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Decarbonisation of Heavy Goods Vehicles with a Catenary System: The „eHighway“

Dr. Armin Sue

Information about the German funded project at Volkswagen

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- **title**: Technologieerprobung elektrischer Antriebe bei schweren Nutzfahrzeugen und deren Energieversorgung per Oberleitung (“Oberleitungs-LKW”)
- **project partners:** Volkswagen AG Group Innovation (leader)
  Siemens Mobility GmbH
- **funded by:** German environmental ministry (BMU)
- **project start:** 01.01.2018
- **project end:** 31.12.2020, possibly prolonged until 30.06.2021
- **targets:**
  - simulation tools and requirement for e-highway trucks
  - improvement of the robustness of the trucks for real driving including the pantograph
  - development, testing and optimization of a new pantograph generation (Siemens part)
  - analysis and optimization of other powertrain components (“next Generation“)
  - tests with 2 Scania trucks with different strong electrified power trains (type 1 and 2)
  - real drive tests on all three German test roads
  - sustainability analysis and strategical outlook
  - drive tests on German eHighways with 2 Scania trucks

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Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit
aufgrund eines Beschlusses des Deutschen Bundestages

Erneuerbar mobil

SCANIA

Our Goals: The Paris climate Agreement

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- PARIS AGREEMENT

PARIS AGREEMENT

UNITED NATIONS
2015

Article 2

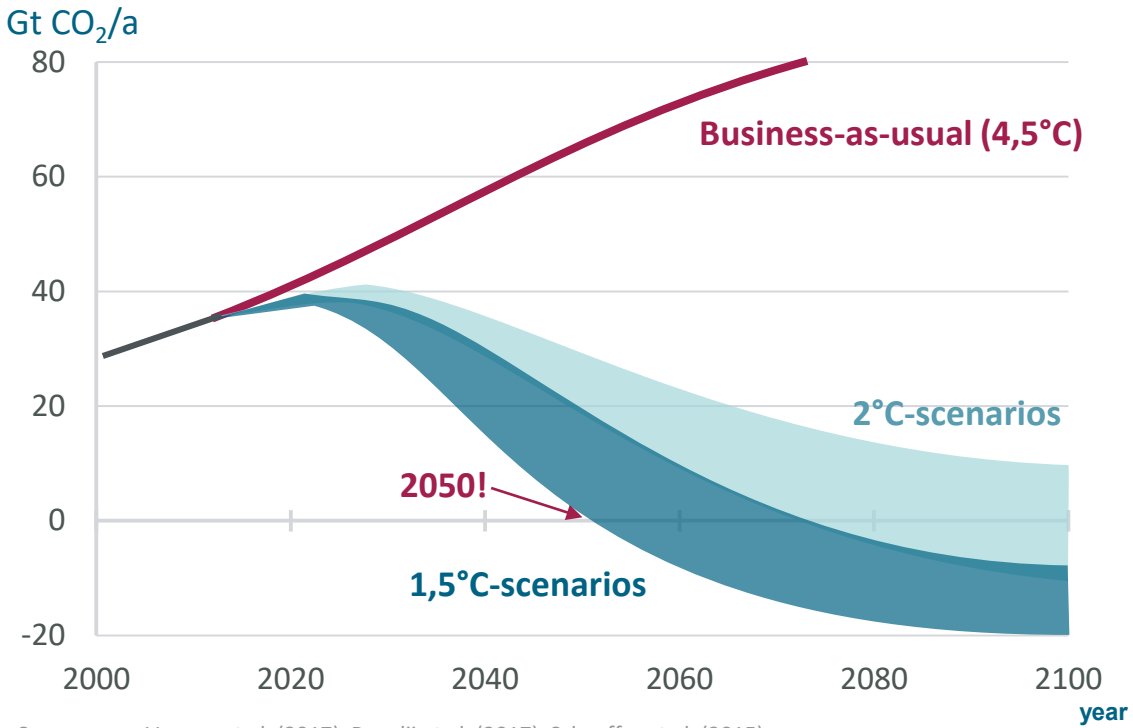
(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

Article 4

1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

Source: UNFCCC (2015)

- GLOBAL WARMING SCENARIO CALCULATIONS



Sources: van Vuuren et al. (2017), Rogelji et al. (2017), Schaeffer et al. (2015)

Volkswagen Group committed to reach the targets of the Paris climate agreement

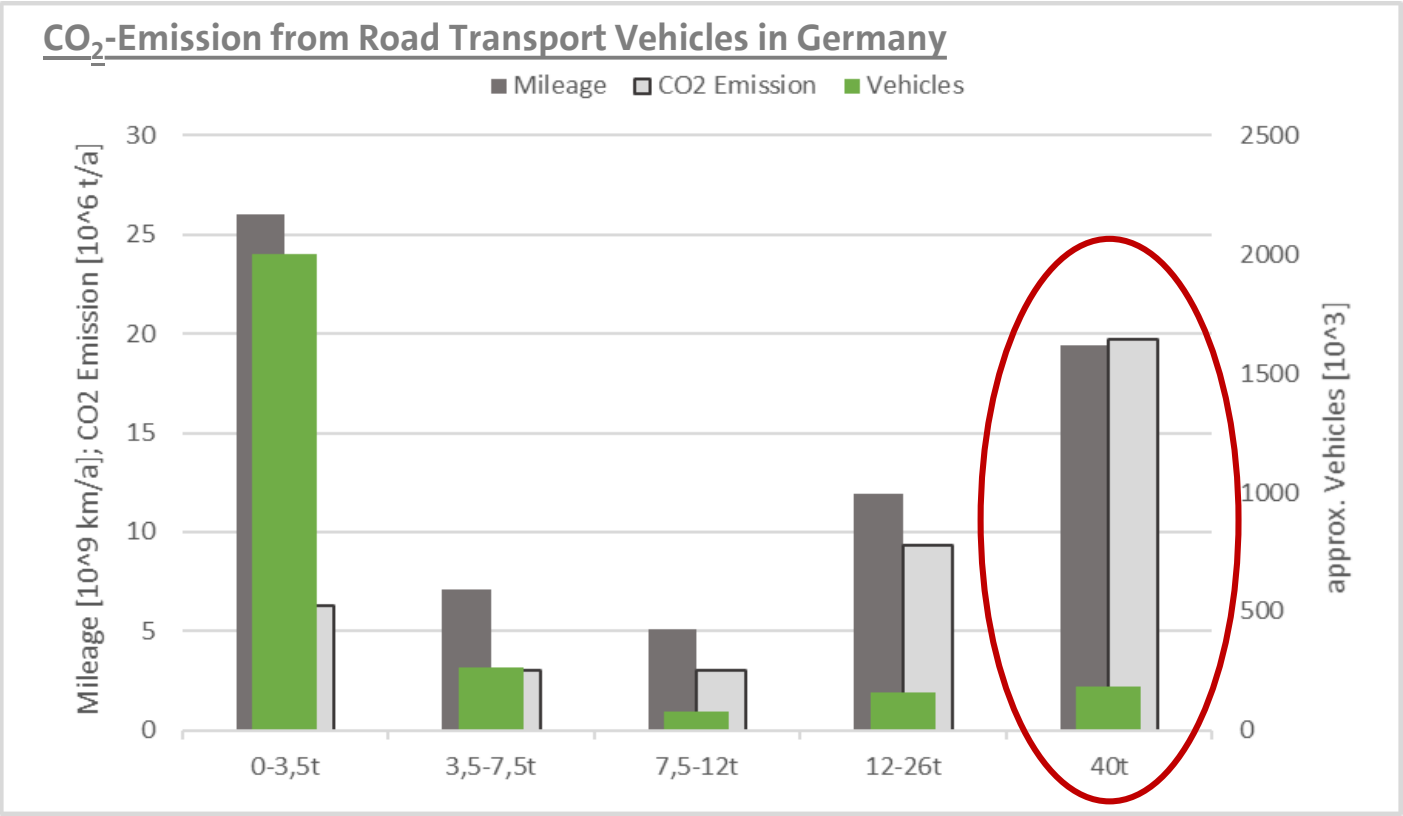
Our Goals: The EU “Green Deal”

