THE POTENTIAL ENERGY USE & CO_2 EMISSION REDUCTIONS OF ELECTRIC TRUCKS POWERED BY OVERHEAD LINES

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July 2016: First eHighway in Sweden

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Source: Siemens AG

WCTRS International Conference: Transport, Climate Change and Clean Air, Paris, June 21, 2018

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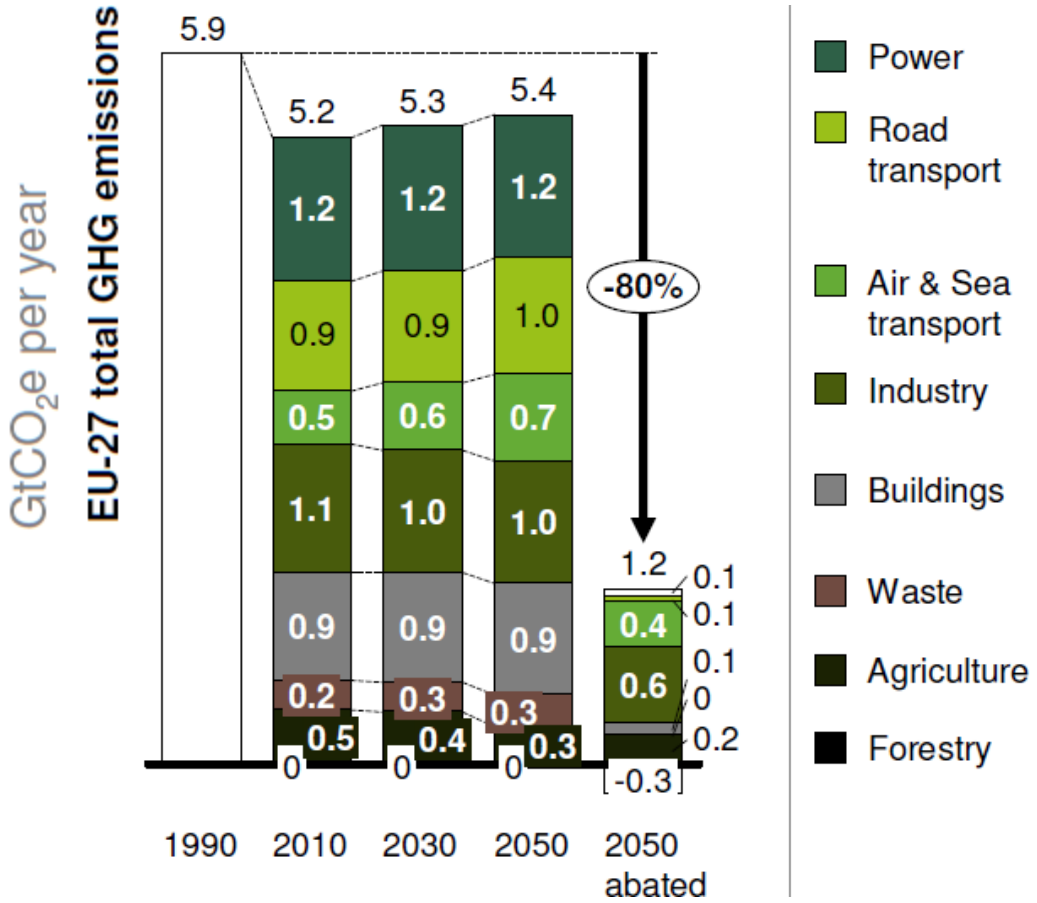
A drastic reduction of CO_2 emissions is required to reach Europe's climate targets.



Source: www.roadmap2050.eu

- EU target: reduction of GHG emissions by 80% compared to 1990
- Transport sector has to contribute, but goals not achievable with combustion engines vehicles
- Solutions for Transport required if we want to maintain our present way of life
- It is not about cost compared current technology but most cost-efficient future technology

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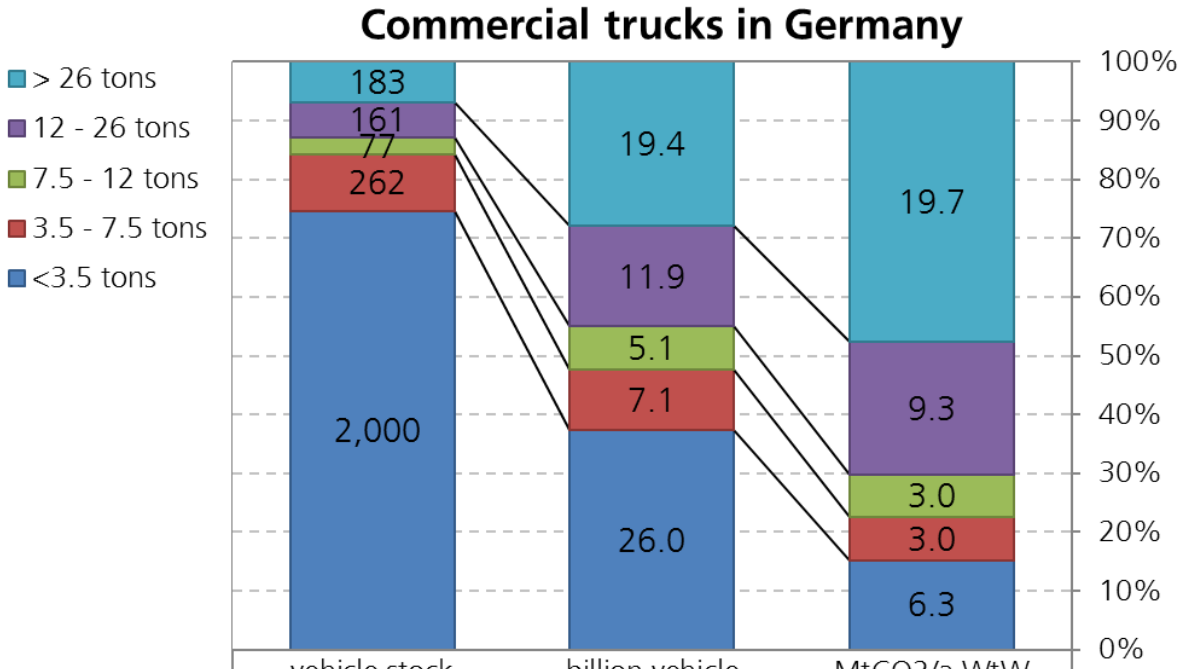
Heavy duty trucks make up only 5% of truck stock but 50% of truck CO_2-Emissions

