Reaching goals in time

The potential of dynamic charging of HDVs on motorways

EUPAVE EU Debate “Deployment of innovative infrastructure for a climate-neutral mobility”
Brussels, Dec 5, 2023

SIEMENS

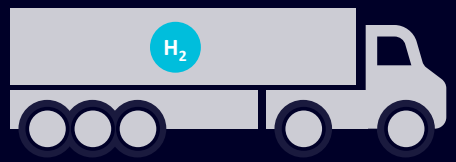
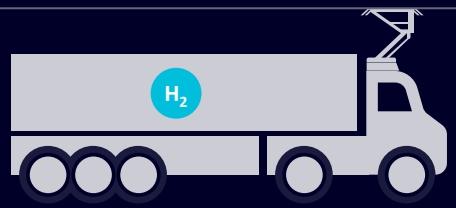
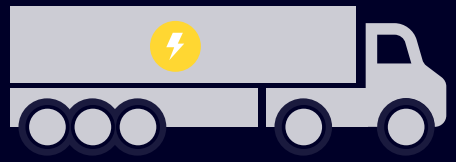
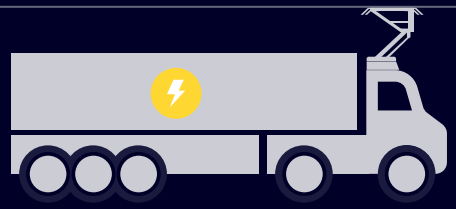
Electrified trucking on roads with Dynamic Charging (DYC)

Proven in daily trucking operations on German motorways

Sustainable road freight solution based on overhead contact lines (OCL)
– available today for deployment on long and busy corridors

A system compatible with and complementary to other alternative technologies

Decarbonization of heavy-duty trucks is accelerated by dynamic charging

Technology options	Key characteristics	Technology options w/ OCL	Key characteristics
 Hydrogen fuel cell power	+ High range to mass ratio − High operational cost (e.g., scarce green H_2, efficiency)		+ High range to mass ratio + Reduced operational cost when using dynamic charging
 Battery electric power	+ Technology eco-system proven with light duty vehicles − Limited range, charging anxiety		+ Technology eco-system proven with light duty vehicles + Under OCL unlimited range and charging w/o stand-still
 Hybrid with synthetic/bio-fuel	+ Available infrastructure, suitable to decarbonize existing fleet − Limited availability of fuels		+ Available infrastructure, suitable to decarbonize existing fleet + Reduced demand of fuels when using dynamic charging

All three drive technologies and their business cases can be **boosted** by dynamic charging.

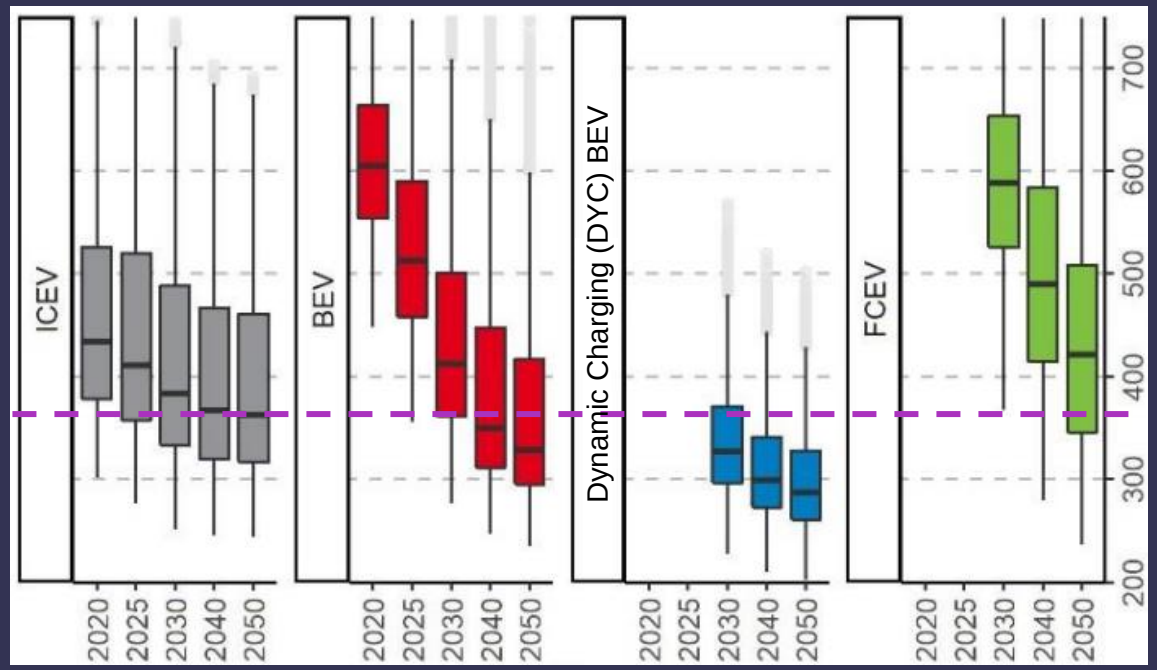
Modular approach enables optimized truck config. for each use case.

SIEMENS

The electrified future of trucks and their infrastructure
Offering lowest Total-Cost-of-Ownership & CO_2-emissions

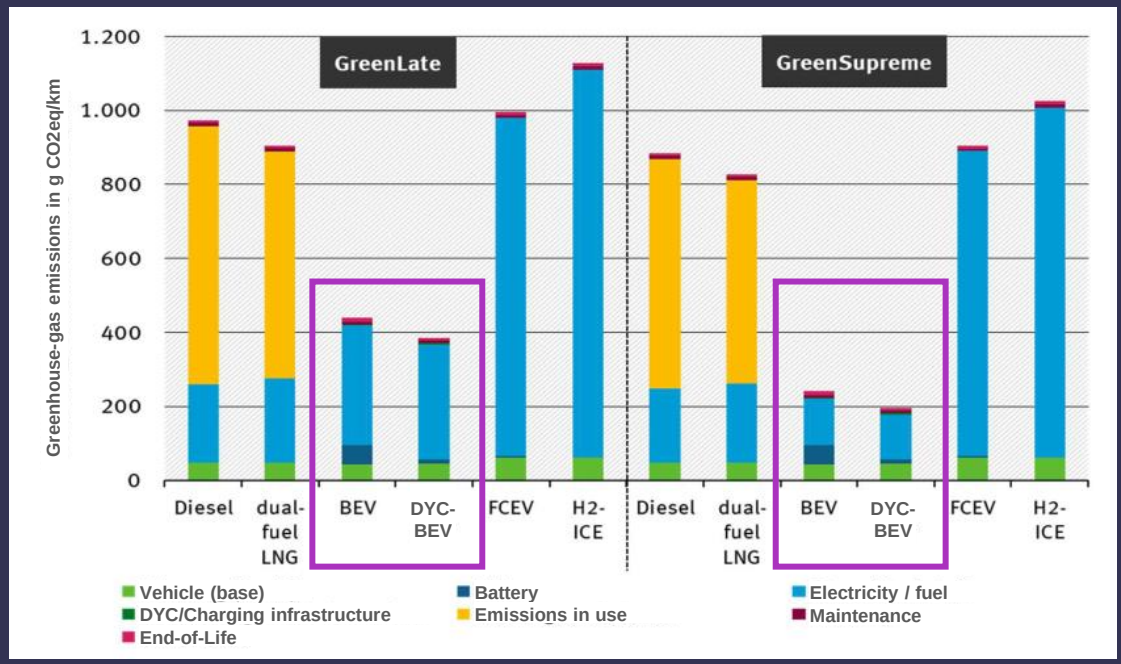
Lowest cost and uncertainty[1]

Total Cost of Ownership (TCO) in k EUR, for vehicle group 5 (4x2 tractors)



Strong CO_2 reductions already in this decade[2]

GHG-Emissions in g CO2-eq./km for tractors in 2030 (medium payload of 11 t)