- CO_2-neural until 2050
- 55% CO_2-reduction in the traffic sector until 2030

Motivation

Impact of heavy duty trucks on CO_2 Emissions

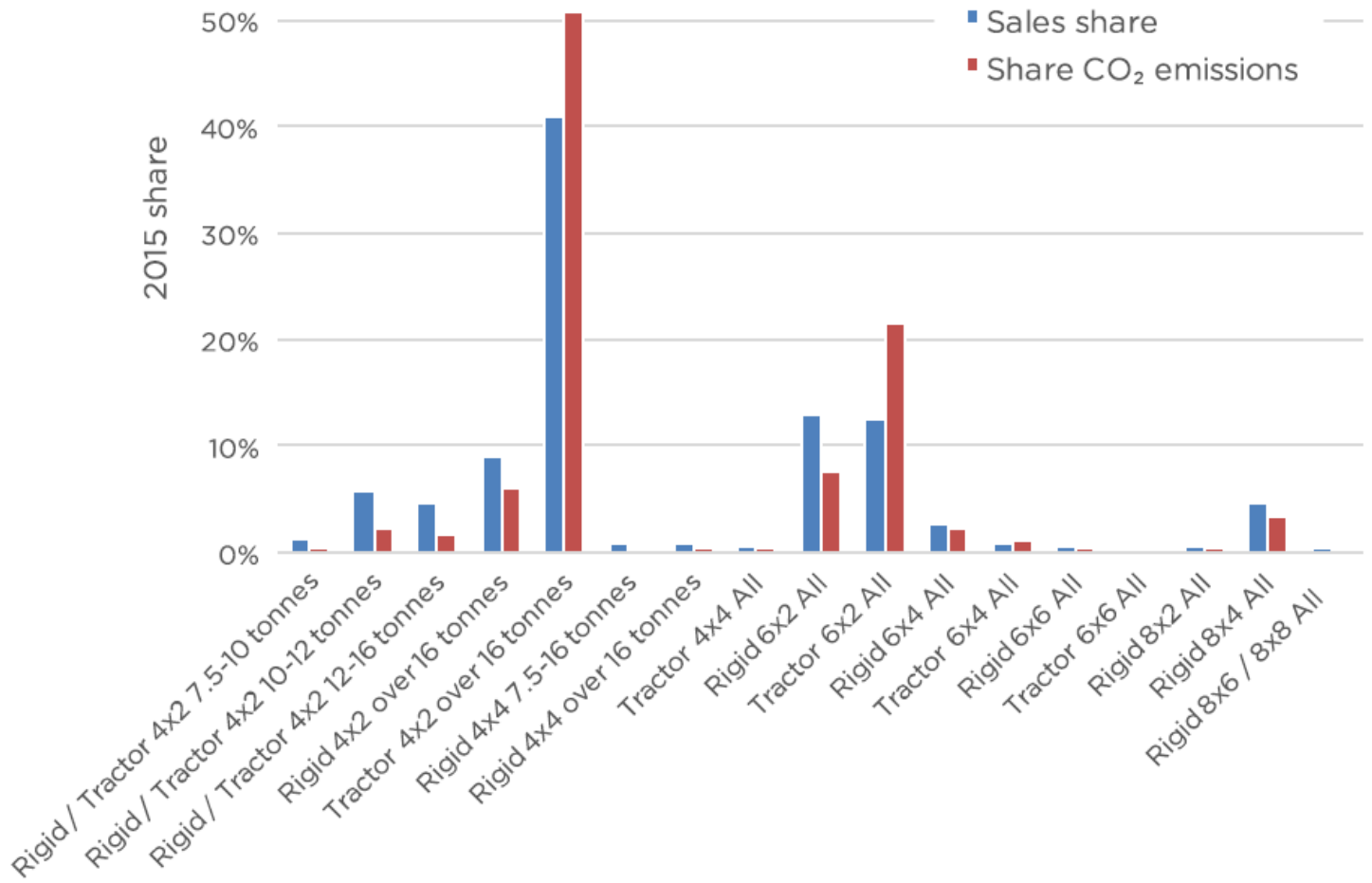
- 1/5 of the German CO_2 emissions are from traffic.
- 1/3 of the CO_2 traffic emissions are from road transport.
- However, the impact of heavy duty trucks despite their small number is enormous (see below)!



Small amount of vehicles – big influence in CO_2 emissions!

Source: Values acc.: Wietschel, Martin: *Einstieg und Übersicht über die aktuelle Untersuchung: Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid Oberleitungs-Lkws,* Unterlage zum Fachworkshop des BMVI, Hamburg, 2016

>70% of CO_2 from HDVs are emitted by tractor trucks – these drive far and are often away from base