- Heavy trucks have high annual mileage and high energy consumption
- For long-term CO_2-neutrality in the transport sector, we need solutions for the heavy truck transport (today Diesel only)
- Batteries not feasible for long-distance trucks
- Possible solutions:
  - Hydrogen FCEV
  - Power to gas, e.g. renewable LNG
  - Overhead line-trucks



	vehicle stock (1000 veh.)	billion vehicle km/a	MtCO2/a WtW CO2 emissions
> 26 tons	183	19.4	19.7
12 - 26 tons	161	11.9	9.3
7.5 - 12 tons	77	5.1	3.0
3.5 - 7.5 tons	262	7.1	3.0
<3.5 tons	2,000	26.0	6.3

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The alternative electricity paths have advantages and disadvantages

	Direct use of electricity	Hydrogen	Electricity-based hydrocarbons
Advantages	• Most efficient path • In many cases cheap	• medium efficiency • Can be stored	• Infrastructure partly exists • Existing storage can be used
Disad-vantages	• Necessary expansion of grid and possibly storage infrastructure • For high share of fluctuating RE, flexibility measures incl. storage must be expanded • Energy density too low for some applications	• Converting infrastructure is complex and expensive • Path dependency	• CO_2 input necessary • Potentials for "carbon-neutral" CO_2 severely limited • Expensive (avoidance costs more than 500 EUR/t) • Most inefficient of the three options (highest losses)
Efficiency today (WTT)	~95 %	~60-70 %	~50-60 %
Efficiency today (WTW)	**85 %**	25-35 %	20-25 %

RE= Renwable electricity

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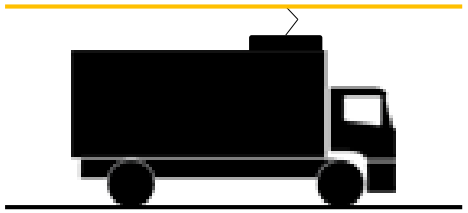
Different variants and energy connections for electric trucks are under discussion

Overhead line or catenary trucks

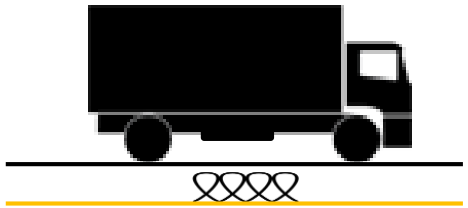


- Established technology for rail
- Modifications needed

Conductor rail-truck

- New technology
- Difficult in bad weather

Inductive charged-truck



- Rather low efficiency

Two possible execution variants

Electric motor + 200 kWh battery → long-term electrification?

Serial diesel hybrid with small traction battery as puffer (~10 kWh) → Today preferred for full flexibility

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Potential of overhead line construction