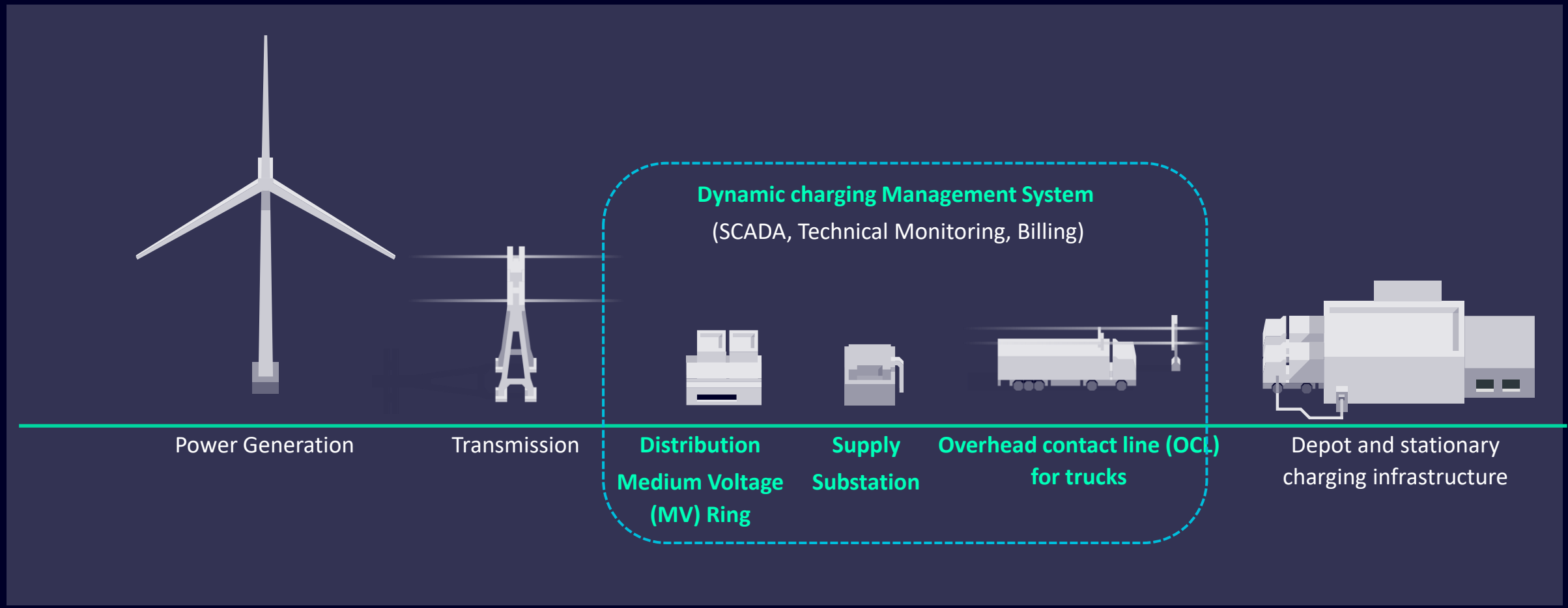
* Siemens & DHL break-even calculation for a 2,000 km DYC network in Germany by 2030 is available in the back-up slides

1. https://www.itf-oecd.org/decarbonising-europes-trucks-minimise-cost-uncertainty Nota bene: ITF uses the term ERSV (electric road system vehicle) for DYC BEV
2. ifeu: Vorläufige Projektergebnisse „Umweltbilanz von Fahrzeugen mit alternativen Antrieben oder Kraftstoffen"; FKZ 3720 57 1010.

SIEMENS

The building blocks of the dynamic charging solution

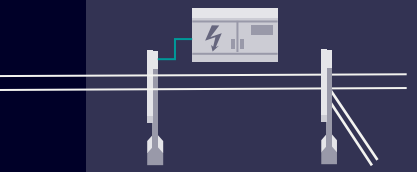
Based on extensive experience in rail electrification and years of operation



SIEMENS

Dynamic charging (DYC) is used in real trucking operations on busy highways

Autobahn GmbH: “Proven in daily operations….OCL technology is ready for roll-out!”

	Start (2010)	Today (2023)
DYC Infrastructure 	Mature and well-known technology from rail. **Can it be built and operated on busy highways?**	• 7 years experience on EU highways • 30 km OCL on very busy roads • 96%-99.6% availability
Pantograph (current collector) 	Rail and trolley-bus experience. Need new solution**:** • That fits on tractor truck • Provide at least 200kW • Connect/disconnect at speed	• Fits on tractor truck • Max. power: >500 kW • Works at up to 100 km/h Conti cooperation for industrialization
Electrified truck 	• Some hybrids available • Battery-electric trucks pretty much unheard of	22 trucks (PHEV tractors & BEV rigids) have driven >2,000,000 km in **real trucking operations**

More information on field trials available: https://www.ifeu.de/publikation/current-technical-findings-on-the-ehighway-system-from-field-tests-and-accompanying-research-in-germany/
https://www.verkehr.tu-darmstadt.de/media/verkehr/fgvv/veroeffentlichungen_2/20230320_Evidenzbasierte_Forschungsergebnisse_ELISA.pdf

Autobahn company FAQ on OCL field trials: Link

SIEMENS

Interest in DYC for long-haul trucks is growing in Europe and beyond

Enabling zero emission trucking on core motorways

Projects and plans in EU

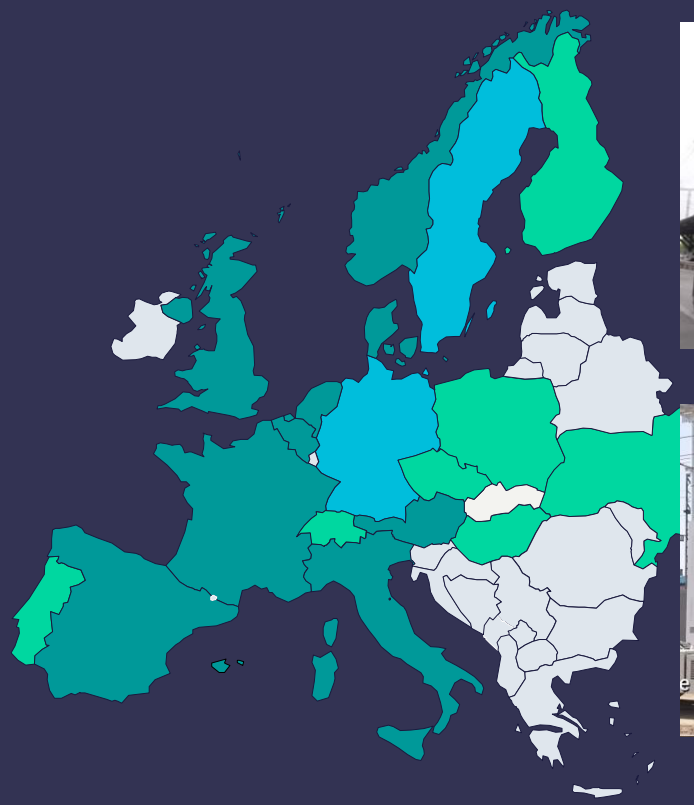
- DE: Climate law (2023) confirms intention for innovation clusters with OCL DYC
- SE: Tendering 20km DYC on highway (in 2024). Earlier DYC highway demo used OCL
- NL: 50m EUR allocated for DYC pilot for HDVs on highway
- FR: DYC demo projects (1-2 km) announced for highways (usage type unclear)

Studies and reports in EU

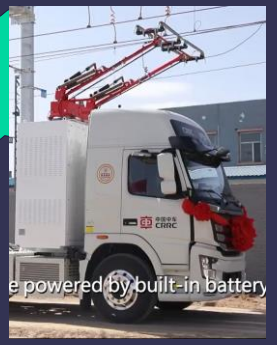
- IT: Ministry strategy for trucks focus on electrification, incl. use of OCL
- AT: Study "Energy Roads" completed seeing benefits with OCL DYC
- BE: Study finds each 1 EUR investing in OCL saves 8 EUR over next 20 years
- HU: Part of E-CORE, a multi-national corridor study, so far also with NL, DE & AT

Interest and activities beyond EU

- UK: Study finds OCL "cost-effective solution", see also podcast.
- China: Companies CRRC and SANY developed first DYC pilot using OCL
- India investigating 1,300 km long overhead contact line "e-corridor", see link
- North America: Studies in USA and Canada also find DYC highly economical.



