
# Electric Vehicles

## Annex A of the Handbook 'Navigating Transport NAMAs'

## TRANSfer Project – Towards climate-friendly transport technologies and measures

### The concept

Besides alternative liquid and gaseous fuels, electricity is often promoted as an environmentally-friendly and low-carbon vehicle technology. Electric motors have a well-to-wheel efficiency of 70 to 80 %, whereas combustion engines typically have only an efficiency of 15 to 25 % (Creutzig and Kammen, 2010). Electric locomotives or electric light rail systems and electric streetcars are already in common use in Europe and Asia. Many countries are trying to promote electric motors for private vehicles as well. Over the past decade, 2.5 million electric vehicles (either hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) or all electric vehicles (AEV)) have been sold worldwide. In the US, electric vehicles have a market share of 2 %. In Japan they even reach a share of 9 %. Over the last decade, electric bikes and scooters gained large market shares in China and India (IEA, 2011b).

However, the use of electricity as energy source for transport vehicles is associated not only with advantages, but also with several social, technological and infrastructural barriers and the GHG mitigation potential varies strongly depending on the technology and the local electricity production system. Therefore, the different aspects of electric vehicle use are discussed below. The information provided should enable decision-makers to carry out a first evaluation of the potential for electric vehicles in their transport system.

### Technological options

Mainly three different vehicle technology systems are available for private vehicles that use an electric motor (Vossenaar, 2010):

- **Hybrid electric vehicles (HEV):** These vehicles use an internal combustion engine running on conventional fuel and additionally have an electric motor. The electricity for the electric motor is solely gained by regenerative braking, *i.e.* the battery is charged during braking by using the motor as a generator. Thus, HEV do not use electricity as alternative fuel, but use the conventional fuels more efficiently. Thereby, the GHG emissions per kilometre travelled can be reduced by 30 % if the whole life-cycle (*i.e.* including vehicle production) is considered (Samaras and Meisterling, 2008).
- **Plug-in hybrid electric vehicles (PHEV):** In contrast to HEV, plug-in hybrid electric vehicles can be connected to an external electricity source to restore the battery in addition to regenerative braking. Thereby, external electricity can be used as an additional energy source and substitute fossil fuels for a portion of travel. As PHEV also have a large tank to store diesel or petrol, these vehicles can also be used for longer trips.
- **All electric vehicles (AEV):** Vehicles than run solely on electricity are termed "all electric vehicles", "battery electric vehicles" or just "electric vehicles". Today, the battery costs for these vehicles are very high and the driving ranges are still relatively short. For a driving range of 500 km a battery capacity of 75 kWh is necessary. This would result in battery costs of USD 35 000 to 40 000, even assuming near term reductions in battery cost. Thus, AEV are mainly suitable for short distance travel, *e.g.* in urban areas. The IEA (2011b) estimates that in the near term AEV may typically have a driving range of 100 to 150 km. Battery costs to achieve such a range would amount to USD 15 000.

In the next section, the application of AEV and PHEV, which offer a lager GHG mitigation potential by facilitating the use of external electricity, is discussed.

### The market potential for electric vehicles in transport

There are several barriers that currently inhibit a large-scale market penetration of vehicles with drive systems based on external energy supply (PHEV, AEV). These are technological/economic as well as infrastructural difficulties:

- **Battery technology:**
  AEV are still very cost-intensive, which is mainly due to high battery costs. Thus, considerable advances in battery production cost are necessary to make AEV and PHEV economic competitive. An additional barrier to the use of AEVs is the limited energy storage capacity of current batteries that lead to short driving ranges.

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- **Recharging system:**
  An additional barrier for the use of PHEVs and AEVs is the need for a dense network of charging stations with a high voltage connection. Furthermore, currently charging time for batteries is still very long and thus not acceptable for most motorists. To address this issue, currently researchers are developing battery technologies to reduce charging times. Another approach is to develop switch stations to exchange batteries rather than recharge them (Vossenaar, 2009).

