Electrification of the road transport sector
› The prime option to cope with climate targets?

Netze BW
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Ein Unternehmen der EnBW

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Agenda

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1 Introduction

„Electrification of the transport sector: The prime option to cope with climate targets?“

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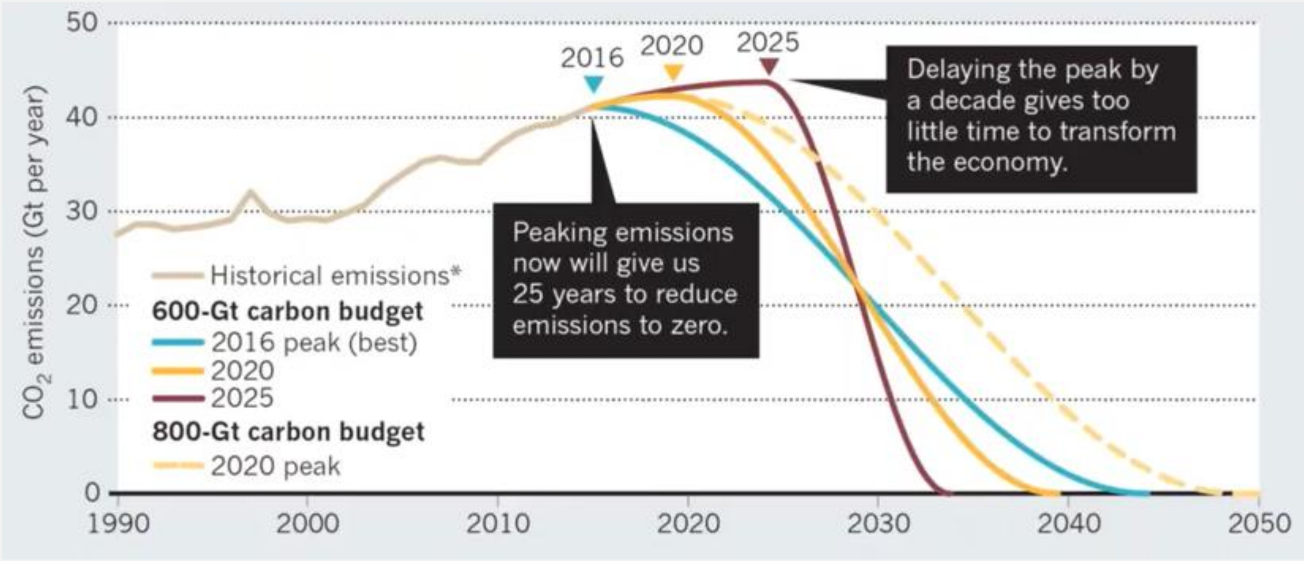
Development of carbon dioxide (CO2) emissions and the time to act



Source: Siemens AG, 2018; based on Figueres et al, 2017

Putting the emissions, including those from, road- freight

- on path towards zero,
- with minimum total emissions getting there.

- Action on climate change **urgently needs to be performed** in order to prevent disruptive developments
- **Electrified mobility** has been given the main priority in countries worldwide
- The transformation from conventional to more/full electric mobility contains **structural questions**
- Current roadmaps are portraying **different decarbonization approaches** and different ways of technology applications
- Electrification of the transport sector requires a **direct involvement of the energy sector**

1.1 A general take on European climate targets and their fulfillment

European Climate Strategies for 2020/2030/2050

2020
Climate and Energy Package

- **20%** cut in **Greenhouse Gas emissions (GHG)** (from 1990 levels)
- **20%** of **EU energy** from **Renewable Energy Systems (RES)**
- **20%** improvement in **energy efficiency**

Set targets **will be reached** by the EU

2030
Climate and Energy Frameworks

- **At least 40%** cuts in **GHG emissions** (from 1990 levels)
- At least **32%** share from **RES**
- At least **32.5%** improvement in **energy efficiency**

Additional efforts needed to reach the targets

2050
Long-term Strategy

- Becoming **climate-neutral** by **2050**
- **Clean, safe and connected mobility**
  - Low or zero-emission vehicles
  - hydrogen and biogas
  - Mobility systems based on digitalization