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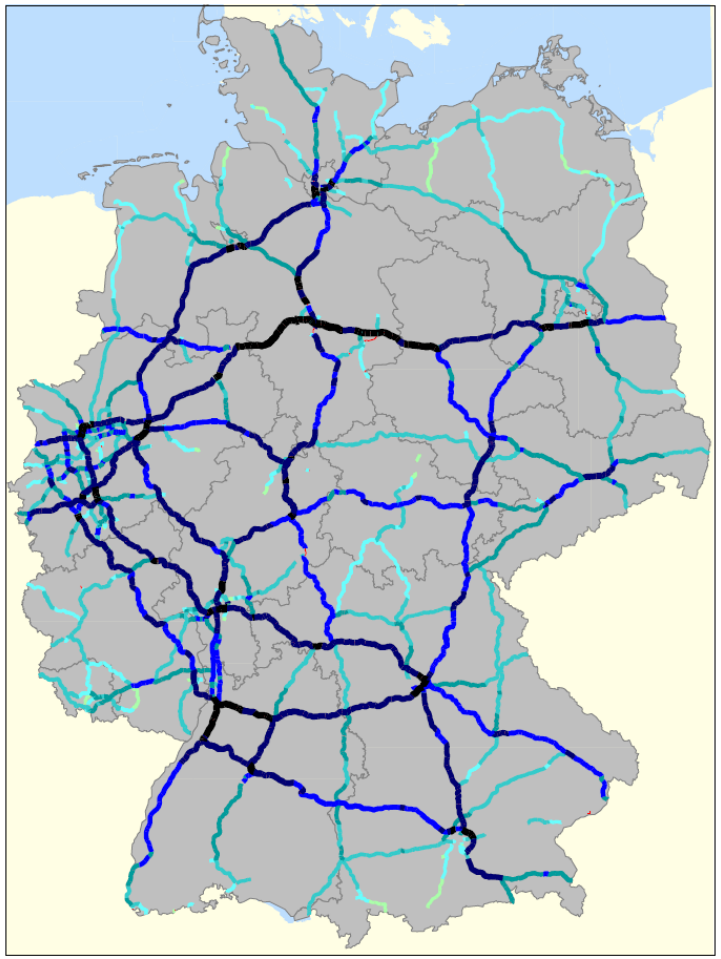
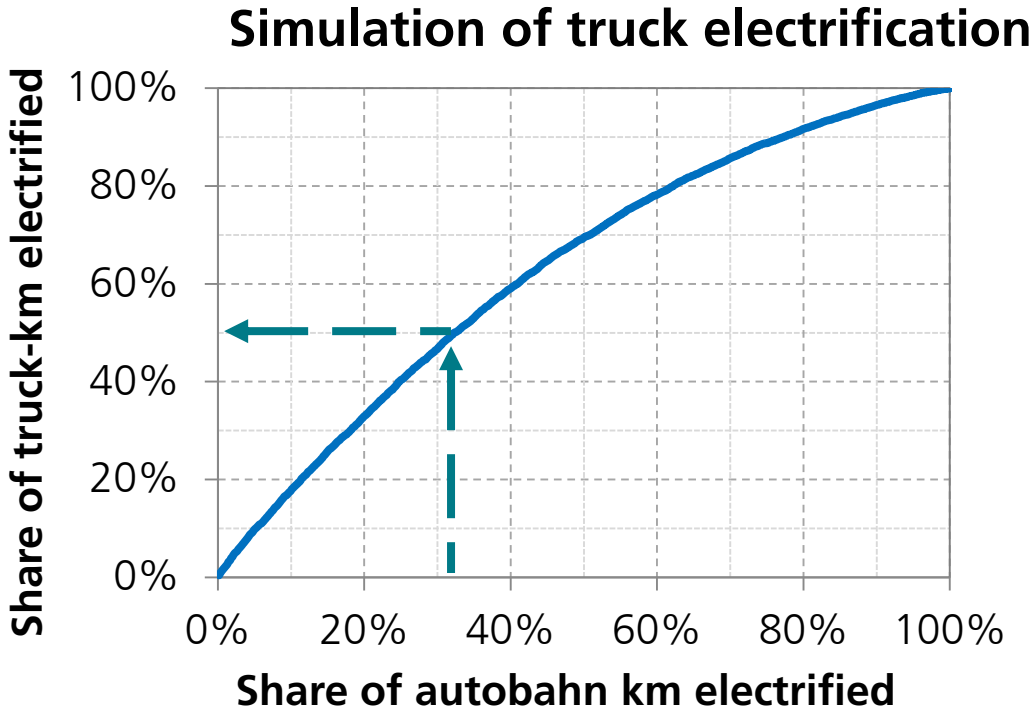


- Car and truck traffic concentrated on some highways
  → Highways with higher loads should electrified first
  → 33% expansion electrify 50% of truck VKT



Sources: http://www.bast.de/DE/Statistik/Verkehrsdaten-Downloads/2010/Manuelle-Zaehlung-2010.html and http://www.mauttabelle.de/maut.html as well as calculations of PTV AG

$$u_{BAB} = 1 - \Phi\left(\Phi^{-1}\left(1 - \frac{km_{el}}{12980}\right) - 1{,}19^2\right)$$

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Expansion of electrification – connected highway sections of high intensity needed

1‘000 km of e-highway

1- 4‘000 km of e-highway

Heavy trucks within Germany

trucks per hour

- < 1‘000
- 1 – 2‘000
- 2 – 3‘000
- > 3‘000

electrified

- 1st 1‘000 km
- 2nd 1‘000 km
- 3rd 1‘000 km
- 4th 1‘000 km

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Sales share for trolley trucks in 2030 for **1000 kilometers** of overhead lines