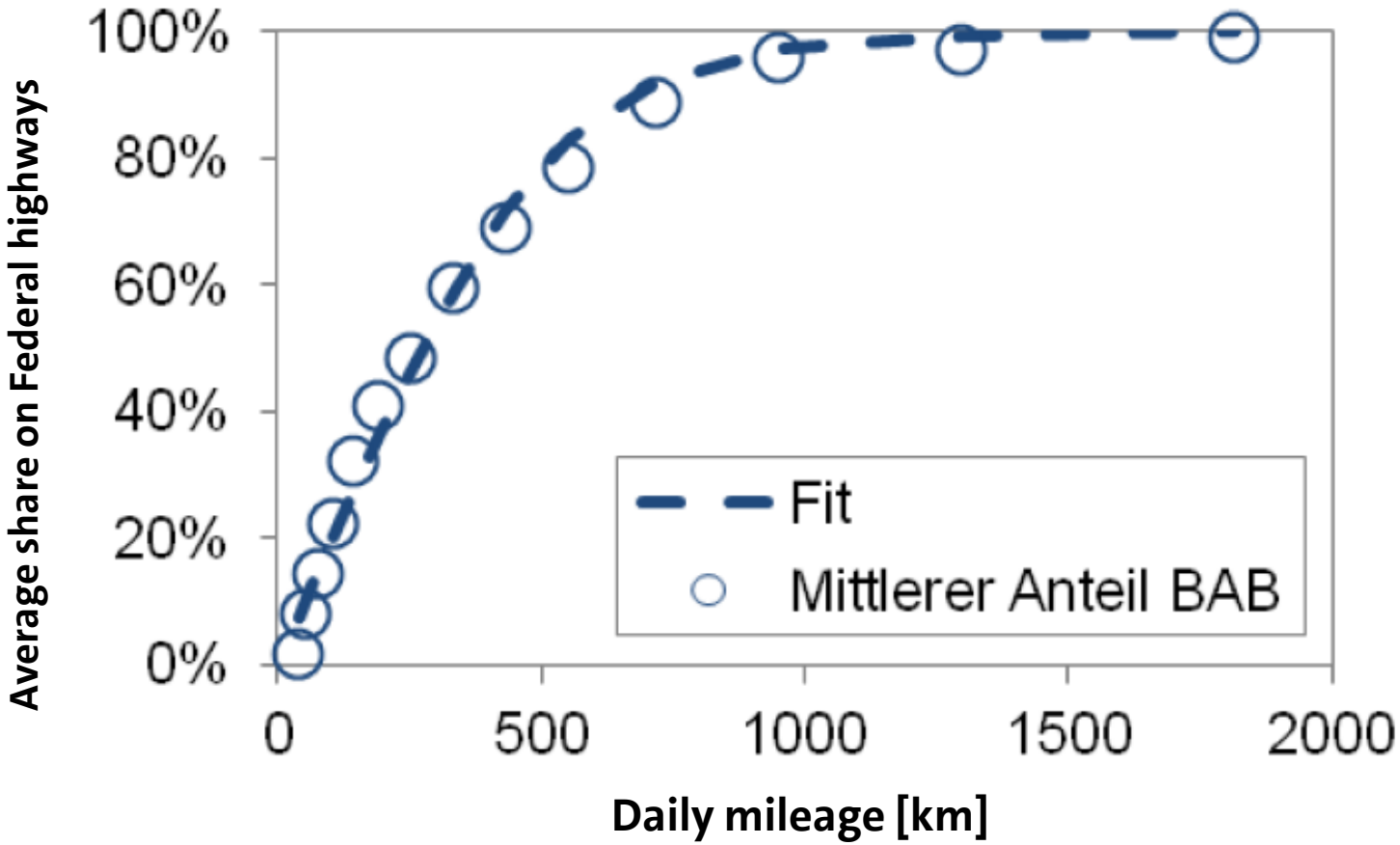
CHEV tractor 4x2

Rigid 6x2

[1] New sales data supplied by © IHS Global SA
[2] CO_2 emissions calculated from mileage and FC assumptions used in LOT1 and LOT2
[3] Due to high aggregation in the database, French distribution is assumed to mirror the rest of the EU

Source: Felipe Rodriguez (ICCT) *Heavy-duty vehicle fuel efficiency potential in the EU (2017)* page 5

Long trips are to a very large extent highway trips



Range Anxiety = Highway anxiety

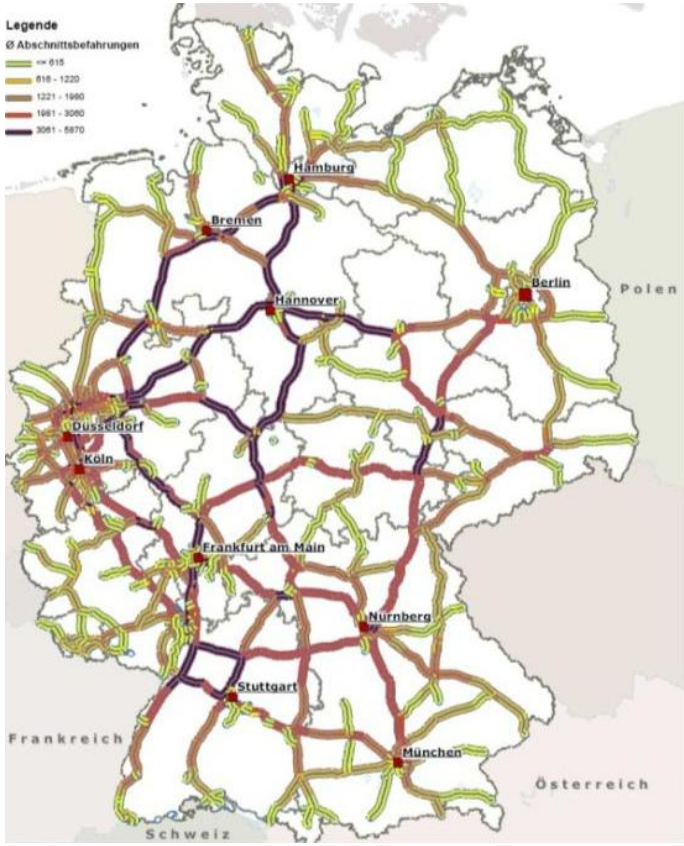
Source: BMVI website. Study available here

Zero Emission Drivetrain for Long Haul Heavy Duty Trucks?

- In the long term the powertrain for **small and medium trucks** will (can) be pure electrical (**BEV**)
- But, what is the zero emission powertrain for the **long haul ≥40 t truck?**
- 500 km to 800 km per day!
- **BEV**: approx. 1,5 kWh per 1 km => **750 to 1200 kWh battery**: weight, space, charging
- **FCEV**: approx. 10 kg H_2 per 100 km => **50 to 80 kg hydrogen**: space, system- and fuel-costs

Is there another technology **now** available?
Yes, the electrical power supply via overhead wire (catenary): **The eHighway**

- Less truck weight and cost because of a small battery only for gaps in the infrastructure
  e.g. difficult topology, electric drive from the depot to the e-highway or in urban environment
- Main question: What about the **infrastructure?**



sources: HDV density on BAB-network ; Verkehr in Zahlen 2012; TREMOD 2012

eHighway System is based on well proven and known technology and subsystems

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The complete system

... and its subsystems

- 1 **Vehicle**
  - Pantograph
  - Drive System
  - Energy Storage
  - Control System
- 2 **Power Supply**
  - Substation
  - Contact Line
- 3 **Drive Way**
  - Infrastructure
  - Traffic Mgt.
- 4 **Operation**
  - Maintenance
  - SCADA

Sources: Siemens Mobility GmbH

Hybrid Powertrain for eHighway Trucks

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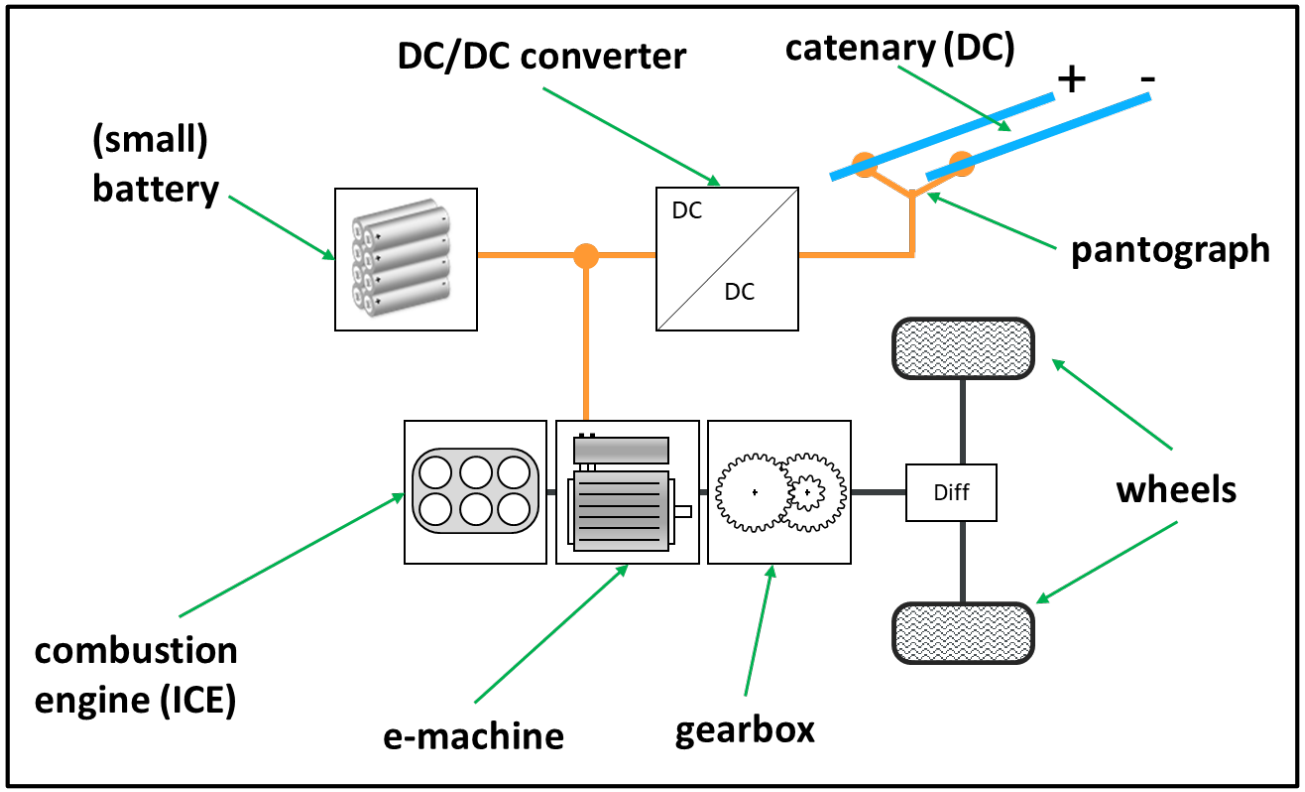
Schematic powertrain layout



