Project deliverable D2.1

Stakeholder needs on the exploitation of MCS

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EXECUTIVE SUMMARY

MACBETH aims to support the deployment and scale up of Megawatt Charging Systems in logistics to electrify long haul freight, through the development and demonstration of multipoint MCS hubs combined with tools that facilitate scale up. The project will set up two demonstration sites, one in Sweden and one in Belgium, to test MCS integration under different operational conditions and to generate evidence for best practices and policy recommendations.

This deliverable reports the outcomes of Task 2.1, which collected stakeholder insights on current challenges, stakeholder specific needs for successful MCS adoption, and concrete use cases and deployment scenarios. The work recognises that the truck charging ecosystem is multi layered and interdependent, with each stakeholders facing distinct constraints and decision logics. The 65 interviews carried out from September to November 2025 were anonymised and analysed in aggregated form to provide a user-oriented vision for MCS deployment and to support subsequent definition of pilot requirements.

The interviews show that MCS is widely viewed as a critical enabler for electrifying the most demanding freight operations. However, its early deployment will be concentrated in a limited number of routes and actors that can justify the investment and operational change. Business case uncertainty is the dominant barrier. Stakeholders repeatedly link viability to total cost of ownership (TCO), electricity price exposure, grid fees, and the cost and timeline of grid connections and upstream works. This interacts with a second major barrier, which is the uncertainty on charger utilisation and on the ability of early hubs to achieve reliable throughput without excessive queuing or charger blocking. These concerns help explain why some fleets remain reluctant to invest in electric trucks due to insufficient public infrastructure and cost risks, while charging operators remain cautious due to expected low utilisation and limited profitability in the early years. In response to this uncertainty, it still an open question among the trucks manufacturers whether the future BETs models will be equipped with a single plug (either CCS or MCS) or both.

Operational integration emerges as a decisive success factor. Stakeholders emphasise that charging concepts must fit real operations and legal driving and rest rules, and that solutions must reduce friction for dispatchers and drivers. A fragmented system for payment, booking, and route planning is perceived as a potential obstacle as adoption grows, as it may complicate the charging-event planning handled for dispatchers and create uncertainty about the reliability of charging-bay availability at scheduled vehicle arrival times. Respondents therefore stress the need for interoperable booking and billing systems, better data availability, and tools that connect charging planning with routing and operational constraints.

On infrastructure and energy integration, many stakeholders prioritise controlled depot and private site charging where feasible, since it offers predictable access and can be combined with onsite renewables, battery systems, and energy management systems. These elements are seen as practical levers to reduce energy costs and improve the economics of electric trucking. Flexibility and grid service revenues are generally viewed as a longer-term opportunity rather than a near term driver, and stakeholders note that realising this opportunity requires clearer permitting and market pathways, and control requirements that do not compromise operational reliability.

When asked about innovations needed to scale up, stakeholders prioritise a combination of policy, business model, and technical developments. Policy levers that directly affect competitiveness, such as toll exemptions and weight allowances, were described as critical to compensate for payload impacts and to make electric operations viable on more routes. Business model innovation is needed to distribute investment risks across actors and to support shared, high utilisation infrastructure models. Technical and digital innovation is needed to standardise and simplify planning, booking, billing, and data integration, and to enable smart energy management that supports both operational needs and grid constraints.

Overall, the deliverable concludes that scaling MCS requires aligning infrastructure rollout with real operational patterns, reducing investment uncertainty through clearer policy and cost signals, and building interoperable, digitally enabled hub operations. These findings provide the foundation for the next project steps, including the definition of pilot requirements and the validation of deployment pathways in the Swedish and Belgian demonstration sites.

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Transport & Enviroment
Tank&Rast
TIP Group
Trafikverket
VIL
Volvo

LIST OF ABBREVIATIONS AND ACRONYMS

Acronym	Meaning
ALICE	Alliance for logistics innovation through collaboration in Europe
BESS	Battery Energy Storage Systems
B2B	Business-to-business
B2C	Business-to-Consumer
CCS	Combined Charging System
CPO	Charging Point Operator
DC	Distribution Centre
DSO	Distribution System Operator
EC	European Commission
eMSP	Electric Mobility Service Provider
EU	European Union
FTL	Full Truckload
GA	Grant Agreement
HDV	Heavy-Duty Vehicle
HD-ZEV	Heavy-Duty Zero Emission Vehicle
HD-BEV	Heavy-Duty Battery Electric Vehicle
HCV	High-Capacity Vehicles
JRC	Joint Research Center
KoM	Kick-off Meeting
KPI	Key Performance Indicator
LTL	Less-Than-Truckload
LSP	Logistics Service Provider
MCS	Megawatt Charging System

