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Challenges and requirements of megawatt charging infrastructure for long-haul trucks

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Executive Summary

This study deals with the definition of requirements and challenges in the design of high-performance charging infrastructure for battery-electric long-distance trucks. As part of funding project HoLa, these requirements are implemented in real operation, evaluated and optimized for the further rollout. The focus of this initial work stream is to design prototypical charging parks and derive standard layouts for various use cases represented in HoLa. In addition, the specification of a pilot reservation system to further optimize the design and operation of the charging parks is targeted.

BEV (battery electric vehicle), electric vehicle supply equipment (EVSE), ultra-fast charging, heavy-duty, truck

1 Introduction

1.1 Motivation

Over the past years, efforts to extend electrification from the passenger transport to logistics have gained momentum. Despite technical ambitions, several factors undermine development. Political actions complicate the continued use of combustion vehicles. The European Union's CO2 fleet regulations for heavy-duty vehicles and the German government's climate protection plan require a significant reduction in CO2 emissions from trucks by 2030. The European Union has set definitive CO2 standards for the commercial vehicle sector, originally demanding a 30% reduction in CO2 emissions by 2030 compared with 2019/2020. It recently announced a revision of the initial resolution in February that is supposed to raise this bar and echoes similar sentiments of some industry players. The ICE model is getting financially more and more unattractive as the fulfillment of standards (e.g., EURO VI) requires high technical implementation effort. CO2 taxation is used as an important climate policy tool to penalize pollution, and cities are increasingly implementing low- or zero-emission zones in their attempt to achieve emission reduction goals. Yet most importantly, first European countries show ambitions to completely ban ICE sales over the next decades.

Electric vehicle concepts are becoming a financially and technically attractive alternative. The highly price sensitive transportation sector is benefitting from governmental funding programs and subsidies as well as technological advances. Both shift the TCO in favor of BEVs, a trend that is expected to continue as experience and economies of scale effects will further decrease battery and maintenance costs.

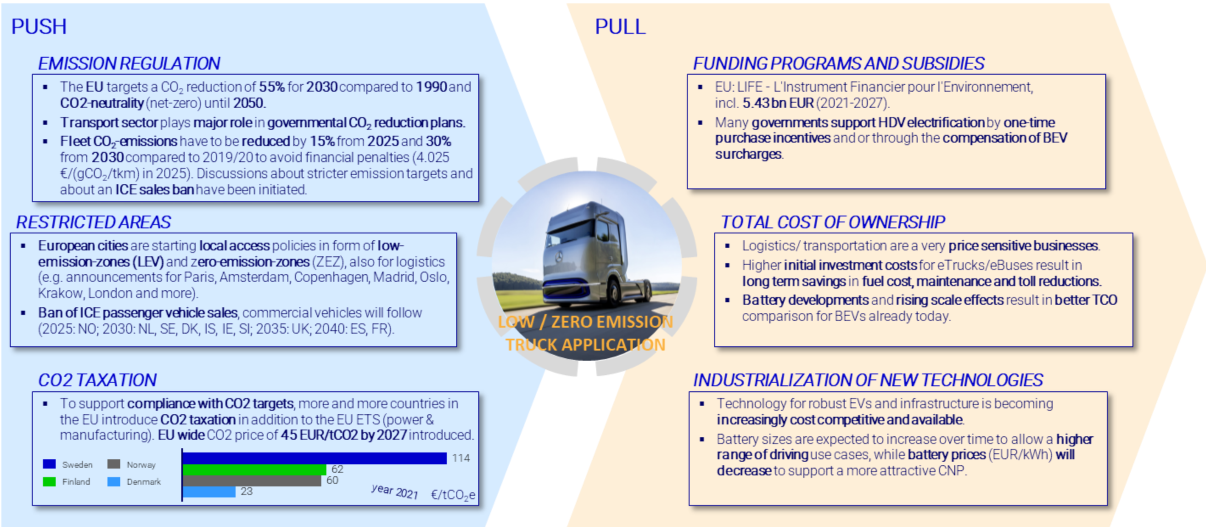

Figure 1: Push and pull factors for electrification

The response of major heavy-duty truck manufacturers is swift and unequivocal: ambitious electrification targets have been announced. Daimler Truck, striving for CO2-neutral transport by 2050, set interim targets for ZEV sale shares of 20-25% in 2025, 60% in 2030 and 100% in 2039. With TRATON setting out to achieve full ZEV sales by 2040 at the latest, brands such as Scania and MAN are targeting a 50% share of electrified sales by 2030.

