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eHighway

Catenary electrification of heavy road freight: a rationale and a path forward

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Highway electrification for trucks has already started

Agenda:
Catenary electrification of heavy trucking corridors

Why

What

How

Climate action is urgent, because waiting makes the necessary transition to zero carbon emissions much shorter and disruptive

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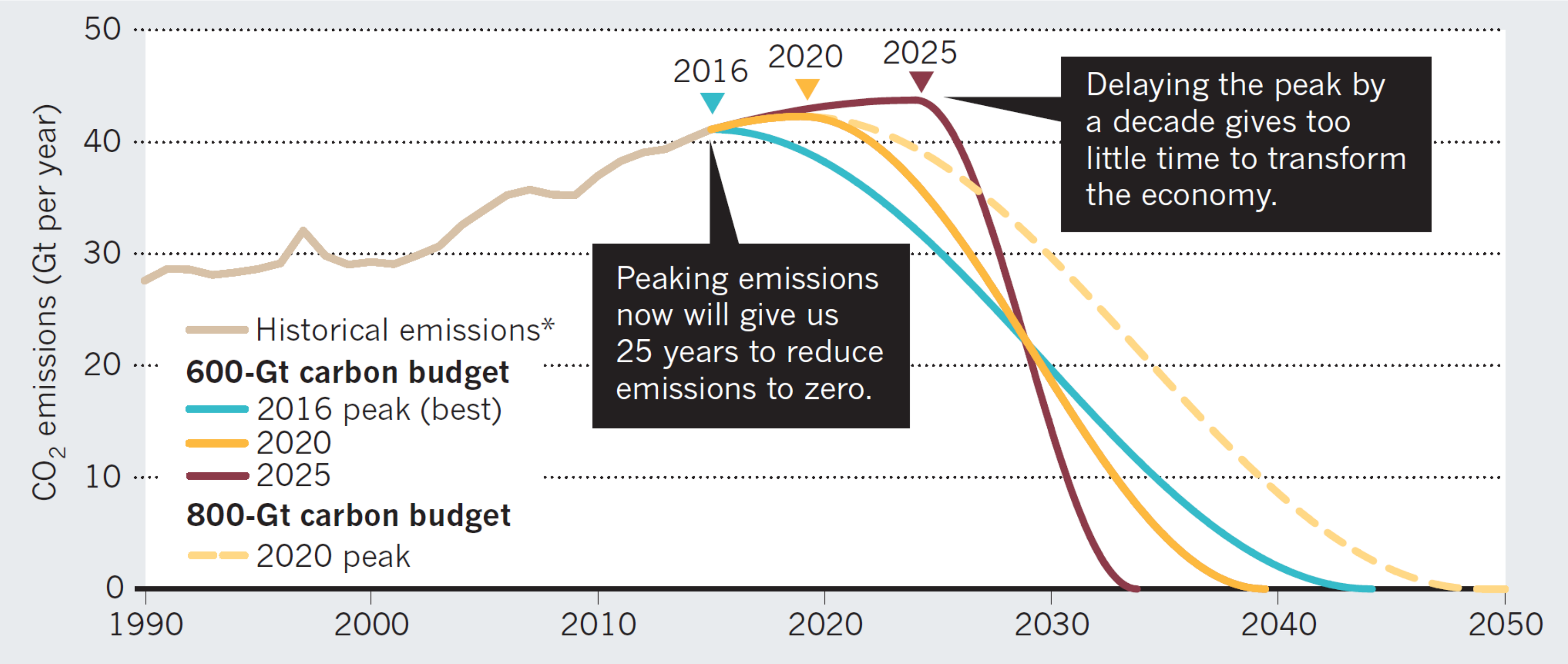

Source: Figueres et al, *Nature* June 2017

We need to put emissions, including those from road freight,

- on a path towards zero
- with minimum total emissions getting there

Decarbonization is a challenge for all sectors, but transport and in particular heavy long-haul transport is seen as especially difficult

