The Transport and Energy research group of the Karlsruhe Institute of Technology's (KIT) Institute for Industrial Production (IIP) discusses how electric vehicles can help mitigate greenhouse gas emissions

Road to climate mitigation

According to the fifth assessment report by the Intergovernmental Panel on Climate Change (IPCC), the increase in global average surface temperature is very likely due to the observed raise in anthropogenic greenhouse gas emissions. The required efforts to keep global warming below the 2°C target increase year after year (IPCC, 2015).

Currently, the transport sector is the second largest emitter of carbon dioxide (CO_2), the main anthropogenic greenhouse gas (IPCC, 2013). On the global scale, transport emissions are increasing rapidly and might catch up with those from the electricity and heat supply sector (International Energy Agency (IEA), 2015).

In 2013, transport generated more than seven gigatonnes of direct CO_2 emissions. Driven by the fast development of emerging economies, transport might have doubled its emissions by 2050 (IEA, 2015).

Decarbonising transport is deemed more challenging than the decarbonisation of other sectors. However, transport has not yet been the focus of the political agenda (*cf.* Creutzig *et al.,* 2015). One reason for this is that policy makers believe that the economy is strongly dependent on affordable mobility and fear putting their voters off.

In road transport, which is by far the main contributor of greenhouse gases in the transport sector, electric vehicles – besides non-motorised modes and public transport in urban areas – are considered the main white hope for a sustainable transport system. Even though electric vehicles do not cause direct emissions during electric operation, the climate impact associated with vehicle production (including the battery) and electricity supply is not marginal and depends on a number of conditions.

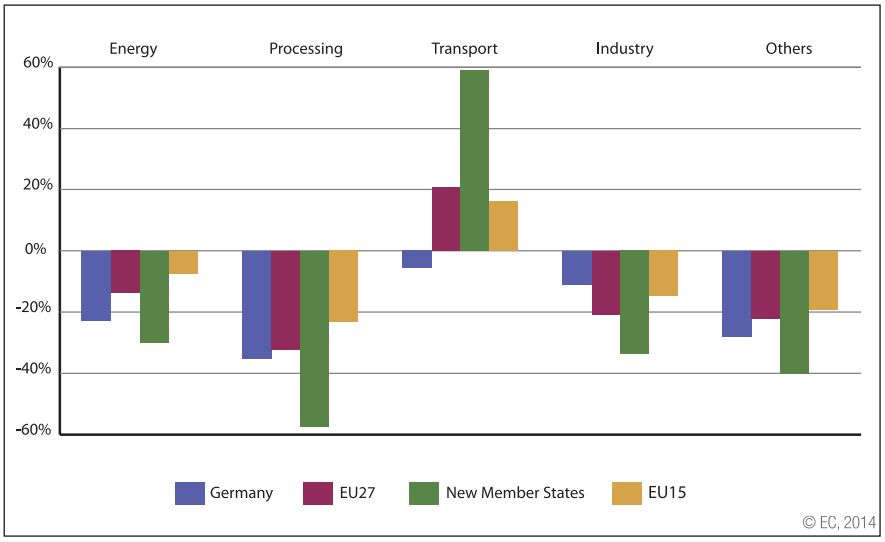

Fig. 1 Development of CO_2 emissions from 1990 to 2010 in different sectors

Energiewende

Research conducted by the research group 'Transport and Energy' at the Karlsruhe Institute of Technology (KIT) focuses on the impact of electric vehicles on the energy system.

The German electricity sector is famous for its contribution to the German energy transition – the Energiewende. German greenhouse gas emissions declined by more than 20% in the last two decades. This is due to the collapse of CO_2-intensive industry in eastern Germany, ambitious installation targets for electricity generation from renewable energy resources, efficiency gains and emission trading, etc.