Although many new specialized OEMs have entered the heavy-duty vehicle market, such as Tesla or BYD, the majority of new electric truck models will be launched by established manufacturers over the next year. Already listing first BEV trucks in their portfolio, major OEMs have announced new entries within the heavy-duty and semi-trailer segment within 2023-2025. This commitment to electrification has been reinforced at the IAA Transportation 2022, where various new BEV models have been disclosed. MAN for instance intends to bring three new models to the market by 2024. Higher battery capacity and increased charging power are making longer ranges feasibly, thereby removing one of the main barriers to electric long-haul heavy-duty transportation.

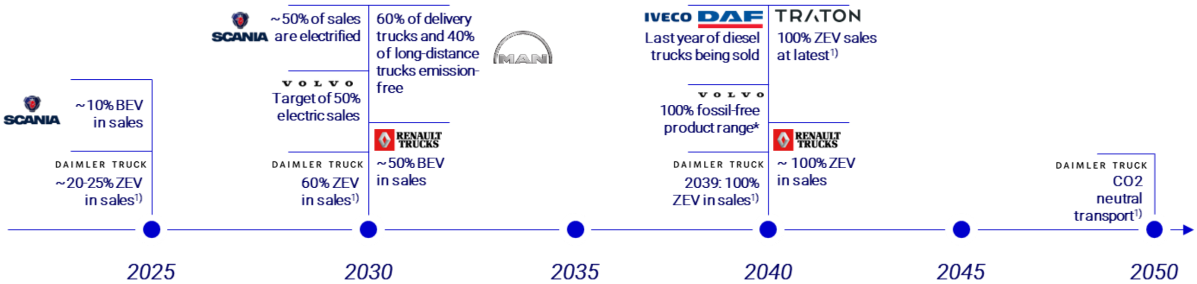

Figure 2: Electrification roadmaps of European truck OEMs

The application of battery-electric trucks in regional distribution transport is already a key use case. However, the transport profiles in the area of long-distance transport with heavy-duty trucks present special challenges with regard to charging systems, energy supply, locations and operational planning in order to be able to charge battery-electric trucks sufficiently quickly within the statutory break times of 45 minutes between two driving assignments [1].

The aim of the project "High-Performance Charging for Long-Distance Trucks" (HoLa) is to plan, set up and operate selected high-performance charging infrastructure for battery-electric trucks on a demonstration route between Berlin and the Ruhr region in Germany, and to answer research questions related to the subsequent nationwide expansion of high-performance truck charging parks in Germany. HoLa is being funded by the German Federal Ministry of Digital Affairs and Transport (BMDV) with a total of approximately 12 Million Euros as part of the BMDV's Electric Mobility Funding Guideline. The funding guideline is coordinated by NOW GmbH and implemented by Project Management Jülich (PtJ).

HoLa corridor specifications

Route	Ruhr area to Berlin along highway A2
Total distance	490 km
# of sites	5
# of CCS charge points	10
# of MCS charge points	8
Total grid power	7.8 – 8.4 MW
# of vehicles	12

