



Ludwig Bölkow Systemtechnik

ELECTRIFICATION OF HEAVY-DUTY ROAD FREIGHT TRANSPORT

Challenges for the charging
infrastructure and the expansion of the
power grid along the motorway network

18.12.2025





IF ALL HEAVY LONG-HAUL TRUCKS WERE ELECTRIC – WHAT WOULD THAT MEAN FOR OUR POWER GRID?

- How large are the energy and power requirements?
- Is the planned infrastructure expansion sufficient?
- What contribution can hydrogen make?

What this study is about – and what it is not about

This study...

- ... explicitly commits to climate protection and to the necessary transformation of the transport sector. The challenges highlighted are both incentive and call to action.
- ... provides a clear, model-based classification of the electricity and infrastructure requirements of a fully electrified long-haul transport.
- ... is based on simplified assumptions – the results provide guideline values, not figures suitable for planning.
- ... shows that the energy consumption of the German long-haul fleet alone is enormous and poses very major challenges for the energy system.
- ... evaluates, under the same simplified assumptions, how far the planned expansion of charging infrastructure along motorways goes and where structural gaps arise.
- ... explicitly supports battery-electric mobility – and discusses hydrogen as a possible complementary pathway.
- ... creates transparency regarding the relevant magnitudes.
- ... aims to convey a realistic assessment of the challenge, not to derive detailed infrastructure plans.



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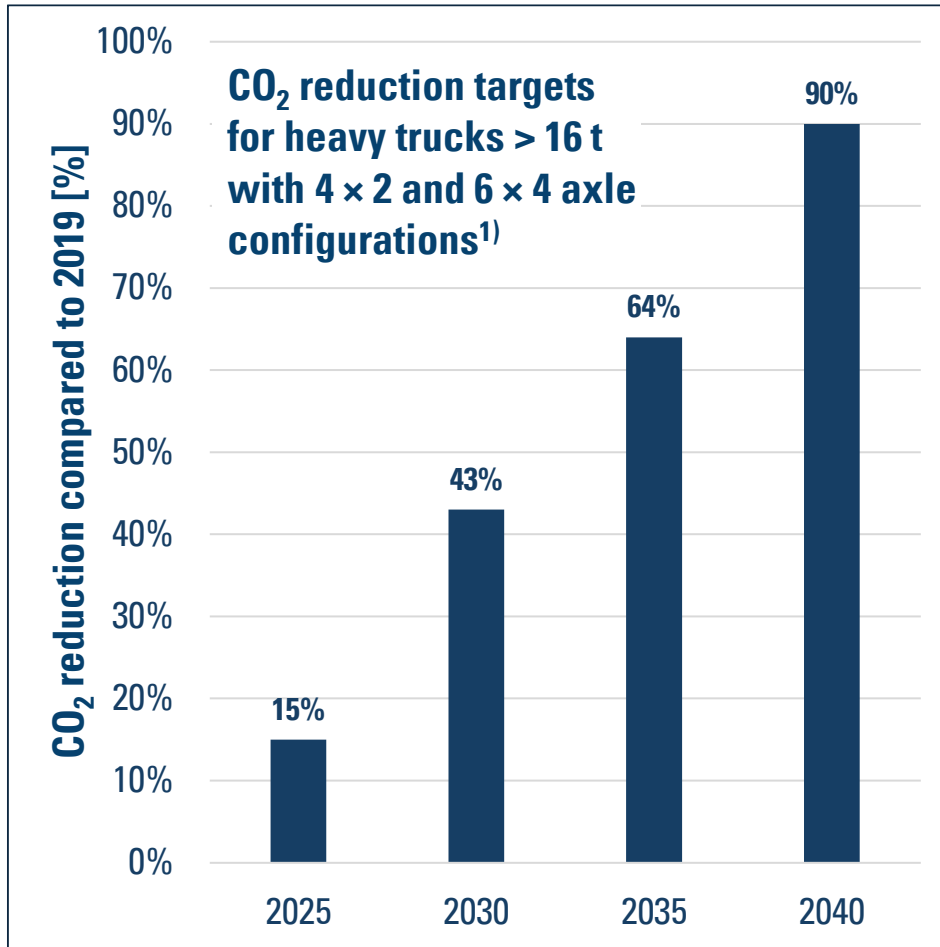
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01

● BACKGROUND AND ● OBJECTIVES

● By 2040, CO₂ emissions of heavy-duty vehicles must decrease by 90 % – there is no way around zero-emission long-haul vehicles



- **Road transport as a climate factor:** it causes around 21 % of the CO₂ emissions of the EU-27, with a significant share attributable to heavy-duty vehicles²⁾
 - **Rapidly tightening EU regulations:** CO₂ reduction targets rise sharply from –15 % (2025) to –90 % (2040)¹⁾
 - **High sanction pressure:** penalty payments amounting to €4,250 per vehicle per gram CO₂ and tonne-kilometre → even small shortfalls in targets mean fines amounting to billions for OEMs
 - **Zero-emission long-haul vehicles (ZE-LHVs) become unavoidable:** Diesel gradually loses its market dominance – electrification is inescapable
- **Infrastructure as key:** only a viable charging and refuelling network provides the necessary conditions to realise the ZEV-LHV ramp-up – with enormous challenges for the energy system

1) EU Regulation 2024/1610 <https://eur-lex.europa.eu/eli/reg/2024/1610/oj?eliuri=eli%3Areg%3A2024%3A1610%3Aoj&locale=de>

Also: https://theicct.org/wp-content/uploads/2024/05/ID-130-%E2%80%93-EU-CO2_policy_update_final.pdf

2) <https://www.eea.europa.eu/en/analysis/publications/sustainability-of-europes-mobility-systems/climate>

● Electrification forces a rethink – BEV und H₂ as complementary building blocks of decarbonisation

- Background and modelling approach of this study

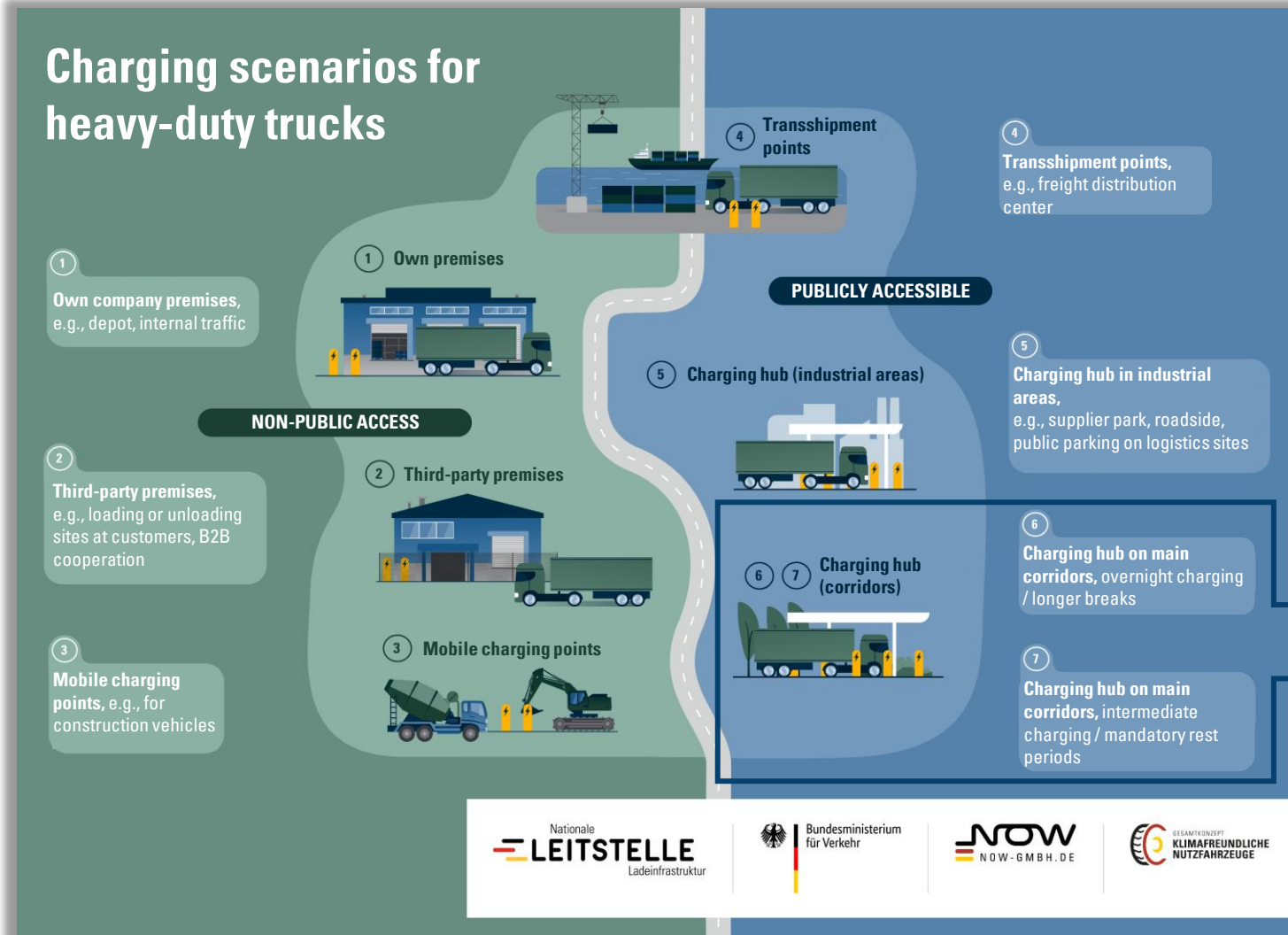
Background:

- **Strict EU CO₂ requirements** and **looming penalties** force a rapid ramp-up of **zero-emission fleets** in long-haul transport.
- This leads to a **substantial increase in electricity and power demand**, particularly **along the motorway corridors** with high mileages and short dwell times.
- For battery-electric long-haul trucks (VECTO classes 4-LH, 5-LH, 9-LH and 10-LH), **demand-oriented charging facilities** must be designed that realistically represent **mileages, logistics processes, driving times and mandatory rest periods (4.5 h → 45 min → 4.5 h)**.
- A **purely electric strategy** would, with **high expansion costs**, lead to **high grid loads and waiting times** during peak periods.
- **Complementary hydrogen mobility** can **significantly mitigate** these load peaks and **contribute to grid and system stability**.