The prospects of future emission reductions in the energy sector are excellent. On the European scale, the situation is rather similar in the electricity sector. In the transport sector, however, CO_2 emissions increased by about 20% between 1990 and 2010 – in the new member states this increase was almost 60% (see Fig. 1). The future trend is alarming.

Mitigation potential

There are several measures to counteract this development in the transport sector. However, they were not successful in the past and current integrated assessment models indicate no breakthrough in the future either.

According to a recent study we conducted in co-operation with the Mercator Research Institute on Global Commons and Climate Change (MCC) and other international partners, the mitigation potential of non-motorised modes, public transport and electric vehicles might be underestimated (Creutzig *et al.,* 2015). This is a promising discovery, especially because it is associated with social benefits including more convenient cities with less congestion and fewer air pollutants, and more outdoor activities leading to better physical health.

This development might even be accelerated by the upcoming mobility services for multi-modality that are presently being

analysed by KIT's Karlsruhe Service Research Institute (KSRI). Of these potential options, electric vehicles seem to be the most promising – at least in the midterm – because the user patterns hardly seem to have changed. The results of our user-acceptance analysis of electric vehicle users support our optimism that the application of electric vehicles is highly appreciated by a broad majority of test users (Ensslen *et al.,* 2015).

The results of our user-acceptance analysis of electric vehicle users support our optimism that the application of electric vehicles is highly appreciated by a broad majority

Currently, the mitigation potential of electric vehicles varies and depends mainly on the national electricity mix. While electric mobility in Sweden causes only 6g of CO_2 per kilometre today, specific emissions in other European member states are significantly worse than those of conventional vehicles. Even if a supplement of 30% on official test results for current conventional vehicles (according to ICCT, 2014) is considered, the European average for electric vehicles today amounts to about 80g CO_2 per km with a decreasing tendency.

Estimations

These values, however, do not consider the emissions from vehicle production and recycling. As global battery production is still in the developing phase, its emissions can hardly be estimated. The currently planned and constructed 'gigafactories' substantially rely on renewable energy resources – at least for their electricity consumption. Together with the decarbonisation of the electricity system, this will lead to decreasing global warming potentials of electric vehicles in lifecycle assessments.

Our current analyses show that significant greenhouse gas emission mitigation in road transport will only be possible with electric vehicles – especially after 2030, when the electricity sector will be significantly decarbonised.

Again, this potential is strongly related to the mitigation efforts in the production of vehicles and electricity supply. But even when considering the marginal electricity mix (i.e. the additional power plant to be commissioned to cover this additional electricity demand), our results reveal large future mitigation potentials (Jochem *et al.,* 2015). This is, however, still dependent on policy measures in the energy and transport sector (Kieckhäfer *et al.,* 2015). Our results also show that electric vehicles might soon pick up speed in key markets (Gomez Vilchez *et al.,* 2014) and it is not yet evident who will take the industrial lead.

The research group mainly analyses how electric vehicles contribute to a more sustainable and decentralised electricity system. We found that the long parking times of vehicles and the corresponding high load shift potentials of electric vehicles by postponed charging may be exploited for a more flexible electricity demand (Babrowski *et al.,* 2014). This will improve the integration of more renewable energy sources into the energy system on the European, national and decentralised levels.

Momentous effect

Particularly at the decentralised level, our studies have revealed the momentous effect that electric vehicles can have on the profitability of different electricity generation technologies such as combined heat and power (CHP) units, wind and photovoltaic (PV) systems and, in particular, domestic PV systems in combination with stationary storage systems.

References

Babrowski, S., H. Heinrichs, P. Jochem, W. Fichtner (2014), Load shift potential of electric vehicles in Europe: chances and limits, *Journal of Power Sources* 255, 283-293, doi: 10.1016/j.jpowsour.2014.01.019.

Creutzig, F., P. Jochem, O.Y. Edelenbosch, L. Mattauch, D.P.v. Vuuren, D. McCollum, J. Minx (2015), Transport – a roadblock to climate change mitigation?, *Science* (Policy Forum), 350 (6263), 911–912.