Link



Link

SIEMENS

DYC eases possible bottle-necks regarding batteries and stationary chargers

Thereby strengthening the case for a stronger policy focus on electrification

Acceptability - By all stakeholders

- **Economical and ecological benefits**
- **Cut critical raw material dependency[1]**
- **Minimizes impact on electricity grid[2]**

Scalability - In time and across geographies

- **Reduced land claims[3]**
- **Fewer stakeholders & approvals[4]**
- **Based on int. know-how and strong supply chain[5]**

Usability - Seamless integration in logistics

- **No time lost during charging**
- **Improved charging experience**
- **Compatible with higher payloads and automation**

Video source: https://ehighway-sh.de/forschungsfahrten/

1) https://www.sae.org/publications/technical-papers/content/epr2022007/ 2) Energienetz - Klimafreundliche Nutzfahrzeuge (klimafreundliche-nutzfahrzeuge.de) 3) https://trans.info/de/lkw-parkplatz-app-294955 4) https://ivr.fh-erfurt.de/aktuelle-forschungsprojekte/esob-rki 5) https://www.railwaypro.com/wp/worldwide-rail-electrification-remains-at-high-volume/

SIEMENS

The [DYC] technology seems very compatible with BEVs and stationary charging - it is not an either or.

Tobias Meyer, CEO DHL Group

Source: https://www.linkedin.com/feed/update/urn:li:activity:6993873117844512768?utm_source=share&utm_medium=member_desktop

We need to use technologies that are available now!

Volker Ratzmann, Executive Vice President Corporate Public Affairs at Deutsche Post DHL Group

Source: LinkedIn on Nov 22, 2023 https://www.linkedin.com/feed/update/urn:li:activity:7133098584672985088/

Foto: Christian Bendel

Dynamic charging is an essential solution for climate protection in heavy road freight transport – Overhead catenary line advantages

… combines the benefits of electric railways with the flexibility of trucks
Proven in daily operations

… makes it possible to reach the climate protection goals
Highest efficiency

… can quickly be rolled out
€10 bn supply chain

… can be realized in an international context
Open standards

… highway landscape change
Unchanged roadway

… is flexibly compatible with other technologies and fuels
Up to 500kW at full speed

… is the most economical solution
Cheapest solution

- Cars & LDVs are going BEV w/o ERS
- Cars & LDVs tend to avoid truck lanes

More details in LinkedIn-Article

SIEMENS

Infrastructures enabling the fastest transition to zero emission trucking

Core messages for policy makers

Knowing the facts-on-the-ground

Increasing electrification

Driven by advantages in

- Total Cost of Ownership (TCO)
- Greenhouse-Gas (GHG) emission reductions
- Maturity (“here and now”)

Address bottle-necks & concerns

Build out grids along TEN-T

- Publicly available infrastructure necessary
- No-regret policy

Recognize synergies with DYC

- Policy support for electrification should also include dynamic charging*

Faster transition to ZEVs

Raise targets

e.g. AFIR can be formulated in MW/km along the TEN-T

* As already called for by Belgium, Denmark, Luxembourg and the Netherlands in January, 2023

Contact

Toon Wassenberg
Mobility advisor, public affairs and sustainability
Siemens Mobility Belgium NV
Huizingen, Belgium
+32 477 200 310
toon.wassenberg@siemens.com

www.siemens.com/ehighway

#eHighway

SIEMENS

Back-ups

Small dictionary:
Acronyms, vocabulary and explanations

DYC (Dynamic charging):

The **charging solution** an electrified truck gets from an ERS

ERS (Electric Road System):

The **infrastructure** built along a motorway that enables DYC

OCL (Overhead contact line):

A more than 100 years old technology, that for 7 years (and counting) is the only ERS proven

- on a highway

and/or

- to provide at least 200kW DYC to tractor trucks in regular, full-speed operations

SIEMENS

AFIR-mandated market review
Electric road systems (ERS) for dynamic charging

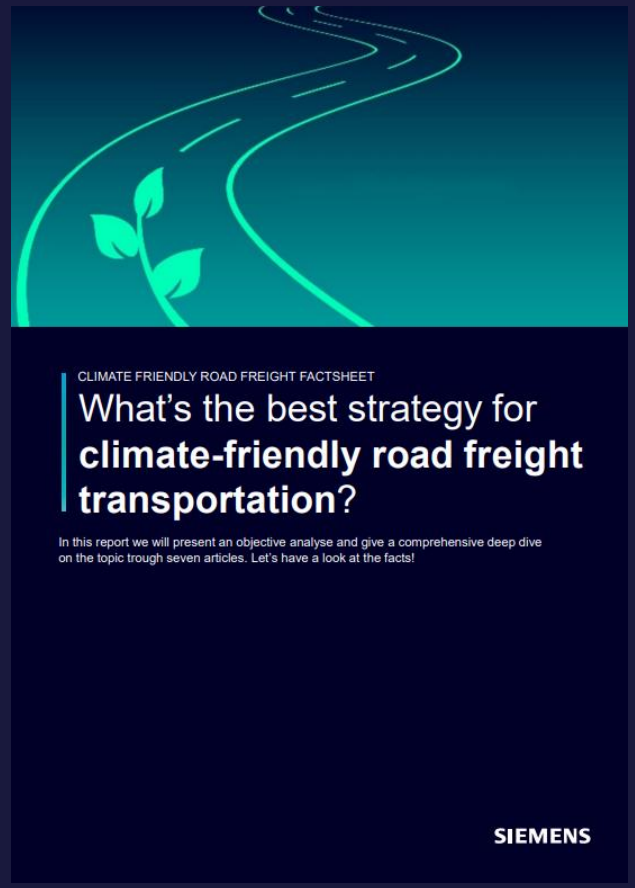
Article 24
Reporting and review

1. ***By 31 December 2024, the Commission shall submit to the European Parliament and to the Council a technology and market-readiness report dedicated to heavy-duty vehicles.*** *That report shall take into account the initial indications of the preferences of the market. It shall also consider technological developments and the development of the technical specifications achieved by that date and developments expected in the short term, in particular regarding recharging and refuelling standards and technologies, such as high-power recharging standards and electric road systems, and the use of liquid hydrogen*

[….]

2. *By 31 December 2026 and every five years thereafter, the Commission shall review this Regulation*

Factsheet for climate-friendly road freight



Available online

Electrified freight transport on roads with Dynamic Charging – ready to go! Proven in daily trucking operations on German motorways