Approach:

- Projection of the **number, mileages and energy consumption of ZE-LHVs** (long-haul VECTO classes 4-LH, 5-LH, 9-LH and 10-LH) up to 2040.
- Modelling of **energy and power demand** during **peak charging times** (e.g. lunchtime) along German and European motorways.
- Derivation of the required **connection capacities, charging park equipment and location requirements** for smooth operations.
- Assessment of the **extent to which a hydrogen infrastructure (refuelling instead of charging) can reduce load peaks**, waiting times and grid vulnerabilities.

- **Focus of this study:** challenges for the charging infrastructure and the expansion of the power grid along the motorway network due to zero-emission long-haul vehicles



Relevant charging scenarios for infrastructure expansion along the motorways



02

METHODOLOGY AND ASSUMPTIONS

How we model the impacts on the power grid and on charging infrastructure

- Basis: real-world driving profiles and energy consumption values of the long-haul VECTO classes
- Ramp-up of the ZE-LHV fleet according to the EU target trajectory (2025–2040)
- Simulation of charging and refuelling processes over typical daily cycles
- Comparison of grid and energy requirements in three scenarios

System analysis of zero-emission heavy-duty long-haul transport in different scenarios

- The ZEV ramp-up curves and daily driving distances are identical in all scenarios!

Scenario 1: 100 % BEV – fleet perspective (demand view)

- How much power and energy does the long-haul fleet require to reflect real-world driving and rest times?
- Focus on midday peak charging: morning consumption is recharged during the 45-minute midday break using megawatt charging (MWC). (cf. FfE¹): vehicles cover 50 % of their daily energy demand via MWC)

Scenario 2: 100 % BEV – infrastructure perspective (supply view)

- What power capacities can the planned public charging infrastructure for heavy-duty vehicles (Federal Ministry for Transport / National Charging Infrastructure Agency (Nationale Leitstelle Ladeinfrastruktur – NLL)) realistically provide?
- Is the planned network sufficient, or do bottlenecks and overload conditions arise?

Scenario 3: hydrogen as complement: relieving the power grid and charging infrastructure

- To what extent can hydrogen mobility reduce grid load and buffer operational peaks?
- What stability- and operations-relevant advantages arise from a significant hydrogen share?

1) Engwerth, Veronika; Sommer, Katharina et al.: Einfluss der Elektrifizierung schwerer Nutzfahrzeuge auf das Energiesystem - FfE Discussion Paper 2024-02.
Munich: Forschungsstelle für Energiewirtschaft e.V., 2024

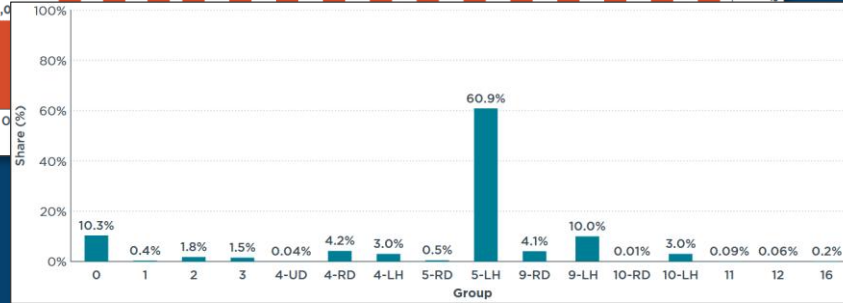
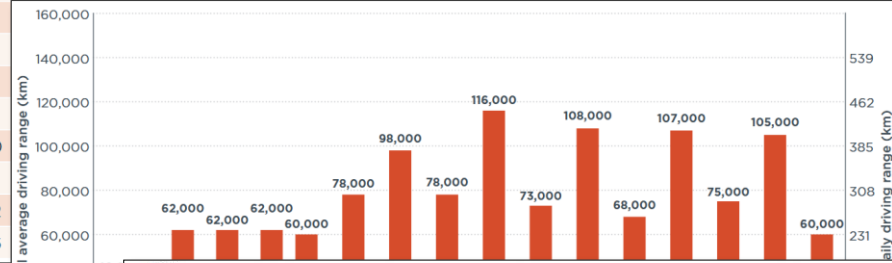
Derivation of vehicle numbers for heavy long-haul trucks (4-LH, 5-LH, 9-LH, 10-LH) in Germany

Due to a lack of precise data, vehicle numbers must be interpreted only as a rough approximation!



- Existing and new registrations of tractor units and heavy trucks
- Average annual mileage

| VECTO group | Axle type | Chassis configuration | Gross vehicle weight (tonnes) | Covered by HDV CO ₂ standards |
|-------------|-----------|-----------------------|-------------------------------|--|
| 0 | 4x2 | Rigid | < 7.5 | No |
| 1 | 4x2 | Rigid/Tractor | 7.5 - 10 | No |
| 2 | 4x2 | Rigid/Tractor | 10 - 12 | No |



- Classification, shares and driving performance of the VECTO classes according to [ICCT]

LH vehicles in Germany 4-LH, 5-LH, 9-LH, 10-LH

| | |
|---|---------|
| Vehicle fleet: | 129.000 |
| New registrations p.a.: | 18.100 |
| Driving days per year | 232 |
| Mileage km/vehicle/year | 123.000 |
| Mileage km/vehicle/day | 530 |
| Average energy consumption [kWh/100km] | 120 |

Modelling result: heavy long-haul trucks in Germany

| | Tractor units – total | 5-LH (4x2 Tractor) | 10-LH (6x2 Tractor) | 4-LH (4x2 Rigid) | 9-LH (6x2 Rigid) | LH trucks total (rounded) |
|---|-------------------------|--|------------------------|---------------------|---------------------|------------------------------|
| Vehicle fleet | 226.103 | 102.531 | 5.051 | 5.051 | 16.836 | 129.000 |
| New registrations p.a. | 31.665 | 14.359 | 707 | 707 | 2.358 | 18.100 |
| Share in LH group | | 79 % | 4 % | 4 % | 13 % | |
| Driving days per year⁵⁾ | 232 | 232 | 232 | 232 | 232 | 232 |
| Mileage km/vehicle/year | 86.585 | 127.600 | 107.000 | 98.000 | 108.000 | 123.000 |
| Mileage km/vehicle/day | 373 | 550 | 461 | 422 | 466 | 530 |
| Database/Source | KBA ^{1),2),3)} | ICCT ⁴⁾ , Comité national routier ⁵⁾ | ICCT | ICCT | ICCT | LBST modelling |

1) KBA 2025: Bestand an Kraftfahrzeugen und Kraftfahrzeuganhängern nach Zulassungsbezirken, 1. Januar 2025 (FZ 1)

2) KBA 2024: Verkehr in Kilometern – Zeitreihe 2014-2024 (VK 2024)

3) KBA 2024: Neuzulassungen von Kraftfahrzeugen nach Umwelt-Merkmalen, Jahr 2024 (FZ 14)

4) ICCT 2023: The European Heavy-Duty Vehicle Market Until 2040: Analysis of Decarbonisation Pathways

5) Comité national routier: <https://www.cnr.fr/en/detail-pays/2> (Annual driving days from this source assumed for all vehicle classes.)

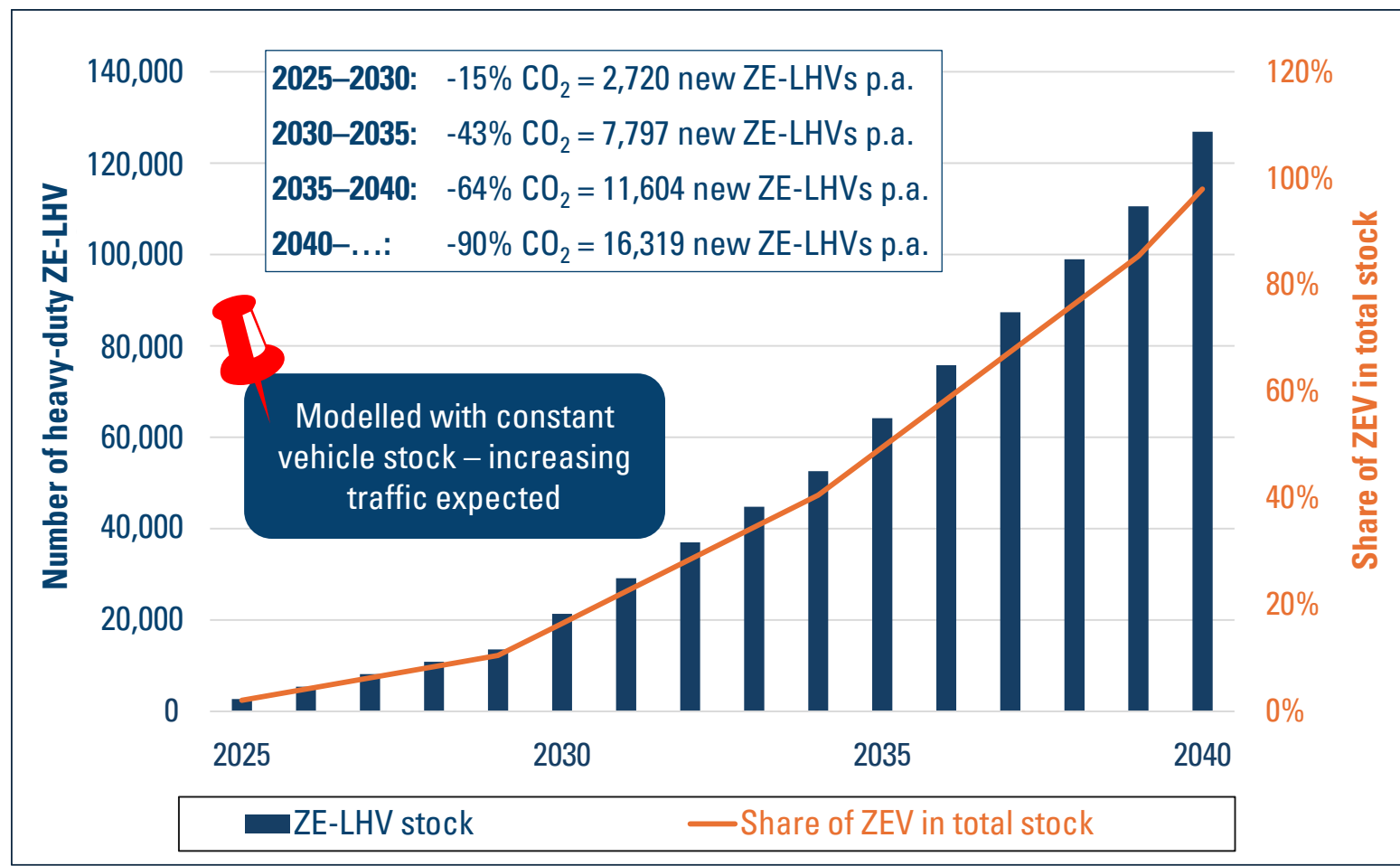


03

● ● ● ● ●
MODELLING RESULTS FOR
VARIOUS SCENARIOS



Modelled ramp-up of zero-emission long-haul vehicles in Germany based on the EU regulation