EC (European Commission) (2014), *Eurostat database,* http://ec.europa.eu/eurostat/data/database.

Ensslen, A., A.G. Paetz, S. Babrowski, P. Jochem, W. Fichtner (2015), On the road to an electric mobility mass market - How can early adopters be characterized?. In: Fornahl, D. & Hülsmann, M. (Eds.), *Markets and Policy Measures in the Evolution of Electric Mobility. Lecture Notes in Mobility,* Berlin. doi: 10.1007/978-3-319-24229-3.

Gomez Vilchez, J.J., P. Jochem, W. Fichtner (2014), Car Technology Scenarios using System Dynamics: Exploring Market Penetration and Energy Consumption in China, Germany and US, *5th Annual PhD Colloquium of the 2014 International System Dynamics Conference,* Delft, Netherlands.

ICCT (International Council on Clean Transportation) (2014), From Laboratory to Road: A 2014 Update of Official and "Real-World" Fuel Consumption and CO_2 Values for Passenger Cars in Europe, Berlin, http://www.theicct.org/sites/default/files/publications/ICCT_LaboratoryToRoad_2014_Report_English.pdf. Accessed 21 February 2016.

IEA (International Energy Agency) (2015), *CO_2 Emissions from Fuel Combustion 2015,* Paris.

IPCC (Intergovernmental Panel on Climate Change) (2015), *Climate Change 2014 – Mitigation of Climate Change,* Cambridge.

IPCC (Intergovernmental Panel on Climate Change) (2013), *Climate Change 2013 – The Physical Science Basis,* Cambridge.

Jochem, P., S. Babrowski, W. Fichtner (2015), Assessing CO_2 Emissions of Electric Vehicles in Germany in 2030, *Transportation Research A: Policy and Practice* 78, 68-83, doi: 10.1016/j.tra.2015.05.007.

Kaschub, T., P. Jochem, W. Fichtner (2013), Interdependencies of Home Energy Storage between Electric Vehicle and Stationary Battery, *World Electric Vehicle Journal* 6(4), 1144-1150.

Kieckhäfer, K., V. Feld, P. Jochem, K. Wachter, T.S. Spengler, G. Walther, W. Fichtner (2015), Prospects for regulating the CO_2 Emissions from Passenger Cars within the European Union after 2023, *Zeitschrift für Umweltpolitik & Umweltrecht* 38(4), 425-450.

In the latter case, the effect is twofold. Firstly, electric vehicles increase the flexible electricity demand, which directly influences the profitability of the system. Secondly, an increased market volume of electric vehicles leads to decreasing battery prices (by economies of scales), which indirectly increases the attractiveness of the PV storage systems that are based on the same battery technology.

In Germany, the market success of these systems is already significant due to high residential electricity prices. A profitable application in households with high self-generation rates is already a reality even without subsidies (Kaschub *et al.,* 2013). We therefore expect a considerable market share in the near future. Our results are based on different methods (e.g. energy system modelling, agent-based simulation, system dynamics, econometric analysis, optimisation techniques and user-acceptance analysis).

Synergy

So; these synergies with the energy system, the high user-acceptance due to advanced driving experience, the energy efficiency of about 75%, a high availability of simple charging facilities (e.g. domestic sockets) and the fast decrease in battery prices combine to make electric vehicles very convincing for a sustainable road transport system. New concepts such as autonomous driving and car sharing also have synergies with this electrification of road transport.

In our opinion, electric vehicles (including buses and two-wheelers) are thus one important cornerstone to avoid the forecasted doubling of CO_2 emissions in the global transport sector.

HORIZON 2020

PD Dr Patrick Jochem
Transport and Energy group

jochem@kit.edu

Professor Dr Wolf Fichtner
Chair for Energy Economics
Karlsruhe Institute of Technology (KIT)

+49 721 608-44590

www.iip.kit.edu