The future role of synthetic fuels in German road transport – estimation of potential fuel demand using technology-based scenario analyses

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Abstract

The reduction of CO_2 emissions from road transport in Germany has been minimal, with only a 6 percent decrease since 1990. However, the national aim is to eliminate greenhouse gas emissions by 2045. This paper outlines a scenario model that estimates the adoption of alternative drive systems and energy sources in the car and truck sector, as well as the resulting energy demand in Germany until 2050. The findings indicate that battery electric vehicles will rapidly become the norm in all scenarios, although even with stricter CO_2 fleet regulations, the German government's climate goals may not be reached without additional measures. The use of climate-neutral synthetic fuels, in combination with other transportation policy instruments, could help to attain the CO_2 sector targets for German transportation.

Key words
alternative fuel; energy consumption; passenger vehicle; freight transport; market development

Introduction

Greenhouse gas emissions from German road transport accumulate to more than 145 Mio. t CO_2-eq in 2021, with 92 % of final energy consumption still based on fossil fuels such as petrol and diesel [1,2]. In order to achieve the German climate targets in the transport sector of max. 85 Mio. t CO_2-eq in 2030 as well as net climate neutrality in 2045 [3], the use of fossil fuels must therefore be gradually replaced. This requires technological solutions such as the use of zero-emission vehicles or synthetic fuels. Synthetic fuels as an option for defossilisation offer the advantage of storing energy at the same high density as fossil fuels, allowing vehicles to travel long distances and can ideally still be used in the existing infrastructure.

Methodology

Within the project BEniVer (Begleitforschung Energiewende im Verkehr) different climate neutrality scenarios of the German passenger car and commercial vehicle market were developed within our Vehicle Technology Scenario Model (VECTOR21, [4]). Focussing on three main technological pathways to a climate neutral transport sector namely Power-to-X (PtX), green Hydrogen (H2) and direct electrification (DEL). Basic differences between the scenarios are higher drop-in shares for e-fuels in the PtX-scenario and faster cost degression of batteries and fuel cell components as well as accelerated infrastructure development in the DEL- and H2-scenario (Figure 1, [5]). As a result of these assumed technology and policy developments, the agent-based model VECTOR21 estimates the future market potential of passenger vehicles and trucks of all relevant powertrains currently on the market (e.g. gasoline and diesel; plug-in hybrid, battery electric, hydrogen) and different vehicle segments.

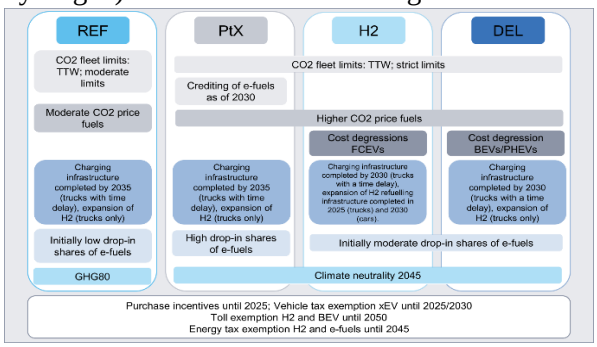

Figure 1: Overview of the most important assumptions of the car and truck scenarios in VECTOR21

Based on the possible developments of the new car markets the VECTOR21 stock model can be used to model Germany's future car and truck stock until 2050. Then, for this stock, the CO_2 emissions of the German road transport can be estimated with the help of the specific energy consumption, the assumed mileage for car and truck traffic and the emission factors. As the passenger car sector accounts for around 60 % of all transport emissions [2], only the passenger car sector is discussed in the following as an example.

Exemplary Results

Figure 2 shows the simulated market potential for alternative drive systems of new passenger vehicle registrations in Germany up to 2050 for the PtX scenario.