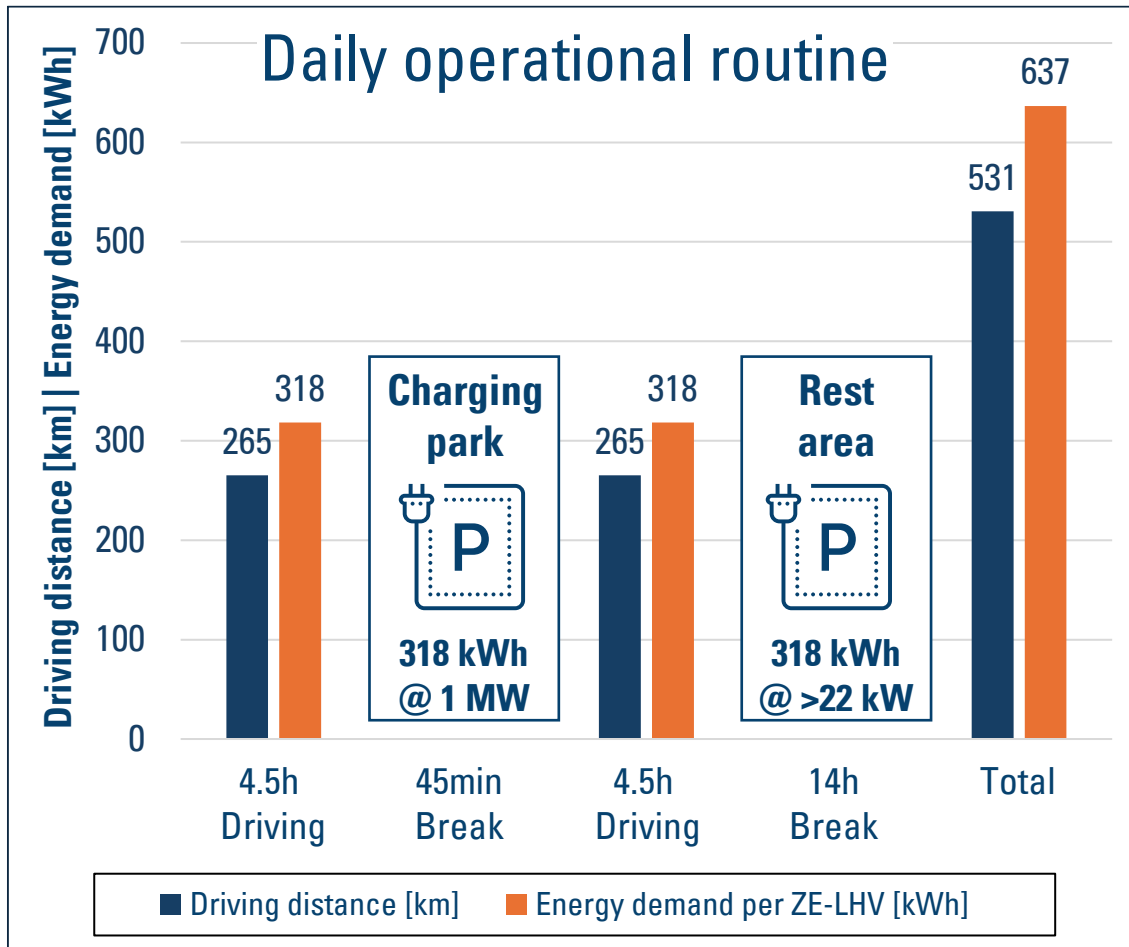


- Under these simplified modelling assumptions, the vehicle stock is 98 % decarbonised in 2040 and reaches approximately 130,000 ZE-LHVs.
- Of these, approximately 100,000 are in operation per day in 2040.

- Assumptions:**
- CO₂ reduction according to the EU regulation is achieved through BEV quotas matching the CO₂ reduction targets (15 %, 43 %, 64 %, 90 %).
 - BEV-optimal ramp-up → internal combustion engines are phased out until 100 % BEV is reached.



- An electric long-haul truck requires as much electricity in
- 5–7 days as a four-person household consumes in an entire year
-

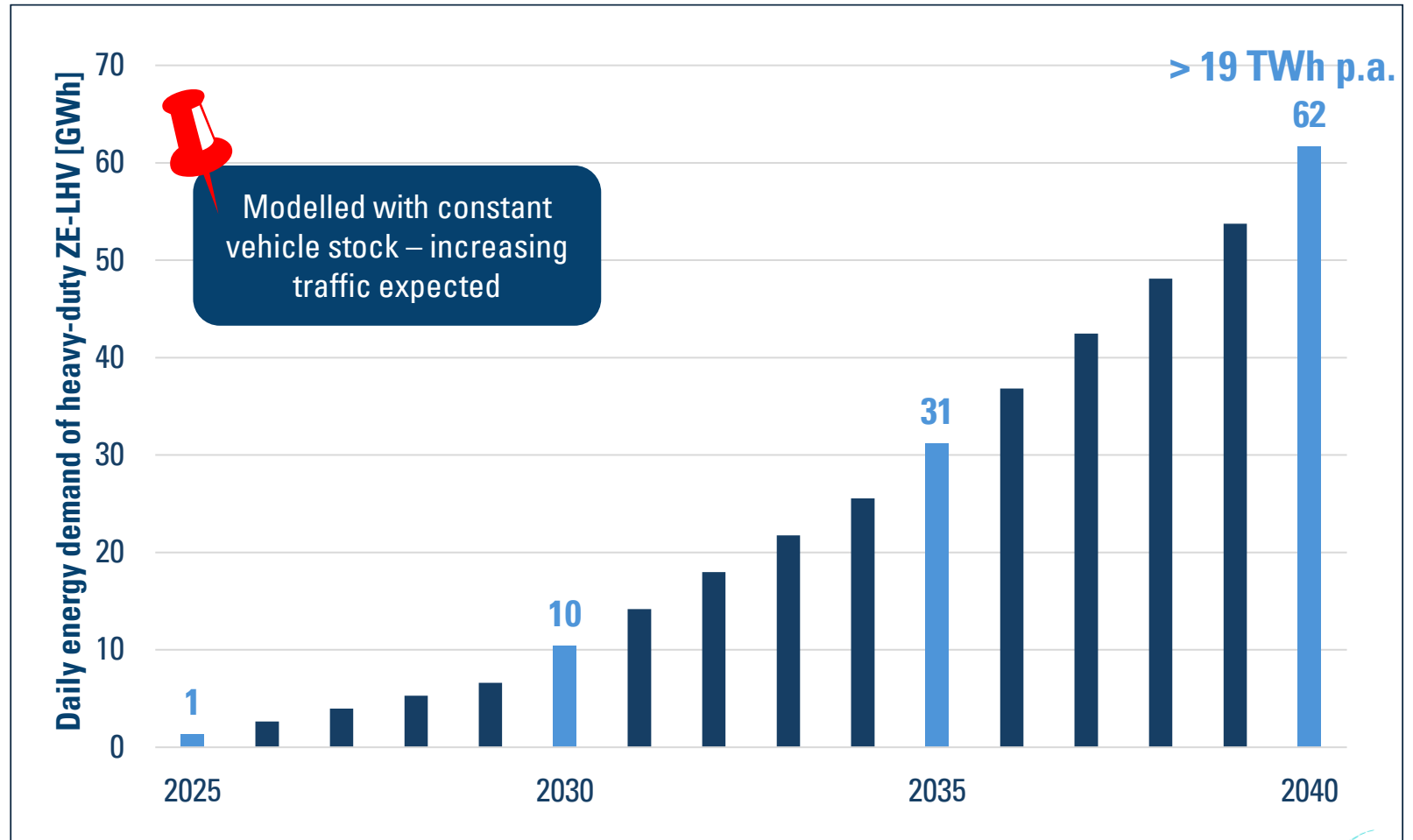


- **Daily operational routine:** 45-minute break after 4.5 hours of driving time and a maximum daily driving time of 9 hours are mandatory for drivers.
- **Modelling assumptions:**
 - Each vehicle starts the morning with a full battery.
 - Charging park: the battery capacity consumed in the morning is recharged at midday via megawatt charging (MWC).
 - Rest & service area: overnight, each truck charges “slowly” (≥ 22 kW)

The electricity demand of the electrified long-haul fleet exceeds 60 GWh per day in 2040



The annual electricity demand (*tank-to-wheel*) of ZE-LHVs in 2040, at over 19 TWh, corresponds to approximately 26 % of Germany's PV generation in 2024¹⁾, or roughly 1.5 times Berlin's current annual electricity consumption²⁾.



Assumptions:

304 regular driving days per year and 232 driving days per vehicle → vehicles are evenly distributed across driving days

1) PV total ~72.2 TWh – https://www.ise.fraunhofer.de/content/dam/ise/en/documents/press-releases/2025/0125_ISE_en_PR_electricity_generation2024.pdf
2) Berlin electricity consumption 2024: 12,3 TWh – <https://www.stromnetz.berlin/en/about-us/facts-figures-and-dates/>



Scenario 1 – 100 % BEV: How much charging power does a fully electric long-haul fleet require?

Objective: To estimate the real energy and power demand necessary to represent daily long-haul operations entirely electrically.

Key questions:

- How much energy and power is needed to support logistics processes while adhering to realistic driving and break schedules (4.5 h → 45 min → 4.5 h)?
- What charging infrastructure would be needed to ensure operation without waiting times?

