EVS35
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Fraunhofer

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» Pathways to carbon-free transport in Germany until 2050

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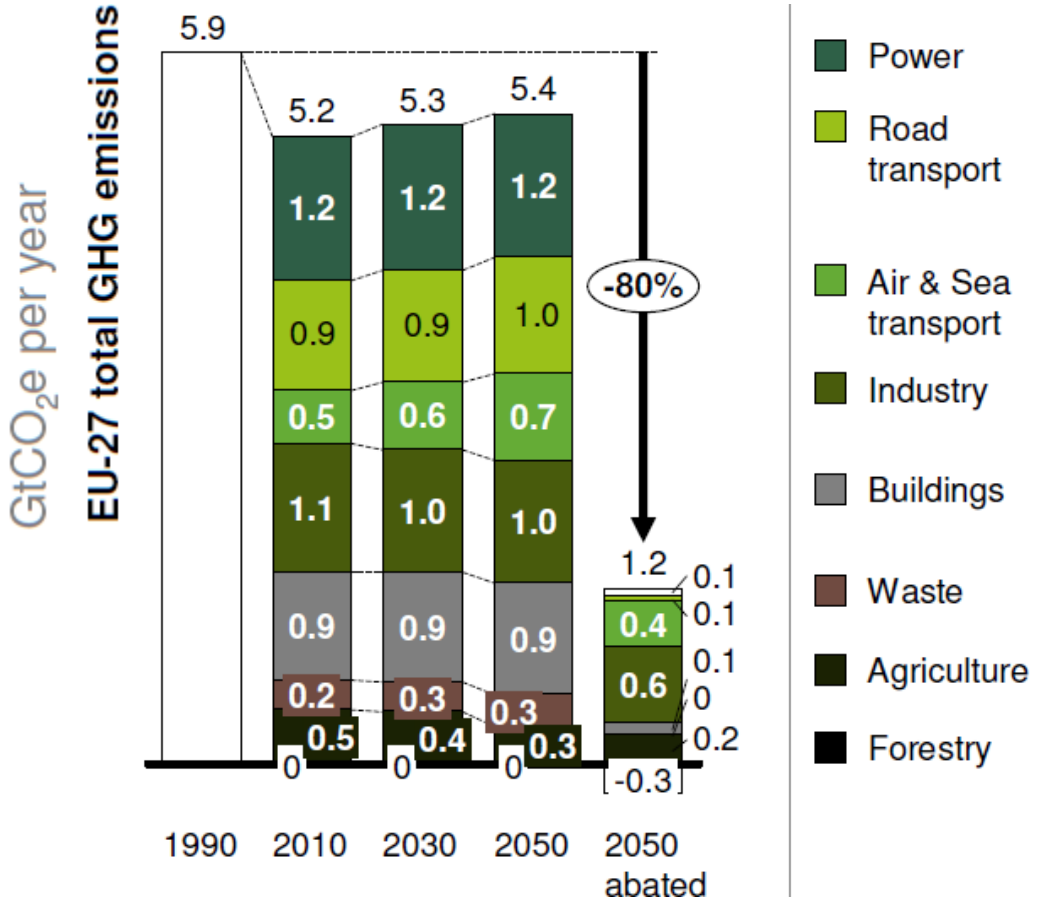
To achieve Europe‘s climate targets, a drastic reduction in transport CO_2 emissions is needed



- The EU‘s long term goal is to reduce GHG emissions by 80% until 2050
- **Germany** wants to be **carbon neutral in 2045**
- Power production and road transport have to become almost CO_2 free
- This is **impossible with** efficiency gains in **combustion engines**
- New technologies and concepts are clearly needed.
- **Electric vehicles powered by renewable energies** can contribute significantly