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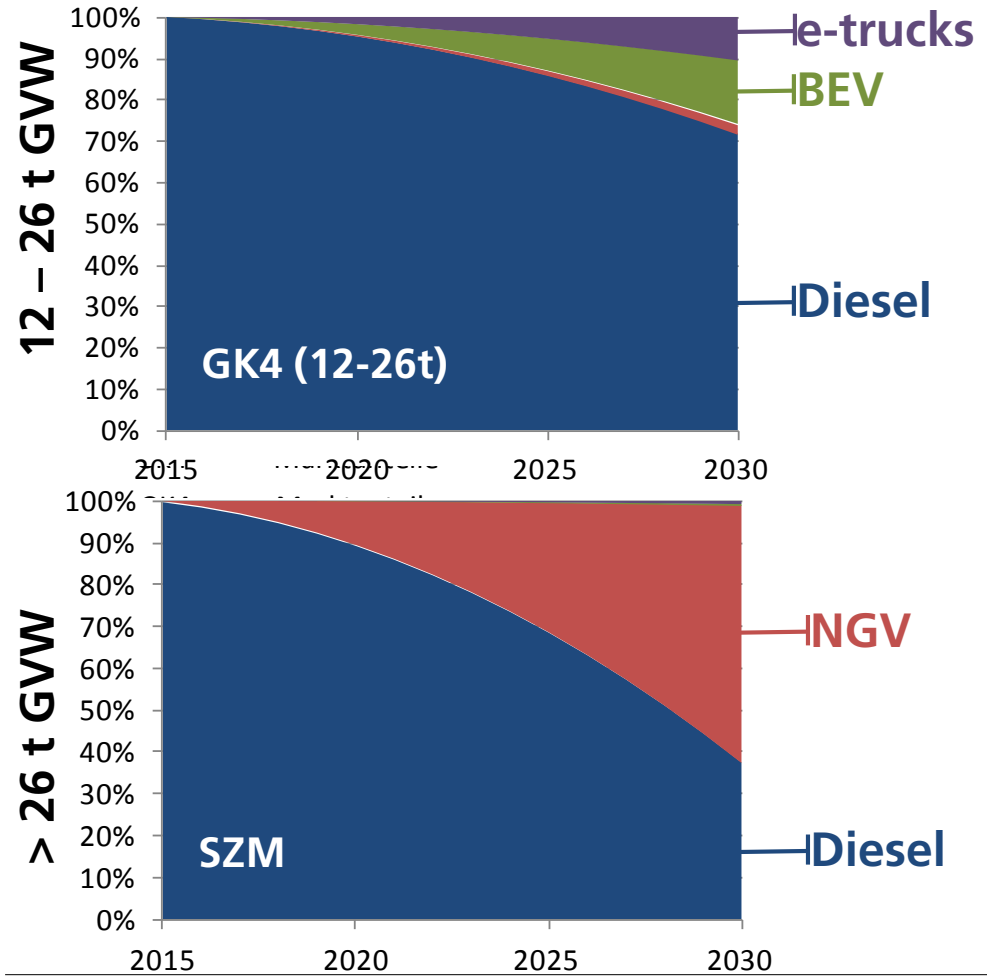

Results from market simulation model ALADIN:
Individual simulation for several thousand duty vehicle driving profiles + TCO calculation + limited availability of new technologies + only German highway usage

Results:

12 – 26 ton GVW:

- e-trucks with 10% Market share in new registrations
- Main fuel remains Diesel

Heavy duty (> 26 tons max weight)

- Only small number of electric trucks
- Natural gas vehicles (NGV) have 60% market shares

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Sales share for trolley trucks in 2030 for **4000 kilometers** of overhead lines

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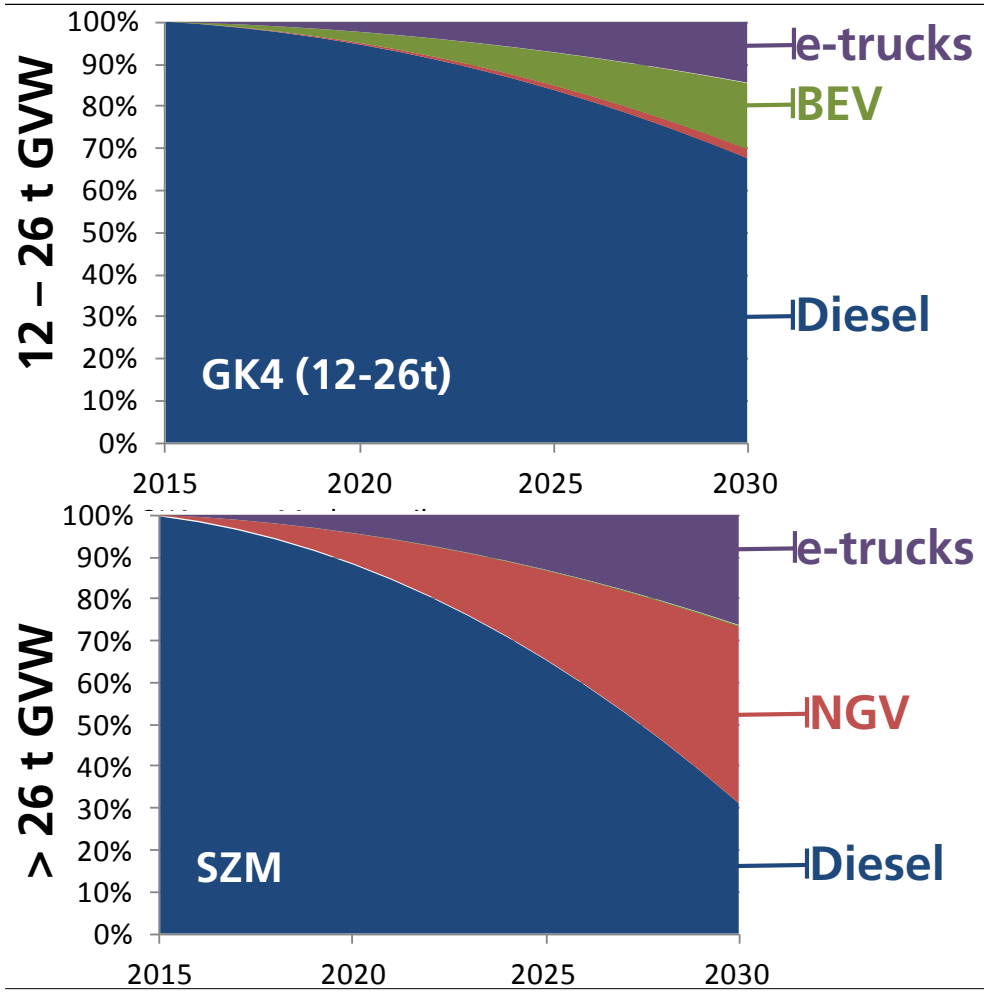