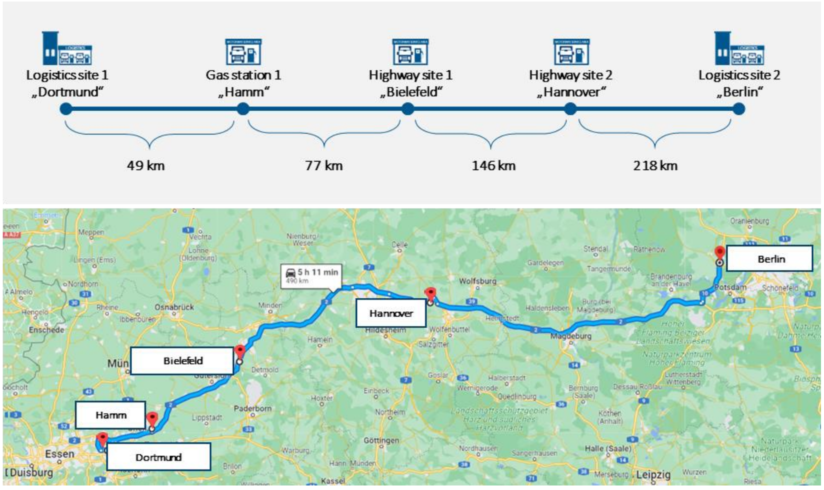

Figure 3: Overview of HoLa charging network

Due to the significant preparation time required for the safe series operation of high-quality charging infrastructure, early planning and construction with sufficient lead time before the overarching market ramp-up of the vehicles is necessary. As a result, the project with its findings and lessons learned from planning, demonstration & operation as well as the scientific support will not only serve as a blueprint for the nationwide development of high-performance charging infrastructure for battery-electric trucks in long-distance transport but also as a best-practice for the European and global rollout of a charging network for long-haul commercial vehicle. The project thus makes an important contribution both to safeguarding the further technical development of vehicles, charging infrastructure and new charging systems as well as to the market ramp-up of electric trucks with corresponding data and energy system integration.

1.2 Challenges, research questions and approach

The operation of battery-electric trucks in long-haul transport requires demand-driven charging infrastructure in order to reduce idle times during opportunity charging to a minimum and thus enable efficient route planning comparable to operation with conventional trucks. Such charging infrastructure must provide charging power levels that are not possible with the current state-of-the-art technology, known as CCS ("Combined Charging System").

With the MCS technology ("Megawatt Charging System"), which is still in the development and standardisation phase, charging capacities of 1 MW and more shall become possible. The increased charging power via MCS shall recharge the battery to the desired target SOC ("State of Charge") in less than 45 minutes, which corresponds to the break time required after a driving time of 4.5 hours prescribed by EU directives.

The expansion of this charging infrastructure in connection with the new technology naturally also brings new questions and challenges with it: In addition to the required grid upgrade and grid expansion due to the increased power demand, the lack of space for charging park spots and the charging hardware reflect a major hurdle. In Germany alone, there is a shortage of up to 40,000 public truck parking spaces according to BGL ("German Federal Association of Road Haulage, Logistics and Waste Disposal") [2]. Across the EU, up to 400,000 parking spaces are missing [3]. This lack of space is another argument for the realisation of short charging times in order to reduce the number of charging points and thus also for space for the hardware to a minimum.

In addition to the space requirements, part of the study is to identify further requirements for the construction of the truck charging parks in order to make the ramp-up for charging infrastructure as transparent as possible for all stakeholders.In addition to technically and economically optimising the charging park layout, efficient operation and use of the charging points play a decisive role. In order to ensure the availability of charging points when trucks approach the charging park and thus to avoid delays in connection with charging processes during driving assignments as far as possible, an efficient and largely standardised reservation system is indispensable.

Within the scope of this study, requirements and standard layouts for MCS charging parks are defined on the basis of the knowledge gained from the HoLa project and through expert interviews. Furthermore, questions around the topic of charging point reservation are addressed and specifications for the development of a prototype reservation system within the project are derived.

2 Intermediary results: Charging park layout

As part of HoLa, five charging parks are being set up along the motorways between the Ruhr region and Berlin. These will involve a combination of CCS and MCS charging points, which will be integrated to the high and medium voltage grid with their separated power units. The charging parks will each be equipped with two MCS charging points and up to three CCS charging points. The grid connection will be designed for up to 2.3 MW per charging park and will take into account a simultaneity factor between 0.7 and 0.85.

Exemplary specification for a HoLa site

# of CCS charge points	2
# of MCS charge points	2
# of parking/charging spaces	4
Grid power	2.3 MW
Charging power per CCS	> 350 kW
Charging power per MCS	1.0 MW
Parking concept	Drive-through
Voltage / Current	1,000 V / 1,000 A (in discussion)
Availability	24/7, (semi-)public
Further components	Transformer, power cabinet, (potentially) stationary battery
Local facilities	Passenger vehicle charging station, gas station, gastronomy, sanitary

Figure 4: Indicative specification of an exemplary HoLa charging site

The following criteria were used for the evaluation of the site search for Hola, which can also be used as a generic set of selection criteria for the infrastructure ramp-up. In addition to space availability, the expandability of the charging infrastructure with regard to the further ramp-up in near future and the distance to the next truck charging parks have been identified as key criteria. Furthermore, the feasibility and lead times for site conversion respectively construction and for the connection to the energy grid are elementary. Guidelines and indicative values for the mentioned key criteria have not been finalized yet, but will further be evaluated and specified throughout the HoLa project.