Modelling assumptions:

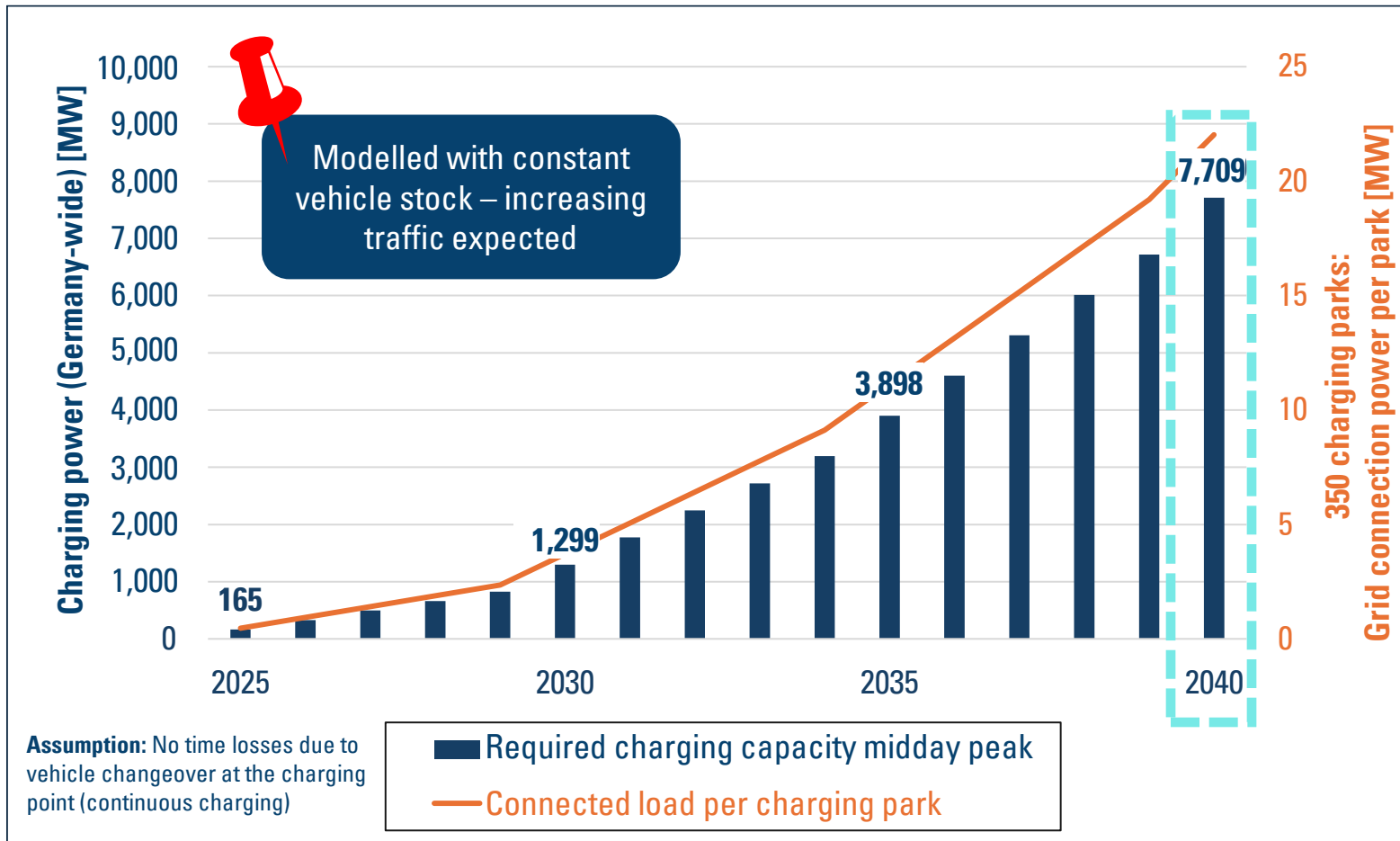
- **Midday peak charging:**
All zero-emission long-haul vehicles in daily operation recharge, within a 4-hour midday window, the energy consumed during the morning (~ 50 % of daily demand) via megawatt charging (MWC) (cf. FfE¹⁾)
- **Overnight charging:**
Each ZE-LHV charges overnight via a CCS charging point at ≥ 100 kW until fully replenished → every active ZE-LHV requires an overnight parking space with a charging connection

1) Engwerth, Veronika; Sommer, Katharina et al.: Einfluss der Elektrifizierung schwerer Nutzfahrzeuge auf das Energiesystem - FfE Discussion Paper 2024-02.
Munich: Forschungsstelle für Energiewirtschaft e.V., 2024



Scenario 1: During a 4-hour midday period, all vehicles recharge the energy consumed up to that point via MWC¹⁾

The modelling assumption illustrates the order of magnitude of energy demand – the real grid load is significantly higher



Results for 2040:

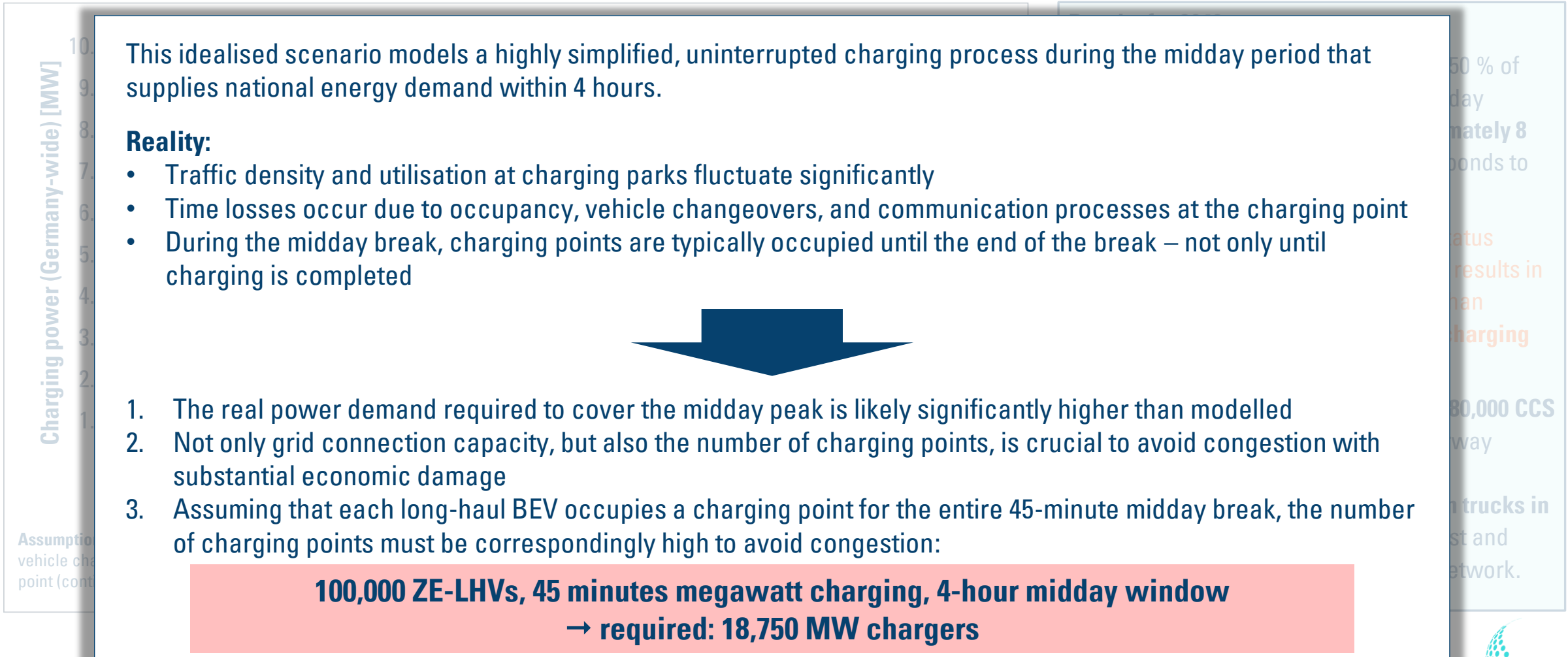
- To recharge the required **31 GWh** (= 50 % of daily energy demand) during the midday period, a **constant power of approximately 8 GW** is required over 4 hours (corresponds to roughly **8,000 MW chargers**).
- With **350 charging parks** (planning status Ministry/Infrastructure Agency), this results in an average power demand of more than **22 MW per site** (alternatively: **1,000 charging parks at 8 MW each**).
- For slow overnight charging, **60,000–80,000 CCS chargers** would be required at motorway service areas in 2040 – based on **approximately 100,000 ZE-LHVs in daily operation**, of which 60–80 % rest and charge overnight on the motorway network.

1) Assumption: half of total energy demand is supplied via MWC. Reference: Engwerth, Veronika; Sommer, Katharina et al.: Einfluss der Elektrifizierung schwerer Nutzfahrzeuge auf das Energiesystem - fE Discussion Paper 2024-02. Munich: Forschungsstelle für Energiewirtschaft e.V., 2024



Scenario 1: During a 4-hour midday period, all vehicles recharge the energy consumed up to that point via MWC¹⁾

The modelling assumption illustrates the order of magnitude of energy demand – the real grid load is significantly higher



● Scenario 2 – 100 % BEV: Is the planned charging infrastructure sufficient?

Objective: Assessment of the performance of the planned public charging network and its limits under full electrification of heavy-duty road freight transport.

Key questions:

- What power capacities can the planned public charging infrastructure (Federal Ministry for Transport / National Charging Infrastructure Agency) realistically provide in the target architecture?
- To what extent do these capacities cover the modelled energy demand of the zero-emission long-haul vehicle fleets, and where do potential bottlenecks or grid overloads arise?