Results from market simulation model ALADIN:
Individual simulation for several thousand duty vehicle driving profiles + TCO calculation + limited availability of new technologies + only German highway usage

Results:

12 – 26 ton GVW:

- e-trucks with 15% Market share in new registrations
- Main fuel remains Diesel

Heavy duty (> 26 tons max weight)

- electric trucks with 25% of sales
- Natural gas vehicles (NGV) still important

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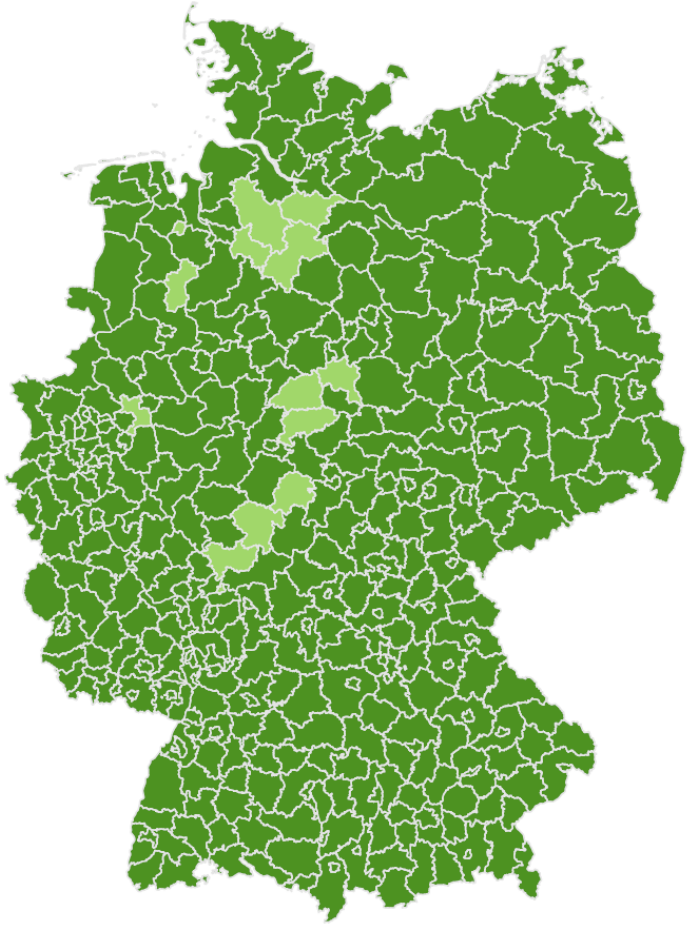
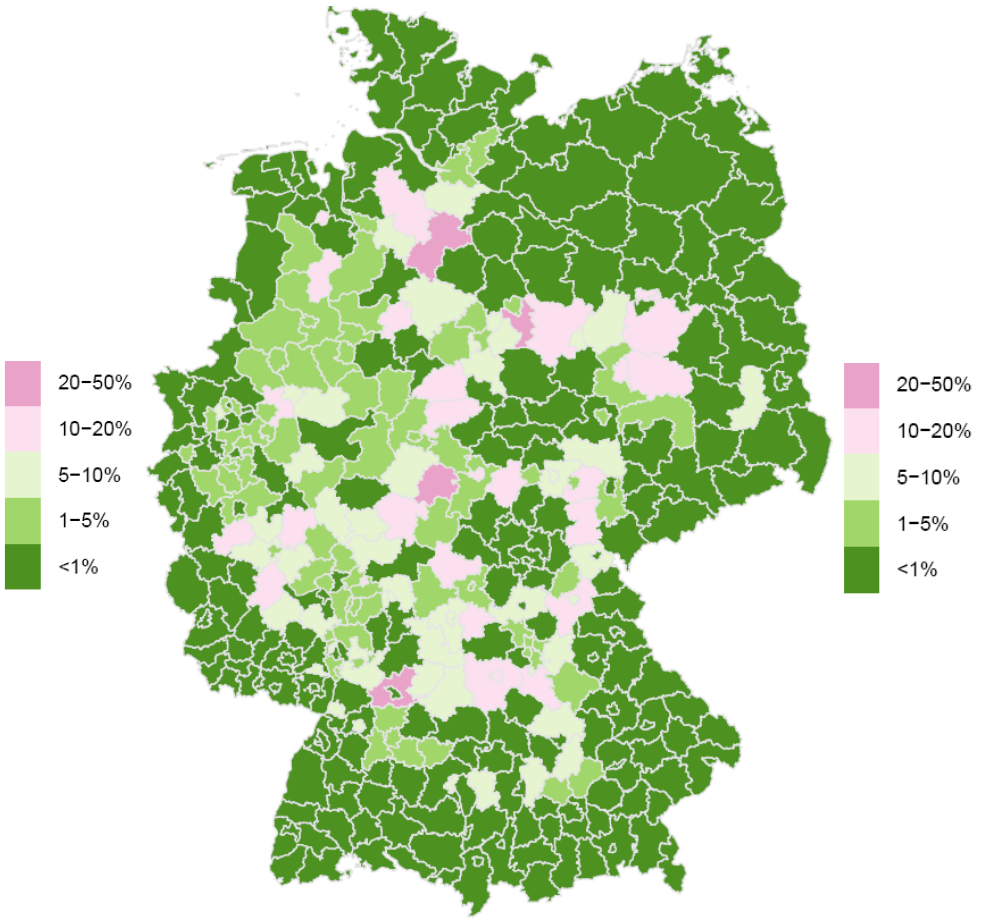
Regional effects after market diffusion 2030