### The GHG mitigation potential for external electricity use in transport

There are several factors that determine whether vehicles with drive systems based on external energy supply (PHEV, AEV) can contribute significantly to mitigate GHG emissions from transport:

- **Composition of the electricity mix:**
  The full mitigation potential from electric vehicles is only achieved if low-carbon electricity sources (*e.g.* from renewables) dominate. In many countries, the current electricity generation is very carbon-intensive, with the highest $CO_2$ emissions per kWh in India and the lowest in Latin America (IEA, 2009). Samaras and Meisterling (2008) investigate the effect of a shift to electric vehicles under the US electricity mix (*i.e.* GHG intensity of 670 $CO_2$e/kWh). It is found that life cycle GHG emissions of PHEV are 32 % lower than life cycle emissions of conventional vehicle. However, emission savings are only small compared to HEV, due to the higher emissions in battery production in PHEV. If the electricity production is mainly based on coal powered plants, the life cycle emissions of PHEV even exceed those of HEV by 9 to 18 %. If a low-carbon energy supply is available, PHEV can reduce the GHG emissions per km by up to 51 to 63 % compared to conventional vehicles and by 30 to 47 % compared to HEV. Up to zero emission can be expected from AEV if they obtain only electricity from renewables (Samaras and Meisterling, 2008).
- **GHG mitigation potential compared to other sectors:**
  Extensive market penetration of PHEV and AEV will require increases in the electricity generation. As outlined above, PHEV and AEV have the largest mitigation potential if low-carbon energy supply is available. However, the limited near term capacity to increase electricity from renewables could also be used to substitute existing fossil fuel power plants. Thus, it has to be evaluated if it is cost and energy efficient to increase the electricity production to fulfil the demand for PHEV and AEV in the transport sector or if it is preferable to enable a substitution of fossil fuel electricity in other sectors (*e.g.* industry). However, it is discussed to use overcapacities from volatile renewable energy production to recharge vehicle batteries.
- **Battery life cycle emissions:**
  It has to be considered that the resource extraction for batteries, battery production itself and its recycling cause additional GHG emissions and can lead to other severe environmental damages such as water pollution, loss of biodiversity or ozone layer depletion. Lithium-ion batteries are responsible for 2 to 5 % of the life-cycle GHG emissions of PHEV. Therefore, HEV with lower battery capacities can have a better life cycle GHG emission performance than PHEV if the country's electricity mix is very carbon intensive (Samaras and Meisterling, 2008).

### Advantages of electric vehicles

In addition to GHG savings, electric vehicles can offer the following advantages:

- Reduction in local air pollution, because AEVs do not generate any direct vehicle emissions;
- Reduction in noise pollution;
- Diversification of the transport fuel mix and consequently less dependency on oil (imports).

### Policies and measures to create a framework for electric vehicles

Decision-makers can promote market penetration of electric vehicles, but they have to ensure that these vehicles offer a sustainable GHG reduction potential over the whole fuel and vehicle life cycle.

Frankfurt Main, Germany – Photo by Jonathan Gómez, 2011

| Instruments | Intended effects |
|---|---|
| Financial rebates for electric vehicles meeting the above mentioned standards (*e.g.* subsidise electric vehicles, vehicle taxation rebates) | ■ Facilitate a market penetration of electric vehicles;<br>*Examples:*<br>■ In China, the national government provides a subsidy for electric-drive vehicles of USD 7 300;<br>■ Several states in India reduced the VAT for electric vehicles from 12.5 % to 4 % (IEA, 2011b);<br>■ In Germany, AEV and PHEV are exempt from the annual registration tax for five years; |
| Invest in electricity and recharging infrastructure | ■ To enable a country-wide use of PHEV and AEVs; |
| Support research and development (*e.g.* funding of research projects) | ■ Progress in battery technology and vehicle design; |
| Introduce low-carbon fuel standards | ■ Ensure that electric vehicles are only promoted if GHG emission can be realised (the standard has to include upstream emissions); |
| Promote renewable energy (*e.g.* via feed-in tariffs) | ■ Increase the share of low-carbon electricity production to realise GHG mitigation effects from electric vehicles. |

## Further reading


- **Creutzig, F. and Kammen D. (2010)** '*Getting the carbon out of transportation fuels*' in Schellnhuber, H. J., Molina, M., Stern, N., Huber, V. and Kadner, S. (eds) Global Sustainability – A Nobel Cause, Cambridge, New York.
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- **Samaras, C. and Meisterling, K. (2008)** '*Lifecycle Assessment of Greenhouse Gas Emissions from Plug-in Hybrid Vehicles: Implications for Policy*' Environmental Science and Technology, vol. 42, pp. 3170–3176.
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- **Walsh, M. and Kolke, R. (2005)** '*Cleaner Fuels and Vehicle Technologies*', Sourcebook Module 4a, Sustainable Urban Transport Project (SUTP), GIZ, Eschborn.


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