Further requirements for truck charging parks will be the charging park sizes based on number of charge points, the ratio between opportunity charging via MCS vs. longterm respectively overnight charging via CCS, the allocation of the different sizes to site types (e.g., smaller highway rest areas, dedicated truck parking stops) and the actual layout (e.g., positioning of charging hardware, parking positions).

The approach for charging park sizes and allocating those to specific site types will be derived from the charge point demand under consideration of various ramp-up scenarios. The share between MCS and CCS charge points, on the other hand, can be derived from historic figures for truck stop durations as seen in *Figure 5* and *Figure 6*. These topics are currently under investigation and targeted to be finalized before EVS 36. However, it can be seen that only around 1/3 of stops in long-haul transport take less than 1 hour. When comparing this with the MCS requirement for charging durations of up to 45 minutes, one can conclude in a first rough calculation that the ratio between MCS and CCS can be about 1:2.

Duration:	½ - 1 hr	1 – 3 hr.	3 – 8 hr.	8 – 23 hr.	23 – 44 hr.	> 44hr.
Long-haul:	35%	24%	6%	31%	2%	2%
Regional:	44%	23%	6%	24%	1%	1%

Figure 5: Mean share of duration classes of truck stops [4]

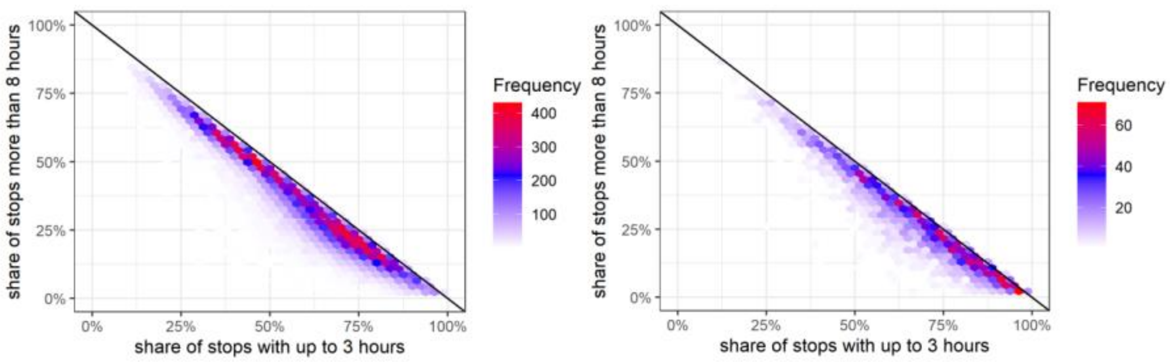

Figure 6: Distribution of stops in long-haul (left) vs. regional operation (right) [4]

Initial derivations show the implementation of three charging park sizes ranging from small, medium to large. While the number of charging points is still in evaluation and won't be further specified yet, the different size types can be already allocated to site types as seen in *Figure 7*, starting with site "small" representing a service area solely with sanitary facilities and less space, accordingly with fewer charging points. The managed service area is allocated to site "medium" and provides additional facilities such as gastronomy or a conventional gas station. Charging park site "large" is typically a location that is not directly on the highway, but at an exit in the vicinity of the highway. Site "large" provides many car and dedicated truck parkings and provides more space for charging infrastructure.

Size	Site type	CCS	MCS
SMALL	Service area with WC	tbd	tbd
MEDIUM	Managed service area	tbd	tbd
LARGE	Truck stop	tbd	tbd

Figure 7: Initial allocation of charging park types to highway stop types

When designing the charging park layouts, it should be noted that, in contrast to MCS, the positioning of the CCS charging socket on the vehicle is not standardised and can therefore be either on the left or right side of the vehicle. This means that it must be ensured that CCS charging stations can be approached from the left as well as from the right, which can lead to complexity regarding the positioning of the dispenser units and less optimal use of available charging park spots. For MCS, the efforts are moving towards a standardisation of the socket positioning on the left-hand side of the vehicle, regardless of left- or right-hand drive. This reduces the complexity of the design and optimises the use of charging spaces and charging points. Further defined requirements for turning radii, space for charging spots and charging infrastructure as well as truck park arrangements for charging, e.g., drive-through vs. drive-in, will be tested and evaluated in real operation (see Figure 8).