Relative change in NUTS3 electricity demand by e-trucks

8 % of highways 2030





30 % of highways 2030

➢ **Noteworthy grid impact at highway intersections in rural area**

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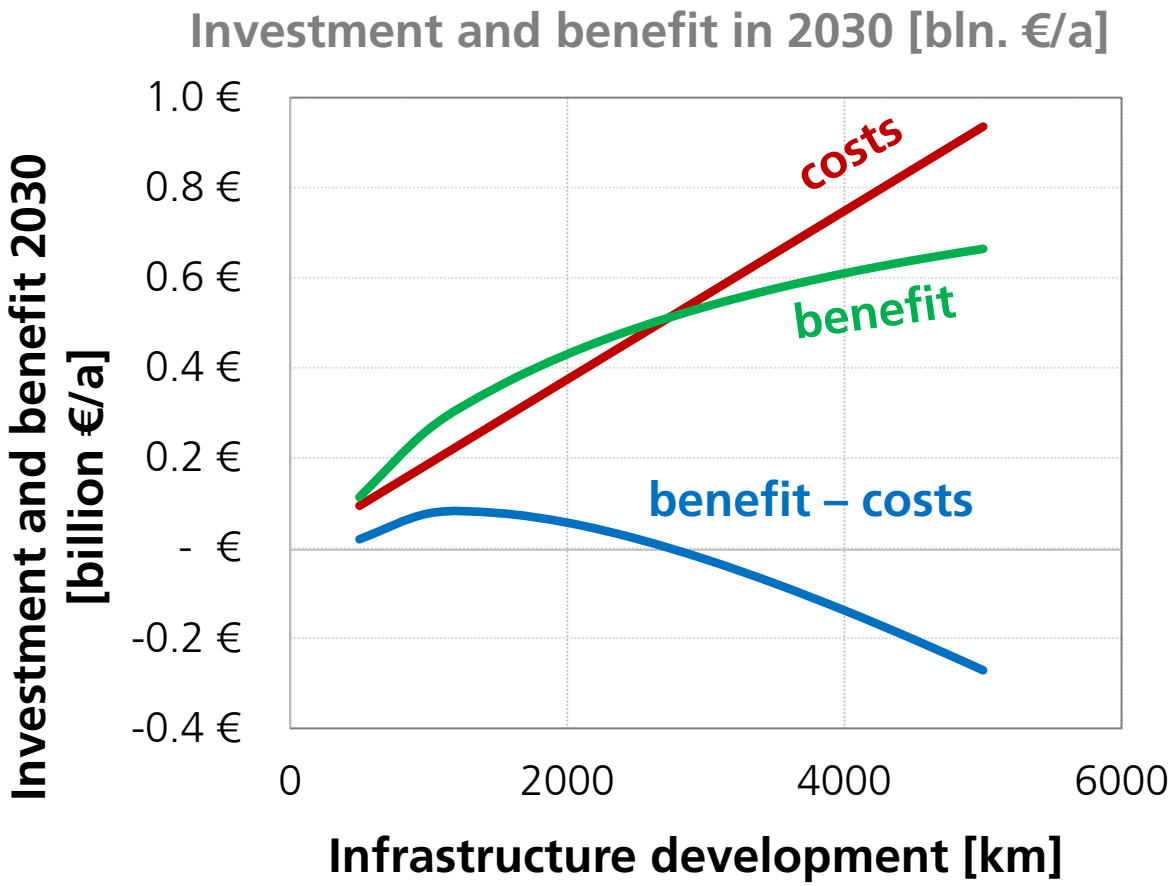
Overhead line system could be cost effective for up to 3000 km in Germany



Overall economic perspective:

- Assumed infrastructure **cost** of 2.2 million € per km e-highway (one lane in both directions all inclusive)
- Annual cost for the infrastructure (annuity for 30 years of usage at 5% interest rate) vs. annual fuel cost savings (**benefits**) from the more efficient electric driving
- Net benefit positive up to 2500-3000 km or about 20% of grid
- BUT: calculations for purely German system of the infrastructure and full intake of users' profits

➢ **Some overhead-line infrastructure for trucks could be cost-effective**

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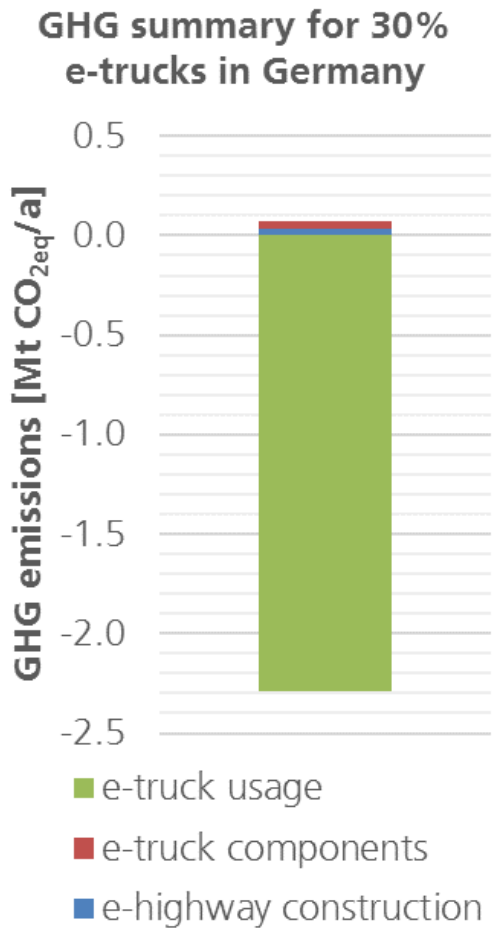
The usage phase dominates the life cycle emissions with a noteworthy net benefit