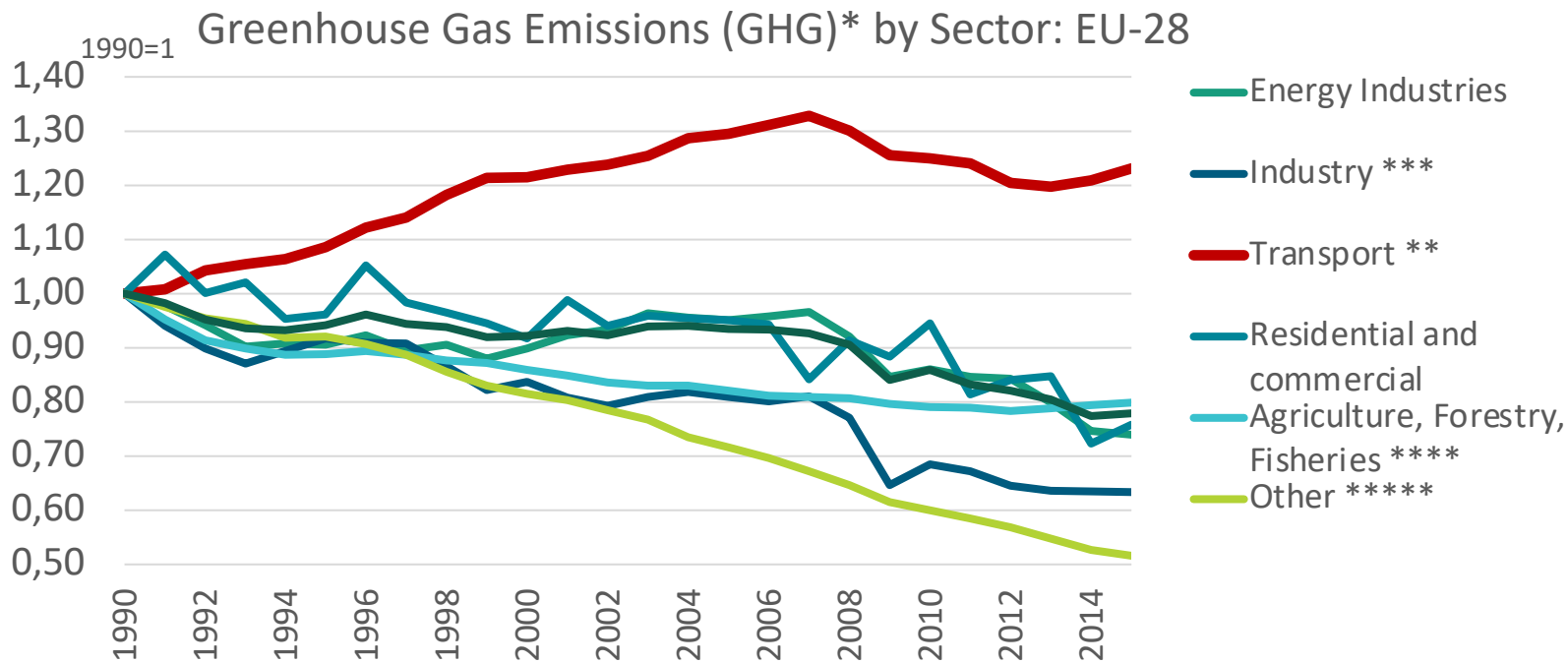
Source: www.roadmap2050.eu

Energy consumption and GHG emissions in transport have been growing though.

Transport is the only GHG sector with growing emissions!

All efficiency increase has been overturned by increased activity (usage)

Both passenger and freight transport are expected to grow further.



Research questions:

How can the different transport modes change to alternative fuels in 2050?

How much renewable eletricity do we need?

Source: European Environment Agency (EEA), June 2017

* Excluding LULUCF (Land Use, Land – Use Change and Forestry) emissions and international maritime, including international aviation and indirect CO2

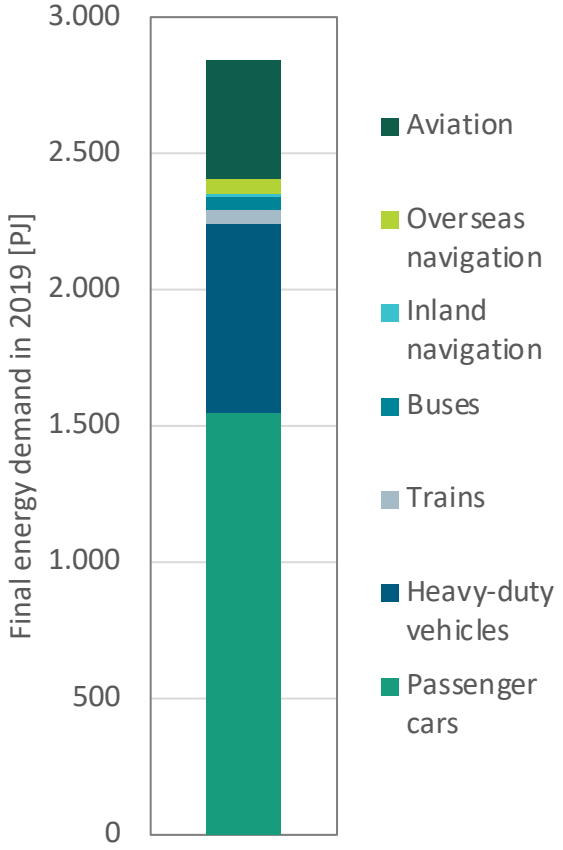
** Excluding international maritime (international traffic departing from the EU), including international aviation

*** Emissions from Manufacturing and Construction, Industrial Processes and Product Use

**** Emissions from Fuel Combustion and other Emissions from Agriculture

***** Emissions from Fuel Combustion in Other (Not elsewhere specified), Fugitive Emissions from Fuels, Waste, Indirect CO2 and Other