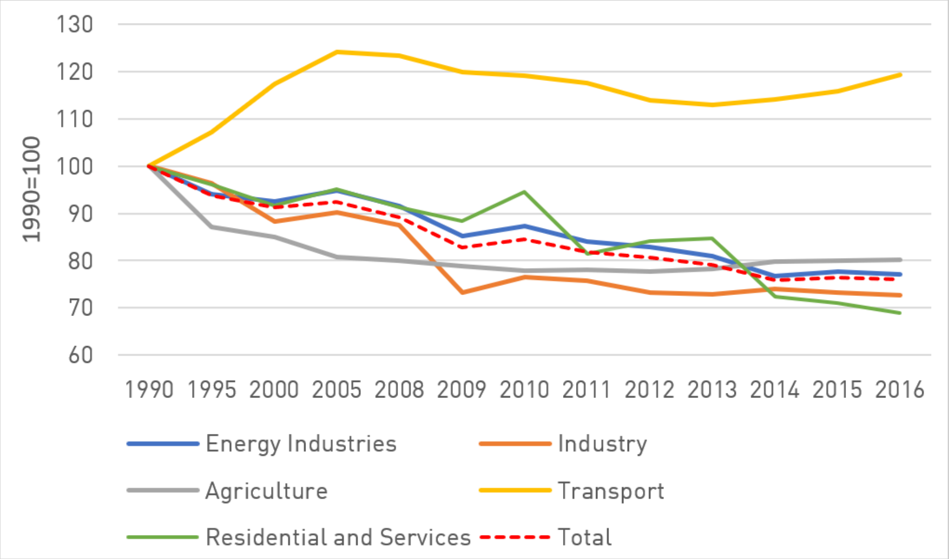
Currently no trend foreseeable

Source: European Commission, 2019

1.2 The transport sector and its impacts on the environment

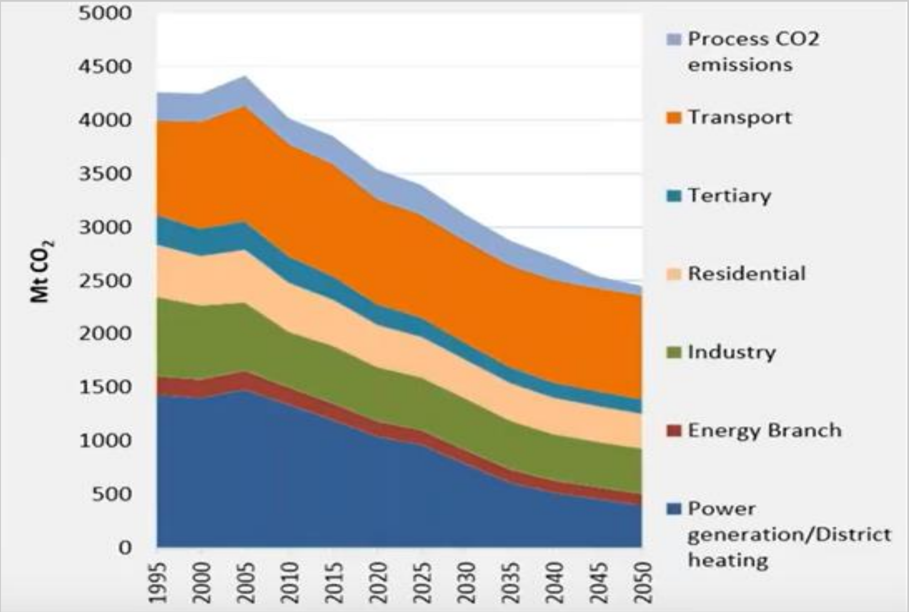
Emissions by sector (EU) and forecasts for sectorial decarbonization

Development of sectorial GHG emissions (EU) in % (1990-2016)



Source: own visualization, based on European Commission, 2018; EEA, 2019

Forecast on the total emissions of the European Union (EU)



Source: Siemens AG, 2018

- GHG emissions related to transport have been **increased by around 20%** (compared to 1990)
- **Road transport** is accounting for **more than 22%** of the anthropogenic **carbon dioxide (CO2)-emissions**

- The **energy sector** is set to be **transformed by 2050**
- **Transport sector** is posing the **biggest challenge** with regards to decarbonization, with long-distance hauling being specifically **important for climate protection**

1.2 The transport sector and its impacts on the environment

GHG emissions by transport type (EU) and global emission tendencies

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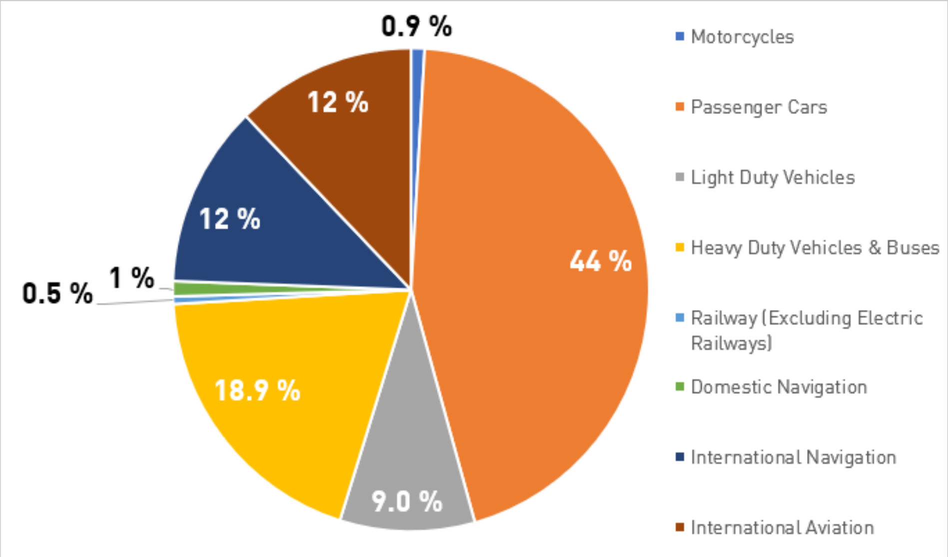
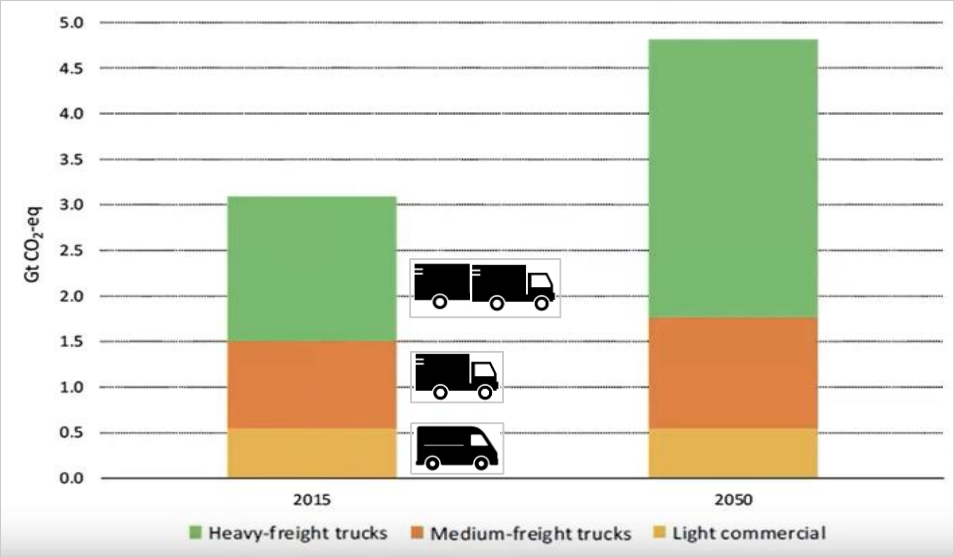
GHG emissions by transport type (2016)