Modelling assumptions:

- Comparison of real energy demand (Scenario 1) with installed and planned grid connection capacity of charging parks
- Assumption: 350 charging parks × 8 MW by 2030 (planning status of the National Charging Infrastructure Agency)
- Assessment of whether this target architecture is sufficient to cover the daily electricity demand (≈ 60 GWh in 2040) without waiting times or grid overload



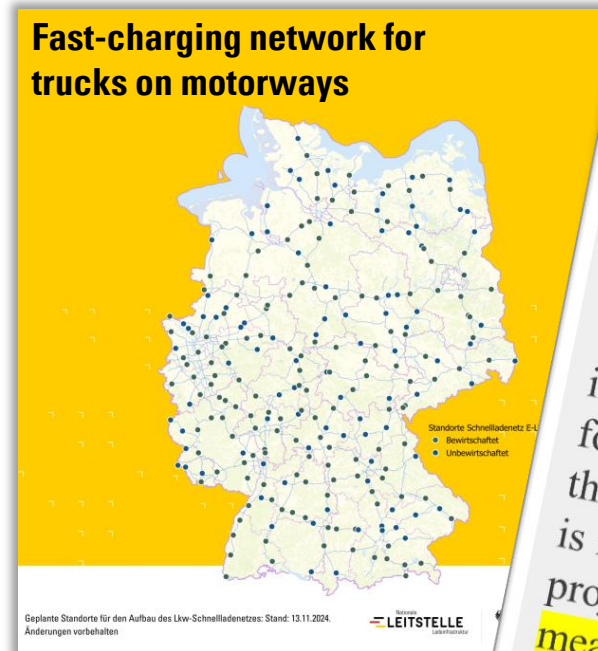
Scenario 2: Planning status of the Federal Ministry for Transport / National Charging Infrastructure Agency (NLL) – Approx. 350 charging parks with an average grid connection capacity of 8 MW by 2030

Planning status (2025):

- 350 sites by 2030
- 1,800 MCS and 2,400 CCS charging points
 - MCS (Megawatt Charging System): ≥ 1 MW per charging point
 - CCS (Combined Charging System)
 - intermediate charging: ≥ 400 kW per charging point
- Average power per charging point: ≈ 660 kW
- Planned total grid connection capacity in 2030: 2,846 MVA ≈ 2.80 GW (corresponds to 67 GWh per 24 hours)

Sources:

- 1) NLL 2025: Charging infrastructure for commercial vehicles, <https://nationale-leitstelle.de/nutzfahrzeuge>
- 2) NLL 2025: Truck charging infrastructure monitoring dashboard, <https://nationale-leitstelle.de/nutzfahrzeuge/lkwlistmonitoring/>
- 3) NLL 2024: Locations for the truck fast-charging network, https://nationale-leitstelle.de/wp-content/uploads/2025/07/20241113_Standortliste_Lkw-Ladenetz_Netzbetreiber_Versand.pdf
- 4) Autobahn GmbH des Bundes 2024: Project exposé for the tender “Truck fast-charging network at unmanaged service areas”, https://www.autobahn.de/storage/user_upload/qbank/Projektexpose_Ausschreibung_LKW-Schnellladenetz_unbewirtschaftete_Rastanlagen.pdf
- 5) dena 2025: Dossier: Ausbau der Ladeinfrastruktur für E-Lkw – Ergebnisse der Begleitforschung zum BMDV-Förderprogramm für klimafreundliche Nutzfahrzeuge und Infrastruktur (KsNI). https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2025/Dossier_Ausbau_der_Ladeinfrastruktur_fuer_E-Lkw_BF.pdf



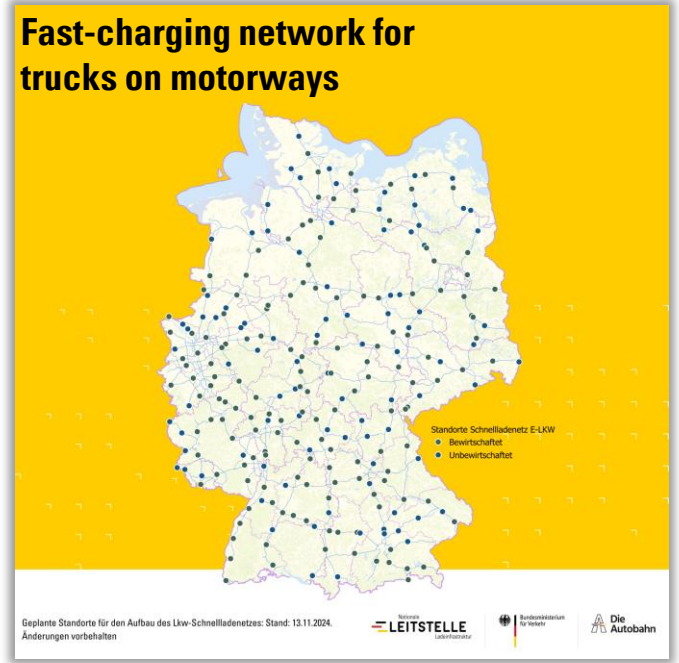
Master Plan for Charging Infrastructure 2030 (Federal Ministry for Transport)

... various use cases. Significant investments are required, particularly for the charging of electric trucks, which is still in an early market phase. The Federal Government aims to activate private capital through targeted investment grants, thereby incentivizing medium- and long-term follow-up investments. Additionally, the provision of federally owned land is intended to support investment projects. **The implementation of all measures in the Masterplan that have a financial impact is subject to the availability of budgetary funds.**

Scenario 2: Planning status of the Federal Ministry for Transport / National Charging Infrastructure Agency (NLL) – Approx. 350 charging parks with an average grid connection capacity of 8 MW by 2030

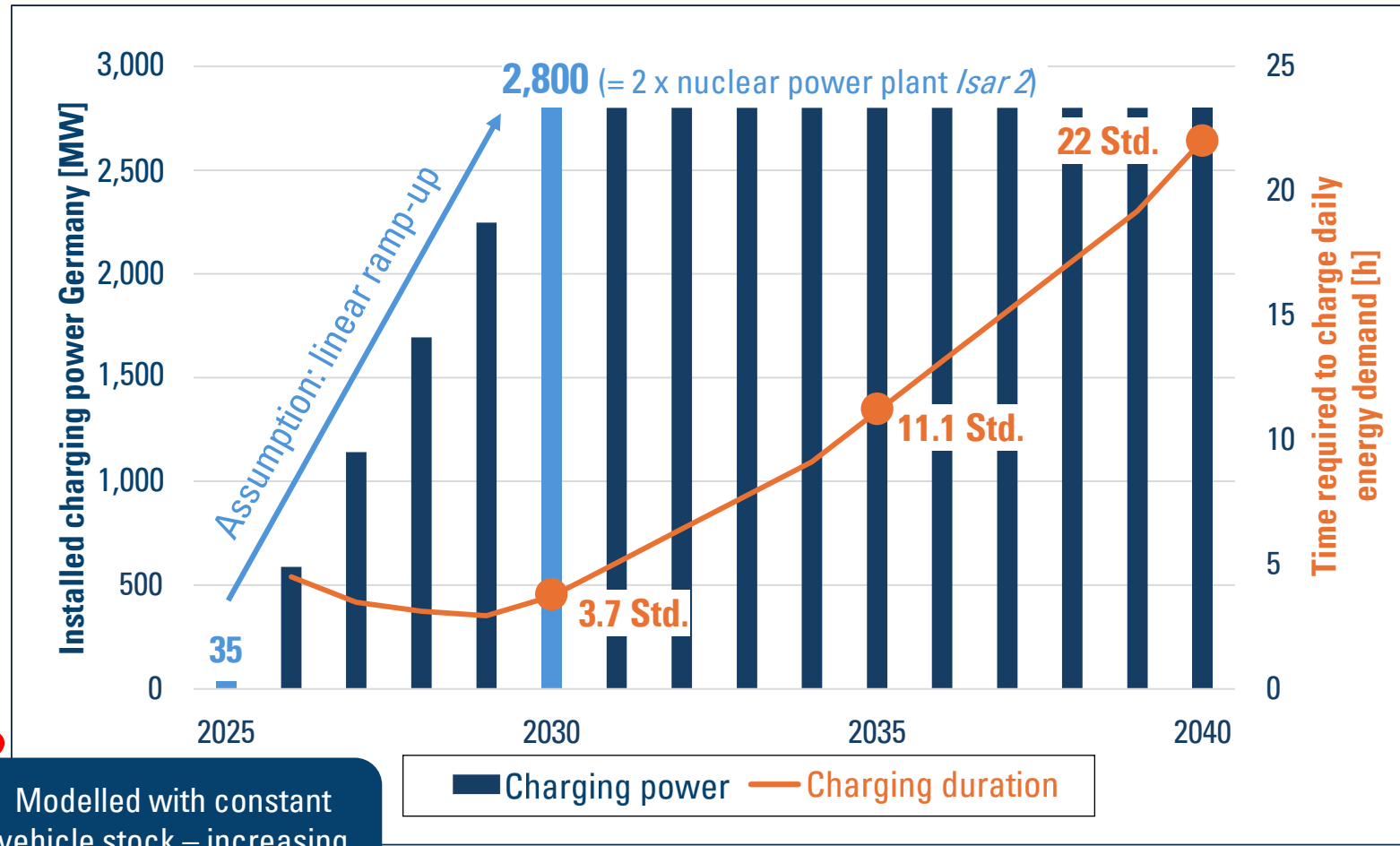


| Federal State | Number of locations | Share of locations | Truck grid connection power 2035 [kVA] | Share of grid connection power |
|--------------------------|---------------------|--------------------|--|--------------------------------|
| Baden-Wuerttemberg | 34 | 10% | 290,840 | 10% |
| Bavaria | 73 | 21% | 627,880 | 22% |
| Berlin | 0 | 0% | - | 0% |
| Brandenburg | 24 | 7% | 184,800 | 7% |
| Bremen | 1 | 0% | 3,960 | 0% |
| Hamburg | 0 | 0% | - | 0% |
| Hesse | 23 | 7% | 237,160 | 8% |
| Mecklenburg-Western Pom. | 21 | 6% | 77,000 | 3% |
| Lower Saxony | 35 | 10% | 311,080 | 11% |
| North Rhine-Westphalia | 48 | 14% | 400,400 | 14% |
| Rhineland-Palatinate | 23 | 7% | 151,030 | 5% |
| Saarland | 4 | 1% | 14,960 | 1% |
| Sachsen | 15 | 4% | 155,760 | 5% |
| Saxony-Anhalt | 20 | 6% | 184,360 | 6% |
| Schleswig-Holstein | 17 | 5% | 90,640 | 3% |
| Thuringia | 13 | 4% | 113,080 | 4% |



Data basis: NLL 2024: Locations for the truck fast-charging network, https://nationale-leitstelle.de/wp-content/uploads/2025/07/20241113_Standortliste_Lkw-Ladenetz_Netzbetreiber_Versand.pdf

- **Scenario 2:** Planning status of the Federal Ministry for Transport / National Charging Infrastructure Agency (NLL) – Approx. 350 charging parks with an average grid connection capacity of 8 MW by 2030



- **2030:** With **2.8 GW** of installed connection power, the planned infrastructure would already be exposed to **3.7 hours of full utilisation per day** to cover the energy demand of the electric long-haul fleet (utilisation rate: 15.4%).
- **Need for action:** Even beyond 2030, a **massive expansion of both power capacity and number of charging points is unavoidable**
- **Critical utilisation:** 11 or even 22 hours of full-load operation per day across all charging parks nationwide are logistically and operationally unrealistic.