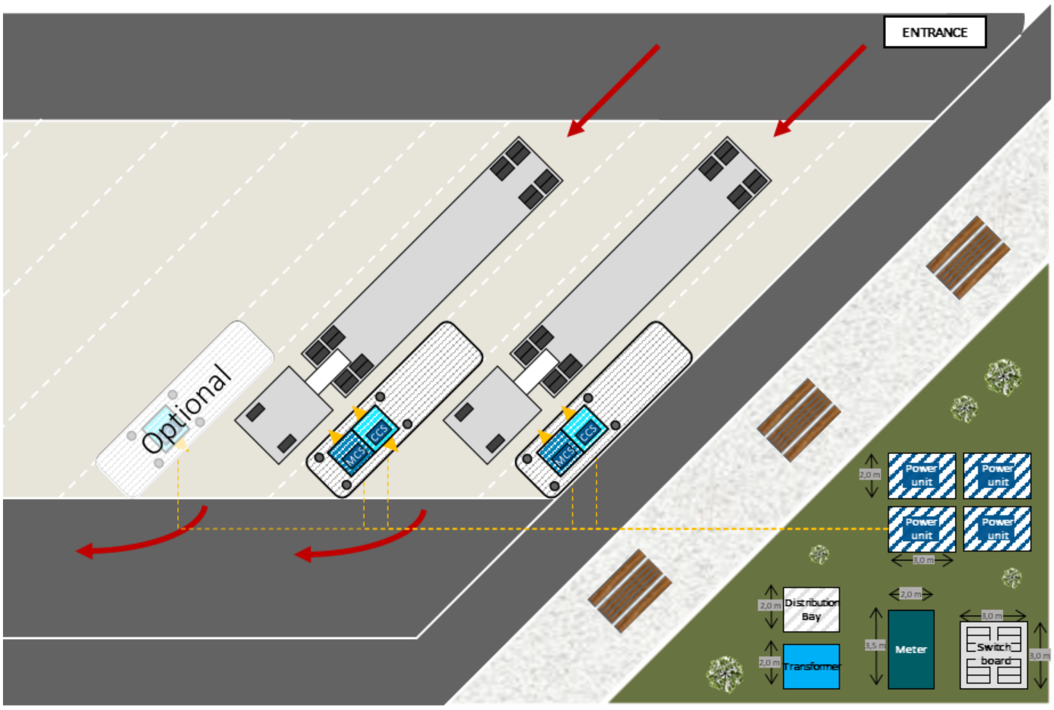

Figure 8: MCS Charging Park Sketch for exemplary HoLa site

These technical requirements defined for the pilot project will be used to further design prototypical standard layouts. Further elements like roofs, telematics equipment, signage and lighting or access and exit roads are matched with user needs and specifications from charging infrastructure manufacturers, charge point operators and site providers via interviews and joint workshops.

3 Intermediary results: Reservation system

Charging point reservation systems will play a much more important role in the commercial vehicle segment than in the passenger car segment. Due to the strict regulations on driving and idle times, the availability of charging points is significant for the efficient operation of long-haul goods transport. A sophisticated reservation system will certainly reduce the need of charging points and thus reduce the need of already limited space.

Within the framework of HoLa, initial requirements for the implementation of a pilot reservation system are defined and open questions and further detailing of requirements for a fully fledged solution ready for series operation are addressed. It should be noted that not only a digital solution via frontend and backend is necessary for reserving the charging point, but for certain use cases also a physical barrier to prevent other vehicles from blocking the charging spot is required. Due to the aforementioned lack of truck parking spaces, it will not be uncommon to find other vehicles parking at charging spots without charging.

Such issues and requirements are discussed and evaluated along the user journey, i.e. from the reservation process during route planning to the start and completion of the charging process. Questions around booking windows, blocking fees and reservation parameters (e.g. time, charging point, power) are only few topics that will be addressed and partly piloted in an initial prototype application.