Source: own visualization, based on European Environment Agency, 2019

Development of emissions (in C02-eq) in 2015 and 2050 (globally)



Source: Siemens AG, 2018, but with own modifications

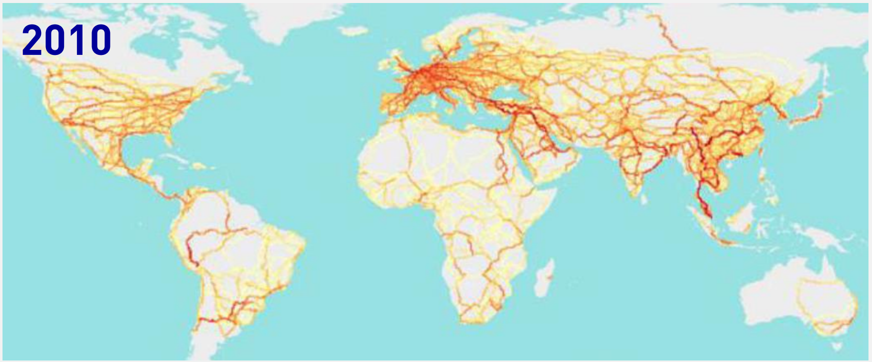
- More than **73% of GHG emissions** related to the transport sector can be **allocated to road transport**
- **Passenger cars** are contributing over **44%** to transport sector emissions, **heavy-duty vehicles for ca. 19%**

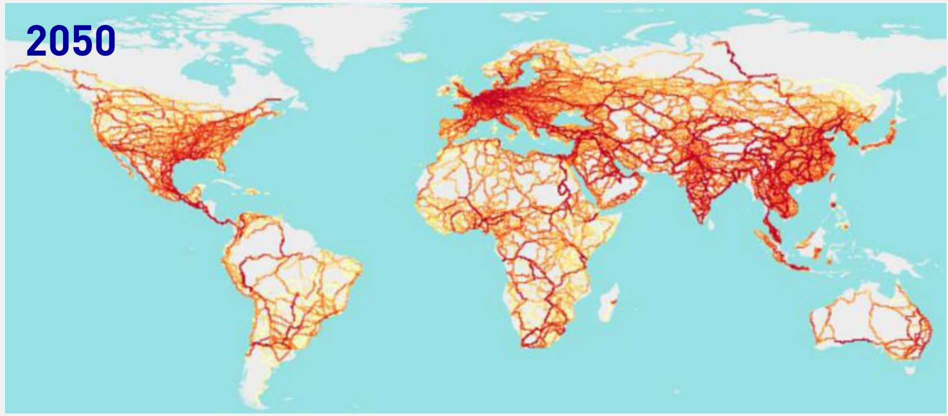
- **Current trend** for road-freight emissions highlight the urgency for decarbonizing solutions
- Global heavy road-freight is expected to emit **3 Gt of C02-eq* by 2050**

*Gigatonnes of C02-equivalent

2 Status Quo of road transport electrification
General overview on current developments

- **Transport in its core will continue to rely on roads** (despite the increasing use of other methods e.g. rail and maritime)





Source: Siemens AG, 2018, based on ITF, 2016

- **This implicates the need for alternative powertrains**
  - Advanced **Internal Combustion Engines (ICE)** and disruptive thermal propulsion systems and fuels (Power to liquids or gas),
  - Novel hybrid systems with next generation lightweight ICE and simplified powertrain components
- **Electric Road Systems (ERS), using catenary trucks might offer additional potential to decarbonize the transport sector**
  - The necessary equipment is currently under development and has been tested in a small number of sites in Sweden, Germany, and the USA

2.1 State of current technology development

Potential for energy efficiency in the transport sector by transport type

	Technological optimization	Governance instruments
MOTORCYCLES	› **Electrification** (battery)	› **Fleet-modernizations** (Bonus-malus system) › **Demand-driven system**
PASSENGER CARS	› **ICE efficiency** (alternative fuels) › **Electrification** (battery)	› **Fleet-modernizations** › **Bonus-malus system** › **Emission Trading-Schemes**
LIGHT DUTY VEHICLES	› **ICE efficiency** (alternative fuels) › **Electrification** (battery)	› **Incentivation of alternative technologies** (e.g. CO2-taxation) › **Fleet-modernization**
HEAVY DUTY VEHICLES & BUSES	› **ICE efficiency** (alternative fuels) › **Electrification** (battery & centenary)	› **Incentivation of alternative technologies** (ERS) › **CO2-taxation**
RAILWAYS (EXCLUDING ELECTRIC RAILWAYS)	› **Electrification of non-electrified infrastructure** › **Efficiency in drive-trains**	› **Common electrification policies** (supranational)
DOMESTIC NAVIGATION	› **Structural improvements** (hull, propulsion) › **Alternative fuels** and **partial electrification**	› **Tighter emission controls** (i.e. CO2, NOx, SOx)
INTERNATIONAL NAVIGATION	› **Structural improvements** (hull, propulsion) › **Alternative fuels** and **partial electrification**	› **Tighter emission controls** (i.e. CO2, NOx, SOx)
INTERNATIONAL AVIATION	› **ICE efficiency** (alternative fuels) › **Electrification** (battery)	› **Adoption of CO2 emission standards** › **Carbon offsetting**