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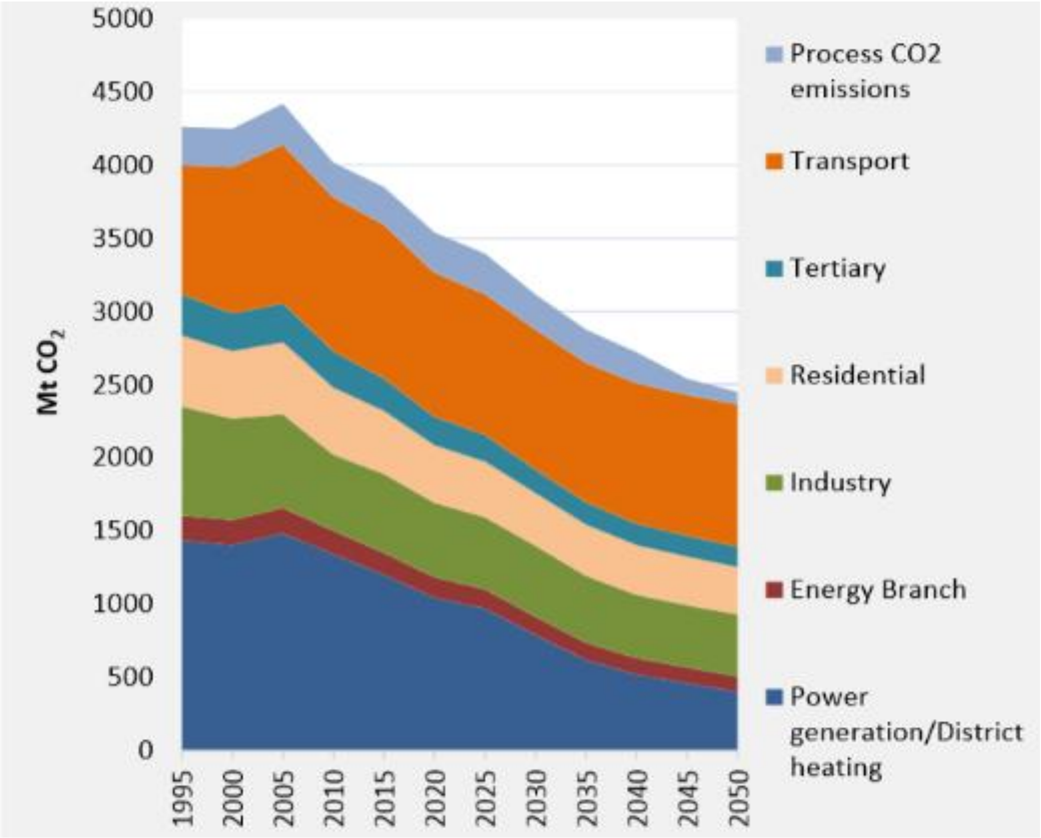
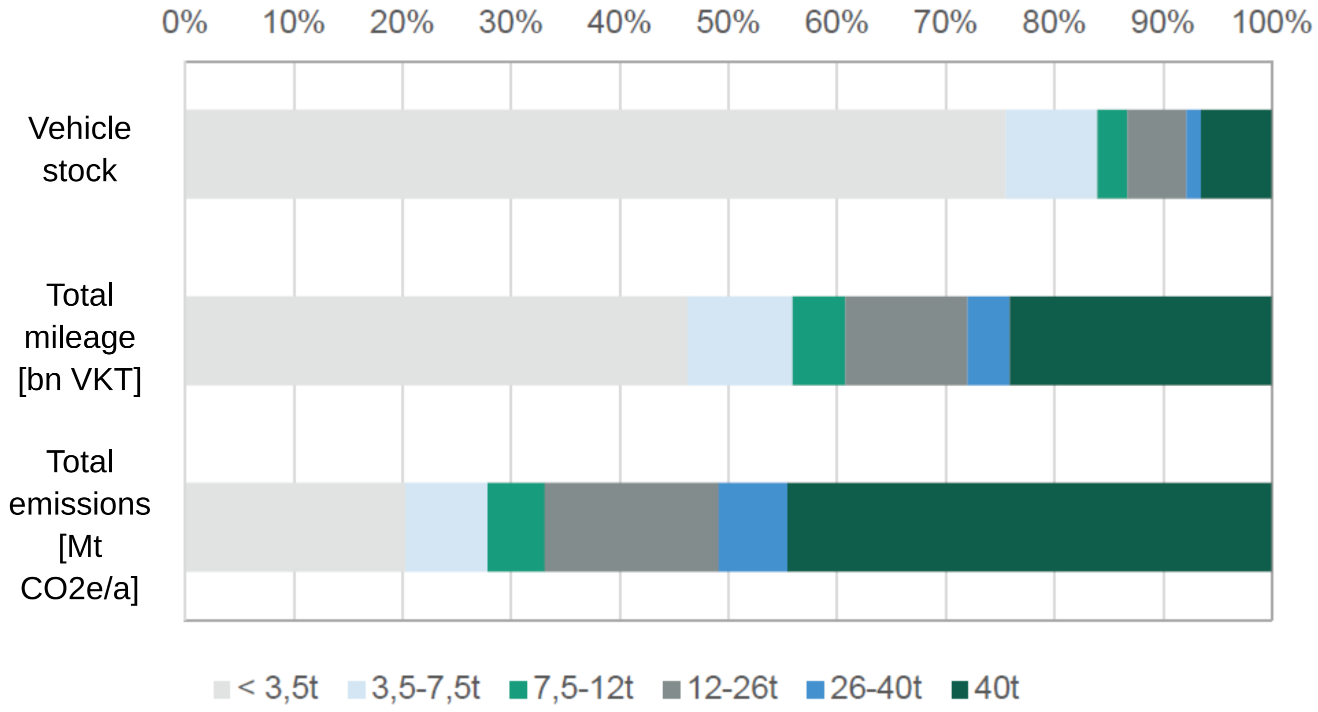
As power and other sectors decarbonize, transport is forecast to cause 40% of EU CO_2



Source: European Commission reference scenario for 2050 (2013) page 53

Road freight decarbonization is particularly a challenge for the few vehicles that emit the majority of CO_2



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

Surface freight density: 2010
Shows high density of freight on European corridors