Current prototype vehicle

Sources: Scania

How does an optimized system for a heavy duty overhead wire truck look like?

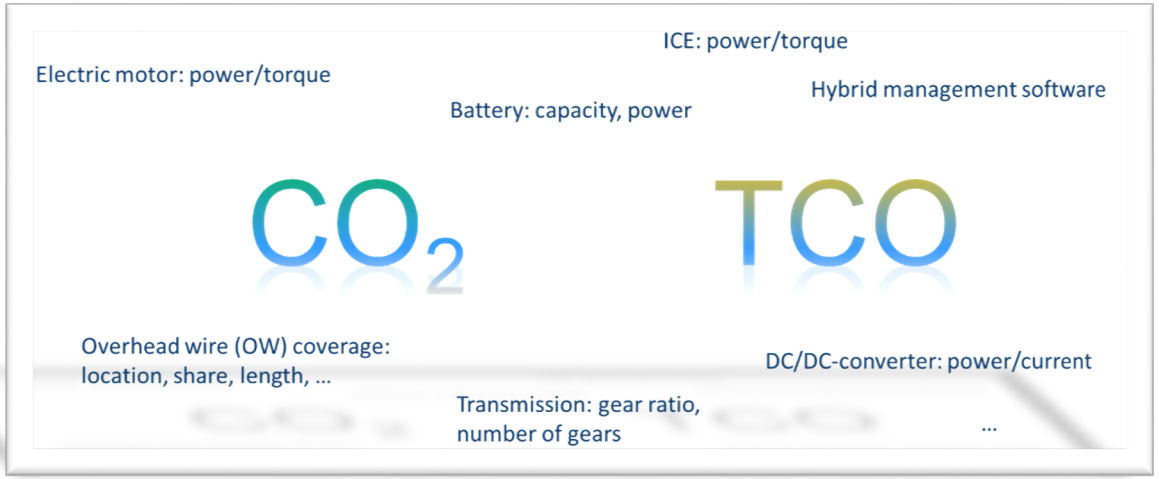
Situation at the start of commercial use:

- very small length of electrified roads

Main goals:

<u>Not</u> pure electrical driving in any situation! They are:

- optimum of CO2 reduction (LCA), costs (TCO) and weight
- no negative influence on the logistics of the customers
- ability of electric driving in sensitive (urban) areas

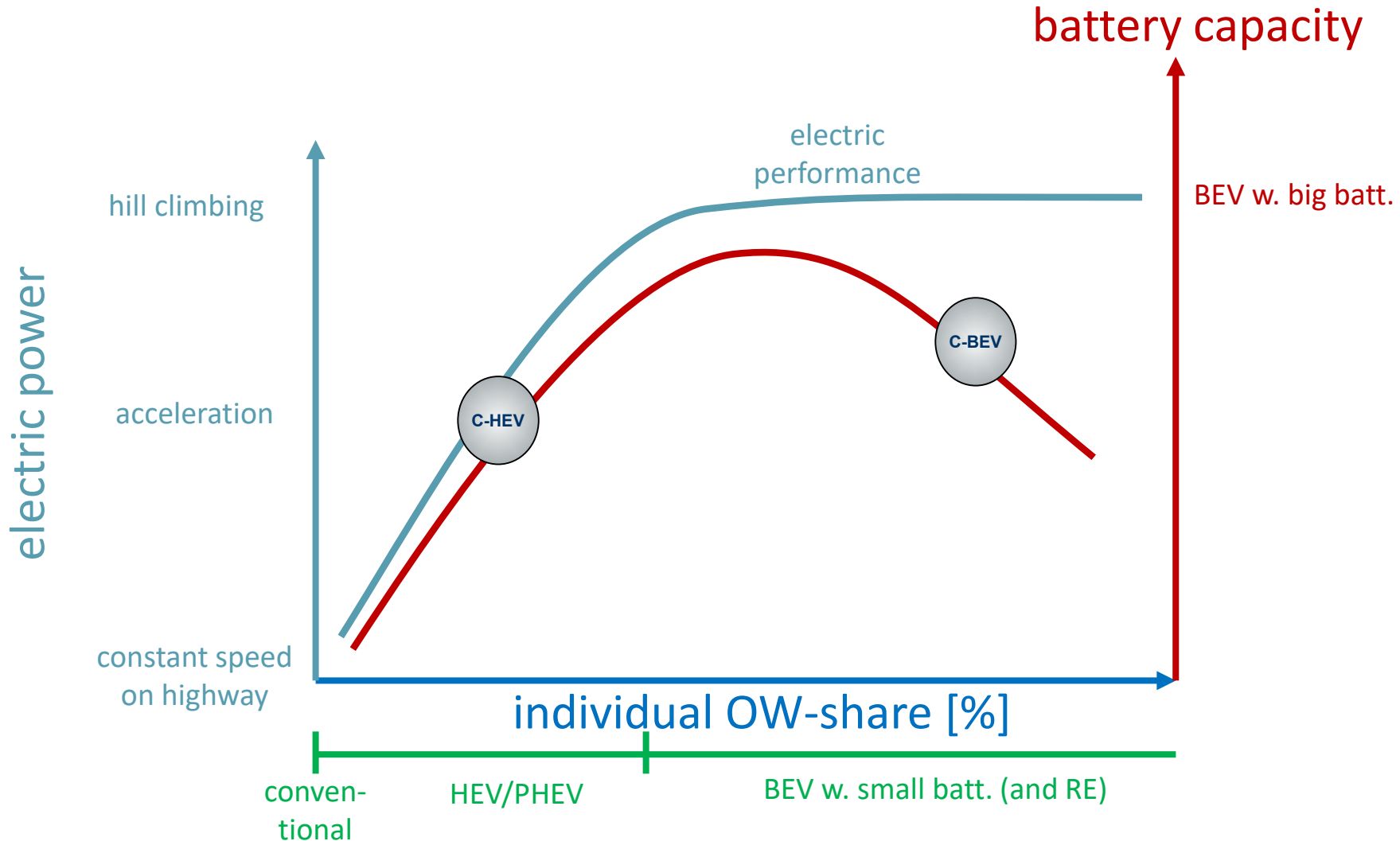


Solution:

Hybrid drivetrain (HEV) as base for eHighway trucks, pantograph charging makes it to a PHEV truck

