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# New FVV meta-analysis of LCA Studies on Alternative Powertrain Technologies

## Taking stock



*Life cycle analyses (LCA) provide information on how climate-friendly new powertrain technologies really are. A new meta-analysis by the FVV Research Association for Internal Combustion Engines, conducted by Frontier Economics, analyses existing life cycle studies from the last 15 years. A supplementary paper derives central recommendations for drafting future climate protection regulations and guidelines: they should be economically efficient, cross-sectoral, open to technologies, global and long term in nature.*

*The study shows that in a global energy and carbon system, various technology options are available from a climate perspective. There is not one single solution for CO<sub>2</sub> neutrality in the mobility sector. The key to sustainable mobility lies in fair technology competition and the defossilisation of energy production.*

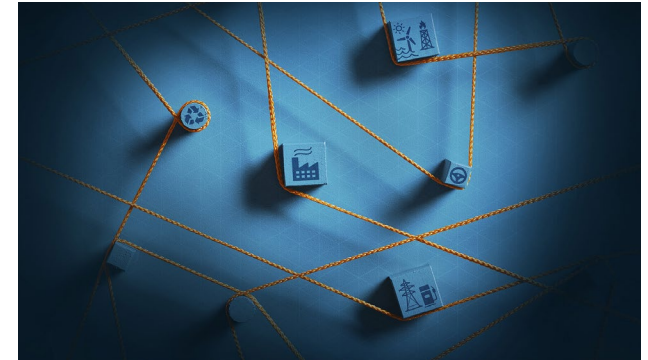
*Text: Petra Tutsch & Johannes Winterhagen*

*Illustrations: Frontier Economics*

### CO<sub>2</sub> targets must consider the entire life cycle

**Electric vehicles (BEV), hydrogen fuel cells (FCEV) and the use of synthetic fuels in internal combustion engines (ICEV):** Various technologies and fuels are currently being discussed in order to significantly reduce harmful CO<sub>2</sub> emissions from road transport. From a scientific point of view, not only the direct emissions during **operation** must be taken into account, but also those greenhouse gases that are **emitted during the production** of the vehicles, the **generation of the energy sources/fuels**, their **distribution** and, last but not least, **recycling** at the end of the vehicle's life. The method of life cycle assessment, usually abbreviated as LCA, has established itself as a means of producing a conclusive overall balance sheet. One challenge here is that the results of LCA studies depend heavily on the assumptions made.

In a **meta-analysis**, the specialist consultancy **Frontier Economics on behalf of the FVV** has now **evaluated for the first time more than 80 individual studies from the past 15 years**, which consider a total of 110 different scenarios and 430 individual analyses. In order to ensure comparability, the results of all studies were standardised to a compact passenger car with a total mileage of 150,000 kilometres.



**CONCLUSION:** Calculated in this way, there is a relatively narrow band of total emissions over the lifetime of all combinations of powertrains and energy sources/alternative fuels. The average value over all studies ranges from 25 to 35 tonnes of CO<sub>2</sub> per vehicle, provided that fossil fuels are still used proportionately for the production of **electricity, hydrogen** or **synthetic fuels**. If, on the other hand, only regeneratively produced energy sources are used in operation, the average value is between nine and 16 tonnes of CO<sub>2</sub> for the entire service life of the vehicle. The remaining emissions then result mainly from the production of the vehicles, the production facilities and the infrastructure for the distribution of the energy sources.

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### Life cycle emissions from current energy sources



*If cars are powered by fossil fuels, with electricity from the current energy mix or with conventionally generated hydrogen, battery electric vehicles and internal combustion engine vehicles have comparable life cycle emissions.*

### Life cycle emissions when using 100% renewable energy for operation



*If only renewable energy carriers are used during operation, a vehicle powered by synthetic fuels may even have lower CO<sub>2</sub> emissions than a battery electric vehicle. There is still room for optimisation of the fuel cell.*

### There is no clear winning technology

"There is no clear winning technology," summarises Dr David Bothe, Associate Director at Frontier Economics and author of the study.

For example, in none of the studies the GHG emissions resulting from the installation of the energy infrastructure were calculated down to individual vehicles. In addition, there are fewer than average results available on the influence of recycling - which can certainly improve the CO<sub>2</sub> emissions of battery

production, for example - and the results, moreover, scatter widely. While vehicles with battery electric drives or conventional internal combustion engines were considered in almost all studies, only a quarter of all studies make statements on the overall balance of plug-in hybrid vehicles, which are expected to achieve a significant market share in the 2020s. Fuel cell passenger cars are also only included in 22 studies. Valid results for the use of synthetic fuels are almost completely missing.