Motorway owner's experience of field trial

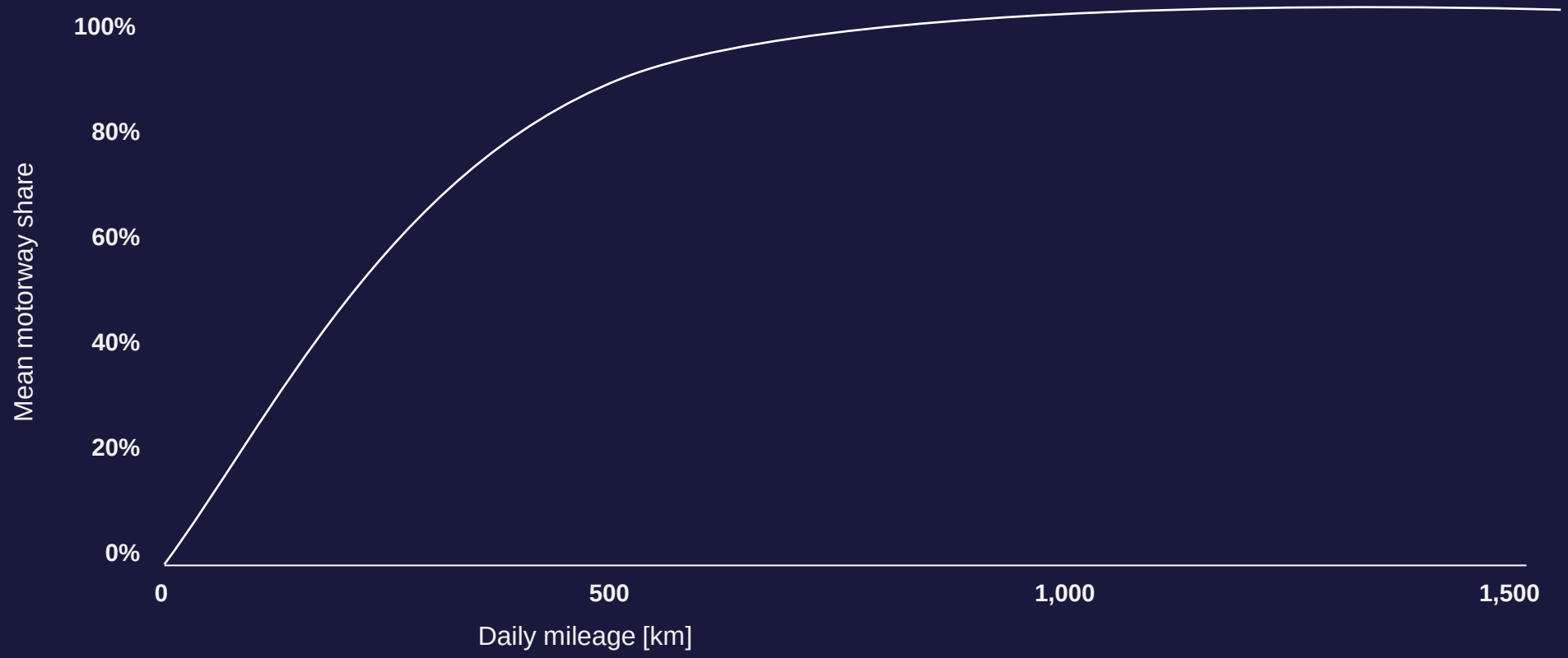
https://www.youtube.com/watch?v=gAUff-fz_MM&t=0s

Experiences of a truck driver

https://www.youtube.com/watch?v=NHSofIc31rw

Range is especially important for long-haul operations

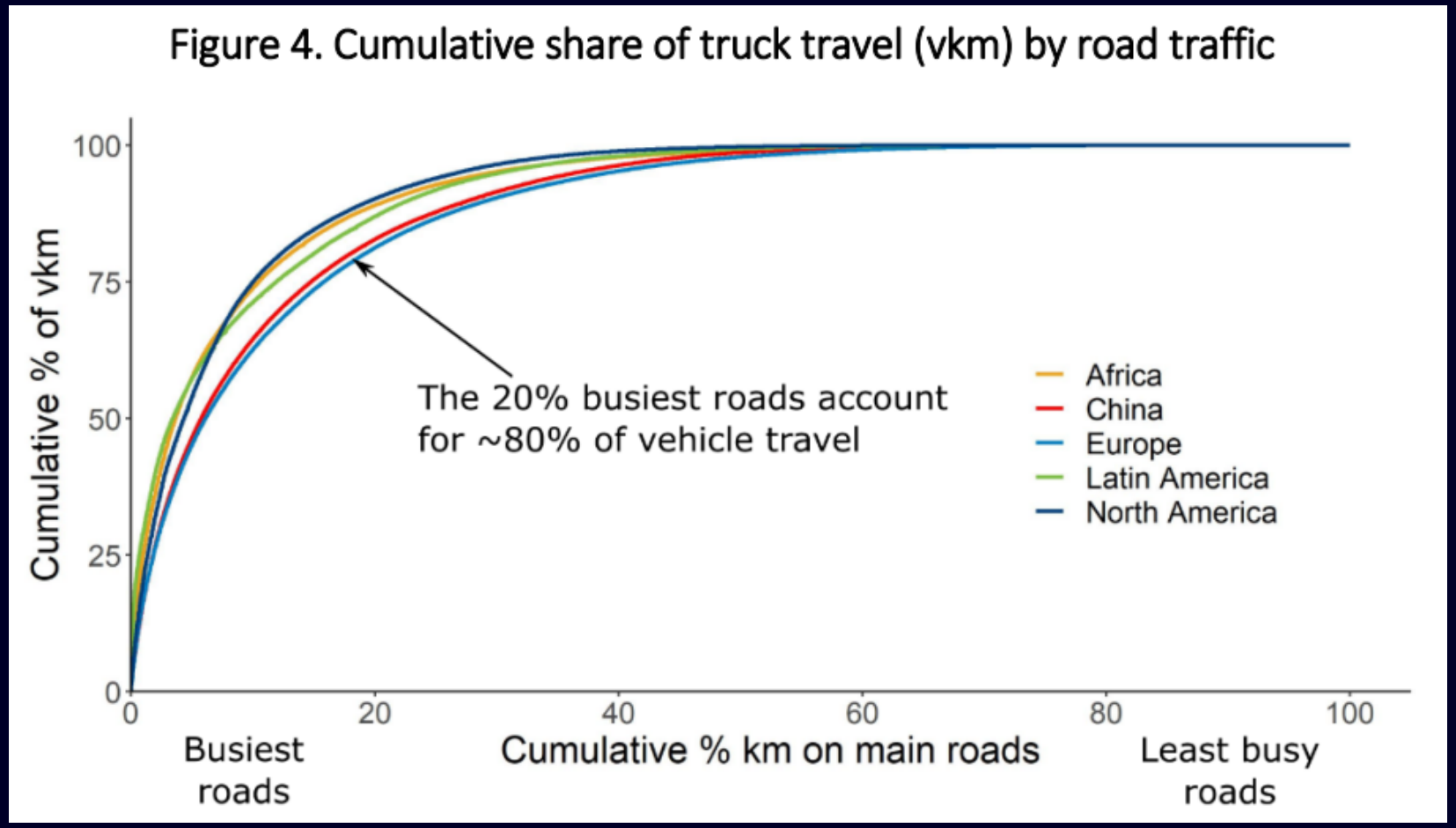
Long range happens almost exclusively on highways



Journeys of **500 km** or more are almost entirely on motorways **(>80%)**

BEV: Battery electric vehicle | **FCEV**: Fuel cell electric vehicles | **RF**: Renewable fuel (for combustion engine)
Source: Fraunhofer feasibility study of catenary trucking, on behalf of the German Transport Ministry, page 131

Road freight traffic is highly concentrated across the world



Source: https://www.itf-oecd.org/cleaner-vehicles-achieving-resilient-technology-transition

SIEMENS

Truck range need off-highway is limited

Germany: 89% of trips are <50 km

In einem Vergleich der Summenlinien (Abbildung 30) kann man erkennen, dass 89 % der Lkw-Fahrten weniger als 50 Kilometer im nachgeordneten Netz abwickeln.