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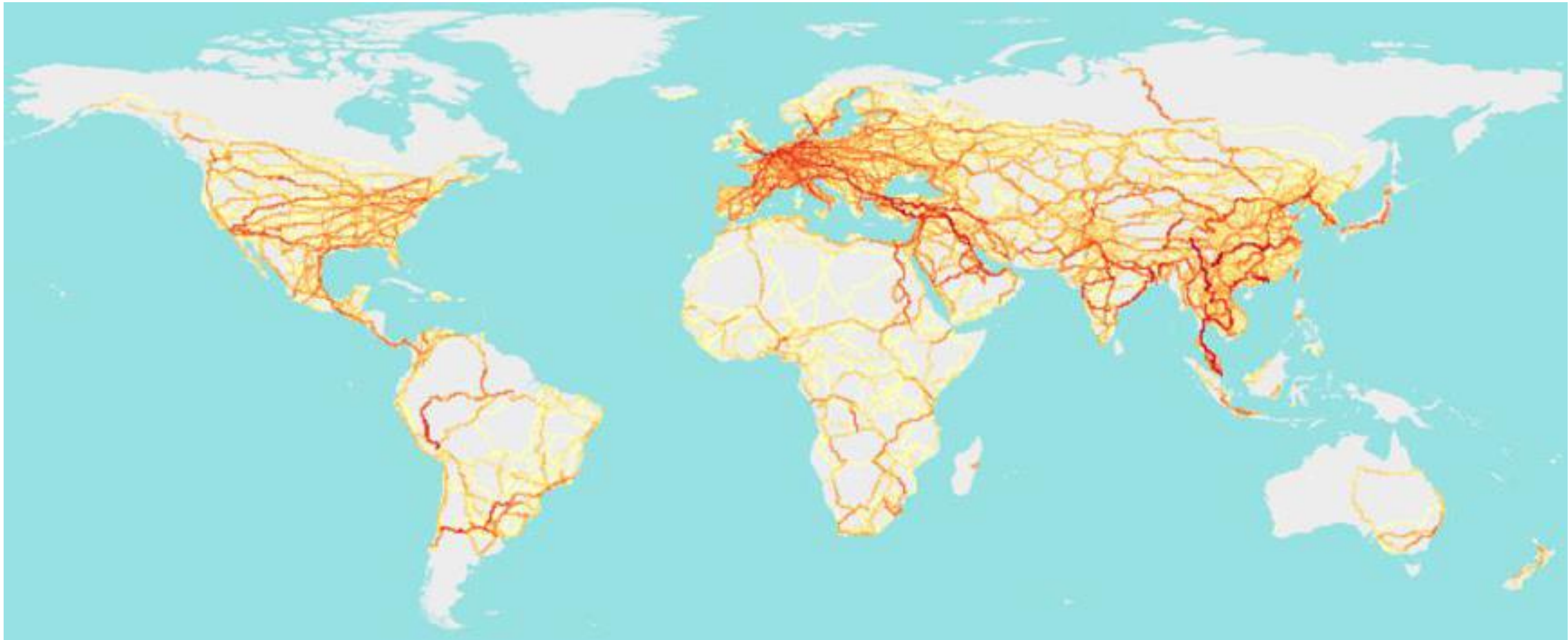

Source: ITF - Transport Infrastructure Needs for Future Trade Growth (2016) page 31

Surface freight density: 2050
Shows global need for road freight sollutions suitable for corridors

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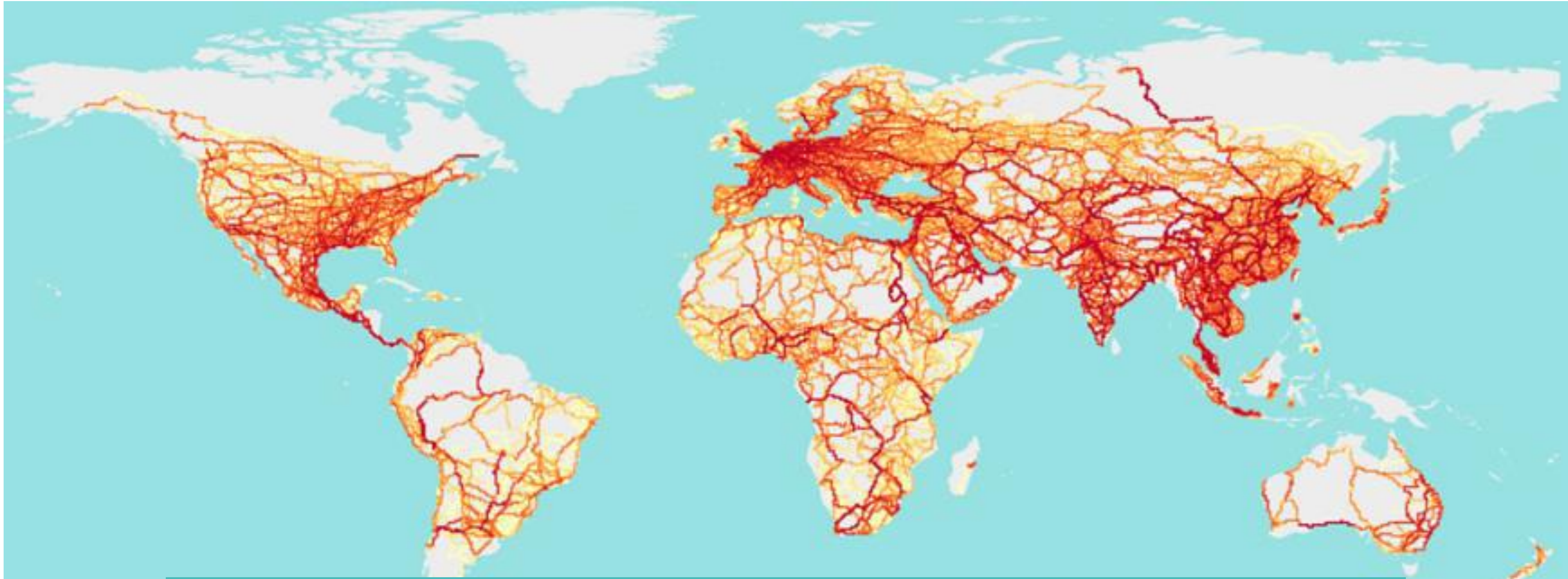

Remember: 2050 needs to be a world with no net green-house gas emissions

Source: ITF - Transport Infrastructure Needs for Future Trade Growth (2016) page 31

Long haul road transport is highly concentrated to the highway network, as illustrated by German data