› There is a high emphasis on **general "electrification","alternative fuels"**, as well as **"batteries"** as the main methods of energy supply
› **Comprehensive policies** are required to resolve issues that technology **cannot solve**

2.1 State of current technology development

Alternative concepts for climate-friendly transport

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On-board storage

- **Alternative fuels**
  - CNG/LNG
  - Bio fuels
- **Electricity**
  - Battery
  - Fuel cell

External power supply

- **Contactless**
  - Inductive power supply
  - Linear motor concepts*
- **Conductive**
  - Ground-based contact line
  - Overhead contact line

- **Electric and fuel-cell vehicles**, contain the potential to be mainstreamed in the **near-term**,
- However they're prone to the issues of **size and weight** of the storage and **general technology development**

- **External powered** vehicles are posing an **economic alternative** to on-board storage-driven vehicles
- However they underly the necessity of **additional infrastructure** as well as the **appropriate vehicles**

*Maglev-System (e.g. in Shanghai, connecting the airport with the city)

2.1 State of current technology development

Areas of application of alternative drive concepts within heavy-freight transport

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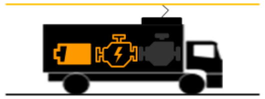
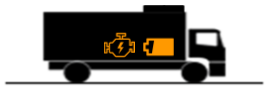


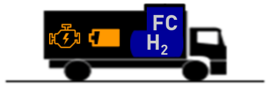
Overhead Hybrid Truck (O-HEV)

- When **high shares of utilization** are covered on **electric stretches**
- **Point-to-Point commuting** with short up- and downstream runs
- Easing of **local emissions** is required



Battery Electric Truck (BEV)

- Suited for **urban and regional distribution**
- Locations which require **less emissions**
- Areas where **charging-infrastructure is well established**



Fuell Cell Electric Vehicle (F-CEV)

- Utilization within **long-distance traffic**
- Within corridors where **appropriate charging-infrastructure** is established
- **Complementary option to BEV**

Source: Scania AG (left, right); Volvo (middle)

2.2 Limitations and potential barriers for wide-scale implementation

Current barriers (near-term) for electrification by sector (Light/Heavy Road, Rail)

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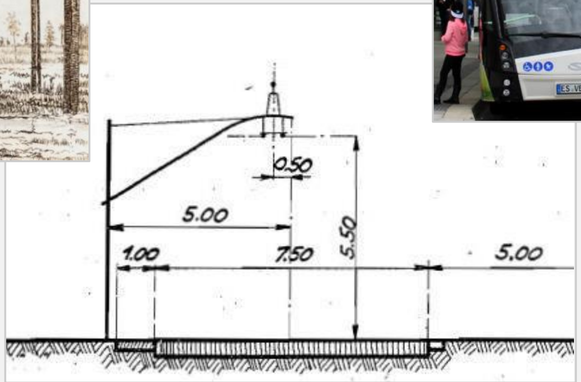
Subsector	Cost barriers	Infrastructure barriers	Other barriers
Light Road	› **Total cost of ownership nearing parity** (depending on pricing of conventional fuels) › **Battery cost** (depending on ICE)	› **Development of charging infrastructure**, particularly within dense urban environments › **Fast-charging** to support high-utilization	› **Range limitations** due to (current) technological restrictions
Heavy Road	› **Total cost of ownership nearing parity** (short-haul, high utilization fleets), relative to conventional fuels › **High capital costs** highly relative to conventional fuel options	› **Fast-charging** needed to support high-utilization fleets	› **Range limited** by **weight**, **size** and **cost of the battery** (heavy vehicles) › **Interventions into the environment** (Catenaries)
Rail	› **Limitation of electric rail infrastructure** to specific regions (high population density, high modal share and energy density) parity (short-haul, high utilization fleets, conventional fuels) › **Lack of investments** to expand mode share (electric trains, overhead lines as well as other connected infrastructures)		› **Modal shift** depending on the utilization of **other transport methods**

3 Electrification of road transport systems

Developments and tendencies in the technological application of Electric Road Systems (ERS)

Siemens Elektromote (1882)

German Highway Concept (1936)



Trolleybus in German (2019)

Electric mining truck

eHighway in Germany (2018)

- Electric road applications date back to more than **135 years**
- **Over 300 trolleybus systems** are operating worldwide
- Road applications demand **early standardization** (for vehicles)

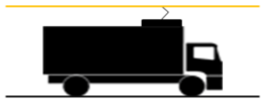
- Electric traction system can be **successfully implemented** on **highways** as well
- Applicable to **long-distance trucks/busses**
- **DC-charging** through catenary type contact lines

Source: Siemens AG, 2018 (left, middle left and middle right, right); Trollino, 2019 (middle right)

3.1 ERS-Technology development and its utilization

ERS technologies within the heavy-freight transport with external power supply

Source: Scania AG (left, right); Volvo (middle)