Acronym	Meaning
OEM	Original Equipment Manufacturer
O/D	Origin-Destination
RES	Renewable Energy Sources
ROI	Return on investment
TMS	Transport Management System
TSO	Transmission System Operator
V2G	Vehicle-to-Grid
V2X	Vehicle-to-Everything
WP	Work package
3PL	Third-Party Logistics
4PL	Fourth-Party Logistics

1. INTRODUCTION

1.1. Project summary

MACBETH aims to support the deployment and scale-up of Megawatt Charging Systems (MCS) in logistics to electrify long-haul freight, through developing and showcasing multipoint MCS hubs combined with tools facilitating the scale-up. MACBETH intends to address many of the technical, social, and economic challenges of mass deployment of MCS by setting up two demonstration sites, one in Sweden and one in Belgium to address various operational conditions, users' needs, and business cases.

By exploring these diverse environments, the project will generate valuable insights into the practical integration of Megawatt Charging Systems within real-world logistics operations. This approach will not only demonstrate the feasibility of large-scale electrification for long-haul freight but also inform future deployments by identifying best practices and potential obstacles. Ultimately, the knowledge gained from these pilot hubs is expected to lay the groundwork for broader adoption, fostering collaboration among stakeholders and shaping policy recommendations to accelerate the transition towards sustainable freight transport across Europe.

1.2. Attainment of the objectives and explanation of deviations

The objectives related to this delivery have been achieved in full and as scheduled.

1.3. Objective of the deliverable

This deliverable is part of **Task 2.1 "Identification of stakeholder needs and challenges towards deployment and use of MCS"**, whose aim was to collect insights from a list of targeted stakeholders groups involved, either directly or indirectly, to the truck charging ecosystem. The project aims to identify:

- Current technical, operational, infrastructure, economic, and regulatory challenges in relation to MCS deployment and use;
- Stakeholder-specific needs and expectations for successful MCS adoption;
- Concrete use-cases and deployment scenarios for MCS across different settings.

To delve deeper into the topics introduced and the list of stakeholders involved, it is important to highlight the multi-layered nature of the truck charging ecosystem. The project engaged a diverse set of actors, including fleet operators, truck manufacturers, infrastructure developers, energy companies, local authorities, and regulatory bodies. Each stakeholder group brings unique perspectives and faces distinct challenges, ranging from technological compatibility and investment barriers to operational integration and regulatory compliance. By considering input from these different sources, MACBETH ensures a holistic understanding of the factors influencing the deployment and uptake of Megawatt Charging Systems, ensuring that the solutions and pilot demonstrations that will be carried out during the project address the needs of all parties involved. A particular emphasis will be placed on the users of this infrastructure, as current circumstances indicate that the adoption of this technology is being slowed down by fleet owners' reluctance to invest in electric trucks due to insufficient public infrastructure and cost concerns. On the other hand, truck OEMs are unable to scale the production of MCS-compatible BETs or achieve effective cost reductions, while CPOs remain hesitant to construct hubs owing to anticipated low utilization and limited profitability in the coming years.

In summary, the primary objective of this research is to provide a comprehensive understanding of stakeholder needs and challenges, thereby enabling effective strategies for the large-scale adoption and integration of Megawatt Charging Systems in long-haul freight logistics.

1.3.1. Intended audience

This deliverable is intended for public dissemination, covering a wide range of stakeholders, including logistics operators, charging infrastructure providers, energy suppliers, researchers, and policymakers interested in the deployment and scale-up of MCS. By addressing stakeholder needs and challenges, the report aims to support informed decision-making and foster cross-sector collaboration.

1.4. Structure of the deliverable and links with other work packages/deliverables

1.4.1. Structure of the deliverable

This rest of this deliverable is organised into 6 chapters , each contributing to a comprehensive exploration of stakeholder needs and challenges for the deployment and use of MCS technology.

Chapter 2: Literature Review - Summarize findings coming from relevant EU projects such as ZEFES, FLEXMCS, ESCALATE, and NextEtruck, or from similar initiatives, with special focus on existing background on stakeholder needs for truck charging hubs that was used for this research.

Chapter 3: Methodology - Outlines the methodology employed in the research to map the relevant actors to be engaged and the processed used to identify the stakeholder needs and challenges.

Chapter 4: Stakeholder needs and requirements - Synthesize the results of identification of stakeholders and subsequent clustering activities. Then it illustrates the identified stakeholder requirements grouped into the cluster described.

Chapter 5: Results - Presents the key findings from the stakeholder analysis, highlighting the main needs, challenges, and opportunities identified for the deployment and integration of Megawatt Charging Systems in long-haul freight logistics.