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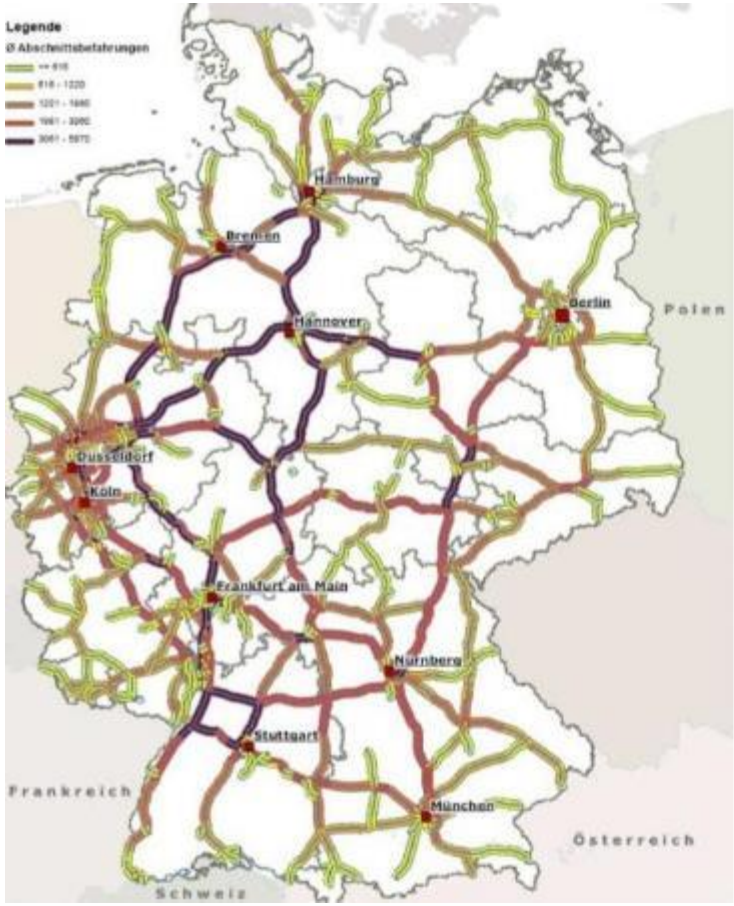

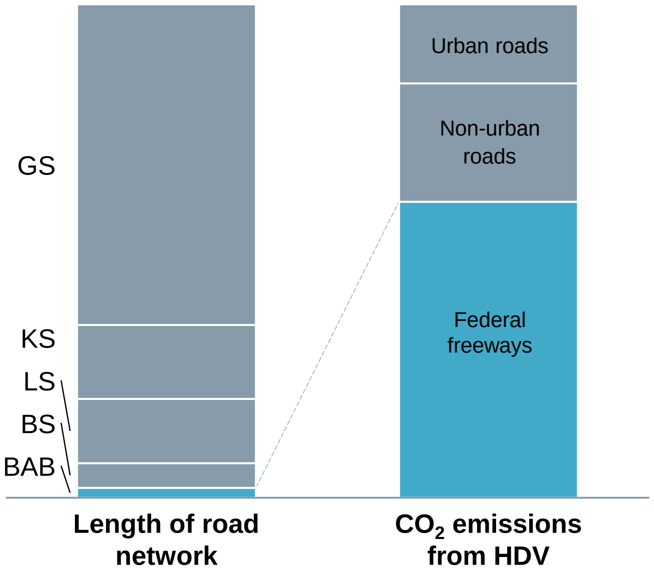

BAB = Federal freeways (12,394 km)
BS = Federal roads (40,400 km)
LS = State roads (86,600 km)
KS = District roads (91,600 km)
GS = Municipal roads (>420,000 km)

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

The analysis of the German road network leads to the following key messages:

1. **60%** of the HDV emissions occur on 2% of the road network (BAB = 12,394 km)

2. **89 %** of German truck trips after leaving the highway are **50 km or less**

Source: BMVI website. Study available here

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eHighway truck technology – from proof-of-concept to field trials

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Development of the eHighway vehicle technology

2010 — 2019

1. Generation
Proof of concept

2. Generation
Swedish and US
Demonstration projects

3. Generation
Field trials

- **Operations up to 100 km/h possible**
- **Connection and dis-connection to catenary in motion**
- **Recharging of onboard energy storage while driving**
- **No limitations for first and last mile**

Catenary solution for trucks is seen as the most efficient and economical among known alternative propulsion solutions

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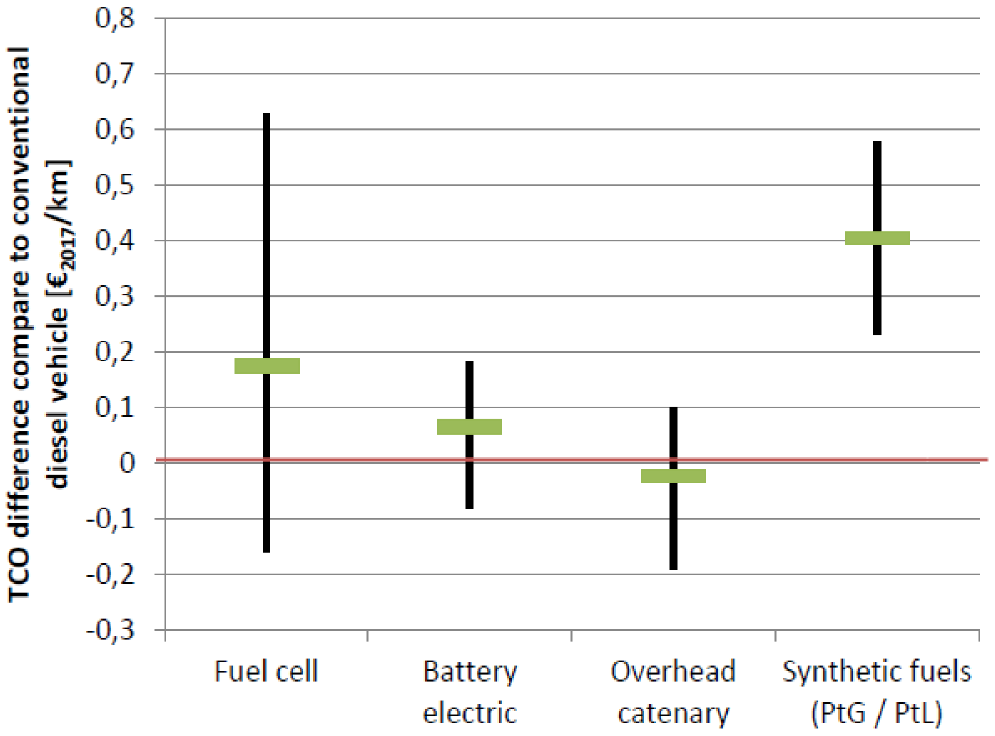
- Price between 1,5m - 2,3m EUR/km* largely depending on no. of trucks, topography, distance of net-infeeding points and condition of the motorway according to studies**
- Upgrade of initial infrastructure design possible when more hybrid trucks with additional power demand are deployed later
- Price for Catenary Hybrid Truck expected to be in the range of 20% on top of standard tractor with ICE***
- BEV Truck expected to be even cheaper compared to standard tractor with ICE by 2050 in ERS scenario****