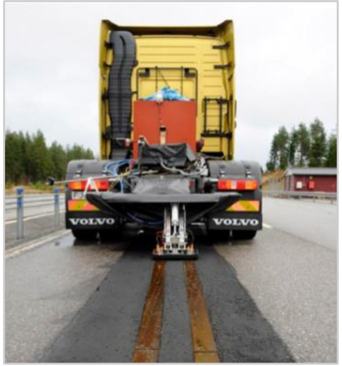


Overhead Contact Line

- **Most economical** variant
- Comparatively **low losses**
- **Dynamic loading** possible
- **Low maintenance**

Video-eHighway

Conductor Line



- Implementation possible within **road construction work**
- **Dynamic loading** possible
- **Preservation** of the landscape

Inductive System

- **Least economical** variant (as of now), excessive changes needed (road)
- **Non-visible** (preservation of the landscape)
- Comparatively **high losses**

3.1 ERS-Technology development and its utilization

Areas of application of ERS concepts within freight transport

Shuttle transport

- Solution for **short or medium distances** (<50km) which require a high frequency
- Benefits of **lower fuel consumption** and **longer lifetime**
- **Reduction of local emission**, e.g. air and noise pollution

Electrified mine transport

- **Interconnection of areas** e.g. mines and storages to enhance the transportation capabilities
- **Improvement of operational aspects**, like sustainability and economic factors

Electrified Long-Haul traffic

- **Economical feasible** alternative to conventional road-freight transport
- **Reduction of CO2 emissions** to cope with climate targets
- **Synergy effects** with existing railway systems

Source: Siemens AG, 2015 (left; middle; right)

Projects and initiatives (current developments)

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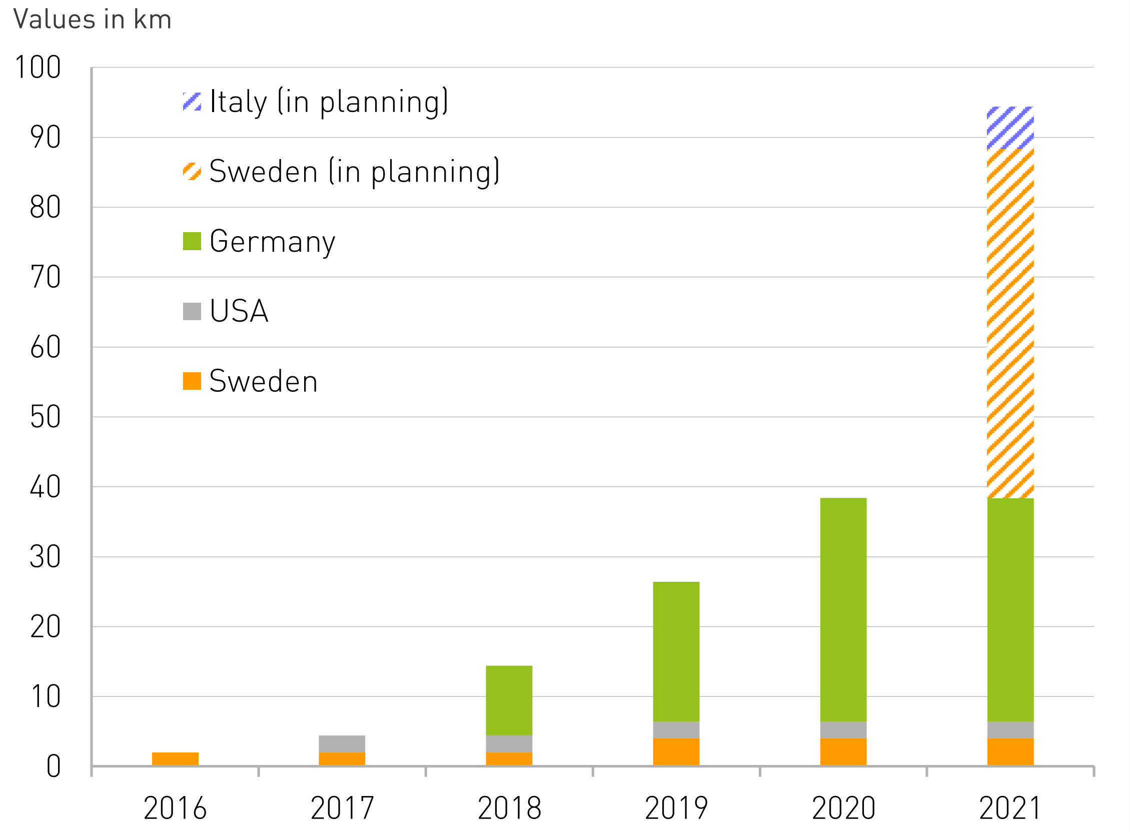
Since 2016, at least one new project has been added every year

- **2010-2016**: Research Projects in Germany (ENUBA I/II, ELANO)
- **2016**: First electrified road section in Sweden
- **2017**: Commissioning of a test track (shuttle between port and rail connection) in California
- **2018**: Completion of the first electrified motorway section in Hesse, Germany (A5)
- **2019/2020**: Planned commissioning of two more test tracks in Germany (Schleswig-Holstein and Baden-Württemberg
- **2021**: Planned start-up of a first electrified motorway section in Italy as well as other electrified long-distance sections in Sweden

Test tracks with overhead contact line on public highways worldwide



Source: Öko-Institut, 2018

3.1 ERS-Technology development and its utilization

Project „eWayBW“ – Objectives, Characteristics and unique features (1/2)