- basic CO2 reduction of the HEV system
- additional reduction under the catenary due to electric driving
- charging of the battery for additional electrical driving without catenary (at once or later e.g. inner city)

Schematic Illustration of possible eHighway Truck Development



The optimum of CO_2 reduction, truck performance and costs is a complex function

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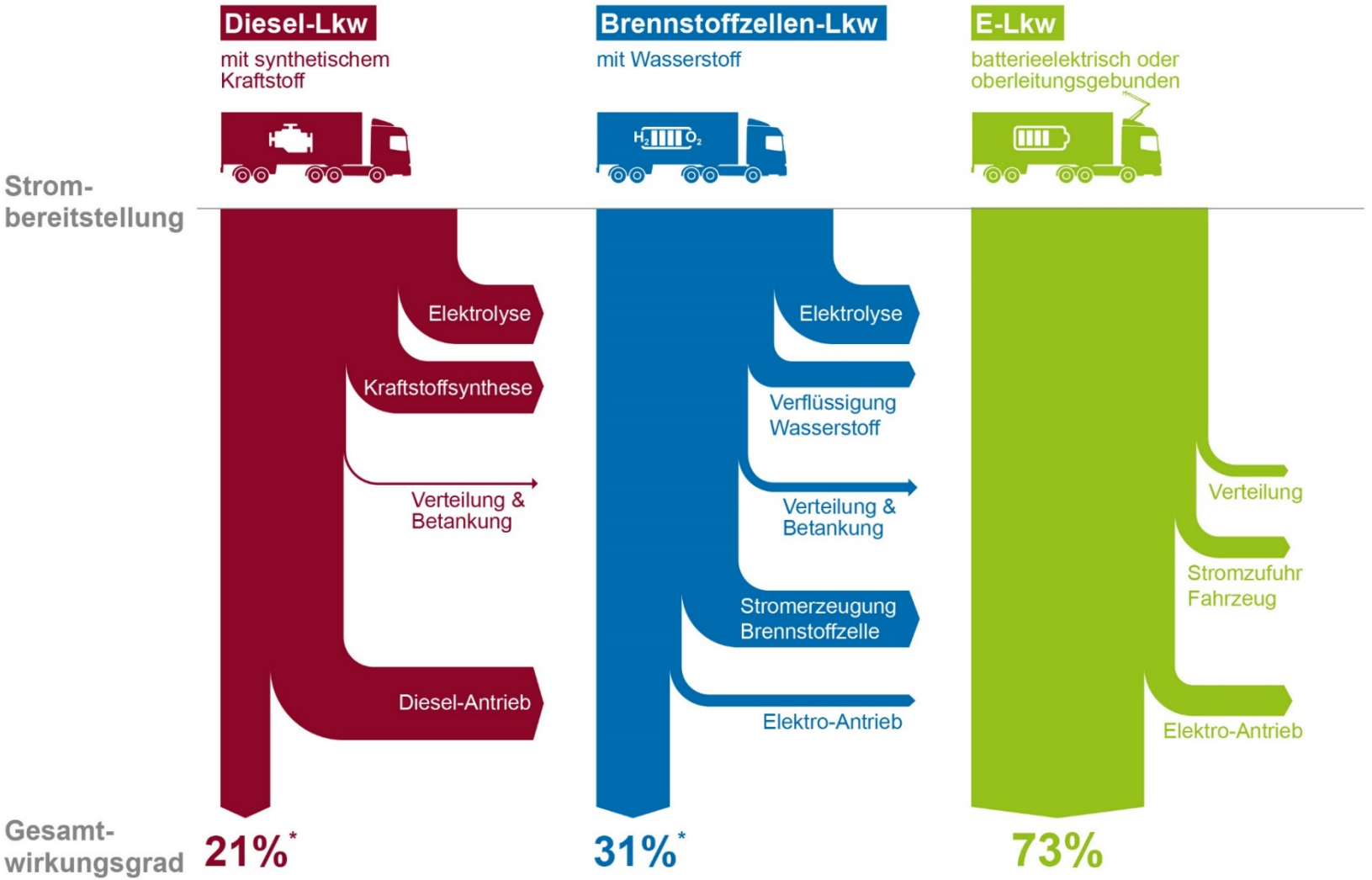
Klimaneutral, erneuerbar, effizient: E-Lkw liegen vorn

Vergleich der Wirkungsgrade verschiedener Lkw-Antriebe



*bei Erschließung von Effizienzpotenzialen bei Elektrolyse, Kraftstoffsynthese und Brennstoffzelle

- E-fuels need about 3 times more green electricity then the direct use.
  Can that ever be cost equal for the users?
- Of course synthetic fuels are interesting, because it´s a good way to store electricity.
  But shouldn´t we use this “precious” fuels for transports and energy supply we can´t do directly electrically, e.g. air transport?
- Synthetic fuels are not locally emission free!
- Don´t forget the noise emission of ICEs!

Life-Cycle Analysis shows climate protection advantage of catenary trucks solutions