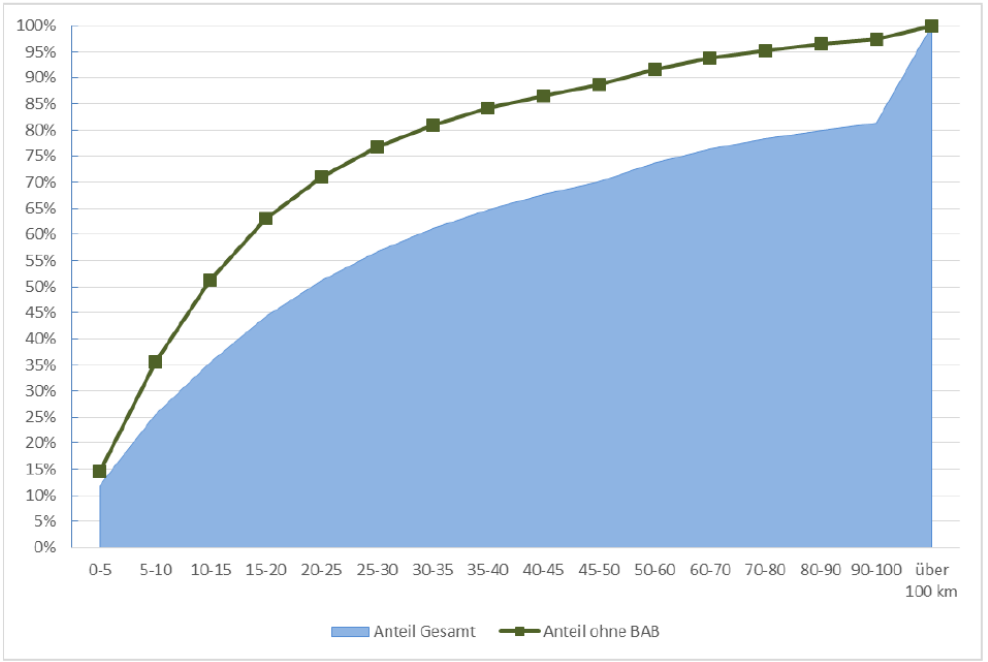
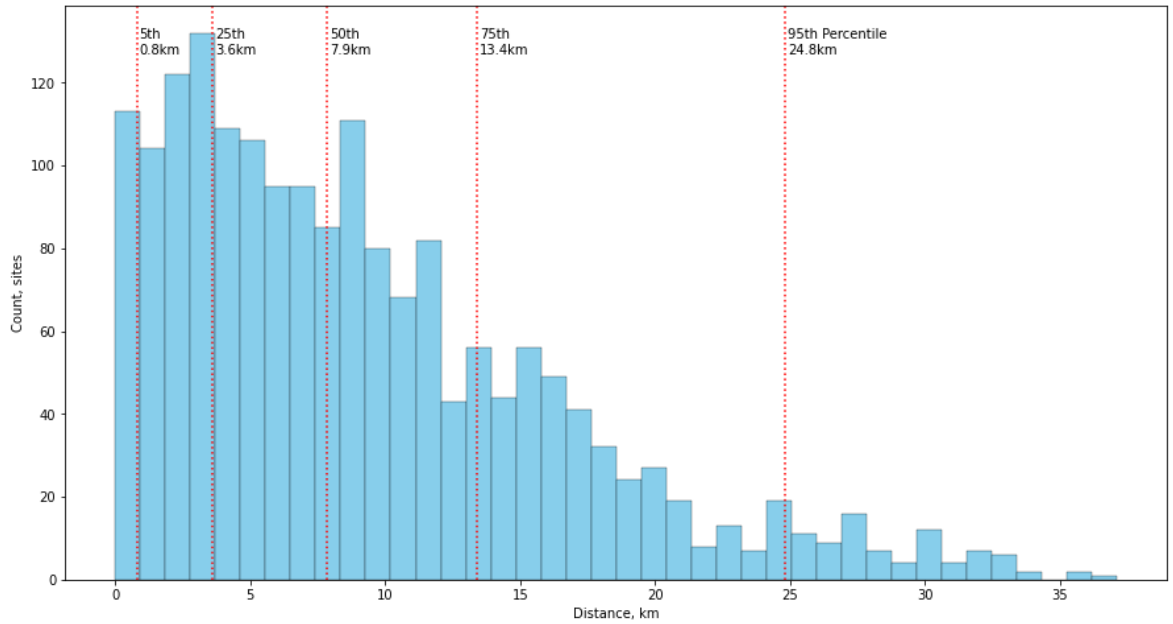


Abbildung 30: Summenlinie der Distanzklassenanteile mit und ohne BAB-Anteil

Source: Fraunhofer Study on behalf of the German Transport Ministry, page 118

Flanders (Belgium): 95% of trips are <25 km

Figure 7 – Driving distance of industrial sites to nearest motorway, Flanders



Source: University of Antwerp study Logibat project

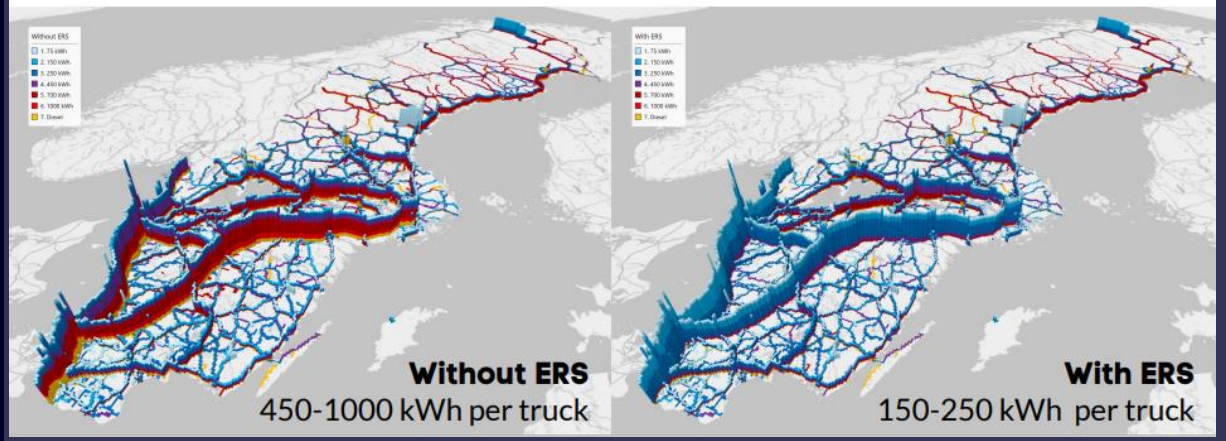
SIEMENS

Dynamic charging makes BEV-trucks with small batteries viable for operators
potentially matching ICE trucks - in weight, cost and flexibility

Swedish ERS Study: HDVs save ~70% battery

Battery capacity per truck

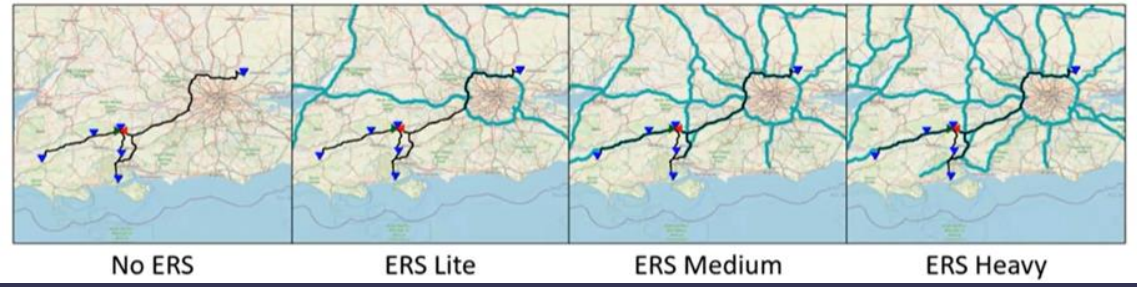
Smaller batteries reduce
1. cost of capital
2. cost of calendar ageing
3. trips required to move total cargo



Online article: https://www.linkedin.com/pulse/interaction-effects-between-battery-electric-trucks-road-rogstadius/

UK ERS Study: HDV save 50-75% battery

Operator H	Required battery capacity (kWh)			
	ERS topography			
	None	Lite	Medium	Heavy
No static charging	1666	1043	290	224
Charge at drop-off sites (600 kW)	397	243	103	81
Charge at public rest stops (600 kW)	794	794	290	224
Charge at both drop-offs/rest stops	388	240	103	81



Online presentation of UK study: https://youtu.be/5Y2FB7J92no?t=2490

2.000 km-scenario of Dynamic Charging in Germany – Break-even point for the system can be achieved with OCL-BEV trucks in the single-digit share of fleet

How much could a **transport operator** save and max. use as a fee for the new dynamic charging system?

35% of diesel TCO or

85ct per km

Potential savings of transport operator

TCO[1] p.a. diesel ~ 136.700 €

TCO p.a. electric ~ 89.200 €

Savings per year -35% or 47.500 €

Spread over 56.000 km/year on a 2,000 km OCL-network

0,85 €/km

Maximum Price accepted to use a new system

Key assumptions for Transport Operator

- Diesel price: **1,60 €/l** Electricity price: **0,14 €/kWh** [2)]
- Diesel Truck price: **110.000 €** eTruck price: **200.000 €** Lifetime: **6 years**
- Depreciation: **17%** O&M: Diesel **0,09 €/km; O-BEV 0,09 €/km**
- Toll: OCL-BEV pays **0,045 €/km vs 0,304 €/km** for diesel truck
- Mileage: overall **140.000 km,** 56.000 km on the OCL and 20.000 km with battery charged via OCL
- Required range off OCL ~ 200km, battery capacity 300 kWh
- No loss of freight capacity (e.g. volume or payload)

How much traffic would an **infrastructure operator** need to run the system at 85 ct. per km?

