Pathways for decarbonizing the road transport sector – the example of Germany

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Overview

In order to achieve a transformation to a long-term low-carbon economy, the European Union has set climate and energy targets to reduce greenhouse gas (GHG) emissions as well as increase the share of renewable energy generation (RES). However, it is not uncommon for member states to define their own climate and energy targets, which then become embedded in this European framework. For example, the German government announced ambitious goals in its Energy Concept aimed not only to decarbonize the energy sector as a whole but also to transform specific sectors. The sector-specific renewable target for the electricity sector, in particular, has helped to trigger the rapid growth in renewable generation seen in Germany over the past several years. As a result, the transformation of the electricity sector has greatly contributed to reducing national GHG emissions.

While several other sectors have jumped on the bandwagon, not every sector has committed to decarbonization. In fact, the amount of carbon emissions emitted in the German road transport sector has remained constant since 2005 at 150 million tons of CO_2-eq per year. Although the Energy Concept mandates a 40% reduction in final energy consumption for the transport sector by 2050, there appears to have been little to no restriction on GHG emissions for this sector over the past decades. More recently, however, initiatives have been taken to instigate an energy transformation in the transport sector, including a sector-specific decarbonization target in the 2016 “Klimaschutzplan”. In addition, technological advances in battery storage and electric vehicles have led to increased interest in zero-emission vehicles and a growing demand for alternatives to gasoline and diesel fuels. Production of synthetic gases and liquids via power to gas and power to fuel is one such alternative, capable of not only supplying ‘carbon-neutral’ fuels for the transport sector but also providing flexibility to the electricity sector.

With sector-specific targets being defined and new technologies entering the market, it becomes increasingly important to understand the economic impacts of decarbonizing the road transport sector in Germany. Moreover, interdependencies between sectors due to electrification or gas-applications in transportation may lead to distribution effects, which may impact the overall transformation to a long-term low-carbon economy. The study at hand seeks to address these issues by examining multiple pathways for decarbonizing the German road transport sector.

Methods

Our study seeks to address these issues by examining multiple pathways for decarbonizing the German road transport sector. Using a large-scale linear investment and dispatch model combining the European electricity, heat and road transport sector, four different scenarios are examined for the passenger, light-duty and heavy-duty vehicle segments (see Table 1 below for the Scenario Matrix).[1] In particular, the effect on the long-term vehicle mix in Germany under a sector-specific CO_2-cap—as is currently being discussed by the German government—is compared to the results when only a fleet target (in g CO_2/km)

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In modelling the road transport sector, a wide range of assumptions must be made and a large dataset is required. Technological advancements, such as heavy-duty vehicles that run on liquid hydrogen, are expected to be a long-term solution. The model accounts for this by defining vintage classes for each vehicle technology that show improved techno-economical characteristics as well as exogenously defining a start year, when the technology is allowed to first enter the market.

on new vehicle registrations is introduced—as the European Commission has already done for years. The model will yield the cost-optimal solution under each of these regulatory schemes, minimizing the total costs of the electricity and heating sectors as well as the total costs for the vehicles, fuel use and infrastructure needed to reach the CO_2 reduction goals. At the same time, the need for investments in infrastructure for new vehicles will be reexamined. In other words, in two scenarios, the model will assume that the necessary infrastructure for low- or zero-emission vehicles will be available and does not affect the model's investment decisions. This should simulate a policy in which the German government provides financial support by investing in the infrastructure for an alternative vehicle technology.

Scenario	European CO_2-Cap	National CO_2-caps in road transport sector?	Fleet target for new registrations?	Infrastructure support?	Time Horizon	Spatial Resolution
Scenario I	Yes	Yes	No	No	2050	Europe
Scenario II	Yes	No	Yes	No	2050	Europe
Scenario III	Yes	Yes	No	Yes	2050	Europe
Scenario IV	Yes	No	Yes	Yes	2050	Europe

Table 1: Scenario Matrix

Results

We find cost-efficient electricity generation portfolios (installed capacity, generation) given German and European decarbonization targets. Specifically, coal capacity in Germany is subsequently replaced by renewable energies and gas. The European framework allows for the determination of electricity exchange among EU member states. While Germany remains a net electricity exporter until 2020, this trend is reversed from 2030 onwards.

Next to the electricity generation portfolio, our results include the cost-optimal power to gas and power to fuel capacities to serve the fuel demand of a subsequently decarbonized road transport sector. The resulting increase in electricity consumption is thereby quantified and is found to counterbalance the reduction in electricity consumption due to energy efficiency projections in the base demand (excluding E-Mobility and power to x). Finally, our main findings include a prominent role for gas engines and electric vehicles for passenger cars, while heavy-duty vehicles are mainly decarbonized via liquefied hydrogen fuel cell trucks and power to fuel synthetic diesel. Interestingly, our results indicate that heavy-duty trucks are the driving force for the application of power-to-x technologies, mainly due to long driving distances and high fuel consumption.

Conclusions

The European Union has set climate and energy targets to reduce greenhouse gas (GHG) emissions as well as increase the share of renewable energy generation (RES) in order to achieve a transformation to a long-term low-carbon economy. The study at hand examines multiple welfare-optimal pathways for decarbonizing the German road transport sector, taking into account EU and German energy policies.

The results show that generation capacities will shift to favor renewable and gas generation, which eventually replace coal capacity in Germany. The decarbonization targets for the road transport sector trigger an increase in cost-optimal power to gas and power to fuel capacity that is capable of providing cross-sectoral flexibility and replacing conventional fuels. For passenger cars, gas engines and electric vehicles become increasingly important, while heavy-duty vehicles are mainly powered by liquefied hydrogen fuel cells or power-to-fuel diesel. In the case of the CO_2 fleet target, investments in FCEV and BEVs dominate in the short term. Nevertheless, under a g CO_2/km fleet target, almost twice as many CO_2-emissions are emitted in the road transport sector in Germany in 2050. In addition, under both a fleet target and a CO_2-cap, emissions are reduced in 2050 if infrastructure support is provided.

By constructing different pathways for the decarbonization of the road transport sector, we are able to compare politically-motivated pathways with a reference case. Such a comparison may be beneficial for researchers, professionals and policy makers alike.