*) per km in both driving directions

**) ICCT P.21ff Fraunhofer P.33/44

***) Oeko Institute. P45

****) European Climate Foundation P.43

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

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Catenary electrification of heavy trucking corridors

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German field trials in 2019 are a necessary near term step for the development of the system

Information and routing

Federal State of Hesse
Infrastructure project awarded to Siemens
Track length / Amount of trucks: 5km / 5
Construction: April-Nov 2018
Demonstration: Official start **May 7** 2019

Project homepage: ELISA

Federal State of Schleswig Holstein
Infrastructure project awarded to Siemens
Track length / Amount of trucks: 5-6km / 5
Construction: Started Oct 2018
Demonstration: Start in 2019

Quelle: Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit / Grafik: DVZ

Project homepage: FESH

Federal State of Baden-Wuerttemberg
Tender published Nov 2018
Track length / Amount of trucks: 5-6km / 5
Customer's targeted start of Demonstration: 2019

Project homepage: eWayBW

Infrastructure construction with minimum disruption, delivered on time and on budget

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Search shafts checking on underground wires and pipes

Bringing in the steel tubes as foundation

Setting up the poles

Installation of the cantilevers

Pulling the wires

Connecting the substations

Commercialization of zero emission trucking starts with shuttles, which are then linked up to form a larger network

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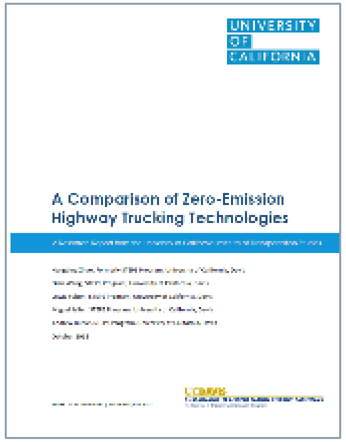
Shuttle applications (ca 20-100 km)

- The next steps should be pilot projects **proving that zero-emission heavy road freight is both economical and practical**[1]
- Experts on highway trucking recommend local or regional catenary trucking projects „**the most feasible approach for the zero-emission technologies”**[2]

CEO of Scania & CTO Volvo Group

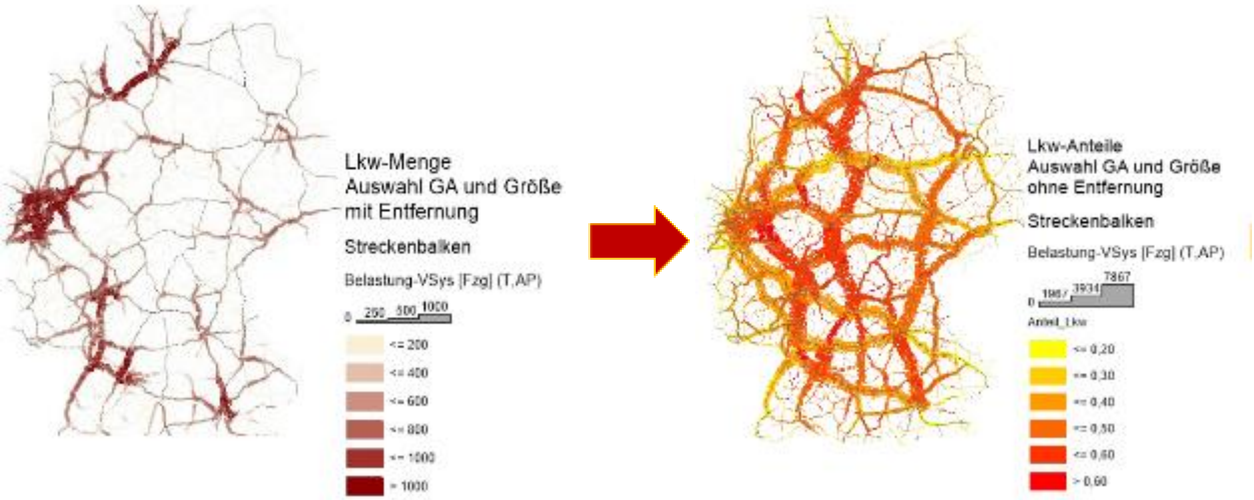


Source 1: https://www.di.se/debatt/volvo-scania-mfl-sverige-ska-bli-en-fossilfri-varldsutstallning/ (April 2018)

Source 2: A Comparison of Zero-Emission Highway Trucking Technologies (Oct 2018)