13.100 trucks or **3,6%** of the relevant German truck fleet

Break even for an infrastructure operator

Invest per km 4.0m € x **OCL network** 2,000 km

Overall invest 8bn € ÷ **Exp. lifetime** 30 years

Annuity 460m € + **OCL O&M cost p.a.** 160m €

Total cost p.a. 620m € p.a.

Max. user price (incl. energy) 0,85 € per km

13,100 user trucks w/ 0,7bn vkm on OCL

Key assumptions for Infrastructure Operator

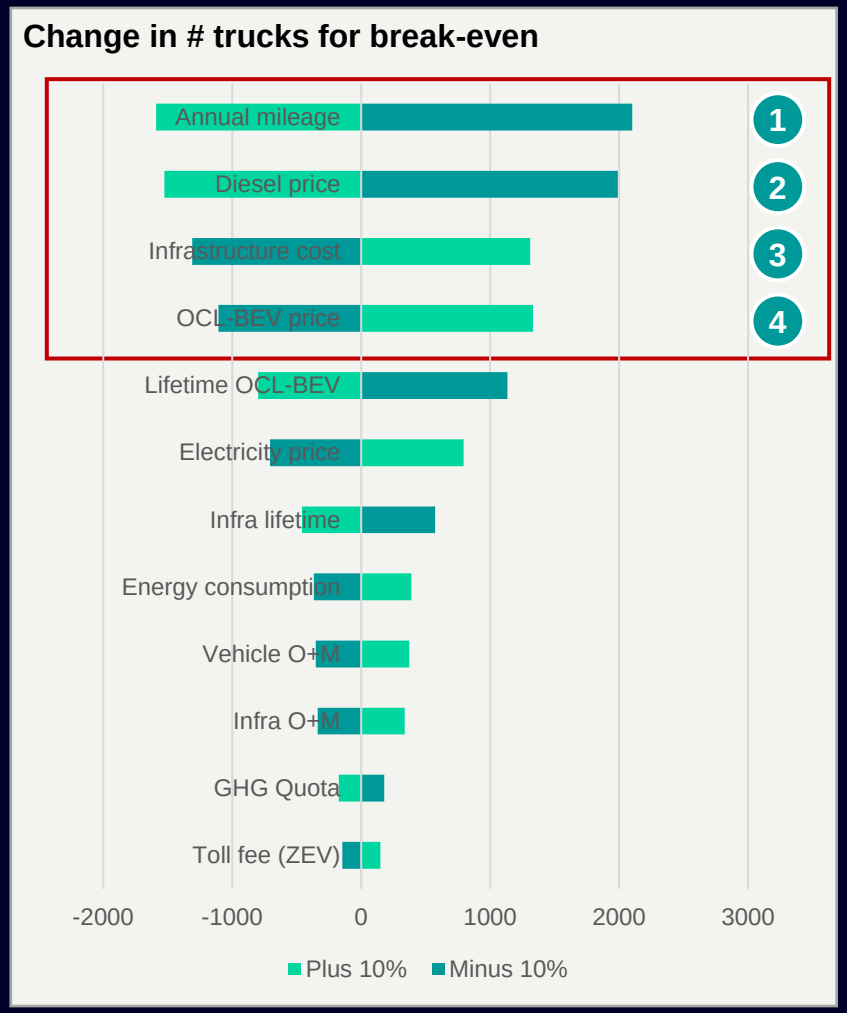
- Forecast investement in dynamic charging infrastructure, incl. OCL, substations, protection and control. Excluding HV-connections and possibly necessary upgrading of guard rails
- Nominal financing cost of investment: **6,00% p.a.** O&M: **2% p.a.**
- Electricity sold without additional mark-up
- Mileage on the OCL: **56.000 km by each OCL-truck**
- **Curr. fleet of ~360 k** long haul trucks in GER (add. pot.: transit[3], busses)

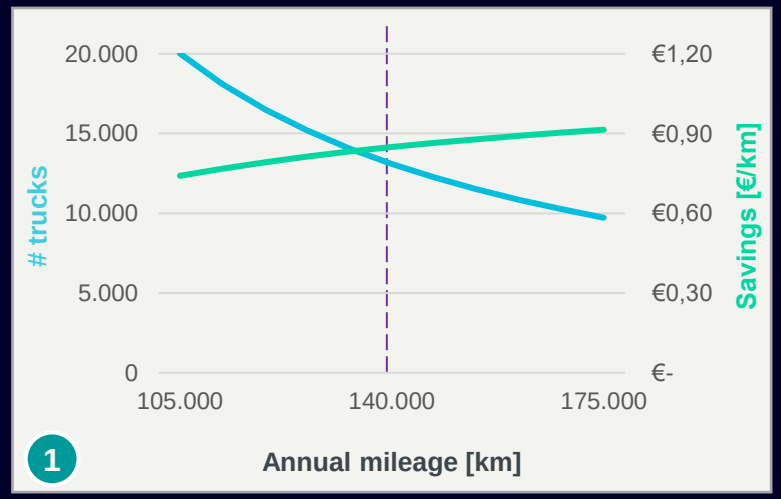
1) Total Cost of Ownership per truck 2) Incl. 0,03 €/kWh grid connection fee 3) 47% of freight traffic in GER

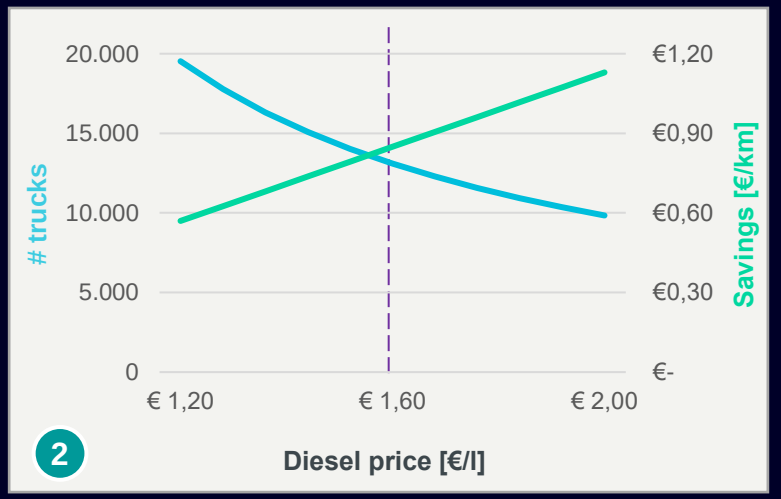
SIEMENS

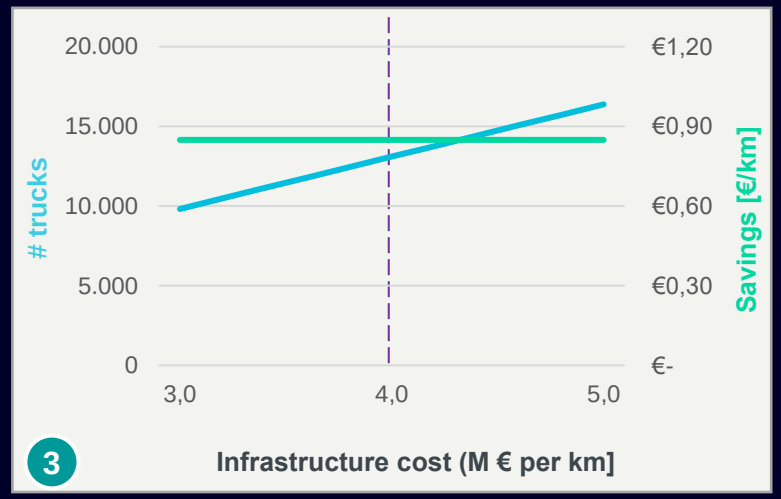
Sensitivity analysis shows robustness of the case