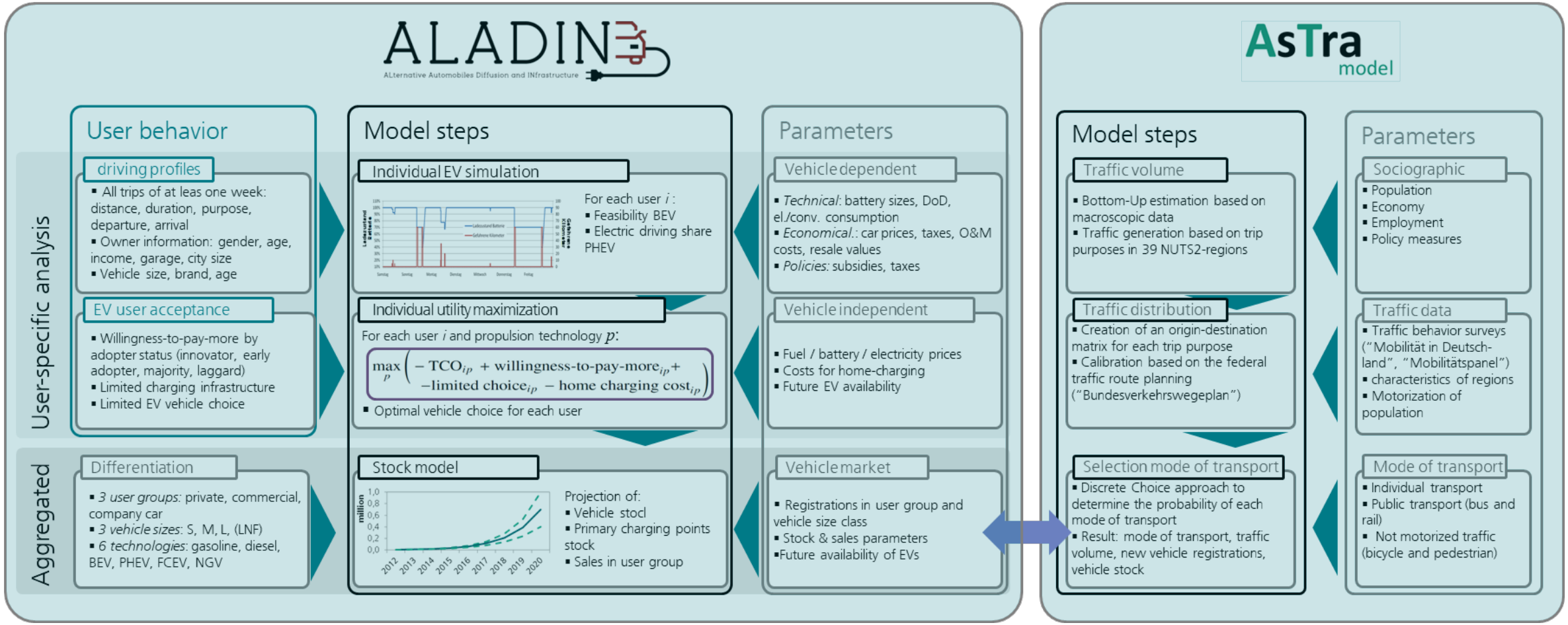
The most important transport modes to address are passenger cars, heavy-duty trucks and aviation.



Mode of transport	Final energy demand in Germany in 2019 [PJ] [1]	Modeling of future market diffusion
Passenger cars	1,549	Individual buying decision based on TCO, favoring and hampering factors and vehicle and infrastructure availability
Light-, Medium-, and Heavy-duty vehicles	692	Individual buying decision based on TCO and vehicle and infrastructure availability
Trains	52	Literature based assumptions on future development
Buses	48	
Inland navigation	11	
Overseas navigation	57	
Aviation	435	

[1] BMVI 2020: Verkehr in Zahlen 2020/21. Federal Ministry for Transport and Digital Infrastructure (BMVI). Study carried out by Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Verkehrsforschung Deutsches Institut für Wirtschaftsforschung Berlin e.V. (DIW).

We use a combination of models to address the diffusion of alternative drives in road transport.



www.aladin-model.eu

We define four scenarios with an ambitious development of energy carrier prices and focus on one energy carrier.

The four ambitious scenarios **reach greenhouse gas neutrality in 2050**. They do **not** show **the most probable development**.