Network roll-out

- The systemic transition to zero emission road freight requires breaking out from early shuttles to large scale network
- Possible **important role of hybrids** (driving a very high share on electricity) as users of partial infrastructure network
- Nearly completed network will **facilitate transition to fully zero-emission mobility**



→ Providing the **right infrastructure is a necessary precondition for zero emission long-haul trucking**

Climate protection measures of German Ministry for Transport include catenary solution for HDV

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UBA-Ö: Reduction of 7,2 Mio. t CO_2 until 2030 in transport sector

- 2,7 Mio. t CO_2 potential reduction through electrification (e.g. catenary)

M6	Einführung eines elektrifizierten Systems auf dem hochrangigen Straßennetz (z.B. Oberleitungen)	Intensität 1: Schaffung eines flächendeckendes Stromversorgungsnetz am hochrangigen Straßennetz für SNF in Anhängigkeit von Fahrzeugen (z.B. Oberleitungen) bis 2040

Potential in Intensität 1: sehr groß (2,7 Mio. t THG)

Quelle: UBA-Ö (2018) Sachstandsbericht Mobilität S. 46

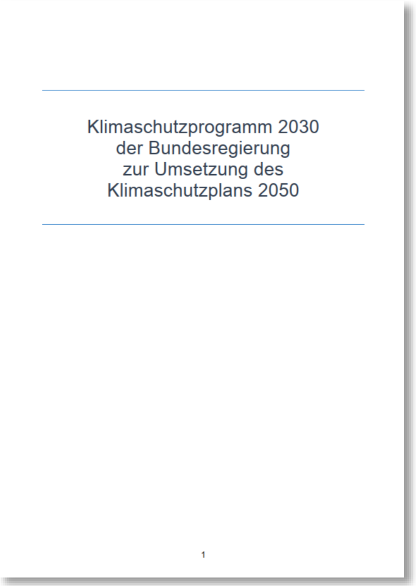
German Climate Protection Program 2030: Major steps towards zero emission by 2050

Kapitel im Klim… schutzprogram… 2030	…sst Maßnahmen …n Eckpunkten
3.4.3.11	22

Kurzbeschreibu… für … - … eine emissionsfreie Logistik im Blick zu haben.

«The goal is that by 2030 about one third of the mileage in heavy road freight transport will be electric or based on electricity-based fuels« (p. 80)

Quelle: BMU (2019) Klimaschutzprogramm 2030



A European and harmonized solution could take shape already today - enabling zero emission trucking on TEN-T corridors by 2050

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UK

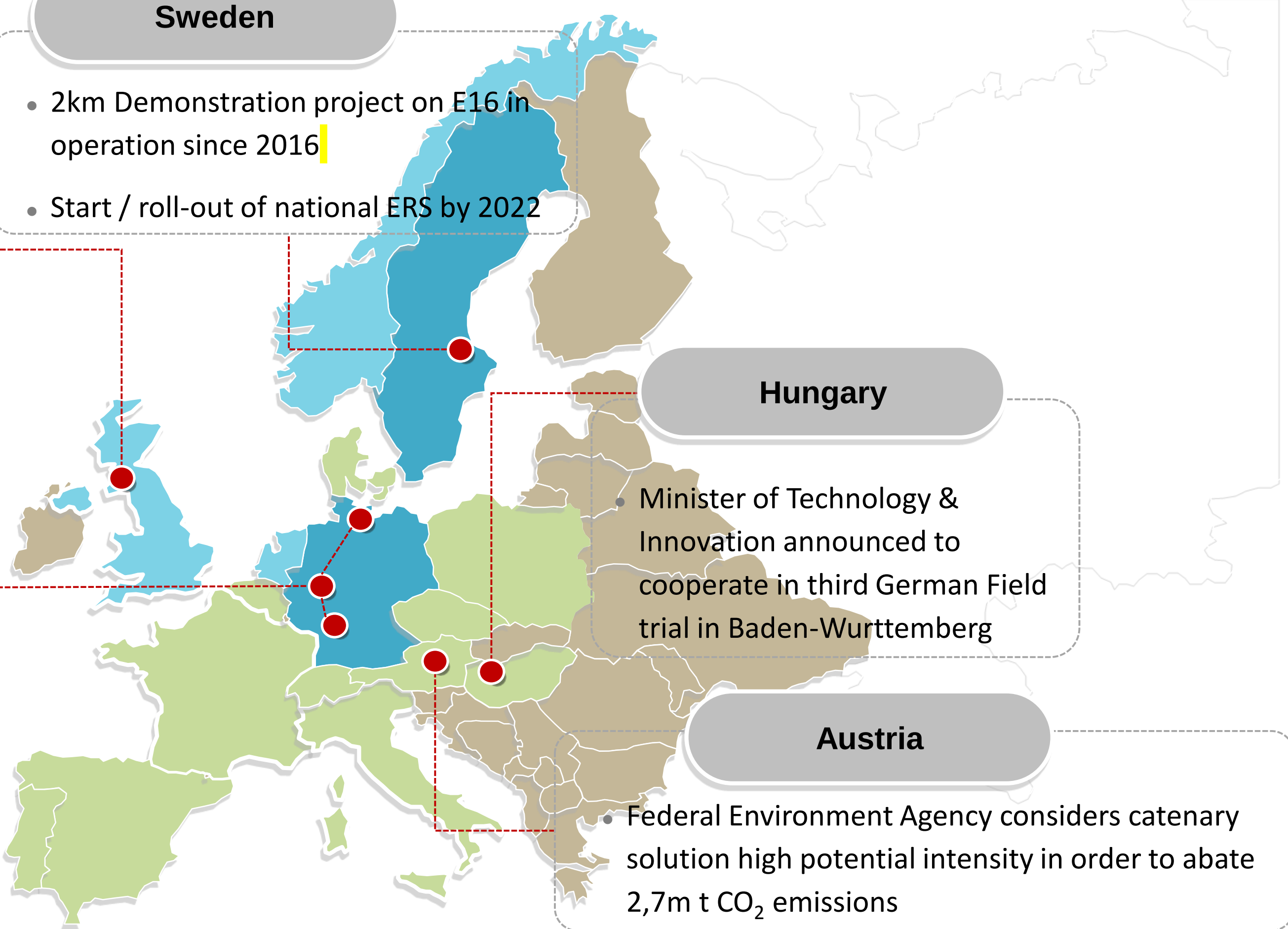
- £ 400m invest in charging infrastructure (PEV) announced
- DfT: dynamic electrification of HDV supports zero emission pathway