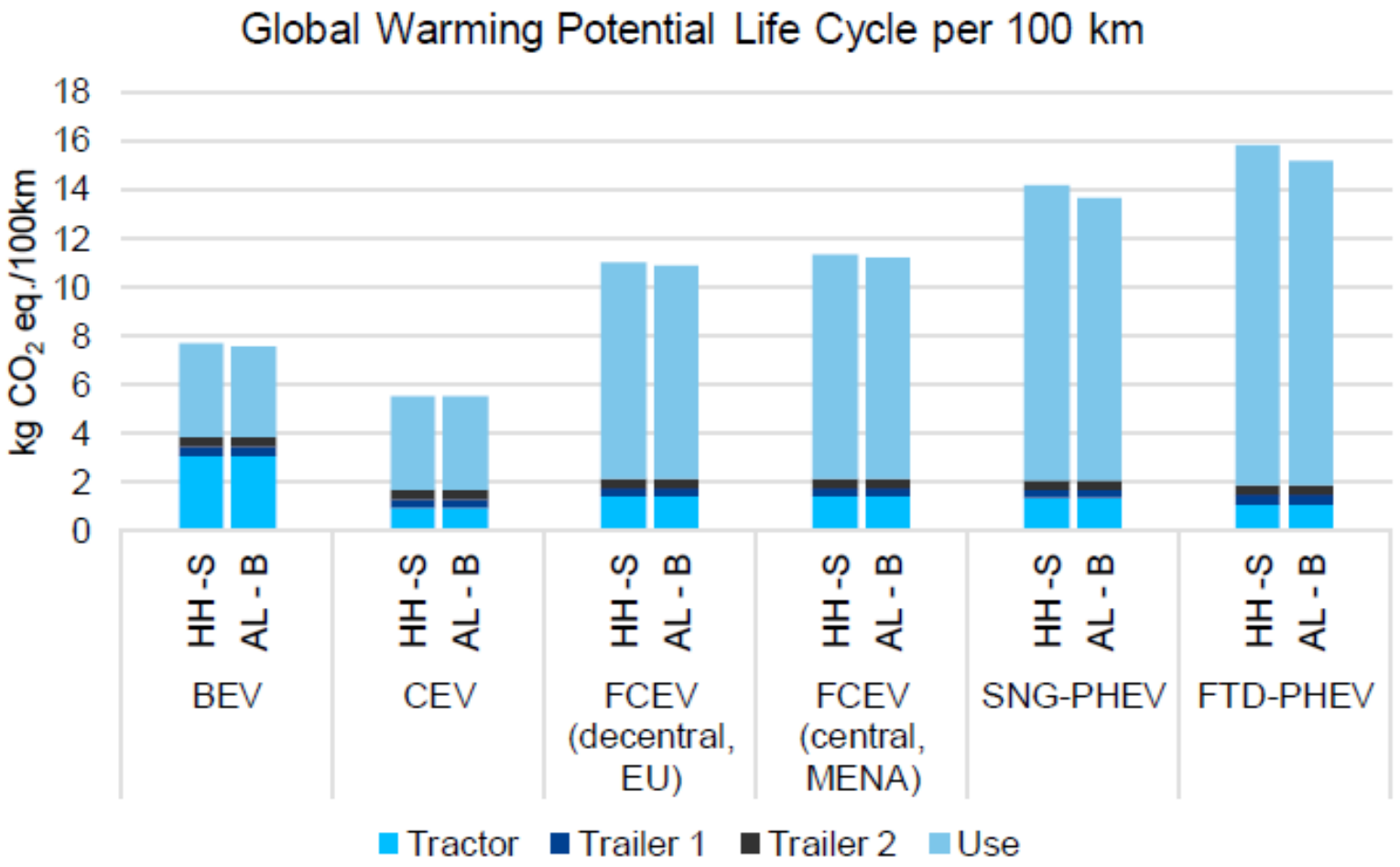


Figure 22: Results Global Warming Potential Life Cycle per 100 km

Source: Final report #1199 “CO2 Neutral Long-haul Heavy-duty Powertrains”, FVV, 2020

How large is the required catenary network in Germany?

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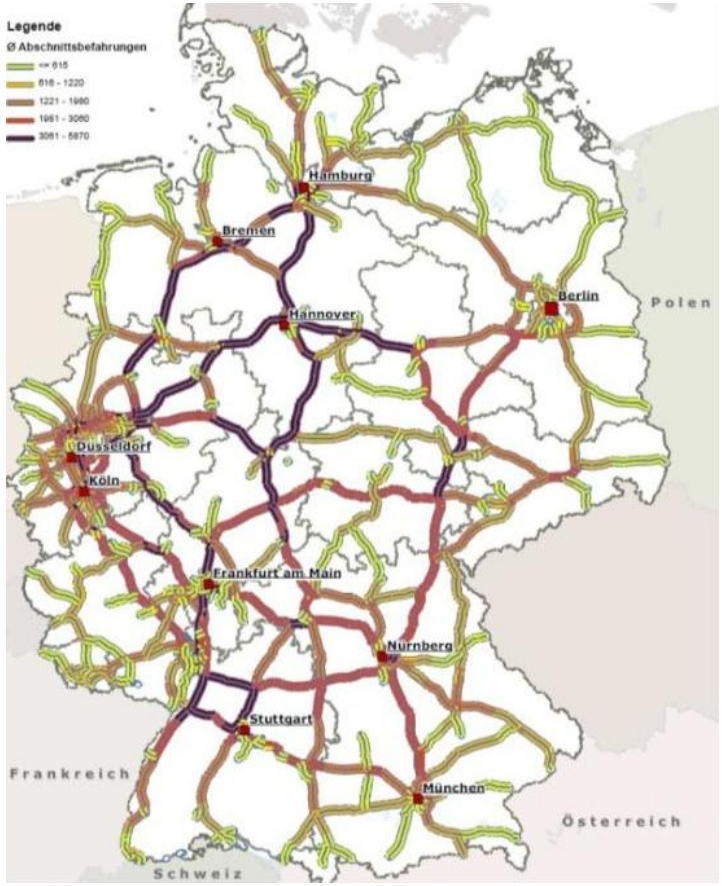
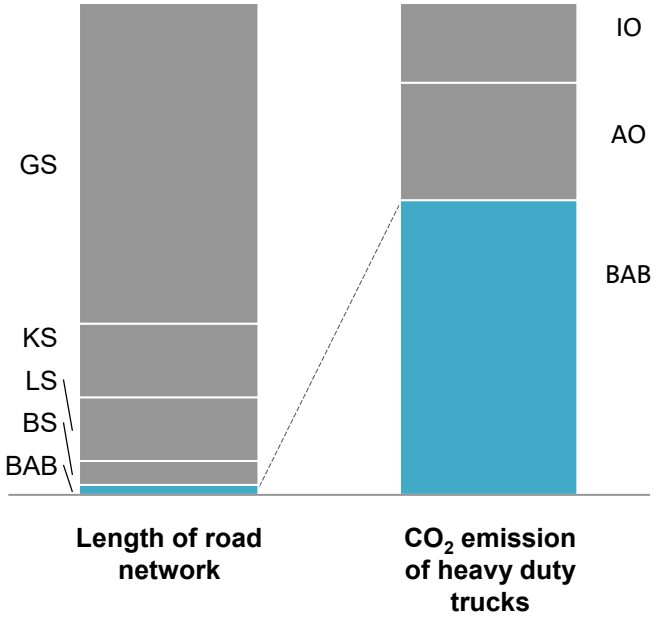
Analysis of road network





BAB = Bundesautobahn (12.594 km)

BS = Bundesstraßen (40.400 km)
LS = Landstraßen (86.600 km)
KS = Kreisstraßen (91.600 km)
GS = Gemeindestraßen (>420.000 km)
IO = Stadtstraßen
AO = Außerstädtische Straßen

sources: HDV density on BAB-network ; Verkehr in Zahlen 2012; TREMOD 2012

Findings

60% of emissions by heavy duty trucks stem from 2% of the road network (BAB = 12.394 km)

60% of all ton kilometers on federal German highways stem from the most intense 3.966 km

89 % of heavy duty truck routes off federal German highways are 50 km or shorter

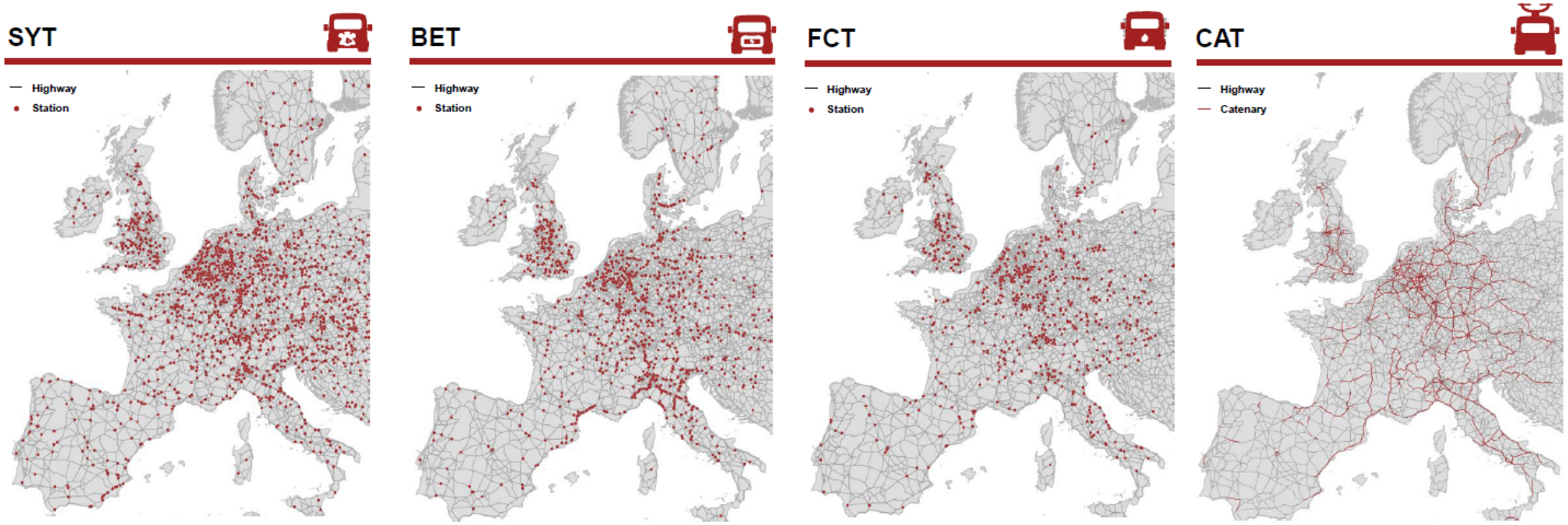
source: BMVI website; study: here

A significant reduction of CO_2-emissions from heavy duty trucks is possible by focussing on the most intense traffic routes

How large is the required catenary network in Europe?