- **Focus electricity**: large construction of charging and overhead line intrastructure, reduction of eletricity prices
- **Focus hydrogen**: construction of hydrogen refuling stations, lower hydrogen prices
- **Focus methane**: conservation and expansion of CNG and LNG infrastructure, lower methane prices
- **Focus synfuels**: lower synfuel prices and allowance as green fuel

Energy carrier price	2020	2030	2040	2050
Gasoline price	0.154	0.233	0.315	0.293
Diesel prices[1]	0.117	0.197	0.281	0.261
Hydrigen price[2]	0.285	0.285	0.282	0.235
CNG price[3]	0.088	0.190	0.273	0.257
LNG price[3]	0.097	0.212	0.317	0.304
Electricity price households[4]	0.329	0.321	0.313	0.311
Electricity price commercial[4]	0.226	0.217	0.210	0.208
Electricity price industrial[4]	0.130	0.131	0.136	0.135

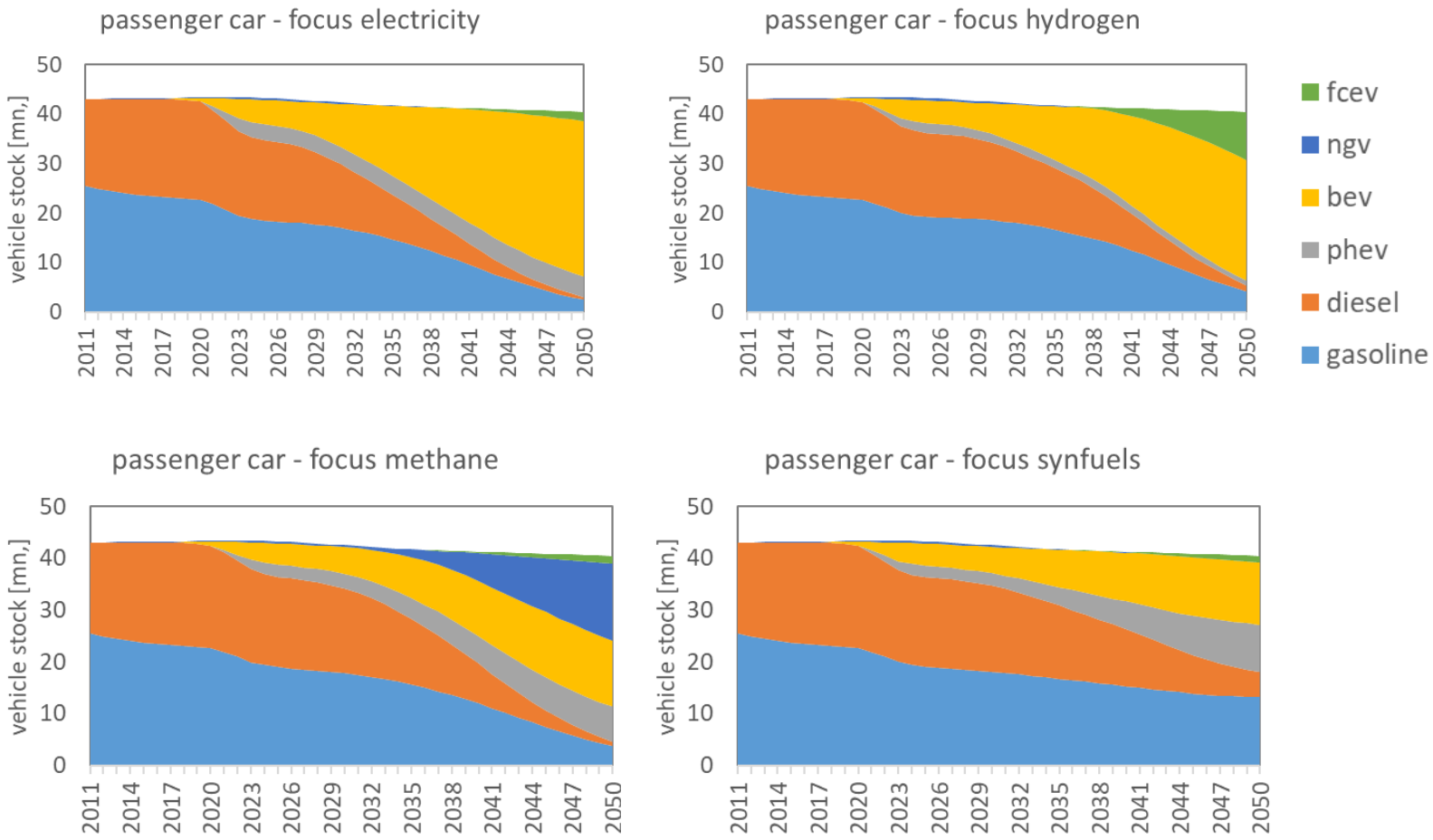
Share of synfuels	2020	2030	2040	2050
Focus electricity	0 %	10 %	20 %	50 %
Focus synfuels	0 %	20 %	50 %	100 %
Focus methane	0 %	20 %	50 %	100 %
Focus hydrogen	0 %	10 %	20 %	50 %

All assumptions explained in Krail, M.; Speth, D.; Gnann, T.; Wietchel, M. (2021): Langfristszenarien für die Transformation des Energiesystems in Deutschland - Treibhausgasneutrale Hauptszenarien. Modul Verkehr. Studie im Auftrag des Bundesministeriums für Wirtschaft und Energie (BMWi).
www.langfristszenarien.de

[1]Lower in scenario focus synfuels, [2]Lower in scenario focus hydrogen, [3]Lower in scenario focus methane, [4]Lower in scenario focus electricity.