Chapter 6: Stakeholder Validation Workshop – This chapter covers how key stakeholders were engaged in an online workshop, held at the conclusion of the investigation, to review, confirm, and refine the identified needs and requirements.

Chapter 7: Conclusions – Summarizes the main findings and recommendations from the previous chapters, highlighting key insights and actionable outcomes to support the successful implementation of the two pilot demonstrations in Belgium and Sweden.

The Annex I, II and III presents respectively the interview protocol used during the research, an example of interview template and lastly the list of preliminary requirements identified.

1.4.2. Links with other deliverables and work packages

Deliverable 2.1 gathers the main high-level requirements, the existing challenges and needs from stakeholders involved in the truck charging ecosystem. These requirements and challenges towards deploying and scaling up MCS laid the groundwork for Deliverable 2.2, which focuses on defining detailed, system-level requirements for the pilot demonstration sites. The results from Task 2.1 ensure that Deliverable

2.2 is built on a solid understanding of user and stakeholder needs, challenges and possible use cases supporting the transition from broad project goals to actionable technical specifications for the two pilot demonstrations. Both the high-level requirements from Task 2.1 and the more detailed findings from Deliverable 2.2 are essential inputs for WP3 to WP6. These work packages will consider the requirements to shape practical use-cases and guide the technical development and implementation strategies throughout the project.

In addition, WP7 – Evaluation, recommendations, business development and scaling up relies on the outputs of Tasks 2.1 and 2.2 to regularly review and refine deployment pathways for MCS technology. By incorporating feedback and requirements from earlier tasks, WP7 can adjust its evaluation strategies as needed, beginning with the framework in Task 2.3, making sure that the project outcomes are aligned with stakeholder expectations and provide real value through the creation of the MACBETH Handbook for MCS deployment.

2. LITERATURE REVIEW

Unlike previous projects that focused on the development and test of specific powertrains and the operational deployment of zero-emission trucks in different conditions and routes, MACBETH (together with its sister project FLEXMCS) stands out as a unique initiative because it directly addresses the deployment of a specific charging technology: the Megawatt Charging System (MCS). This chapter explores the existing study about MCS applications on HD-BEV. As both vehicles and charging infrastructure remain under development, the available literature is still largely limited to testing phases without commercial roll-out. Therefore, the work also systematically reviewed the user requirements gathered through ongoing AEVETO Cluster projects. These deliverables provide valuable background knowledge and reflect the latest developments in the field. Furthermore, because these studies are conducted within the European context, their findings are highly relevant and transferable to MACBETH. By leveraging these insights, MACBETH ensures that its approach is informed by the most up-to-date understanding of stakeholder needs and the real-world barriers and enablers to electrification, which constitute the groundwork for future MCS adoption in all relevant domains and settings.

MCS is a game-changer for the electrification of long-haul routes, moving beyond the limitations of earlier charging technologies such as Combined Charging System (CCS) standard. As will be further explained in Chapter **Error! Reference source not found.Error! Reference source not found.**, the practical application of MCS is currently confined to a specific set of use cases, still limited to a small segment of logistics operations. Consequently, unlike CCS which served as an initial phase of charging infrastructure deployment for majority of heavy-duty electrification logistics mission, MCS applicability remains low, making it challenging to present a compelling business case for the necessary investment and operational adjustment.

MACBETH and FLEXMCS are uniquely positioned to explore and define what is necessary for successful electrification of longer logistics routes, where the adoption of MCS technology is both critical and challenging. The adoption of MCS depends on a complex interplay of factors, including technological readiness, infrastructure compatibility, regulatory frameworks, and user acceptance. It is still an open question whether trucks will only have one plug (CCS or MCS) or both in the long term. Given that MCS will initially be relevant to a relatively limited group of logistics actors, it is crucial to understand the perspectives and needs of this pioneering group. This involves examining their approach to electrification, identifying what they consider successful in adopting electric vehicles for specific routes, and understanding the current limitations they face, whether technological, infrastructural, or regulatory. Addressing these issues is key to bridging the gap and paving the way for wider adoption and full electrification of logistics fleets.