Modelled with constant vehicle stock – increasing traffic expected

Assumption: No downtimes of charging parks considered!

Scenario 3 – Hydrogen as a complement: Relieving the power grid and charging infrastructure

Objective: Assessment of how a hydrogen infrastructure can mitigate the bottlenecks of the 100 % BEV scenario while simultaneously contributing to system stability.

Key questions:

- To what extent can hydrogen reduce electricity demand and grid connection capacity requirements at motorway locations?
- What operational and systemic advantages arise from short refuelling times, high site flexibility, and predictable grid expansion?

Comparative framework:

- Comparison of hydrogen, BEV, and electric diesel (e-diesel) systems with regard to energy consumption, charging/refuelling times, land-use requirements, and electricity demand on a well-to-wheel (WtW) basis
- Assessment of the trade-off between efficiency and resilience – higher WtW electricity demand combined with lower dependence on the power grid
- Conclusion: hydrogen as a complementary technology that can significantly reduce electricity peaks, grid expansion costs, and operational vulnerabilities



Scenario 3 – Hydrogen as a complement: Relieving the power grid and charging infrastructure

Why hydrogen for long-haul transport?

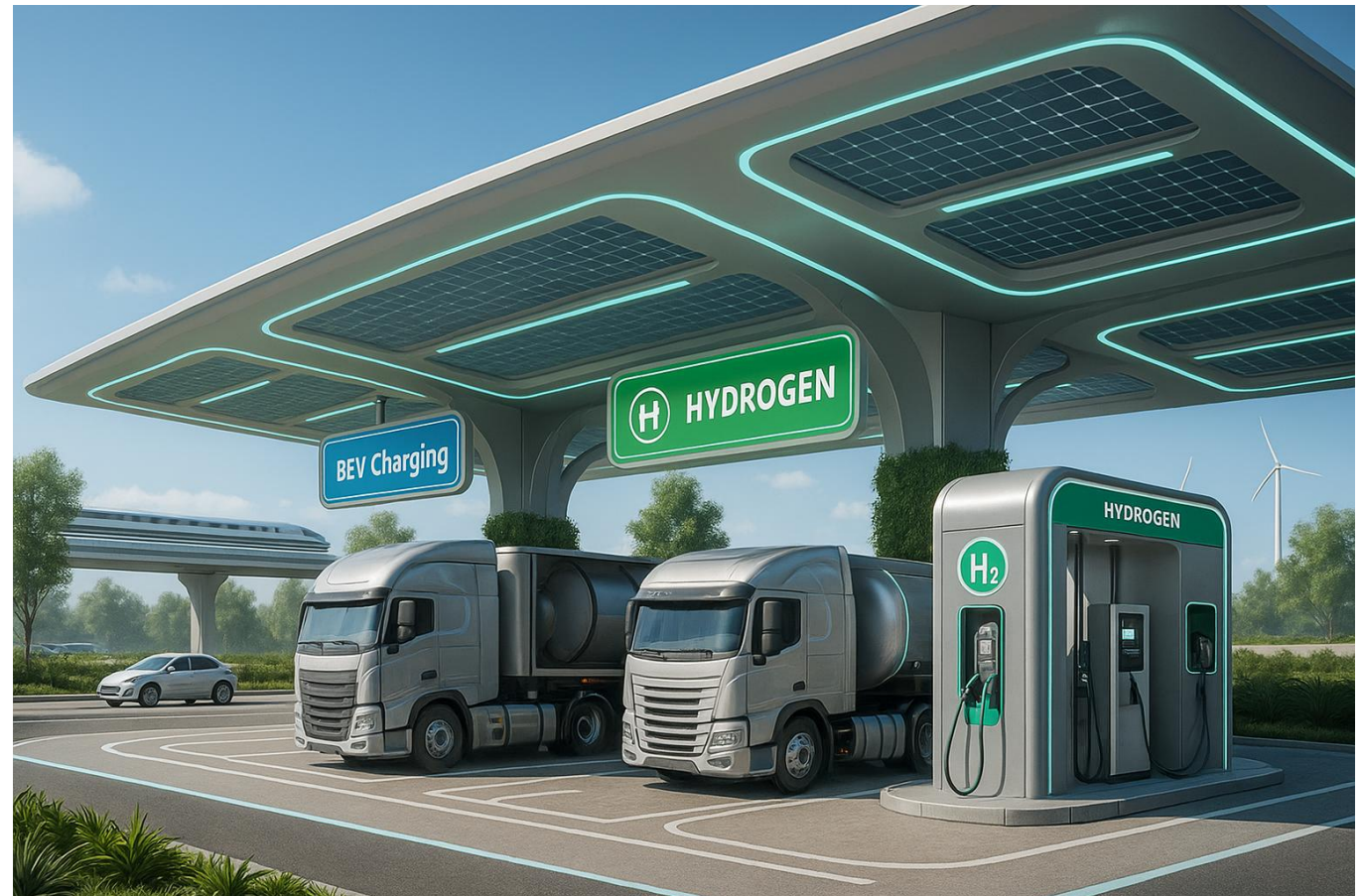
- **Grid relief**
Electricity production and consumption (hydrogen production) are temporally decoupled
- **Low on-site grid connection capacity**
Hydrogen refuelling station < 1 MW instead of > 8 MW (MCS)
- **High energy throughput per site**
Up to approximately 50 MWh per day per refuelling station
- **Short refuelling times – high availability – smooth operations**
10–15 minutes instead of hours of charging → no waiting times, no congestion, high vehicle availability
- **Lower land requirements at motorway service areas**
No parking during charging processes, more compact stations
- **Predictable grid expansion – scalable sites**
Electricity demand shifted to upstream generation
- **Synergy with the overall energy system**
Seasonal storage of renewable electricity, use of surplus electricity, and grid buffering
- **High location and supply flexibility – high security of supply**
Combination of central production, regional hydrogen hubs, trailer or pipeline distribution; no throttled charging power
- **Operational similarity to diesel**
Range, duty cycles, and refuelling logic remain unchanged
- **Scalable at European level**
Compatible with trans-European hydrogen corridors



Scenario 3 – 350 „Clean Energy Hubs“: planned charging infrastructure synergistically expanded with hydrogen

● Proposal for an extended site concept

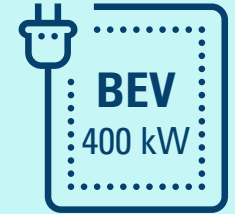
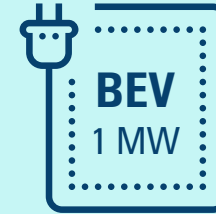
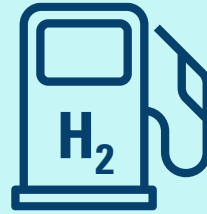
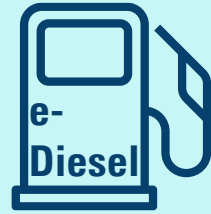
- **Efficient system complement:** Integration of hydrogen infrastructure at existing or planned 350 charging park sites avoids additional land requirements
- **Hydrogen setup:** Extension of sites with refuelling infrastructure and storage (approximately 5 tonnes of hydrogen storage capacity per site)
- **Throughput:** Up to 125 hydrogen trucks per day per site can be supplied¹⁾
- **Substantial relief effect:** More than 40,000 hydrogen-powered long-haul trucks can be refuelled nationwide per day ($\approx 40\%$ the daily driving fleet)
- **Objective:** Significant relief of BEV charging infrastructure through parallel operation
- **Energy system synergy:** Nationwide decentralised hydrogen storage (5 t) enables buffering and reconversion of surplus renewable electricity



Visualisation: AI-generated illustration (OpenAI DALL-E, 2025)

1) Assumption: 530 km daily mileage with 7.5 kg hydrogen per 100 km

- **Hydrogen complements BEV:** short refuelling times reduce dwell times and ensure traffic flow – Relief for the power grid and charging infrastructure
-
-



e-Diesel

H2 (FCEV)