Sweden

- 2km Demonstration project on E16 in operation since 2016
- Start / roll-out of national ERS by 2022

Germany

- 2018-2022: Three fields trials on motorways A1 and A5 and B462 publicly funded by BMU € 45,3m
- Extension of catenary network part of climate protection program 2030



Hungary

- Minister of Technology & Innovation announced to cooperate in third German Field trial in Baden-Wurttemberg

Austria

- Federal Environment Agency considers catenary solution high potential intensity in order to abate 2,7m t CO_2 emissions

USA

- UC Davis study outlines advantages of catenary solution compared to alternative propulsion solutions for trucks

Interest in catenery solution exists

Study with regard to catenery solution for HDV exists

Catenary solution: demo / field trial realized or in preparation


SPEDITION
SCHANZ
CAPAROL
SCANIA

Questions?
Your point of contact for eHighway at Siemens Mobility Germany

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Zero emission trucks are possible with renewable energy, but efficiency varies greatly

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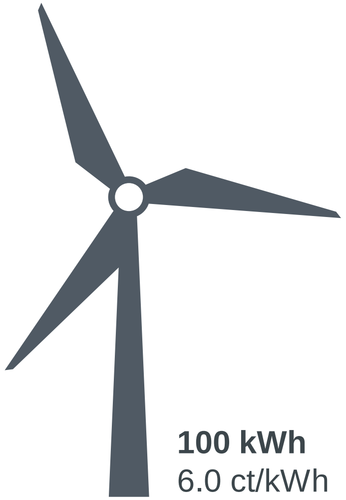

100 kWh
6.0 ct/kWh

Pathway	Range Cost per km	Efficiency WTW	Example vehicle
Electric Road Systems: e^- → Grid (incl. catenary) → e^- (96 kWh, 12 ct/kWh) → eTruck (Catenary-Hybrid) (1,6 kWh/km)	**60 km** 19 ct/km	77%	
Battery: e^- → Grid → e^- (96 kWh, 10 ct/kWh) → eTruck (Battery) (2 kWh/km)	**48 km** 20 ct/km	62%	
Hydrogen: e^- (93 kWh) → Electrolysis η = 70% → H_2 (65 kWh, 15 ct/kWh) → H_2-network[1)] (2 kWh) → H_2 (65 kWh, 18 ct/kWh) → CH_2- fuel station (5 kWh) → $C.H_2$ (65 kWh, 20 ct/kWh) → Fuel cell truck (2.7 kWh/km)	**24 km** 55 ct/km	29%	
Power-to-Gas: e^- (98 kWh) → Electrolysis η = 70% → H_2 (69 kWh, 15 ct/kWh) → Methanation η = 80% → CH_4 (55 kWh, 19 ct/kWh) → NG-network[1)] → NG (55 kWh, 20 ct/kWh) → CNG-fuel station (2 kWh) → CNG (55 kWh, 22 ct/kWh) → Gas-truck (3.2 kWh/km)	**17 km** 70 ct/km	20%	

1) Including storage
Source: German Ministry of Environment

eHighway offers efficient and low cost electricity supply, thanks to smooth load profiles and high connection voltage