2.1. Relevant EU projects and collection methods

Along with MACBETH, several other EU projects are pursuing the deployment of HD-BEVs and are demonstrating their use on long routes, with some of these involving the use of MCS as well. Below is the list of projects reviewed and whose findings in terms of user requirements were used as a baseline for the creation of the interview templates:

1. In the ZEFES (Zero Emissions flexible vehicle platforms with modular powertrains serving the long-haul Freight Eco System) project *preliminary needs and requirements*[1] derived from user experience, expectations, and concerns across the heavy-duty zero-emission ecosystem were mapped. Their

[1] Deliverable D1.3 ZEFES Ecosystem Specification, 30/09/2023

investigation was structured by stakeholder group as well (shippers, transport operators, logistics site operators, infrastructure operators, truck and trailer OEMs, authorities) and combines an online survey with targeted interviews with actors already operating or piloting ZE-HDVs. Below are the main findings relevant for MACBETH:

- Infrastructure is the biggest uncertainty. A central result is that infrastructure generates the highest number of needs and requirements, and also the highest uncertainty for operators. The 25 identified needs and requirements under the “infrastructure” category (charging/refuelling availability and usability), span from availability, usability, predictability, and operational fit of high-power charging sites and weight more than other categories such as operational integration or social acceptance.
- Mission certainty is a core end-user requirement. ZEFES reports that truck end-users want clarity on what missions are realistically possible with ZE-HDVs, and that this need is tightly linked to infrastructure readiness and operational planning. In the survey responses, cross-border operations are highlighted as a key area where uncertainty is high.
- Operational integration goes beyond the vehicle and requires workforce and systems change. ZEFES stresses that ZE-HDV deployment is not only a vehicle issue. It requires reskilling (drivers and also warehouse/depot staff who may operate charging), upgrades of facilities, and updates to fleet management and other software used for charging/refuelling and planning.
- ZE-HDV will only be deployed if the business model of the whole value chain is viable. Due to **INTERDEPENDENCIES** between the infrastructure operators, logistic operators and truck OEMs, the whole automotive and logistic industry needs to move as a whole to make electrification reality.

2. ESCALATE (Powering European Union Net Zero Future by Escalating Zero Emission HDVs and Logistic Intelligence) project focuses on demonstrating high-efficiency zero-emission heavy-duty vehicle powertrain which promotes a concept of standardized, cost effective, modular, and scalable multi-powertrain components. In ESCALATE the pilot requirements for the five zero-emission HDV pilots presented in their report[2] include dedicated sections on infrastructure requirements and end-user requirements, which are directly relevant to this research. Main findings are summarized below:
   - Access to chargers for e-cooled trailers (e-reefers) is marked as a MUST requirement (operationally relevant for temperature-controlled logistics).
   - Roaming and easy payment methods are explicitly mentioned as relevant for cross-border freight.
   - Financial support for depot adaptation and charging installation is highlighted (listed as a SHOULD, with a concrete link to CEF funding as an example).

   ESCALATE separates end-user needs into fleet operator requirements and truck driver requirements and list as “must have” the following items:

   - Safety training and driver training.
   - Charging/refueling option availability.
   - Repair/maintenance cost and downtime minimized, plus warranty period, spare parts availability, and availability of energy storage system maintenance.
   - Road permits and strong attention to CO2 performance/value metrics.

3. FLEXMCS (Flexible Megawatt Charging Systems, open software architectures, and planning modules designed to create multi-charger hubs for the European electric mobility system) is the sister project of MACBETH. Since ALICE participates in both projects, requirements gathering began with FLEXMCS

[2] ESCALATE, Deliverable D2.2 Pilots Elicitation and Requirements, 29/02/2024. Available at: https://www.escalate-eu.com/wp-content/uploads/2025/04/D2.2-Pilot-Requirements.pdf

and was subsequently expanded within MACBETH, both in terms of stakeholder groups and topics covered. FLEXMCS combined workshops and a multi-stakeholder survey to derive needs and requirements to be included in their report[3]. The survey was sent to 105 actors within 10 stakeholder groups and 53 complete responses were received. In this report needs are grouped into six categories: (i) grid capacity and renewable integration, (ii) site planning and design, (iii) operational feasibility and user needs, (iv) policy/regulatory drivers, (v) technology development, (vi) stakeholder coordination. Main findings are grouped per stakeholder group below (only the main two groups are provided):

- LSP findings:
  - Main barriers to installing charging are reportedly space constraints (80%), high installation costs (70%), limited grid capacity (60%), permitting delays (40%).
  - Many operators have adopted "mixed" charging strategy : 40% of operators can cover 100% of daily energy with depot charging, while others report a 50/50 depot vs en-route split.
  - Location logic is led by reducing operational risk: minimise en-route charging needs (60% of respondents think it's a must-have) first, then cost and the ability to return to depot with an SOC buffer.
  - A structural throughput issue emerges from rest rules: 80% say drivers will not move the truck after charging finishes if the rest period is still ongoing. This directly increases charger blocking and queues.
  - Digital maturity is uneven: 50% schedule charging manually (Excel-like), 30% use in-house tools, 20% use third-party platforms. Acceptable "daily charging time" is often 1–2 hours/day, with strong use-case variance.
- CPO-side findings
  - Existing hub power spans 100 kW to 3 MW; the average number of satellites per hub span 2 to 12 (often 8). Some sites already exceed 1 MW.
  - Future plans concentrate around 1–2 MW per site, with some ambitions up to ~4 MW total hub capacity, but expansion is often conditional on EU/national funding.
  - Siting logic is dominated by utilisation: 100% of CPOs marked "located to maximise utilisation/profit" as a must-have.