"In addition, no one has yet investigated where mobility today, despite its harmful impact, may also contribute to climate protection," says Bothe. "For example, the rotor blades of a wind power plant are transported to their location by heavy-duty fossil-fuelled commercial vehicles across the country. In the electricity sector, these plants then avoid emissions. We find such cross-sectoral effects in many places in the economy".

**CONCLUSION:** Despite the considerable uncertainties, a general statement can be made: **Only a valid life-cycle analysis allows an objective assessment of technological options. All technology options that provide comparable CO<sub>2</sub> benefits should be equally supported and promoted.**

**The mobility of the future requires diversity: The intelligent mix of alternative powertrains and fuels is what counts**

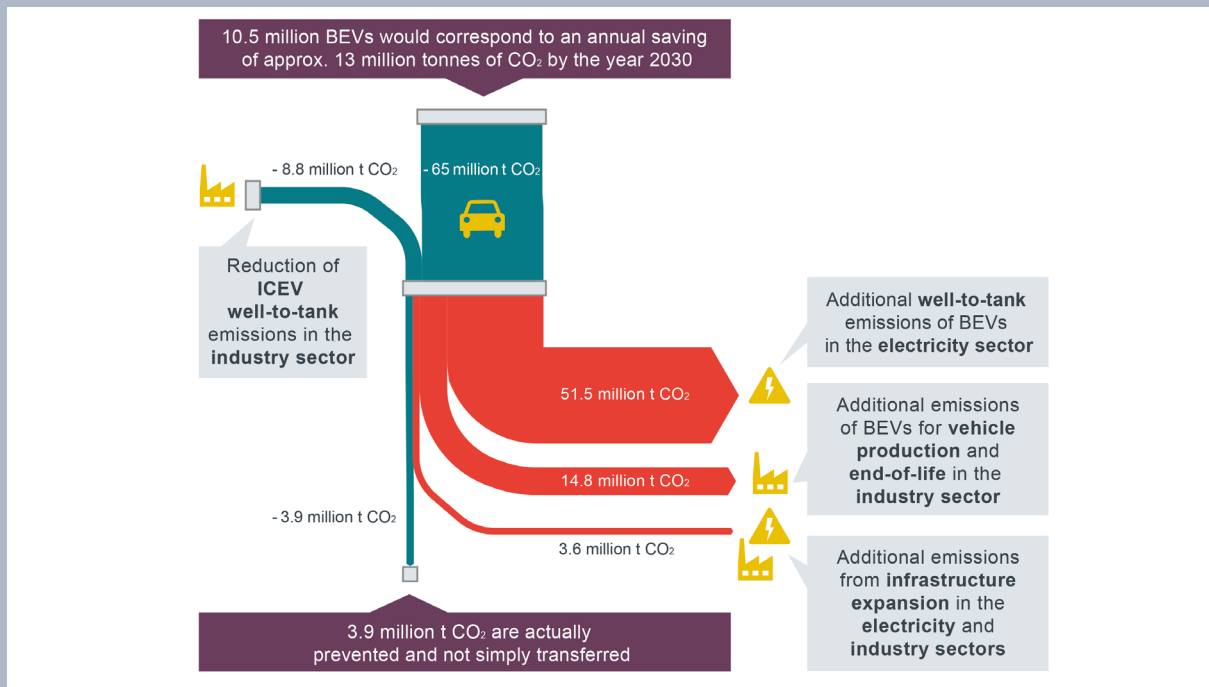
**In particular, it is important to avoid that the emissions from operations allocated to the transport sector are reduced by allocating additional emissions to the energy or industrial sector.** Using a sample calculation, the study points out that if electric mobility were to be introduced on a broad scale without accompanying measures, 90 percent of the cumulative CO<sub>2</sub> savings from individual mobility could reappear in

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### Impact of electric vehicles on the cross-sector CO<sub>2</sub> residual budget



*If we assume that electromobility is ramped up evenly throughout the 2020s, this would result in a total saving of 65 million tonnes of CO<sub>2</sub> in vehicle operations. This would be boosted by savings of a further 8.8 million tonnes of CO<sub>2</sub>, which would otherwise have been generated through the production of petrol and diesel fuels for vehicles with internal combustion engines. Even if the share of green electricity continued to increase, the emissions in the energy sector would rise by 51.1 million tonnes in this scenario. The higher amount of energy expended in vehicle production would result in additional CO<sub>2</sub> emissions of 14.8 million tonnes in the industrial sector. Furthermore, the increased electricity requirement would necessitate additional investments in the infrastructure of the energy and industry sectors. It is possible to save more CO<sub>2</sub> per vehicle if the framework conditions are modified, for example if only green electricity is used for operation.*

other sectors and regions by 2030, and would therefore be of little benefit to climate protection.