We find large shares of electric vehicles in the passenger car sector in 2050.

- Plug-in Electric vehicles (BEV&PHEV) with large stock in 2050 (40-80%)
- Some shares of ICE-vehicles with low annual mileage
- Hydrogen and methane only part of the solution if...
  ...their fuel prices are low
  ...charging infrastructure for PEVs is not errected

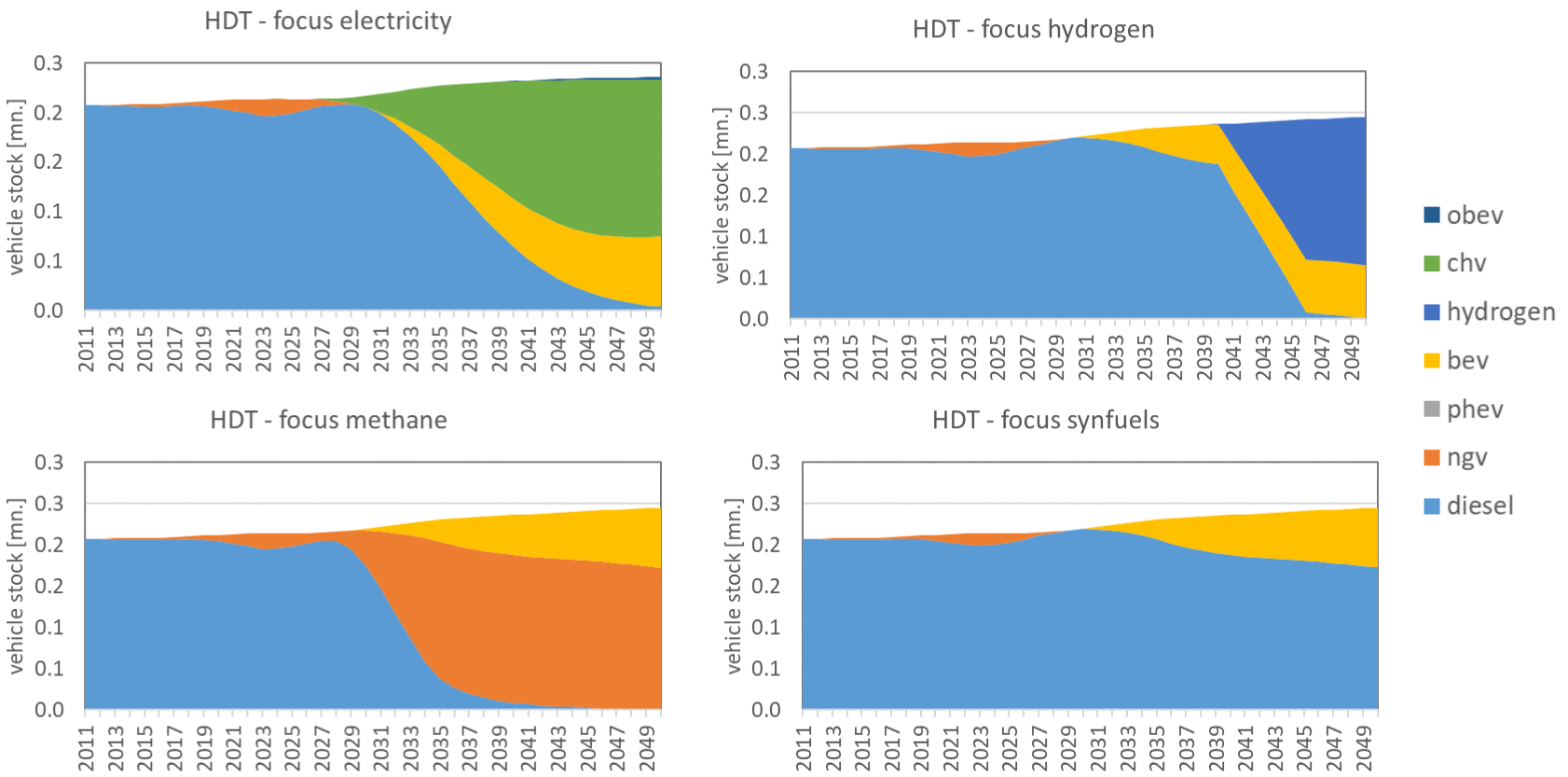


There is not an obvious solution for heavy-duty trucks so far.