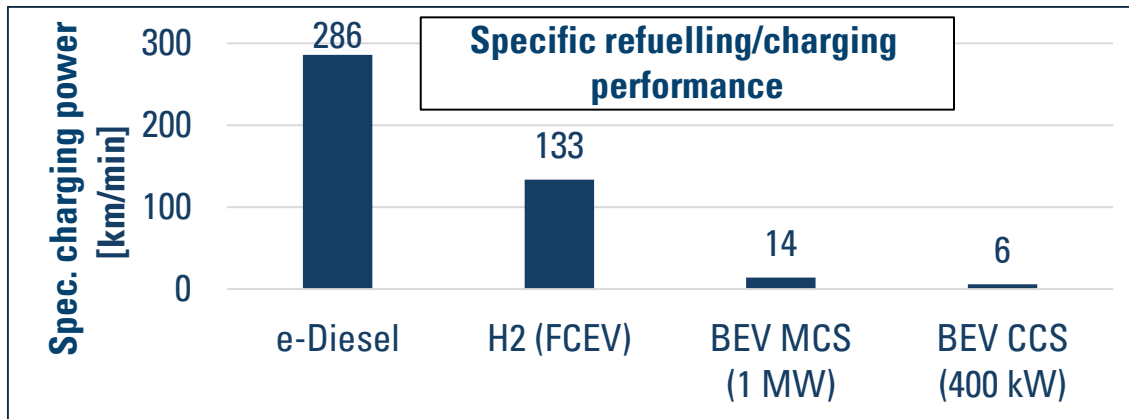
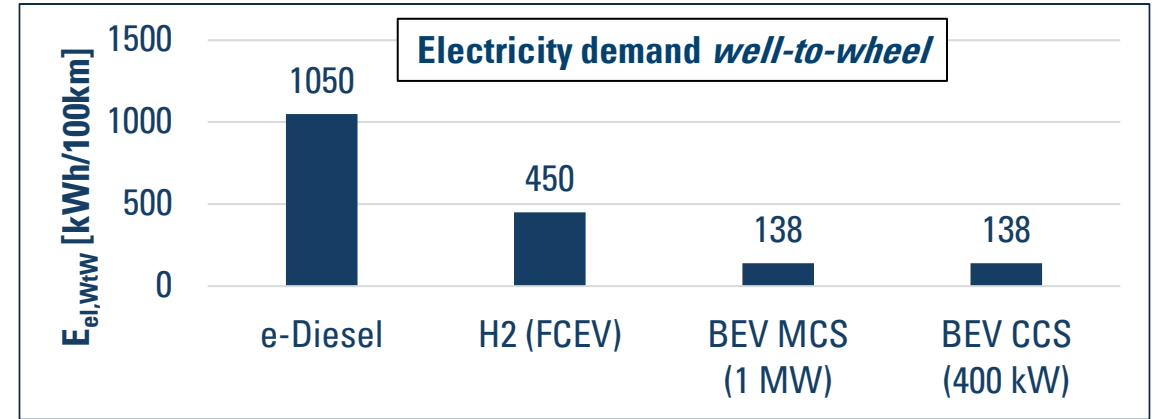
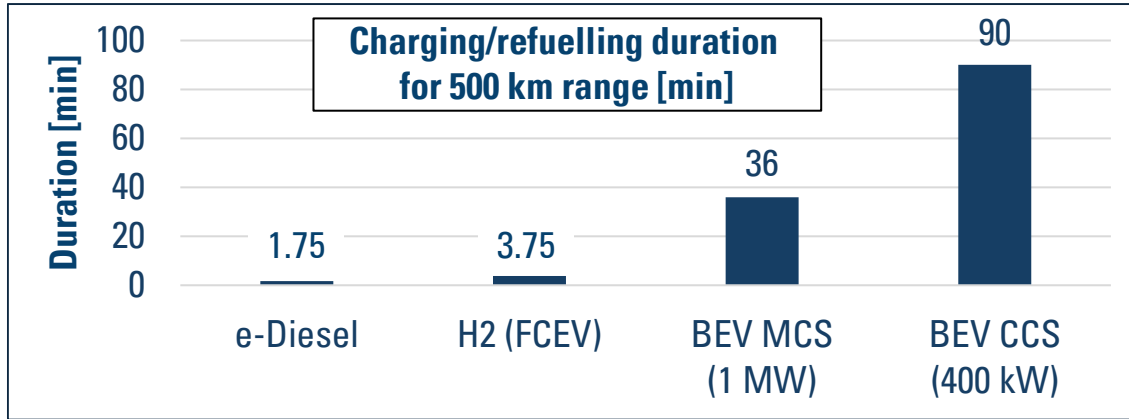
BEV MCS (1 MW)

BEV CCS (400 kW)

| | | | | |
|--|----------------|---------------|---------------|---------------|
| Energy content of fuel | 9.8 kWh/l | 33.3 kWh/kg | 1 kWh/kWh | 1 kWh/kWh |
| Electricity demand <i>well-to-tank</i> | 30 kWh/l | 60 kWh/kg | 1.15 kWh/kWh | 1.15 kWh/kWh |
| Consumption 40t tractor (5-LH) | 35 l/100km | 7.5 kg/100km | 120 kWh/100km | 120 kWh/100km |
| Typical range 40t tractor (5-LH) | 2500 km | 700 km | 500 km | 500 km |
| Range-mileage-ratio (530km per day) | 472 % | 132 % | 94 % | 94 % |
| Refuelling/charging rate at dispenser | 100 l/min | 10 kg/min | 16.67 kWh/min | 6.67 kWh/min |
| Time required for 500 km range | 1.75 min | 3.75 min | 36 min | 90 min |
| Electric power at charging point | 58.8 MW | 19.98 MW | 1 MW | 0,4 MW |
| Specific refuelling/charging performance¹⁾ | 286 km/min | 133 km/min | 14 km/min | 6 km/min |
| Electricity demand <i>well-to-wheel</i> | 1050 kWh/100km | 450 kWh/100km | 138 kWh/100km | 138 kWh/100km |

1) Meaning: recharged driving range per minute

- **Hydrogen complements BEV:** short refuelling times reduce dwell times and ensure traffic flow – Relief for the power grid and charging infrastructure
-



- **BEV is the most efficient option:** Only 13 % of the well-to-wheel energy demand of e-diesel
- **BEV charging is limited by power and time:** Even with 1 MW, recharging 500 km requires more than 30 minutes
- **Energy storage and system resilience with hydrogen:** Higher electricity demand is a legitimate “price” to make renewable energy storable and to build resilience within the energy system

➤ **Conclusion: The combination of BEV (efficiency) and hydrogen (refuelling speed, grid relief) creates a robust overall system**



Derivation of vehicle numbers for Europe (EU)



There are no robust stock data for different vehicle classes from which the long-haul heavy-duty vehicles considered here can be cleanly derived.

➤ **Method:**

- Baseline assumption: German vehicle shares are transferable to the EU → extrapolation from Germany to the EU
- ACEA data¹⁾:
 - Trucks²⁾ in the EU: 5,998,915
 - Trucks in Germany: 977,673 = 16.3 % of the EU fleet

➤ **Result:**

- Approx. 800,000 long-haul vehicles in the EU
- Approx. 110,000 new registrations per year

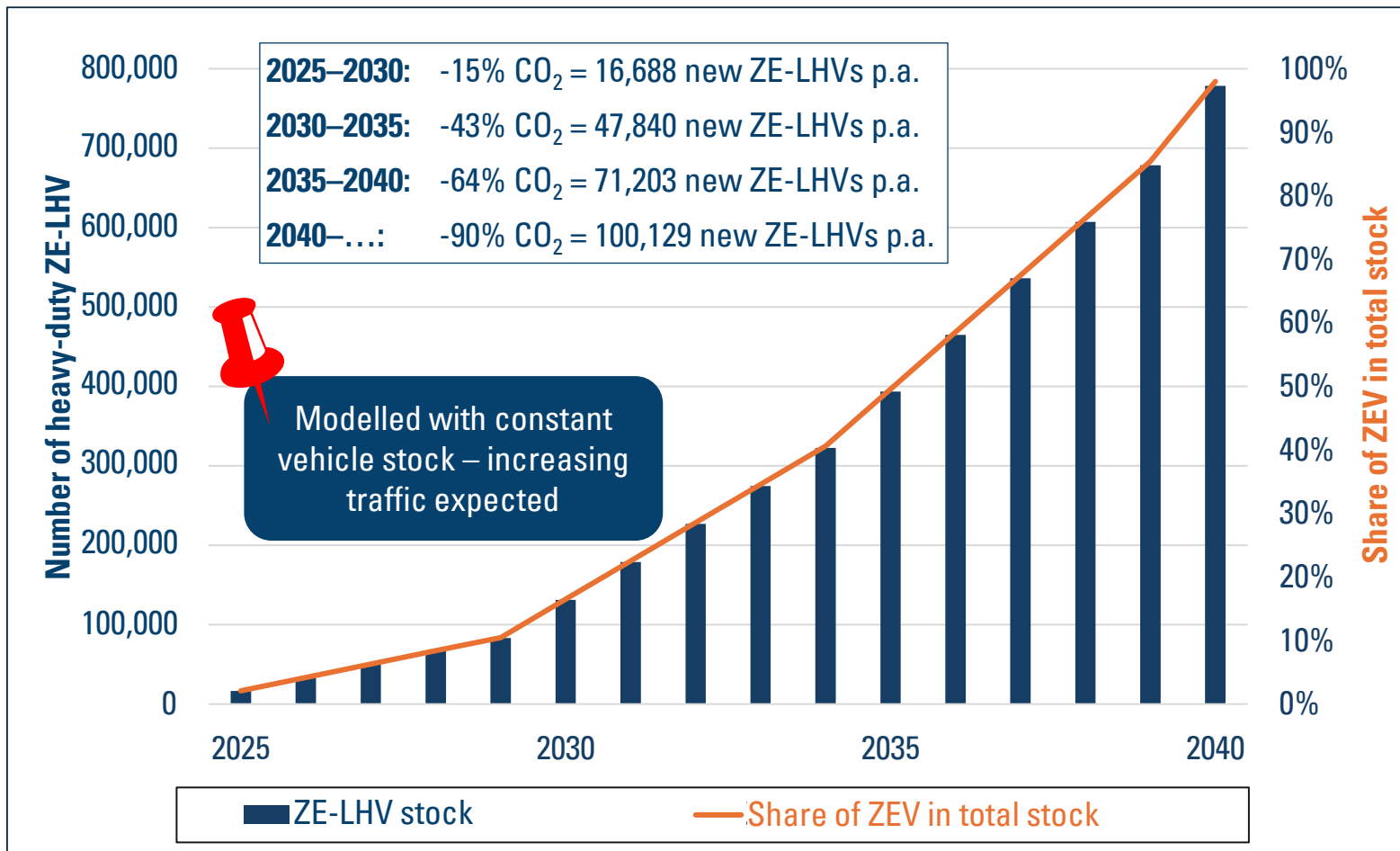
High modelling uncertainty! (± 20%)



1) ACEA Report – Vehicles on European roads 2025: <https://www.acea.auto/publication/report-vehicles-on-european-roads-2025/>

2) Trucks according to ACEA: commercial vehicles >3,5 t (N2+N3)

Modelled ramp-up of zero-emission long-haul vehicles in the EU based on the EU regulation



Under these simplified modelling assumptions, the vehicle stock is fully decarbonised by 2041.