The goal is clear: By 2050, road transport is to become climate-neutral. When determining which paths to follow to achieve this goal, one should also bear in mind the time dimension of one-off events, such as a narrow focus on a sector-specific annual target: Large one-off emissions could lead to an increase in emissions in other years and/or sectors and the total CO<sub>2</sub> budget calculated by the Intergovernmental Panel on Climate Change (IPCC) could be exceeded.

### Research must be technology-neutral, too

**FVV Managing Director Dietmar Goericke** sums up: "From an academic point of view, the results of the study first of all simply mean: **We need more data and more detailed research as a basis for valid political decisions. To do this, we need to keep research open to any new technologies.**" Carbon-neutral as well as near zero emission mobility and energy conversion are priority topics of the pre-competitive industrial collective research in the FVV.

**Technology neutrality is essential for a cost-efficient and effective use of current technology options.** This is the conclusion reached in the second short report of the Working Group 2 on A alternative

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drive / powertrain technologies and fuels for sustainable mobility of the National Platform »Future of Mobility« (NPM), which was presented in Berlin on 8 June. The main focus of the investigations of WG 2, which is co-chaired by **Prof Dr Peter Gutzmer, President of the FVV**, was the comprehensive evaluation of the CO<sub>2</sub> effect of electric mobility concepts, hydrogen and fuel cells, as well as biomass- and electricity-based fuels for climate protection under the current framework conditions. Used appropriately, these technological options could specifically contribute to CO<sub>2</sub> reduction. The prerequisites for carbon-neutral mobility are openness in technology and the accelerated expansion of renewable energies in Germany.

### Life-cycle emissions in a global energy and carbon system

A **life-cycle assessment** (LCA) takes into account all environmental impacts during the product life cycle. These include in particular production, including materials and components, the service life, disposal and recycling. If the assessment is restricted to a specific phase of the life cycle, such as the service life of a vehicle, it is possible that technologies which do not lead to emission savings in the overall assessment may also have a good balance sheet. Therefore, there is no way around a comprehensive analysis that covers all emissions over the entire life cycle of a technology.

Besides

- the operation of a vehicle (Tank-to-Wheel)

this includes in particular

- the manufacture of the vehicle (cradle-to-gate)
- the generation and supply of the drive energy (well-to-tank)
- the construction and operation of the necessary transport networks (roads, railways and waterways) and supply and disposal facilities (infrastructure)
- the vehicle's recycling to recover raw materials (end-of-life).

The **global CO<sub>2</sub> budget** of the Intergovernmental Panel on Climate Change (IPCC), also known as carbon budget or emissions budget, refers to the amount of CO<sub>2</sub> emissions from anthropogenic sources that have been released or can still be released since the beginning of industrialisation in order to avoid global warming beyond a defined limit with a certain probability.

The global CO<sub>2</sub> budget in the sense of a **residual amount** of remaining emissions that can still be emitted into the atmosphere comprises the cumulative total of all greenhouse gases emitted worldwide. For effective climate protection, the cumulative amount of greenhouse gases emitted must be limited. To achieve this, the entire energy industry must be completely decarbonised (closed carbon cycle with net zero emissions). The decisive factor for the extent of climate change is therefore not the current emission of greenhouse gases, as is often wrongly assumed, but the total amount of emissions that will occur over time.

On the basis of the Paris Climate Protection Agreement, Germany and the European Union have set themselves the ambitious goal of reducing greenhouse gas emissions (CO<sub>2</sub>-eq, CO<sub>2</sub>) by 80-95 % by 2050 compared to 1990. Accordingly, the German government's Climate Protection Plan 2050 includes an **interim target for 2030**. By then, CO<sub>2</sub> emissions should be at least 55% below the 1990 level. This target has been broken down

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into individual targets for the energy, buildings, transport, industry, agriculture, forestry and land use sectors.