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Source: Scania AG, 2018

- Track with the **highest capacity utilization** with focus on the energy industry
- **Complementary** to pilot projects in **Hessen** and **Schleswig-Holstein**

The main objective

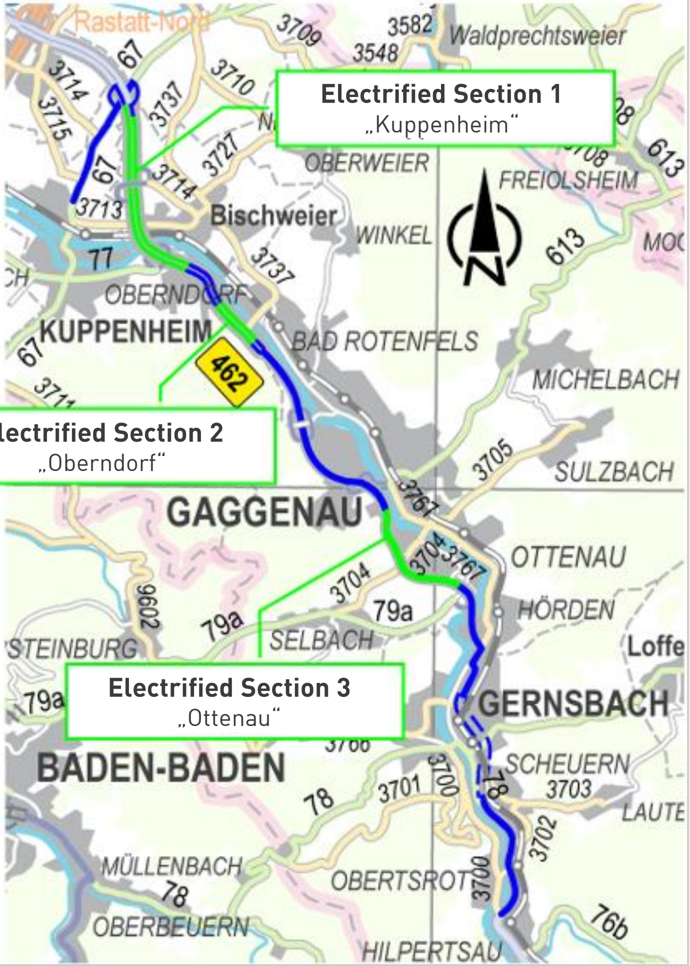
- **Open investigation** of the overhead line infrastructure,
- Utilization of **catenary trucks in shuttle mode** between the paper mill and a warehouse

Characteristics of the route

- **Public test track of 18.3 km** with
- Electrification areas of **6 km** (in both directions),
- annual mileage of **< 140,000 km**

(unique) features

- Volume of transport: **> 500.000 t/a**
- **64** circulations **every day**
- Yearly perfomance/Truck **> 140.000 km**
- Contact wire performance **> 250.000 km**
- Parallel railway line (synergy effects)



3.1 ERS-Technology development and its utilization

Project „eWayBW“ – Targets, Characteristics and unique features (2/2)

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Focus points of the “eWayBW”-project:

- **Energy sector** with focus on the **energy and transport system transition** (“Energie- und Verkehrswende”)
- Project pursues the aim to be **completely CO2-neutral**
  - Integration of renewable energy systems

- **Impact of “moveable”** and **“variable loads”** within the energy system
  - Stability of the system with high traffic/transport volumes
  - Implications of feeding energy regained through **recuperation** to the grid (Vehicle-2-Grid)
- Testing of the **feasibility**, as well as the **implications of Vehicle-2-Vehicle charging**
  - Option to charge passenger vehicles via catenary trucks

- Testing the environment **for partial** and **complete autonomous driving**
- Prospective for the **development for alternative drive-technologies**
- **Governmental Cooperation** between **Hungary and Baden-Württemberg** (Ministries, University of Óbuda)

3.2 Status of current implementation rates

Potential roadmap for the implementation of ERS (Germany)

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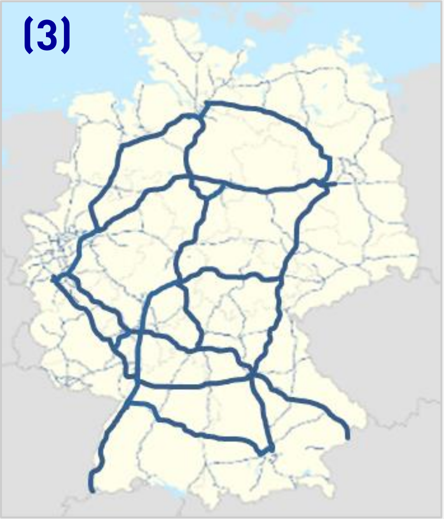
Step (1): Electrification of first corridors between major transshipment points, for example, route Hamburg – Kassel – (by 2025?)

Step (2): Extension of first corridors to **longer axes or regional networks**
For example: network around Hannover or extension of an axe (A7) – (by 2030?)