If all HDT traffic on European highways switched to only one technology option, the required alternative infrastructures would look quite different

High-demand network: Point-of-Supply (PoS) infrastructures for alternative HDTs on European highways



SYT	BET	FCT	CAT
Maintaining about **2,400 conventional highway** stations	Installation of about **1,400 HPC stations** required	Installation of about **920 HDT-HRS** required	Installation of about **21,500 km of overhead lines** required

Making zero-emission trucking a reality
Strategy&

The demand-covering infrastructure networks were derived with an optimization model (NC-FRLM). For more information we refer to Rose (2020).
The high-demand scenarios cover about 80% of European HDT traffic.

September 2020
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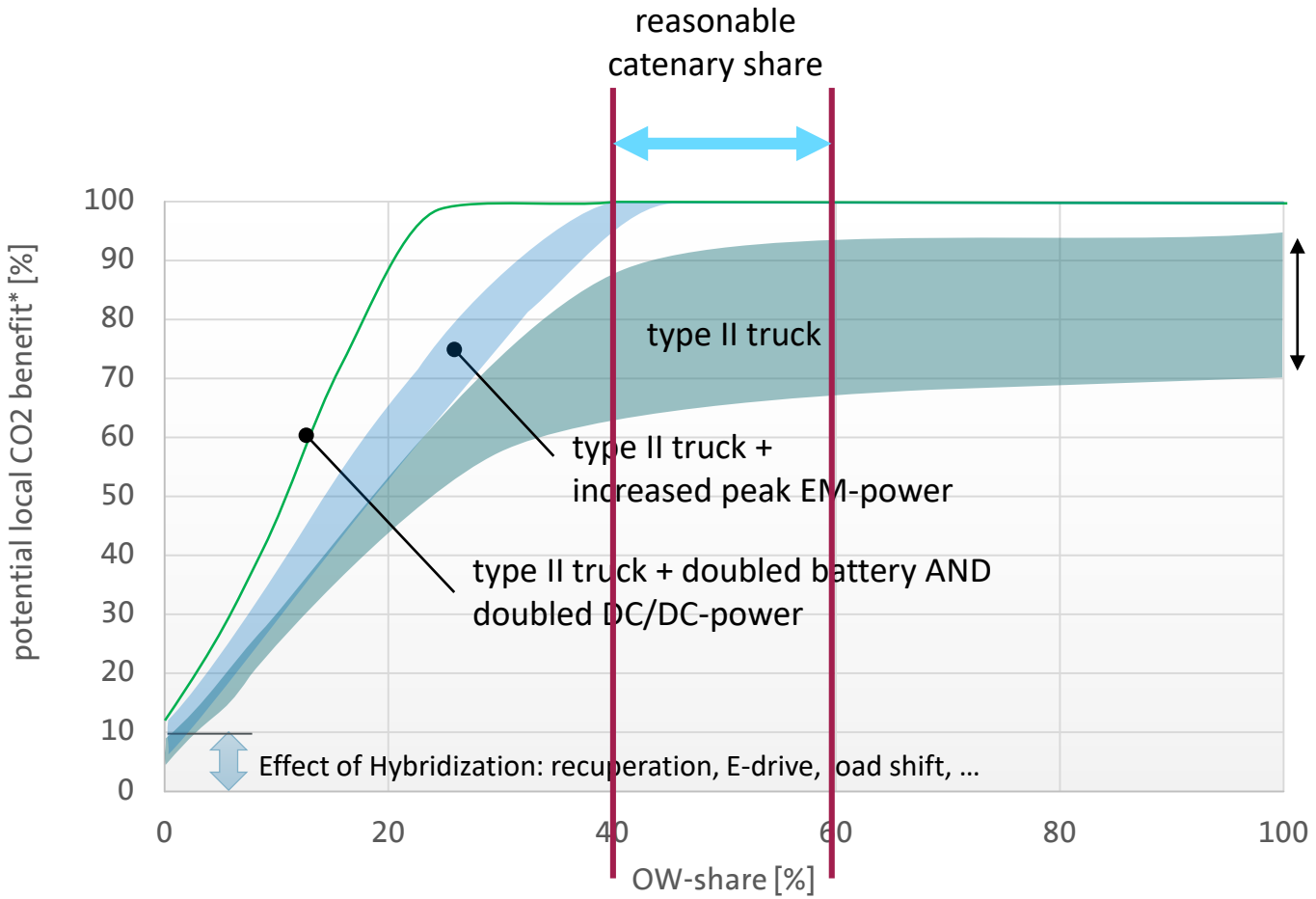
Sources: strategy&, PwC Network, 09/2020

How much of the eHighway must be equipped with infrastructure?

LONG HAUL SCENARIO

type II hybrid truck: 260 kW EM, **74 kWh (gross)**



span caused by different routes

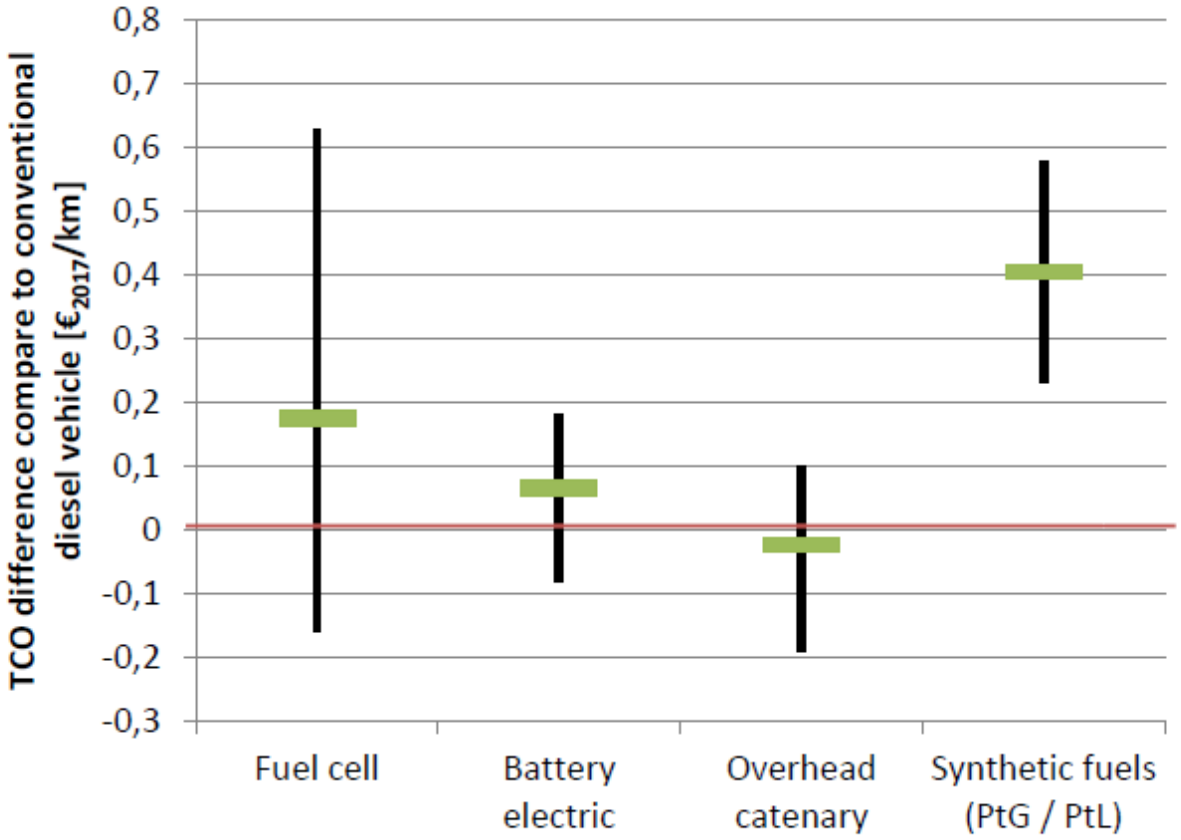
Simulation premises:

- 35 t long haul truck: sufficient drivability with 330 kW system power (no ICE start if EMs can perform at least 330 kW)
- Optimal distributed OW-segments, no OW-power limit
- Example routes BS-Magdeburg and Koblenz-Trier
- Long Haul scenario: Balanced battery SOC

*compared to a conventional 35 t Truck

With increased motor power, complete pure electric driving is possible from 40% OW-share on.
Increasing the max. charging power (battery and DC/DC), the potential CO_2-benefit rises significantly.

Independent institutes in Germany have also found that catenary would be the most effective way to reach climate goals for trucks



Variation in TCO of different alternative drives / fuel options relative to fossil diesel vehicles in the period 2020 – 2030 (mean value (in green) and bandwidth between different studies).[12]

Source: Oeko Institute, Fraunhofer ISI & IFEU – *Alternative drive trains and fuels in road freight transport – recommendations for action in Germany* page 10

Overhead contact line trucks are the most cost effective carbon-neutral solution for German long-haul road freight

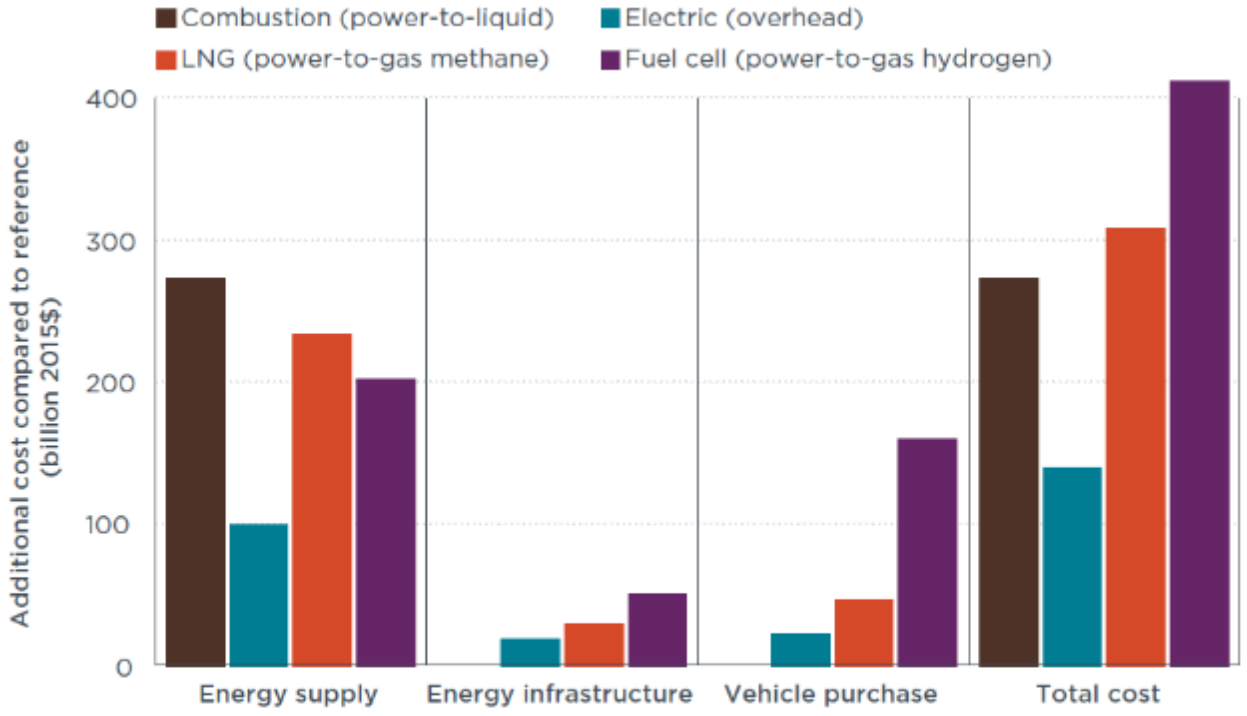


Figure 5. Additional cost for four different greenhouse gas reduction scenarios compared to the reference case (all fossil fuel use) for the long-haul heavy-duty freight transport sector in Germany (based on Kasten et al., 2016).

Key take-aways

- Cost of energy has the greatest impact on total system cost, so energy efficiency should guide decision making
- Up-front costs, like additional vehicles and infrastructure, also factor in, but too a much lower degree
- The cost of refueling (quickly) still deserves to be assessed carefully

Cost assumptions of the study

- Additional costs from 2010 to 2050
- Length of electric network: 4,000 km; Infrastructure costs: €2.2 m/km; Maintenance 2.5% of investment per year
- Additional vehicle costs: Per today €50,000/truck; per 2050 €19,000 per truck; share of direct electric traction: 60% in 2050

Source: ICCT – Transitioning to zero-emission heavy-duty freight vehicles (2017) page 23

TECHNOLOGY READINESS?

... IT WORKS!

Source: Scania

... AND IT REALLY WORKS NOW!

Source: Scania

... AND IT WORKS IN THE DAILY COMMERCIAL TRANSPORT

Source: Siemens Mobility GmbH

eHighway Infrastructure in Germany

3 funded test roads in Germany

different users on a motorway
(project: ELISA)

shuttle transport on a motorway
(project: FESH)

shuttle transport on a federal street
(project: eWayBW)

funded field test with 15 trucks

- 5 trucks on each test track

https://www.youtube.com/watch?v=gAUff-fz_MM&t=0s

Source: Siemens Mobility GmbH

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… BUT STILL MUCH TO DO!

- Optimum infrastructure: length, position?
- How to roll out this technology over Europe?
- What is the optimum drivetrain for the truck?
- High Voltage safety?
- LCA?
- European standardization
- …

conclusion

- The eHighway is an efficient alternative solution for the electrification of Heavy Goods Vehicles
- It has the potential for a CO_2-neutral transport on highways
- Due to simultaneous electric driving and charging, not 100% of the roads has to be equipped with the catenary infrastructure
- In the beginning the trucks will have an hybrid powertrain, later (with more infrastructure) they will be pure BEV with a small battery
- In Germany 2(3) test roads are build up.
- Commercial transport is already done. First experiences are promising.

It is not a technical question to decide this technology for Europe

It is the societal question:

Do we want to build up the infrastructure for the most efficient zero-emission road transport in Europe?

It's up to us!

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Thank you for your attention!