- A share BEVs in 2050 (low-distance trucks without range issues)*
- Long-distance travel based on fuels with lowest cost (independent of investment)
- Large changes after 2030**

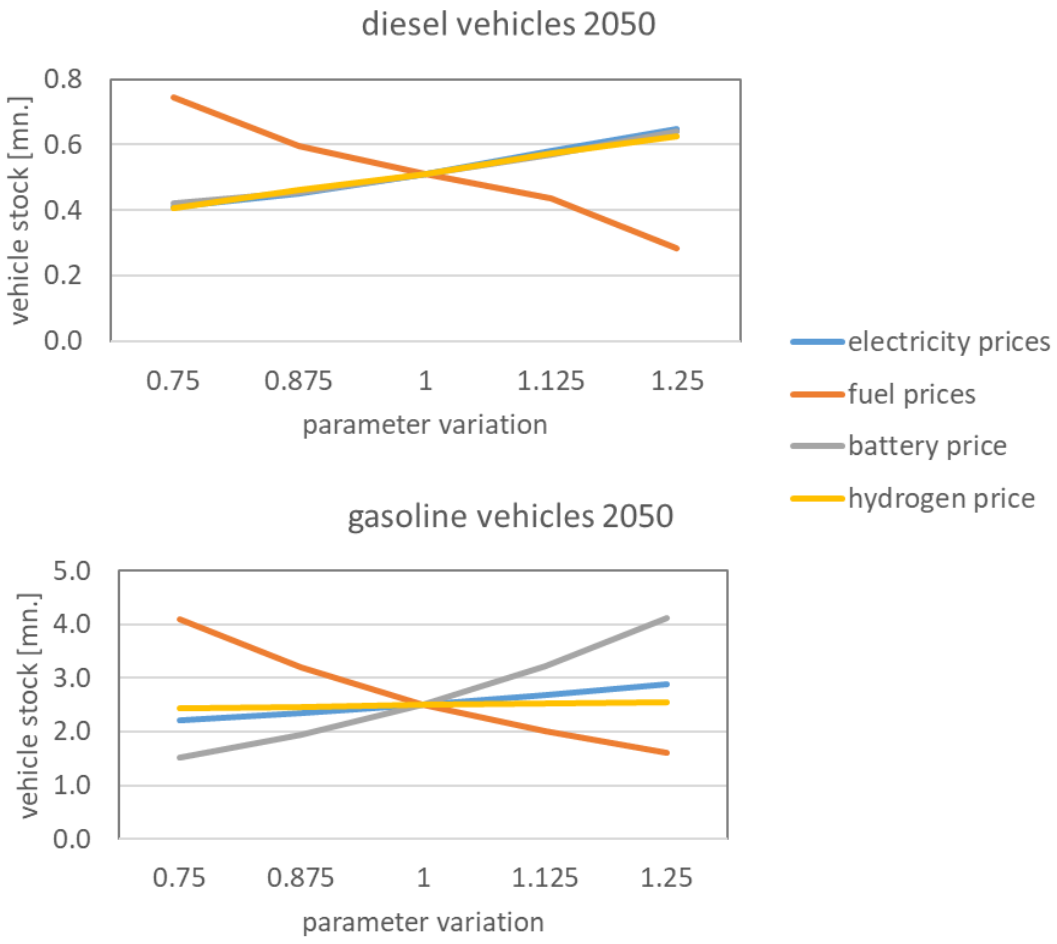
** could change with high-power charging infrastructure*

*** will change due to supporting mechanism (KsNI-program, 80% of additional invest)*

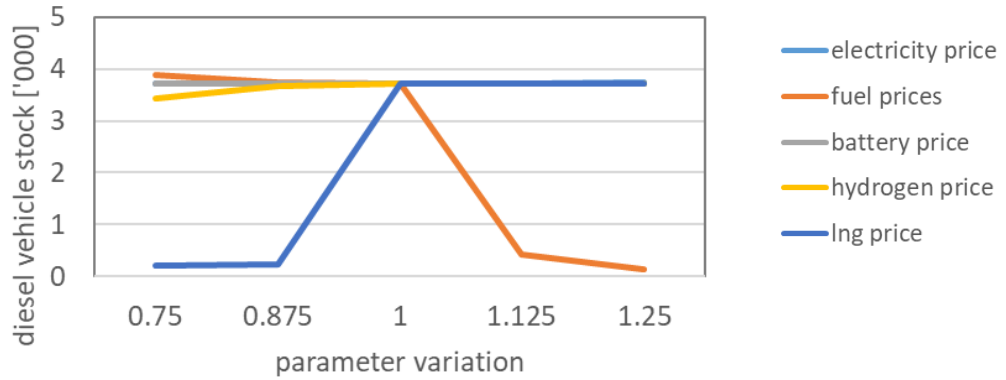


The complete phase-out of internal combustion engines is not possible with energy price adjustments.