Step (3): Successive extension of the infrastructure to the **core motorway network** of approximately 4,300 km – (by 2050?) – **20 billion EUR investment**



› Need for the **development of user-friendly investment and billing models**

Source: StratON, 2018 (middle, left, right)

4 The energy sector and the interplay with electric vehicles

General impacts of electric vehicles on the grid operation

- **Up to 2030** additional overall demand for electric vehicles is **estimated to be limited in Europe** and therefore will **not significantly** influence the electricity system
    - But in the **long-term**, when electric vehicles reach **greater market shares**,
    - the required electricity will **significantly impact power systems** in Europe

- **Electricity systems** and the combination of conventional and renewable generation plants **differ greatly within Europe**
- **Impact of electric vehicles** depends strongly on the degree of individual **electric mobility** in Europe

4.1 General impacts of electric vehicle charging for the grid operation

Different procedures in charging of electric vehicles and their effects

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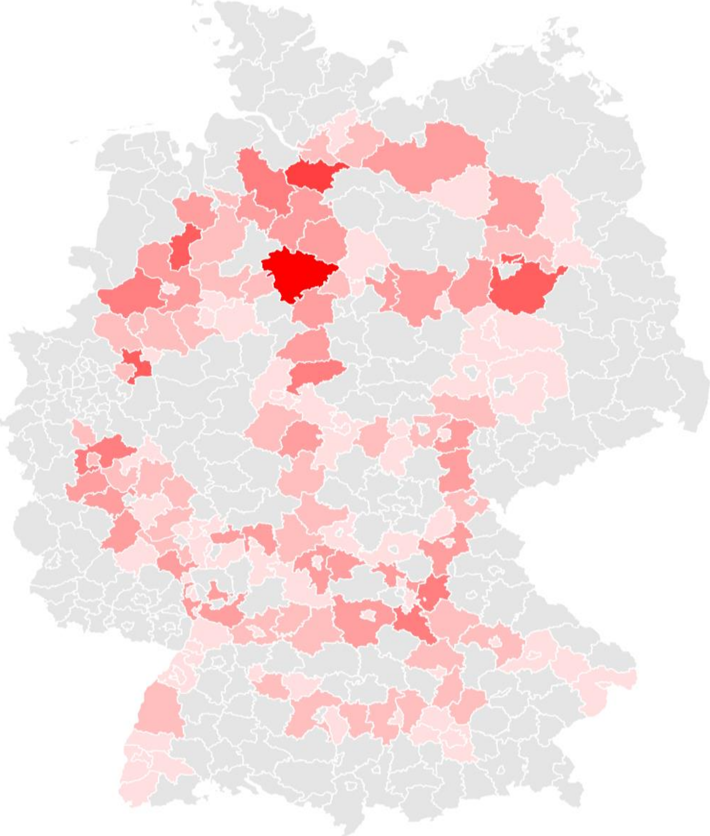
Network-oriented charging

- **Reducing the stress** on the local distribution grids
  - Less equal-charging processes
- **Smoothing** of load patterns
- **Shifting** load-cycles to **night-times**
- Crucial for the **higher penetration of EVs**

- **Positive effects** depending on individual the **energy mix**

Regional distribution of electricity demand by catenary trucks (GER)



Source: Öko-Institut, 2019

RES*-oriented charging

- Charging during **high RES-production**
- **Increased** utilization of **decentralized RES-infrastructure** (workplaces, etc.)
- Shifting charging-times **from night to day**

- Important cornerstone to avoid **non-utilized RES-capacities**

* Renewable Energy Systems

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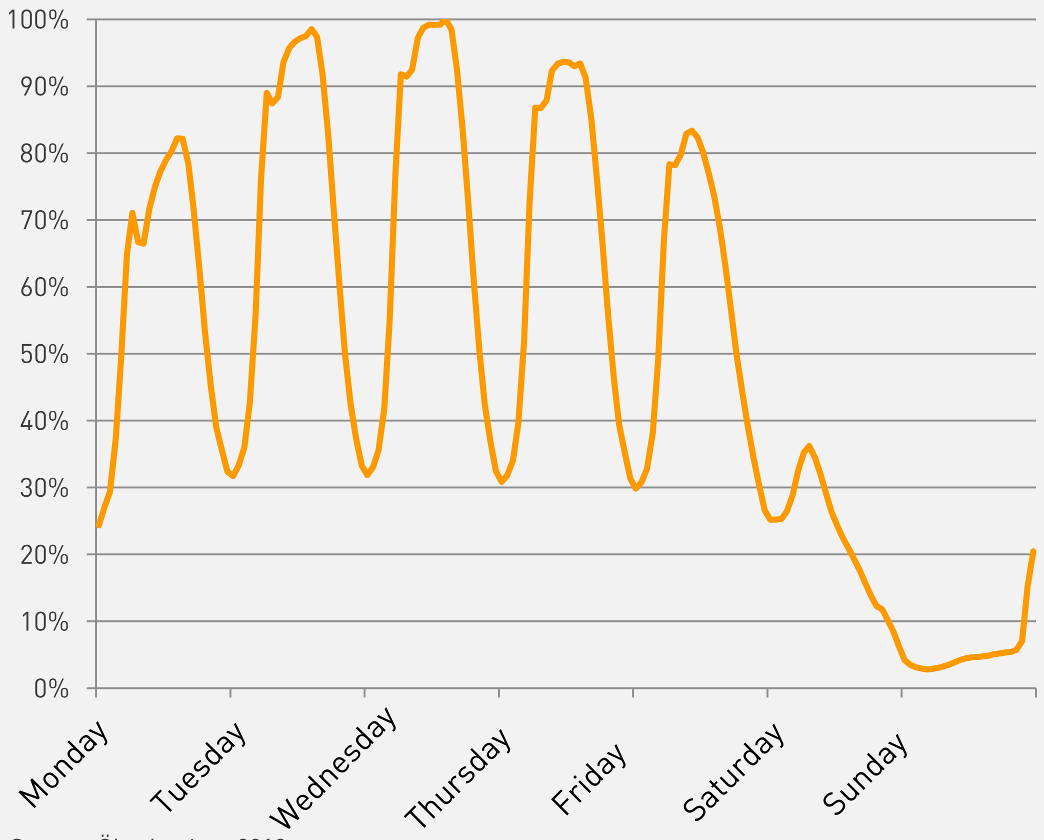
Load distribution during the week

- The extra load of catenary trucks is the **highest during the day** and is **reduced** by around **30% at night**
- **On weekdays** between **7am** and **6pm** most trucks and semitrailers are operating. **In this period**, electricity demand from catenary trucks would be at a **high level**
- **In the night hours** between **10pm** and **5am** the traffic volume of trucks and semi-trailers is typically **reduced to 30-40%** of the maximum demand.
- **On weekends** the demand is significantly **below average**

- **Catenary hybrid trucks** have a **high daily load distribution** with the **lowest demand on the weekend**.