- **Comparison to Diesel truck including**
  - Construction of e-highway & additional truck components
  - and e-truck usage
- Assumed **e-truck is diesel hybrid truck** with
  - Fleet of 60’000 heavy duty vehicles (1/3 of stock)
  - 114‘000 km annual VKT
  - 65% electric drive fraction and 35% diesel
- with 190 gCO2eq/kWh (governmental reference scenario for 2030)

- **Results**:
  - **Infrastructure GHG emissions negligible**
  - **GHG savings of 37 t CO2/a per vehicle**
  - **GHG savings of 2.2 million tons of CO_{2eq}/a in 2030**

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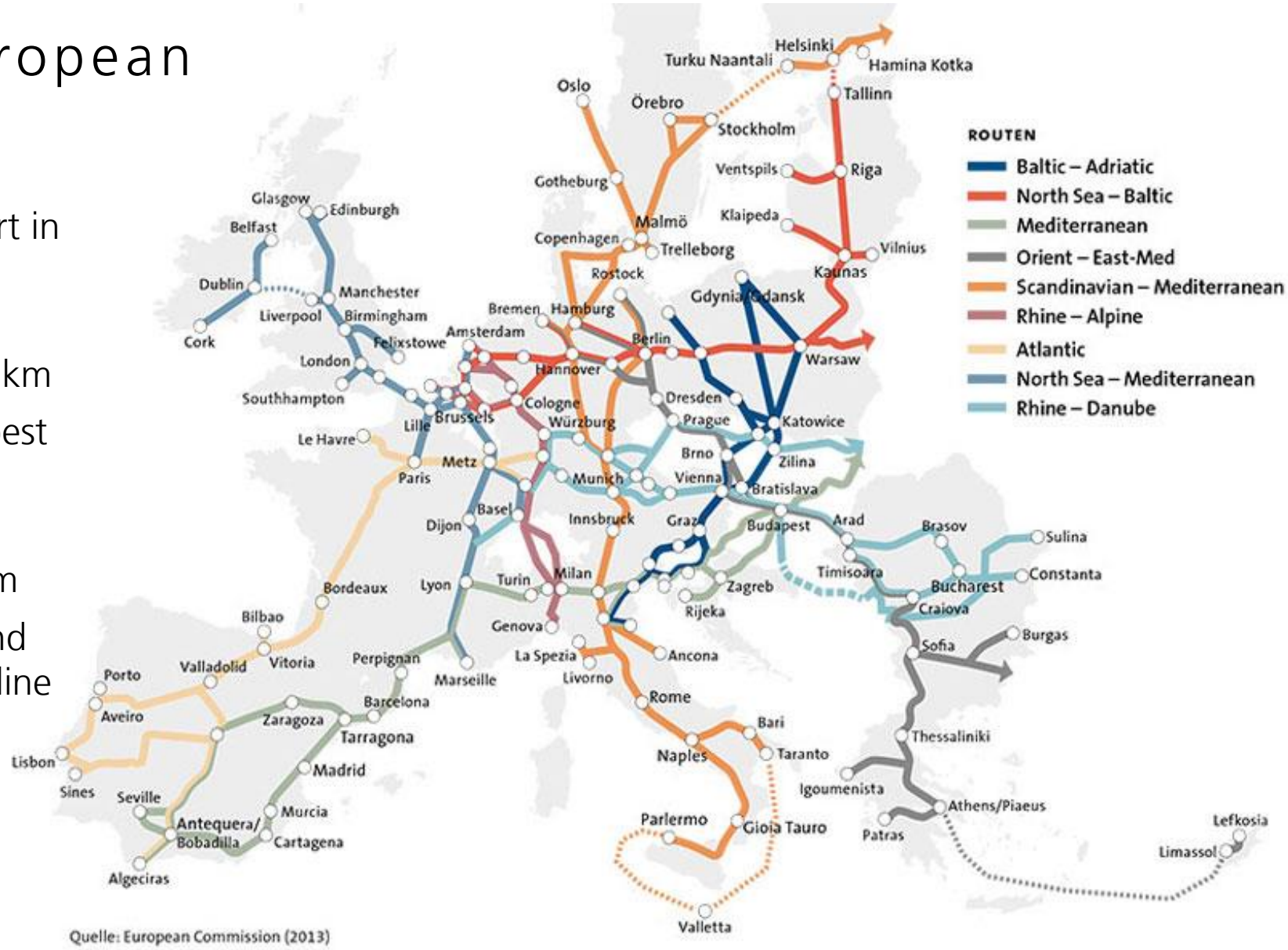
Electrification of European highways?