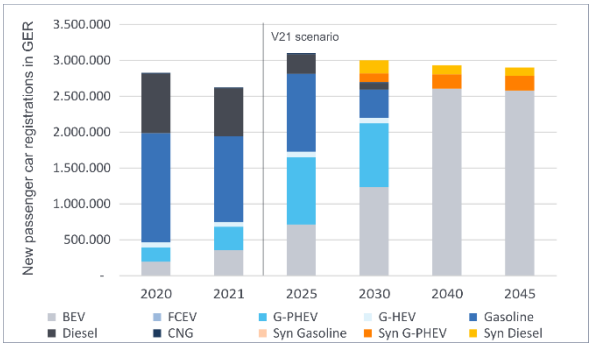

Figure 2: Simulated market potentials for alternative drive systems of new passenger vehicle registrations in Germany up to 2050 (BEniVer PtX scenario)

It can be seen that due to the stricter CO_2 fleet limits in the future, new registrations of electrified vehicles will increase significantly. According to the assumptions in the PtX scenario, from 2030 onwards manufactures will be able to count vehicles with combustion engines as zero-emission vehicles when balancing their fleet limits (up to 10% of the vehicles sold), if they can prove that they are operated with synthetic fuels over their lifetime (e.g. by acquiring certificates). After the CO_2 fleet emissions of new registrations have to be reduced by 100 % in 2035, only battery-electric vehicles or vehicles that are demonstrably powered by e-fuels will be permitted.

Since the share of vehicles with internal combustion engines (ICEV) is higher in the PtX scenario than in the other technology scenarios, the PtX scenario results in the highest tank-to-wheel energy demand due to the lower efficiency of the combustion engine, as exemplified for the passenger car sector in Figure 3.

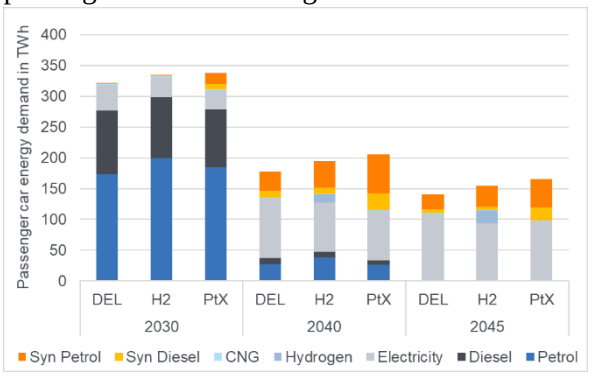

Figure 3: German TTW energy demand in the passenger car sector in different BEniVer scenarios

In general, it can be said that the energy demand will be reduced by more than half by 2045 mainly due to the increased penetration of battery electric vehicles. The same trend can be observed in the truck sector and is described in [5] and [6].

Conclusions

The results of the study show that electric vehicles will dominate the passenger car and truck sector in the future. The drivers for this are, among others, current plans for the design of future CO_2 fleet limits, which were considered in the scenario assumptions. However, due to the long residence time of some vehicles, even in the most optimistic scenario and despite the sales ban on ICEVs in 2035 that has been considered, there will still be vehicles with internal combustion engines in the stock in 2045. Resulting in a possible fuel demand of up to 12.1 million tonns of petrol and diesel as shown in Figure 4. This fuel demand would have to be completely replaced by defossilized fuels by then in order to achieve the German government's goal of climate neutrality this year.

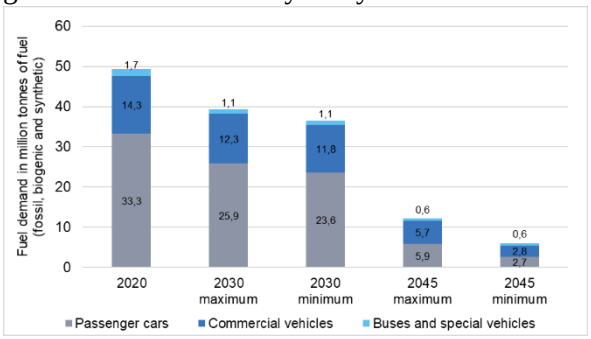

Figure 5: Annual fuel demand of road transport sectors in Germany according to BEniVer scenarios

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