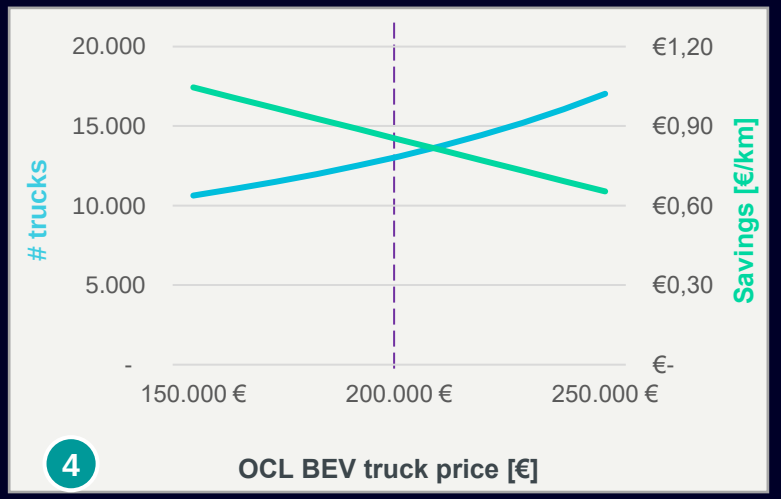
Even with Diesel near 1.20 €/l the break-even No. of truck would be only 5% of relevant fleet











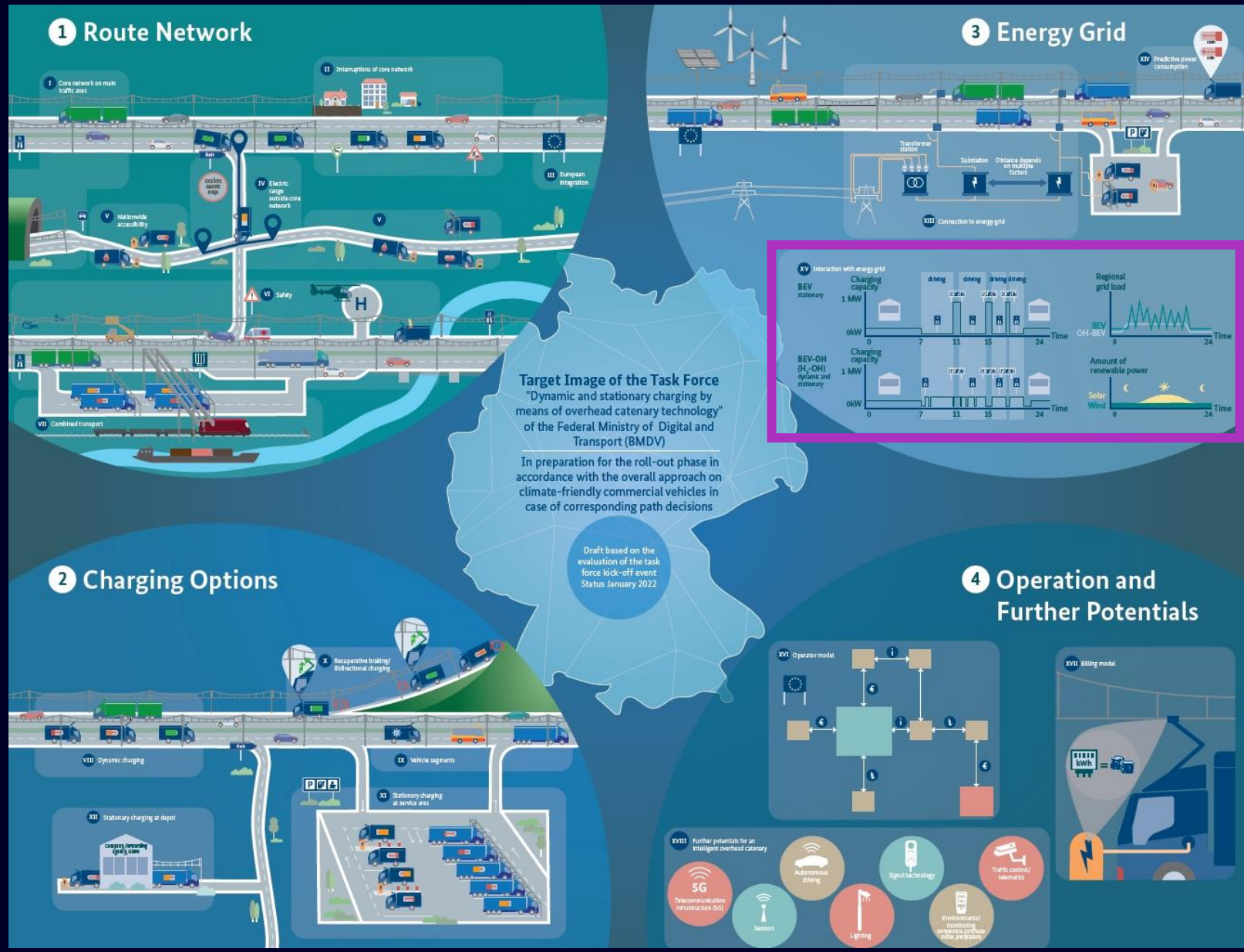
SIEMENS

Ministry task force on dynamic charging

Available online

Including links to many supporting studies for each of the four fields:

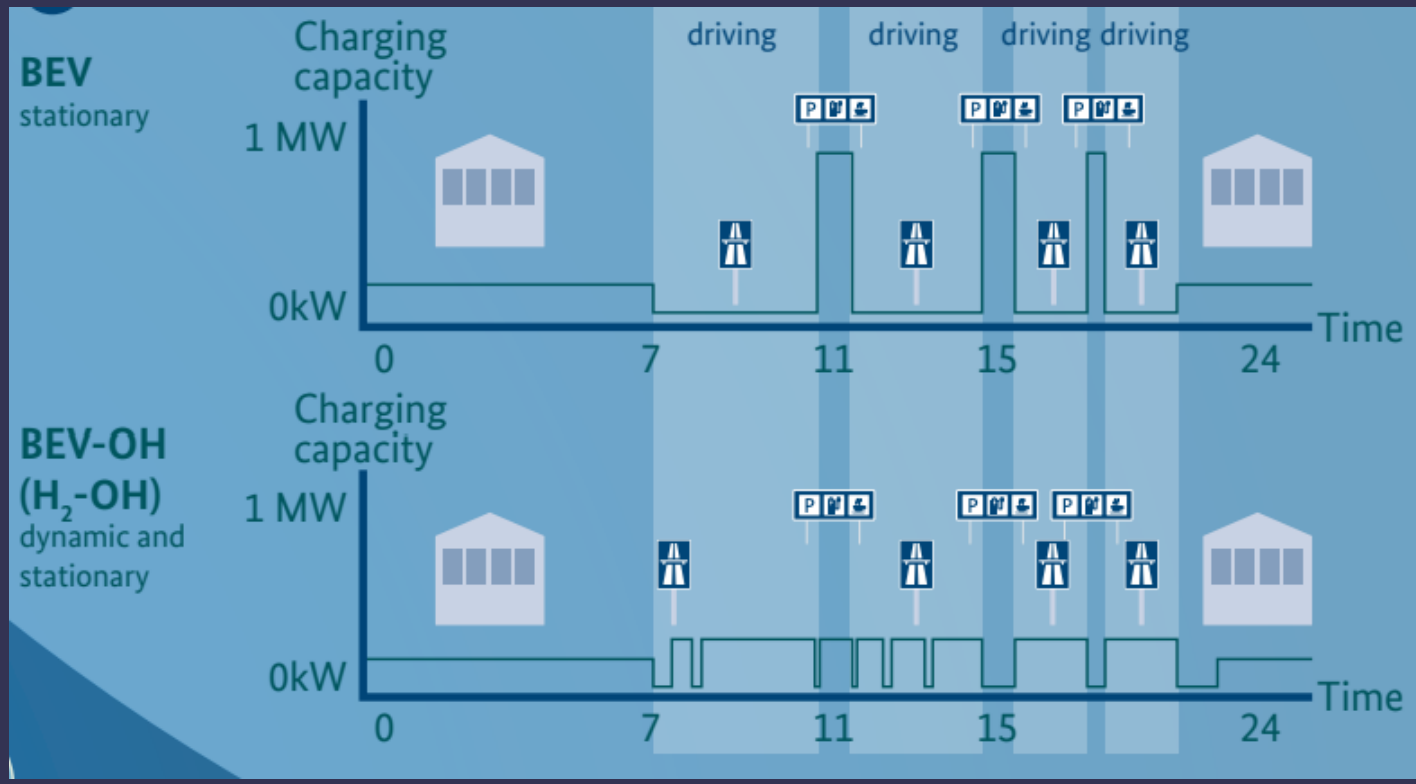
- Route network
- Charging options
- Energy grid
- Operation and further potentials