Most requirements can been clustered into following topics:

- Pre-charging / reservation
- During charging
- Billing
- User experience & interface

Some initial requirements are further elaborated in the following sub-chapter.

3.1 Initial set of requirements

The reservation system for truck charging parks should include several key features to ensure that it is efficient and user-friendly. These features include the ability to reserve a charging station in advance, the ability to cancel a reservation if needed, and the ability to view the status of charging stations in real-time. The system should also allow for payment processing and provide notifications when a charging session is complete. Furthermore, truck drivers need to be able to customize their reservations according to their specific requirements. This may include selecting the charging station type, specifying the charging duration, and reserving multiple stations simultaneously.

The reservation system should be designed to accommodate several types of users, including truck drivers, fleet managers, and charging park administrators. For truck drivers, the system should be simple and easy to use, allowing them to quickly reserve a charging station and pay for their session. For fleet managers, the system should provide detailed reports on usage and charging history. For administrators, the system should provide an overview of all charging stations and allow them to manage the system's settings and user access.

Security is critical when it comes to reservation systems, especially when it involves financial transactions. The reservation system for truck charging parks should include measures to protect user data and prevent fraud. This can be achieved through encryption, two-factor authentication, and other security measures. The system should also have a backup system in place to ensure that data is not lost in case of a system failure.

The integration within various ecosystems and, with that, the standardization of the reservation system will be a key challenge in order to enable seamless communication with various systems. The mandate on a national or even international level may be required to prevent various solutions and segregated markets.

Further challenges and requirements will be defined in joint efforts with similar projects as HoLa. HoLa targets to demonstrate a mock-up solution with initial features to further specify the requirements for a productional solution.

4 Conclusion

The charging infrastructure rollout for battery-electric long-haul trucks is facing significant challenges such as charging times, grid connection demand or lack of space for charging. These have been some of the reasons that until recently other solutions such as hydrogen or catenary technologies were assessed as more suitable. However, with the development of the MCS technology many European truck OEM are in alignment regarding the implementation of battery-electric heavy-duty trucks. The compact design of MCS charging parks with minimized need for space, user-friendly access and usage as well as availability of charging points will be crucial for a future-proof solution which can be adopted by site providers and charge point operators.

A standard layout for truck charging parks can provide several benefits, including improved safety, accessibility, traffic flow, infrastructure utilization, user convenience, and sustainability. A well-designed layout can also promote the adoption of electric trucks and contribute to a more sustainable transportation industry. Ultimately, a standard layout can help create a more convenient, efficient, and sustainable charging experience for truck drivers and charging park operators alike.

In conclusion, the reservation system for truck charging parks should be designed to provide a seamless experience for truck drivers, fleet managers, and charging park administrators. It should include essential features such as reservation management, real-time status updates, and payment processing. The system should also prioritize security and have measures in place to protect user data and prevent fraud. Standardization is crucial for a reservation system for charging as it enables interoperability, consistency, efficiency, innovation, regulation, and data management. Standardization can benefit truck drivers, charging park operators, and the charging industry as a whole, by creating a common platform for development, collaboration, and regulation. By establishing common requirements for reservation systems and charging equipment, standardization can promote a safer, more efficient, and convenient charging experience for everyone. By meeting these requirements, the reservation system can help facilitate the transition to electric vehicles and support the growing demand for truck charging parks.

References

[1] *EUR-Lex*, https://eur-lex.europa.eu, accessed ib 2022-10-20

[2] *BGL,* https://www.bgl-ev.de, accessed on 2022-10-20

[3] *SSTPA,* https://sstpa.eu-study.eu, accessed on 2022-10-20

[4] P. Ploetz et al., *Truck Stop Locations in Europe Final Report*, Karlsruhe, 2021

Presenter Biography

Bonjad Satvat is Senior Consultant in the field of electric mobility at technology consultancy P3. He has been working at P3 since 2017 and is currently the Team Lead for Commercial Vehicle Charging. Since the project kick-off in September 2021 Bonjad is responsible for the overall coordination of German funding project HoLa ("High-performance charging for long-haul trucks") which consists of a cross-industrial consortium of 13 companies. His academic background is based on a Master of Science degree in Industrial Engineering at RWTH Aachen University.