4. A Joint Research Center (JRC) publication[4] on stakeholder analysis of technology readiness was also considered to provide for high-level, stakeholder-driven evidence. Stakeholder engagement was carried out through an online survey carried out from Dec 2024 to Jan 2025and an expert workshop onFeb 2025. Respondents include OEMs, suppliers, research, infrastructure/energy providers, operators, and associations and results are the following:
   - TCO parity (or advantage) versus diesel trucks emerges as the dominant drivers. Costs are consistently ranked as the top enabler across use cases.
   - Long-haul readiness remains lower than urban/regional: BEVs (and especially charging infrastructure for long-haul) are perceived as less mature than urban segments. For long-haul, stakeholders explicitly point to the need for megawatt charging (MCS) and a dense high-power network to unlock operations.

[3] FLEXMCS, Deliverable D1.2 Business needs and mapping, 31/08/2025.
[4] Cheimariotis, I., Decarbonising European heavy-duty transport - A stakeholder analysis of technology readiness and future R&I priorities for zero-emission vehicles and infrastructure, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/4965114, JRC143054.

- Non-technical barriers repeatedly mention are (similarly to FLEXMCS): permitting delays, grid connection capacity and timelines, fragmented implementation, chicken-and-egg investment dynamics, residual value uncertainty, and the need for incentives and demand-side measures.

3. METHODOLOGY

This chapter elaborates in detail on the methodology adopted in this research to collect the user needs, challenges and potential use cases in relation to MCS deployment and scale-up. The team followed a two-step process where the different stakeholder groups along the vehicle charging value chain were initially identified. Relevant stakeholders from the project's ecosystem were then clustered, to achieve comprehensive representation. In the subsequent stage, these stakeholders were invited for interviews to provide their perspectives. The initial set of interviews focused on MACBETH project partners with the goal of verifying or challenging existing knowledge from prior and ongoing projects analysed **Error! Reference source not found.**, and the attention was focused only on the main stakeholder groups. Interview templates underwent review and approval through regular meetings with consortium partners, ensuring all viewpoints and significant considerations for future work packages were included. The results were than later validated by the advisory board and all respondents who agreed to participate in the online validation workshop described in Chapter **Error! Reference source not found.**.

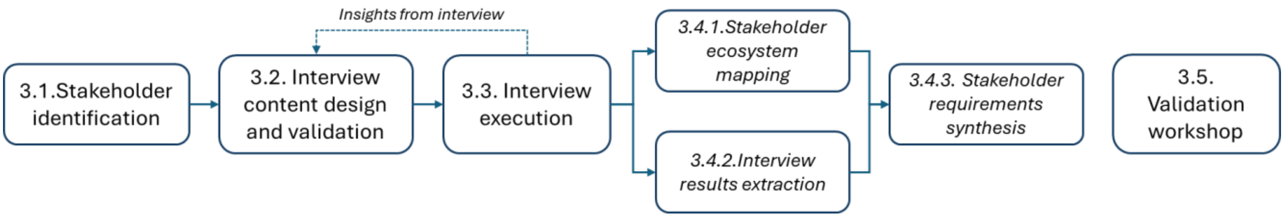

Figure 1 below illustrates the methodology used through a diagram.

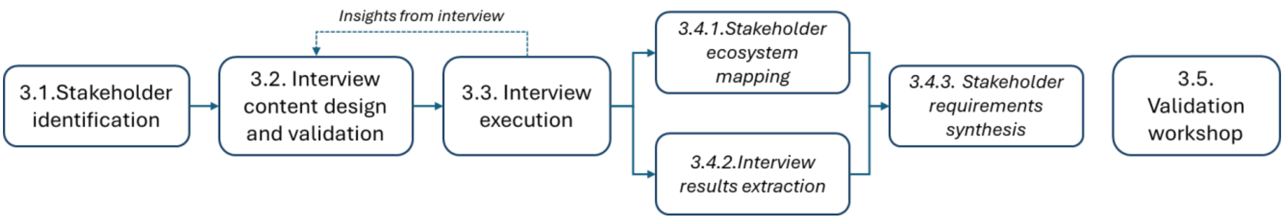

Figure 1: Diagram illustrating the methodology used

3.1. Stakeholder identification

The initial phase of the stakeholder identification process involved mapping the entire value chain associated with MCS deployment, from vehicle manufacturers and fleet operators to grid operators and public authorities. Attention was given to ensure that both established and emerging players were represented, capturing a balanced view of the sector's current dynamics. The team also considered regional diversity to reflect the varying regulatory and operational environments across different European markets.