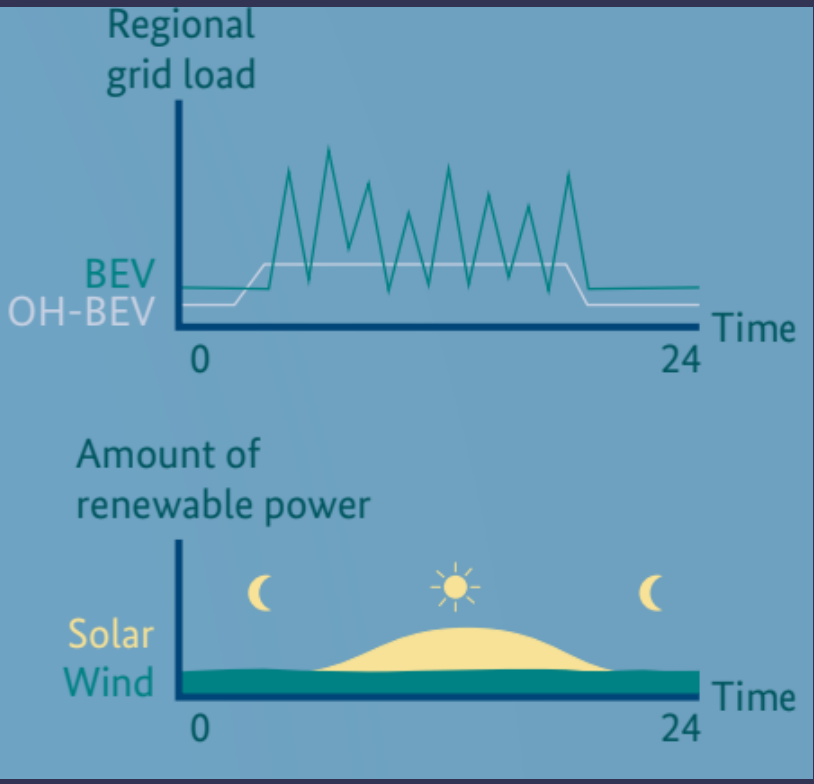
SIEMENS

Dynamic charging
Beneficial interaction with the energy grid

Reduces demand charges



Matches Time-of-Use (TOU) rates

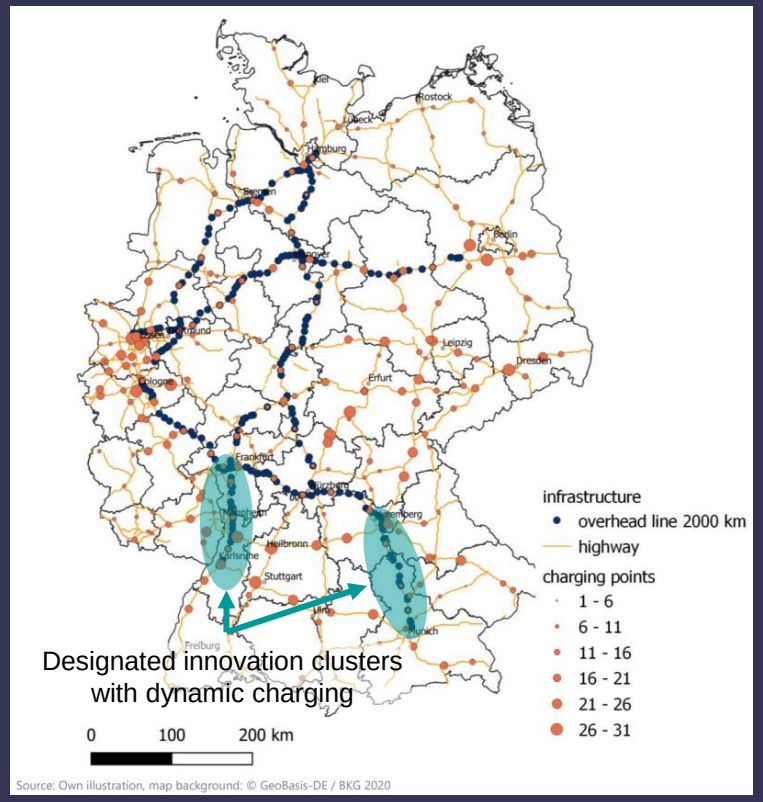


- Study showing significant influence of demand charges on cost of electricity: US DOE (2017) pages 70-83
- Study showing why policy makers should encourage daytime charing: https://www.nature.com/articles/s41560-022-01105-7
- Study showing the challenge power demand from large truck stops: https://www.nationalgrid.com/us/EVhighway

SIEMENS

German build out scenarios:
Initial corridors that grow into a national and international network

Combined stationary & dyn. charging network



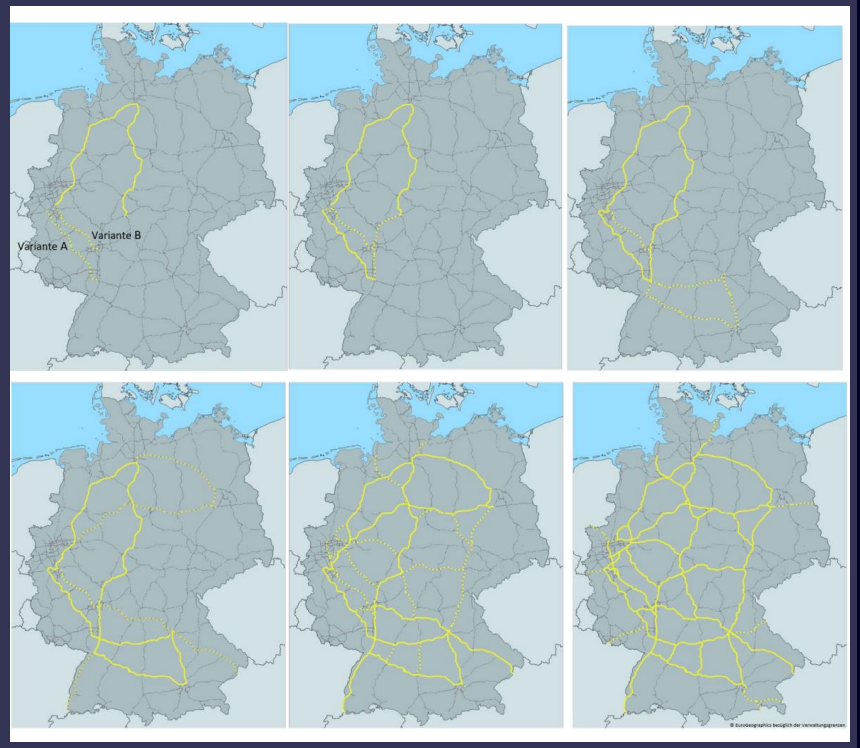
Start-up target:

- Define sufficient charging opportunities for a fast ramp-up
- Start includes a **2.000km** dynamic charging network and complementary stationary charging opportunities
- Network might be **adapted for early movers** (e.g. DHL)

Network growth:

- Reasonable growth to **4.000km** dynamic charging network expected to cover up to 90% of trips on German highways
- Important realization of **connections to other European countries** to connect long-distance corridors

Possible growth of dyn. charging network



Sources: Fraunhofer (2021) and (2022)