passenger cars

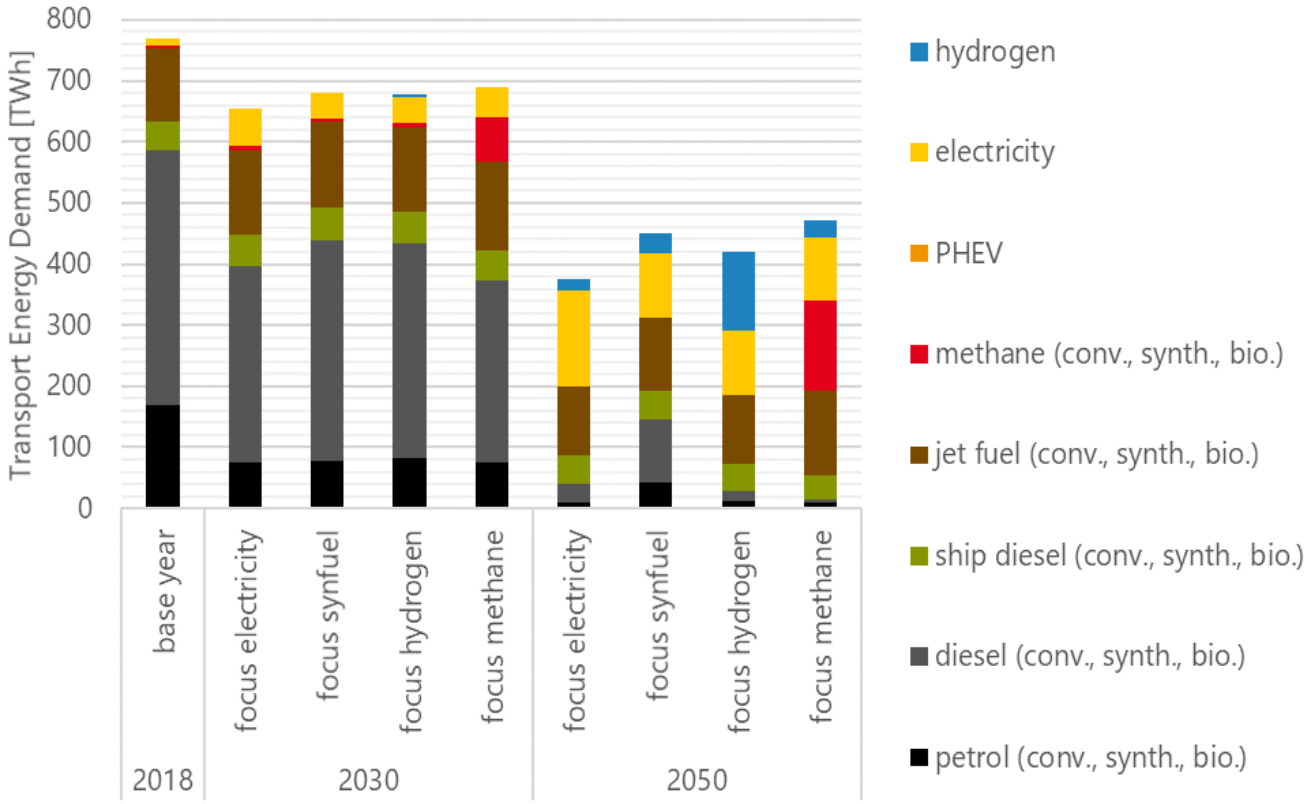


heavy-duty diesel trucks 2050



- Some conventional vehicles will remain in stock in 2050 due to low annual mileage (variable cost benefit not applicable) *(left panel)*
- Malus on conventional vehicle cost or purchase ban in early 2030‘s necessary (cf. Fit-for-55 proposal)
- Trucks that mainly rely on variable cost can be phased out completely *(right panel)*

The final energy demand in transport can largely be reduced.