3.1.1. Defining the relevant stakeholder groups

Key stakeholder groups were identified and categorized in detail depending on each group's interests and day-to-day roles. Relevant stakeholders from the project's ecosystem, including project partners, Advisory Board members, U.S. collaborators, and industry representatives, were mapped to ensure comprehensive representation. This resulted in 21 stakeholder groups which play different and multiple roles in shaping the truck charging ecosystem:

- Distribution System Operator (DSO)
- Grid hardware providers
- Energy producers and suppliers
- Charging hardware providers

- Truck OEMs
- CPOs
- Carriers
- Retailers
- Freight forwarders
- Shippers
- Owner of logistics sites
- Safe and Secure Parking owners
- Gas Stations operators
- eMSPs and eRoaming operators
- Complementary charging technology providers
- EU/National Industry Associations
- Road Authorities
- Public bodies/policymakers
- Funding and financial institutions
- Certification and standards advisors
- Consultancies

not all of these stakeholders could provide relevant information on the challenges and needs towards MCS deployment but their insights were used to question and confirm existing knowledge and represent a diverse range of perspectives within the ecosystem. This approach enabled the research team to validate assumptions, uncover new considerations, and ensure that the requirements gathering process reflected both direct and indirect experiences with MCS technology. By engaging a broad spectrum of participants, the team was able to strengthen the robustness of their findings and support a more comprehensive understanding and holistic point of view of the sector as a whole.

3.1.2. Reaching potential interviewees

For each stakeholder group, the ALICE team explored potential companies or organizations through a combination of desk research, internal connections within ALICE members, recommendations from consortium partners, and direct outreach to relevant stakeholders in the sector. Initial contact was established via email or telephone, outlining the scope of the project and inviting participation. For specific cases, prospect contacts were found on professional media platforms such as LinkedIn where short project introduction and formal email exchange were established through short messages. Of the 117 organizations identified as ideal respondents, 109 contacts were retrieved and reached out to. This resulted in 65 interviewees who agreed to participate in the MACBETH stakeholder requirement gathering.

In the subsequent phase, the identified stakeholders participated in interviews designed to define current challenges related to the deployment and scaling of MCSs, determine the specific needs of each group, and identify possible logistics-related use cases for MCS technology, as it will be described in more detail in Chapter **Error! Reference source not found.**.

3.1.3. Interviewee profiles

By the end of November 2025, 65 interviews had been carried distributed across all relevant stakeholder groups listed above. Table 1 below shows the number of respondents per stakeholder category. Note that some stakeholders were more difficult to engage than others as their involvement (hence their interest) in MCS technology and its deployment is lower, which explains why we failed to interview them. For example, representatives of TSOs and freight forwarders did not reply to the interview requests, so their viewpoint is not represented in this research. It’s also important to mention, as will be further explained in Chapter **Error! Reference source not found.**, that organizations revealed during the interview process to operate across multiple roles (e.g., as both CPO and safe parking operator or as OEM and eMSP) and markets. In most cases only their main role was investigated during the interviews so as not to overwhelm respondents. Some questions relevant to their secondary role were included in the interview template to cover all the aspects.

