effect related pollutants for which external costs are available and which were studied here, are ammonia ($NH_3$), nitrogen oxides ($NO_x$), sulphur dioxide ($SO_2$), fine ($PM_{2.5}$) and coarse ($PM_{2.5-10}$) particulate matter and non-methane volatile organic compounds (NMVOC) (Nijs et al., 2011). For the climate change impact we consider $CO_2$ emissions as most of the environmental impact is related to this (Ayalon et al., 2013). This study was done as part of the EU 7th Framework DATASIM project (http://www.datasim-fp7.eu/).

## Methodology

In general air pollution emissions related to electricity production and exhaust emissions for conventional ICE cars (including well-to-tank emissions (WTT) and tank-to-wheel emissions (TTW)) were calculated for each of the EU-27 countries and multiplied by the specific country's external cost per tonne of emission. An overview of major assumptions made in this calculation exercise is given in Table 1. The WTT emissions were taken into account to get a more complete picture of the emissions during the entire life cycle of the fuel. Therefore, in a final analysis also emissions related to battery production for EV have been included, corresponding to ICE's WTT emissions. Vehicle production, transportation, maintenance and end of life (EoL) were not considered because for the pollutants studied here, they are considered to be very similar for ICE and EV cars of the same market segment. When calculating the replacement of ICE cars by EV, the assumption was made that the country specific gasoline/diesel ratio was kept constant over time (EC, 2012) and that "one EV" replaces "one ICE car". The difference between external costs for electricity production dedicated to charging EV and external costs related to replacing ICE cars and avoiding their emissions gives the total benefit or loss. The analysis was performed according to the ExternE methodology developed by the European Commission (Bickel and Friedrich, 2005; Maibach et al., 2008). In ExternE, health cost estimates are based on considerations of both direct medical costs, absenteeism costs and on the willingness to pay to avoid health effects from air pollution.

## Emissions

### *Electricity production*

Air emissions resulting from electricity production depend on the fuel mix which differs by country and varies over time. For this study we have used the annual current (2010) and prospective (2030) energy mixes (EC, 2010). Nine fuel sources are

[1] www.elia.be.
[2] http://www.rte-france.com/en/.
[3] http://www.ren.pt/.
[4] http://energinet.dk/Flash/Forside/UK/index.html.
[5] http://www.bmreports.com/bsp/bsp_home.htm.
[6] http://transelectrica.ro/widget/web/tel/sen-grafic/-/SENGrafic_WAR_SENGraficportlet.