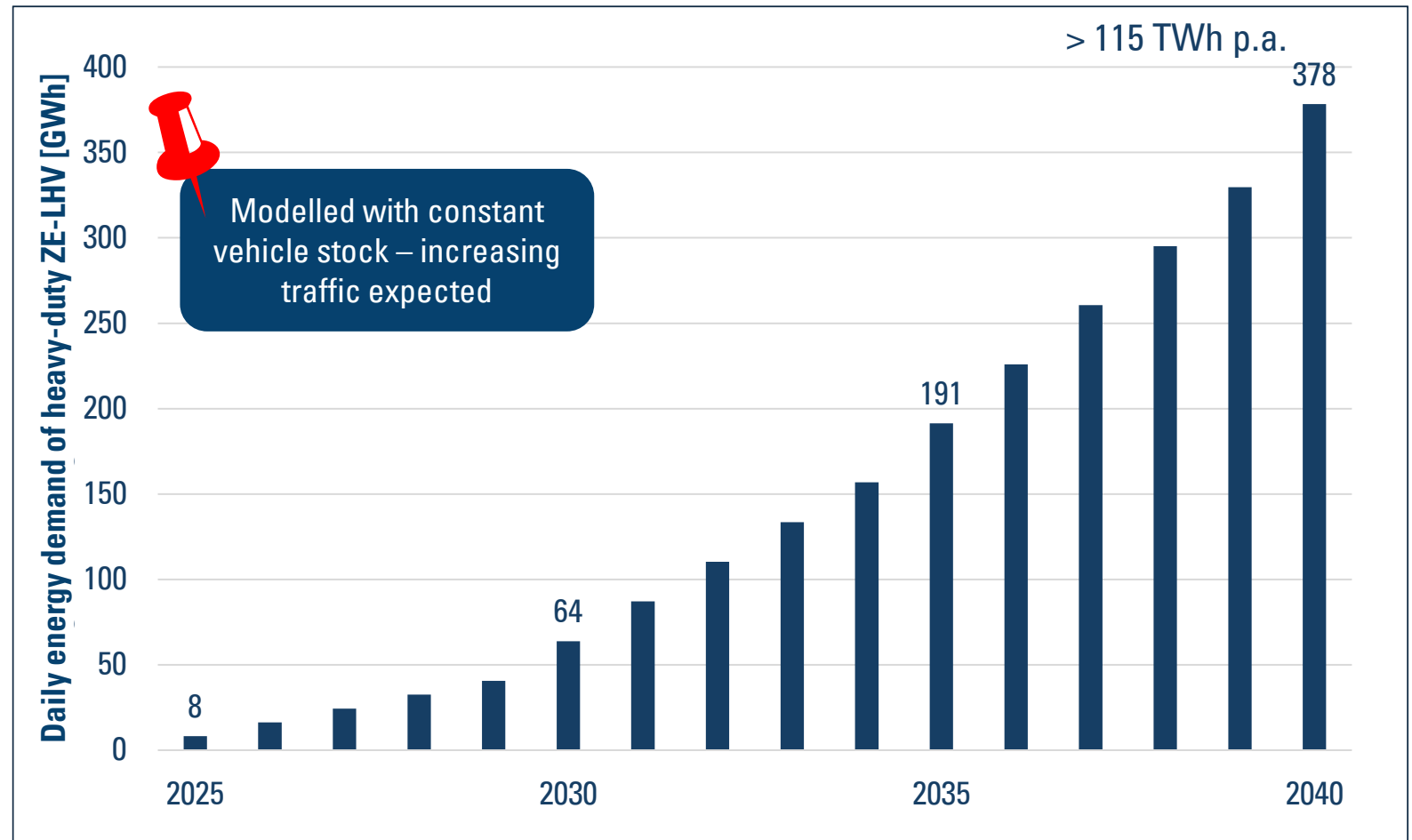
Assumptions:

- CO₂ reduction according to the EU regulation is achieved through BEV quotas matching the CO₂ reduction targets (15 %, 43 %, 64 %, 90 %).
- BEV-optimal ramp-up → combustion engines are phased out until 100 % BEV is reached.



The electricity demand of the electrified long-haul fleet in the EU exceeds 375 GWh per day in 2040

The annual electricity demand (*well-to-wheel*) of European ZE-LHVs in 2040, at over 115 TWh, is approximately equal to the gross electricity generation of the Netherlands¹).



Assumptions:

304 regular driving days per year and 232 driving days per vehicle → vehicles are evenly distributed across driving days

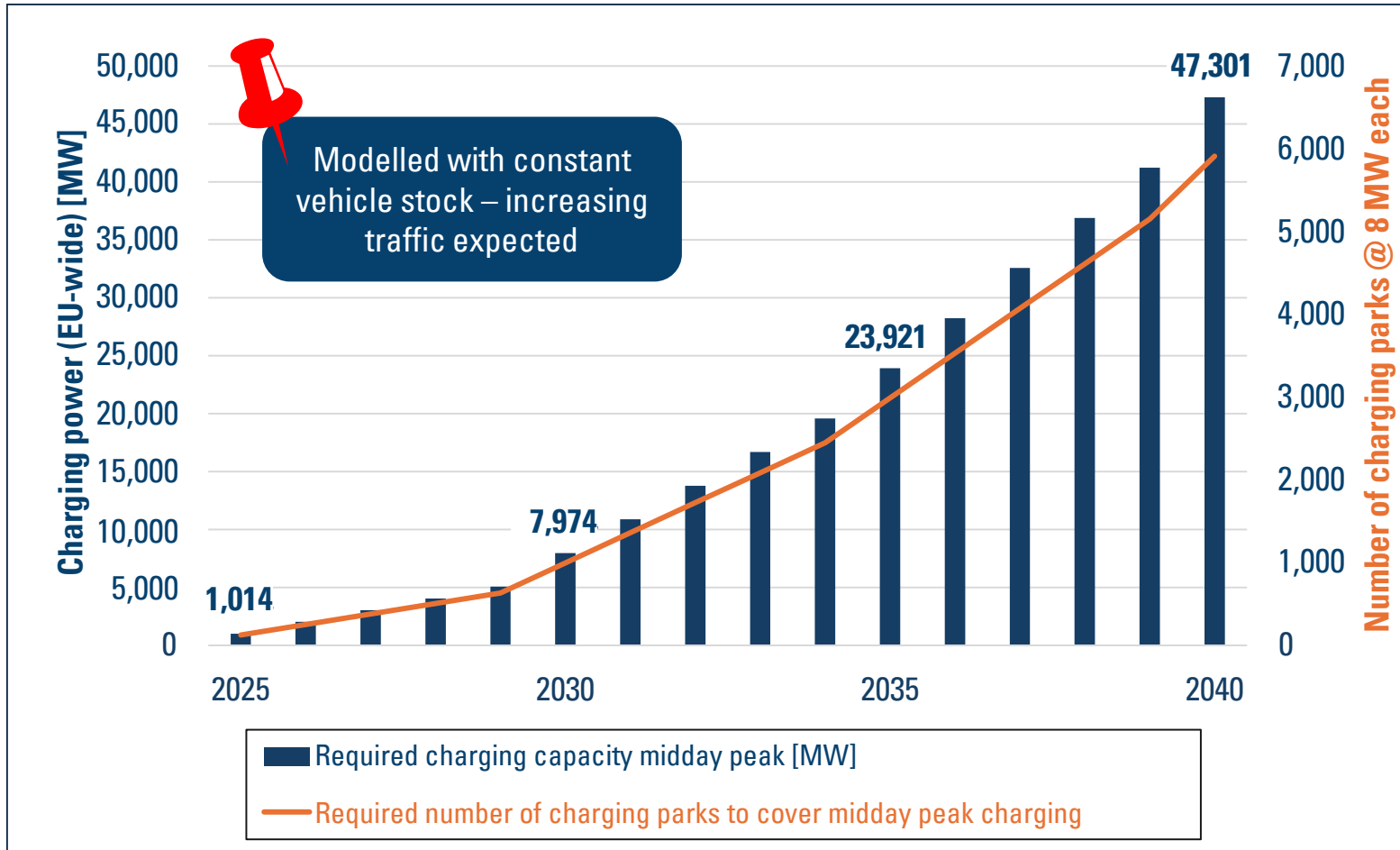
1) Gross electricity generation Netherlands 2022: 121 TWh (<https://www.weltenergieat.de/energie-fuer-deutschland-2023/energie-in-der-europaeischen-union-zahlen-und-fakten/>)





Scenario 1 (EU): During a 4-hour midday period, all vehicles recharge the energy consumed up to that point via MWC¹⁾

The modelling assumption illustrates the order of magnitude of energy demand – the real grid load is significantly higher



Results for 2040:

- To recharge the required **189 GWh** (= 50 % of daily energy demand) during the midday period, a **constant power of approximately 47 GW is required over 4 hours** (corresponds to roughly **47,000 MW chargers**).
- At 8 MW per charging park, this would require approximately 5,900 charging parks.
- For slow overnight charging, **360,000–480,000 CCS chargers** would be required at motorway service areas – based on **approximately 600,000 ZE-LHVs in daily operation**, of which 60–80 % rest and charge overnight on the motorway network.

Assumption: No time losses due to vehicle changeover at the charging point (continuous charging)

1) **Assumption:** half of total energy demand is supplied via MWC. Reference: Engwerth, Veronika; Sommer, Katharina et al.: Einfluss der Elektrifizierung schwerer Nutzfahrzeuge auf das Energiesystem - fE Discussion Paper 2024-02. Munich: Forschungsstelle für Energiewirtschaft e.V., 2024





04



SUMMARY

Key findings of the power grid study

- **Electrification of heavy-duty road freight transport fundamentally changes the energy system**
 - The German long-haul segment alone will cause > 60 GWh of electricity demand per day in the future
- **Charging infrastructure becomes the bottleneck factor**
 - For daily operation, approximately 1,000 charging parks at 8 MW or 350 charging parks at > 22 MW, plus > 60,000 CCS charging points for overnight charging, would be required in Germany
 - The planned network in Germany (\approx 350 parks at an average of 8 MW by 2030) covers only a fraction of demand after 2030
- **High grid loads arise particularly during peak periods**
 - Simultaneous midday charging generates power peaks > 8 GW – in reality even higher due to blocking times and load shifting
- **Hydrogen can significantly relieve the power grid and operations**
 - < 1 MW grid connection capacity per refuelling station, no charging-related waiting times, predictable grid expansion
 - Hydrogen uses renewable electricity more flexibly (temporal decoupling) and increases system resilience
- **Trade-off: efficiency versus resilience**
 - Hydrogen has higher well-to-wheel electricity demand, but offers decisive advantages in terms of usability in the transport sector, grid stability, security of supply, and scalability

Without hydrogen as a complement, a 100 % BEV scenario remains technically, economically, and operationally scarcely feasible. Only a dual infrastructure pathway enables the achievement of CO₂ targets and provides planning certainty for fleet operators and energy infrastructure stakeholders.

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Über HyMobility



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Koordiniert durch:



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