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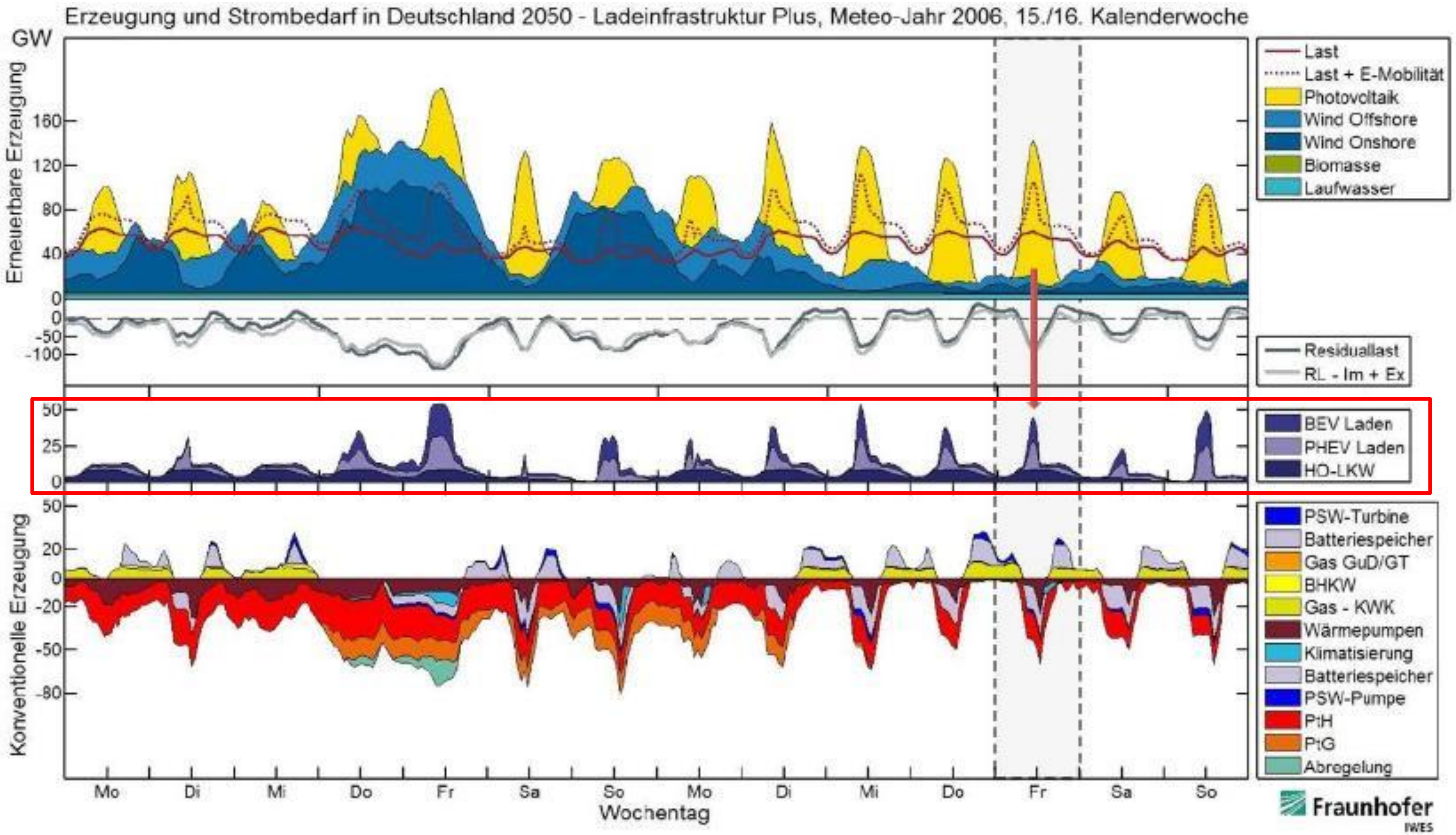
Detailed load profiles from BEV, PHEV and eHighway, and supply though conventional and renewable generation in Germany



- **Flexible distributed loads are essential** for an energy supply based mainly on fluctuating renewable based generation
- The charging of BEV and PHEV vehicles leads to daily peak loads. **eHighway exhibits a smoother load profile.**
- **eHighway-enabled trucks** using hybrid drives (e.g. combustion engine using sustainable biofuels) can contribute to system peak load reduction (active load management/deferrable load).
- Grid connected eHighway truck systems enable a more **efficient use of energy**.

Source: http://www.energieversorgung-elektromobilitaet.de/Kernaussagen.html

Translated Table 7 from German Transport Ministry (BMVI) report

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Components	Basis for calculations	Costs (EUR/km)
Grid connection point	Ca. 15.000 EUR per connection. At a pattern of a connection point every 3 km leads to 5.000 EUR/km	5.000,--
Feed line from grid connection point to substation along the route	Ca 200 EUR per m of cable trench (underground, built up area), ca. 100 EUR per m cable; At an average of 2,5km connection length leads to 750.000 EUR per connection. At a pattern of a connection point every 3 km leads to 250.000 EUR/km	250.000,--
Substation	Ca. 300.000 EUR per MVA (incl. communication and safety technology); A 6 MVA power rating results in costs of 1,8m EUR per substation; At a pattern of a connection point every 3 km leads to 0,6m EUR/km	600.000,--
Poles	Ca. 10.000 EUR per pole (incl. cantilever and foundations); A pole distance of 50m results in costs of 400.000 EUR per km (covering both road directions)	400.000,--
Catenary (contact line)	Ca. 300 EUR per m, e.g. 600.000 EUR per km (covering both road directions)	600.000,--
Guard rails	Ca. 100 EUR per m; under the assumption that the entire route needs to be equipped, costs are 200.000 EUR/km (covering both road directions)	200.000,--
Planning, Procurement and Project management	Ca. 10% of the investment costs	205.000,--
Total		**2.260.000,--**

Source: BMVI - Machbarkeitsstudie zur Ermittlung der Potentiale des Hybrid-Oberleitungs-Lkw (2017) page 36

Overview of alternative power trains and fuels for trucks

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	Fuel cell (FC)	Battery electric (BE)	Overhead catenary (OC)	Synthetic fuels (PtG /PtL)
Motors and technology	Electric motor and fuel cell with hydrogen as energy storage	Electric motor and battery as energy storage	Electric motor and power from overhead lines, if necessary with battery as energy storage or additional combustion engine	Internal combustion engine and pressurized gas or liquid tank as energy storage device
Conversion steps Fuel production from electricity	Conversion to hydrogen (electrolysis)	Direct Use	Direct Use	Conversion to hydrogen (electrolysis) and further to carbonaceous fuel
Efficiency today with the use of renewable electricity	Circa	Circa	Circa	Circa
tank-to-wheel	40 – 50 %	90 %	90 %	35 – 40 %
well-to-tank	60 – 70 %	90 %	90 %	50 – 60 %
well-to-wheel	25 – 35 %	80 %	80 %	20 – 25 %
Technological readiness level of vehicles	Several test projects (TRL 6-7)[11]	First commercially available vehicles (TRL 8)[11]	Several test projects (TRL 6-7)[11]	Conventional vehicles
Key challenges	Infrastructure development and increased power requirements due to high conversion losses, cost reduction in fuel production	Limited range, long charging time and payload losses	Infrastructure development, acceptance, integration in logistics processes	Strongly increased power demand due to highest conversion losses, cost reduction in vehicle and fuel production

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