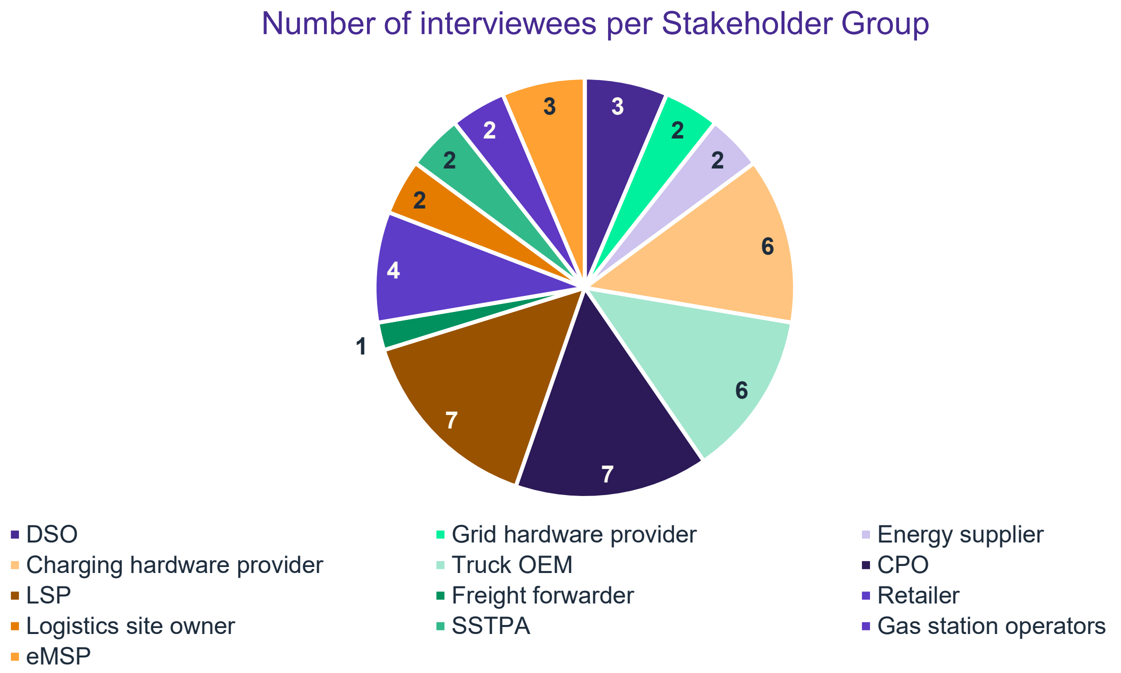

Figure 2: Visualization of interviewees per stakeholder group

Stakeholder Group	Number of interviewees
Distribution System Operator (DSO)	3
Grid hardware provider	2
Energy producer and supplier	2
Charging hardware provider	6
Truck manufacturer and OEM	6
Charging Point Operator (CPO)	7
Logistics Service Provider (LSP)	7
Freight forwarder	1
Retailer	4
Logistic site owner or operator	2
Safe parking owner or operator	2
Gas Station operator	2

Stakeholder Group	Number of interviewees
EMSPs and eRoaming operators	3
Complementary charging technology providers	2
EU/National Industry Associations	5
Road Authorities	2
Public bodies/policymakers	2
Funding and financial institutions	3
Certification and standards advisor	2
Consultancy	2

Table 1: Stakeholder groups and number of interviewees

3.2. Interview content design and validation

As described **Error! Reference source not found.** the interview content was developed and validated through an iterative process, involving meetings with consortium partners to ensure alignment with subsequent tasks and work packages, as well as targeted discussions with industry representatives. As new topics and areas of interest emerged, the interview questions were updated continuously, and feedback was incorporated from both MACBETH partners and interviewees who introduced additional services or business models relevant to electrification. This adaptive approach allowed the research to capture a broader spectrum of insights and enriched the overall findings.

The interview templates were customized for each stakeholder group, but the structure was common. The templates, of which an example can be found in Annex II – LSP Interview template**Error! Reference source not found.**, were divided into five sections: Introductory question (general overview of the organization), challenges with MCS deployment, stakeholder needs in relation to MCS, use-cases and opportunities, and future outlook on MCS development. Due to the diverging business model of each stakeholder, it was decided to add confirmatory questions to define the organization involvement in truck charging ecosystem on the introductory section, such as ownership of fleets, land, facility, and responsibility on grid connection establishment.

3.3. Interview execution

The objectives of the interviews were to gain an in-depth understanding of the current landscape of Megawatt Charging Systems (MCS) deployment, identify key challenges faced by stakeholders, and assess the effectiveness of existing methods and tools. Furthermore, interviews sought to uncover gaps in knowledge, stakeholder needs, and opportunities for innovation that could inform future project directions and policy recommendations.

Interviews were carried out from September to November 2025. The interview was carried out online through Microsoft Teams platform, where each session lasted for around 45 minutes (maximum 1 hour). The interviewees were provided with several time slot options which could be chosen according to their own convenience.

The semi-structured interview followed a set of procedures which have been defined and verified by project partners. It was important to ensure that each session adhered to a consistent protocol, including clear communication of objectives and estimated duration. Therefore, the question template was shared with the interviewee prior to the session. In addition, the note writing was assisted by AI copilot tools transcription to maintain accuracy. The interviewees were asked for their consent before transcription started. Information confidentiality was strictly observed, and all responses were anonymized to protect participants' identities. The interview protocol, which outlines these procedures in detail, is included in Annex I – Interview protocol for reference.

Some interviewees mentioned additional services that support electrification or are ancillary to it, such as inventive technologies, innovative business models, or supporting organizations. As a result, these new discoveries were added into the stakeholder group scope and further expand the research into new actors.