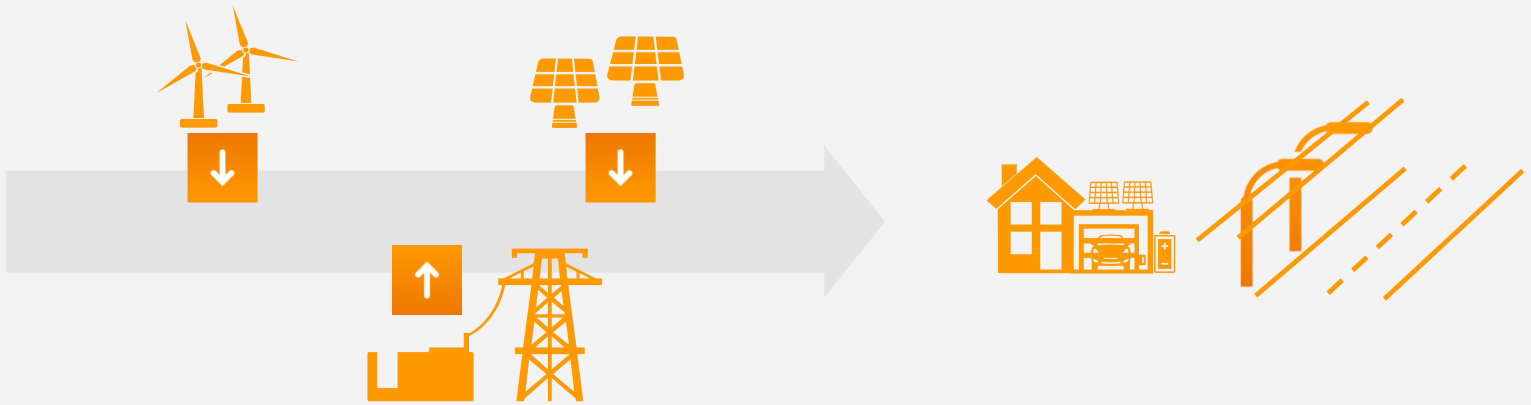
Typical traffic of trucks and semitrailers on motorways during the week



Source: Öko-Institut, 2018

4.3 How the additional electricity demand can be covered

- **Additional electricity demand** needs to be met by **additional power generation**
  - Requirements for the **smart charging** of vehicles
  - **Integration of RES** into the existing grid infrastructure



- At the **national level**, the demand for charging power accounts for **only a small proportion of the total electricity demand**,
- at the **regional level**, the impact of catenary trucks on the **accumulated demand may be significantly greater**
- **Spatial distribution** of **residual loads** strongly depends on the individual RES expansion strategy

5 Summary & Discussion – challenges and potential developments (1/2)

General challenges and developments in terms of road transport electrification

- **Transforming the transport sector** is key to fulfill **climate-related obligations**
  - Electrification of passenger cars **alone is not sufficient**
  - Possible scenarios containing **different combinations of BEV, O-BEV, O-HEV***

**BEV: Battery Electric Vehicle, O-BEV: Overheadline Battery Electric Vehicle, O-HEV: Overheadline Hybrid Electric Vehicle*

- **Electrification of the road transport** underlies different and variable factors
  - **Technological, structural** and **regulative** aspects heavily influence the electrification process
  - **Social acceptance** and the **associated effects** on consumer goods
  - Requirement towards **comprehensive policies** and **national transport strategies**

- **Economic competitiveness** of electrifying concepts are **currently not given**
  - Transport sector is still **heavily reliant on conventional fuels**
  - **Optimal degree of electrification** (cost efficiency vs. security of supply)
  - **High capital costs** and **development of charging infrastructure** are identified as the key barriers for electrification
  - Need for the **development of user-friendly billing models**
  - Separation between upstream and downstream infrastructure **(regulated and non-regulated area)**

5 Summary & Discussion – challenges and potential developments (2/2)

Challenges related to the electrification of freight-transport through catenery trucks

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- **No alternative drive option** has yet been able to assert itself within **road-freight transport**
  - Battery electric trucks in **regional/distribution** traffic with **advantages**
  - In **long-distance transport**, given the higher requirements, **no clear technology preference**
- **Catenary trucks represent a cornerstone**, but lack the potential to solve issues alone
  - **Electrifying the transport** sector should be seen as **complementar**y to the **existing rail transport system**

Source: Siemens AG. 2015; BMVI, 2019

- The **short-term CO2 reduction** contribution of catenary trucks is **relatively low**, but can be much higher in the long-term
- With the increasing **decarbonization of electricity generation**, electric trucks will already reach a significant **climate advantage by 2030**
  - Currently still **low CO2 advantage** compared to **diesel trucks**, but **by 2030** already **40% lower total emissions**

We are looking forward to welcoming you!

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