### CONCLUSION:

- **All measures taken to reduce CO<sub>2</sub> emissions in the individual sectors must be based on how effective they are in making efficient use of the CO<sub>2</sub> residual budget.**
- **In order to be able to evaluate technologies meaningfully with regard to climate and sustainability aspects, all direct and indirect effects from all upstream and downstream stages of the value chain must be taken into account.**
- **For a sustainable technology selection a comprehensive cross-sectoral, global and inter-temporal life cycle analysis is required.**

### Frontier Economics | Die Autoren der Studie

**Dr David Bothe** | Associate Director at Frontier Economics with over 15 years of experience in the energy and transport sectors. Co-founder of Frontier's automotive expert-group. Advises European companies, associations and authorities on economic, regulatory, strategic and competition topics.

Has recently been working intensively on the impact of the green energy transition and climate targets on the energy and mobility markets – including on how to achieve the German climate targets and how this will change the economic environment for individual mobility.

Has led various projects on possible technology options for sector coupling, including the use of hydrogen and CO<sub>2</sub>-neutral gases in the heating and transport sector or the import of synthetic fuels obtained through Power-to-X technologies.

Joined Frontier Economics in 2009. Prior to that, worked as a researcher and consultant at the Institute of Energy Economics (EWI) in Cologne. Lectured on energy and environmental economics and holds a PhD in Economics from the University of Cologne.

**Theresa Steinfert** | Consultant at Frontier Economics. Advises on strategic, regulatory and policy issues in the energy and transport sectors. Has recently focussed on life-cycle analyses, integration of renewable energies and sector coupling technologies and climate protection tools.

Joined Frontier Economics in 2015. Holds a MSc in Economics from Mannheim University and a BSc in International Economics from Maastricht University.

**Frontier Economics Limited** is a specialist economics consultancy that uses economic principles and tools to provide practical solutions to complex problems. Frontier was founded in 1999 and, now with over 250 permanent consulting staff in London, Berlin, Brussels, Cologne, Dublin, Madrid and Paris, is one of the largest specialist economic consulting firms in Europe and works for many of the major companies and most important policymakers around the world.

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### Zero-Impact Emissions Mobility & Energy Conversion | FVV Guidance Studies

**1 | Research Association for Combustion Engines (FVV): Efficient use of the global CO<sub>2</sub> budget in the mobility sector - Four theories based on a meta-study on life-cycle analyses** (Executive Summary | Thesis). Frankfurt/M., 2020

**2 | Research Association for Combustion Engines (FVV): Cradle-to-Grave Life-Cycle Assessment in the Mobility Sector - A Meta-Analysis of LCA Studies on Alternative Powertrain Technologies** (Full Version | Expert Paper). Issue R595 | Frankfurt/M., 2020

*Climate protection in the mobility sector needs a sustainable approach. This is the conclusion from a new meta-analysis on cradle-to-grave life-cycle assessments on alternative powertrain technologies jointly performed by FVV and Frontier Economics. In order to make a good choice among available technological alternatives, it is essential to provide policy makers, industry and consumers with robust and reliable data material. For this new analysis more than 80 studies from the last 15 years have been identified and reviewed that examine the life-cycle CO<sub>2</sub> impact of vehicles and powertrains. From a climate perspective, no single technology came out on top. Zero-impact emissions and climate neutrality by 2050 require a technology-open, cross-sectoral, global and intertemporal approach.*

**3 | Research Association for Combustion Engines (FVV): Energy paths for road transport in the future: Options for climate-neutral mobility in 2050** (Executive Summary | Information Paper). Frankfurt/M., 2018

**4 | Research Association for Combustion Engines (FVV): Defossilizing the transportation sector - Options and requirements for Germany** (Full Version | Expert Paper). Issue R586, Frankfurt am Main, 2018

*Road traffic is to be virtually climate-neutral by 2050. However, this goal can only be achieved if renewable energies are used in the transport sector. A working group at the Research Association for Combustion Engines (FVV) has therefore analyzed various energy paths. The resulting study examines the use of electricity, hydrogen and synthetic e-fuels as energy sources in road transport, taking both technical and economic factors into consideration.*

**Further studies on zero-impact emissions and alternative fuels as well as on openness in technology by society are currently in progress.**

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Research Association for Combustion Engines (FVV) eV  
 Lyoner Strasse 18  
 60528 Frankfurt / M., Germany  
 T +49 69 6603 1457  
 F +49 69 6603 2457  
 tutsch@fvv-net.de

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