- High share of heavy duty transport in Europe is cross-national
- About one third of the European highway grid are approx. 25,000 km
- Trans-European traffic corridors best start
- Alternative fuels infrastructure directive for joint European system
- Debate is still in an early phase and likelihood of European overhead line grid unclear



Quelle: European Commission (2013)

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Energy consumption e-Trucks by country

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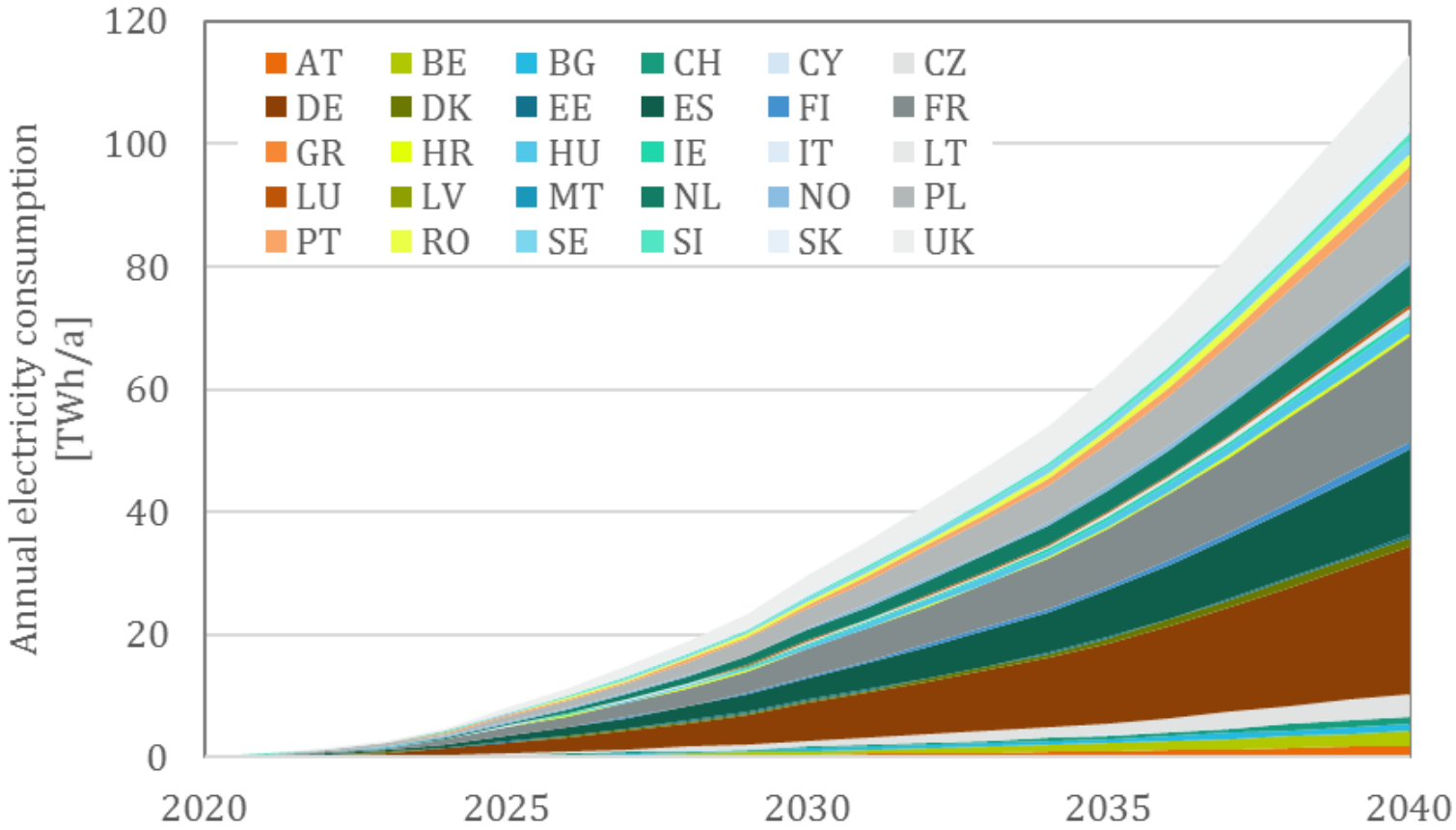
- Transfer of fast market diffusion to all of Europe leads to noteworthy electricity consumption

	2020	2030	2040
Stock	2,000	285,000	837,000
Stock share	0.2%	18%	49%
Electricity (TWh)	0.1	29.5	115.0



Plötz et al. (2018): Impact of Electric Trucks on the European Electricity System and CO_2 Emissions.

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Overhead line e-trucks are an interesting option for zero emission heavy duty transport

- **First steps in GHG emission reductions: (1) avoid and (2) shift to electric rail**
- **Electric highways are a potential step towards zero emission heavy duty vehicles**
  - Technology readiness level quite high (close to commercialization)
  - pro: high efficiency from direct use of electricity and efficient electric motor (implies lowest use of additional renewable generation) → most efficient heavy duty option
  - con: infrastructure invest and difficult electric driving away from e-highway
- **Some infrastructure could be cost-effective but further solutions needed** for driving off the highway
- **Open issues**:
  - 50% of heavy duty highway traffic in Germany is transit: Full European system would generate higher benefits → political commitment would be required
  - Full energy system analysis (generation, infrastructure etc.) and comparison to import of renewable fuels, e.g. from north Africa or middle east

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Thank you!

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