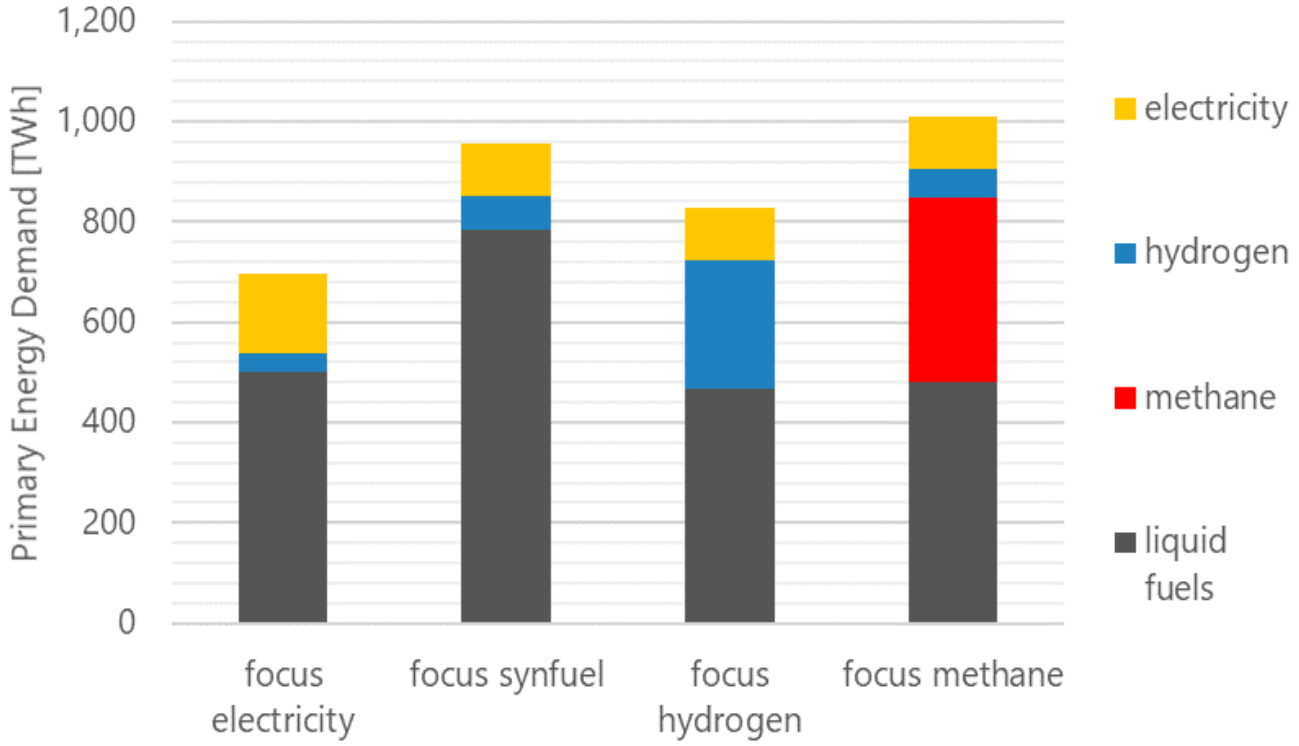


- Reduction of final energy demand by ~50% compared to 2018 due to efficiency gains and alternative fuels
- In 2030, still large shares of conventional (+partly synthetic/biogen) fuels
- In 2050, 30-40% of final energy demand electricity
- Jet fuel/Aviation will become more important

The demand for renewable electricity largely varies between scenarios.

- The production of **synthetic fuels** (kerosene, diesel, methane) **requires 2-3 times more renewable electricity than direct use** due to energy losses
- **Hydrogen** production needs about **twice as much electricity**
- **Aviation and overseas navigation have to use liquid fuels** because of space restrictions
- Scenarios vary from **700-1,000 TWh renewable eletricity demand** in 2050 mainly due to earthbound transport.
- *For comparison: the total renewable electricity generation in Germany ~250 TWh in 2020*

Renewable electricity demand in 2050 distinguished by energy carrier type in the four scenarios



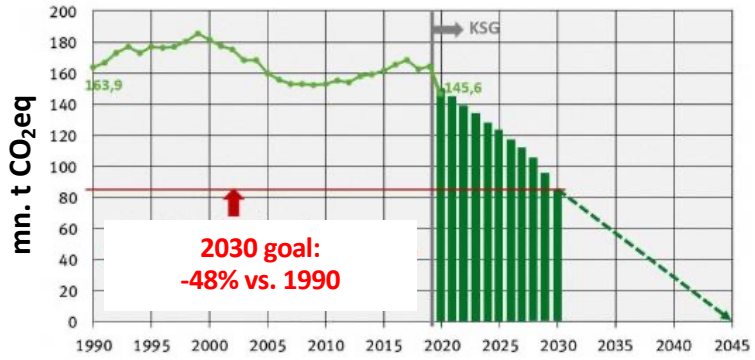
Large efforts are required to decarbonize the transport sector completely.

Summary

- **High shares of electric vehicles** in all scenarios, since most energy efficient and economical option in future
- **Hydrogen, methane or synfuels** powered vehicles only **with a low price** for hydrogen, methane or synfuels
- **Primary energy necessary rises with more gaseous or liquid fuels** (about 300 TWh of additional electricity from renewables if converted to methane or synfuels and used in the transport sector)

Conclusions

- **Import of renewable energy/fuels** to Germany will be **necessary** and require enormous investments
- **Direct electrification also important for energy security**, even more with the Russian wa against Ukraine
- **Decarbonization of the transport sector will require large efforts** (no real progress in Germany so far and scenarios very ambitious)
- **Sales bans for internal combustion engine cars from 2031 necessary for 2045 decarbonization** [2]



Developt of GHG emissions in transport in Germany and goals of climate law from April 2021
Source: Environmental protection agency and Federal German Government

[2] Plötz, P., Wachsmuth, J., Gnann, T., Neuner, F., Speth, D., & Link, S. (2021). Net-Zero-Carbon Transport in Europe until 2050—Targets, Technologies and Policies for a Long-Term EU Strategy. *Karlsruhe: Fraunhofer Institute for Systems and Innovation Research ISI.*

THANK YOU FOR YOUR ATTENTION

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