3.4. Analysis of results

3.4.1. Stakeholder ecosystem mapping

Given the variety of stakeholders identified and the dynamic nature of their roles within the charging ecosystem, the interview revealed the complexity of relationship between all involving actors. On the first section of the interview, the questions explored the business model and the organization role in the truck charging ecosystem. Depending on their business model and strategy, their operational responsibilities and influence in relation to the needs of MCS infrastructure vary.

A categorization of 'roles and involvement' in truck charging was developed to enable a clearer visualization of the ecosystem and illustrate the influence between various groups. This resulted in six clusters as follows:

1) Demand-side users (LSPs)
2) Site hosts and facility operators
3) Charging point operators
4) Energy and grid actors
5) Technology and solution providers
6) Governance, finance, standards and knowledge

It is evident that certain stakeholders play multiple roles through vertical integration strategies. Therefore, each stakeholder can be categorized into more than one group, forming a matrix of the truck charging ecosystem, which can be found in Chapter **Error! Reference source not found.**

3.4.2. Interview results extraction

The process began by cleaning and revising the transcription generated by AI-assisting tools which served as reference for notes-taking. As previously mentioned, the semi-structured interview was divided into five sections starting with introduction to define the organization role in truck charging ecosystem. Additional sources include secondary data from organizations' websites or publication referred to by the interviewee and interviewer's note. The clean transcription was recorded in a dedicated document for each interviewee.

The analysis continued at stakeholder level, where each question and related answer was associated with a specific stakeholder requirement aspect. Challenges on charging infrastructure deployment for site owners or standardization of the MCS protocol between CPO and Truck OEM are few examples of stakeholder-specific needs. Meanwhile, some questions, especially related to the general outlook, were common to all stakeholder groups and aimed at getting a common analysis based on different viewpoints. For instance, the future trends in relation to CCS plugs and their role as the MCS standard evolve were asked to all interviewees, same as the complimentary technologies or strategies towards decarbonization.

3.4.3. Stakeholders' requirements and results synthesis

The stakeholder requirements were then aggregated into the new stakeholder clusters, which are listed and defined in chapter **Error! Reference source not found.**. As each stakeholder might belong to more than one group due to their diversified portfolio of services and products, the analysis also considered needs from a "dual role" or a complementary service. For example, the logistics carriers, whose main role is fleet owner or operator, are also investing in charging infrastructure through another business unit or subsidiary. The requirements identify describe what those specific stakeholder need for electric trucks to become part of their real long-haul operations and for MCS to be used, installed and scaled up effectively. Some requirements are defined based on the value proposition to be achieved by MCS and on the specific condition needed for value achievement. For each cluster, a unique ID is assigned; xx refers to the ID number:

i. Demand-side users: URxx
ii. Site hosts & facility operators: LSRxx
iii. Charging point operators: CRxx
iv. Energy and grid actors: ERxx
v. Tech & solution providers: TSRxx
vi. Governance, finance, standards and knowledge: GVRxx

The user requirements consist of requirements for value propositions to be achieved by electric trucks and MCS in long haul operations and criteria or conditions for fulfilling those value propositions. For example, *LSR2 - Operational planning, reliability and service quality.* Value: *charging concepts at logistics facilities must fit real operations.* Then, the requirement for value fulfilment were breakdown into multi-dimension aspects grouped by a specific topic: *…charging infrastructure <u>must deliver stable, predictable power</u> over planned sessions…"; "…should be aligned with loading/unloading and driving/rest rules…".* The user requirements are summarized in chapter **Error! Reference source not found.**.

Alongside assessing stakeholder needs, the analysis identified recurrent challenges, expectations, prospective use cases, and potential deployment pathways for MCS. These findings were synthesized to establish a comprehensive stakeholder vision that integrates multiple perspectives, which can be found in Chapter 55: RESULTS.

3.5. Validation workshop

The user requirements and results presented in Chapter 5 were validated through a dedicated interactive workshop involving organization who participated in the study. During the interview session, each interviewee was asked their willingness to participate in the workshop in advance to make sure the following communications on results and possible next steps only reached interested parties. In addition, both FLEXMCS and MACBETH consortia were invited from the ALICE network to contribute to the discussion and align the two projects as it was done in the first online workshop on the FLEXMCS survey results organized in July 2025. The workshop was held on 28th January 2026 from 10:00 to 11:30 CET and was conducted online to ensure the participation of the largest number of respondents. The event aimed to verify the user requirements and challenges which had been defined from the interviews, explore aspects that were overlooked, and discuss the potential solutions and best practices reported by interviewees on how to solve those barriers. The event targeted the participation of at least 50 interviewees from diverse stakeholder groups and in the end 72 people were present online.

The session combined short presentations with interactive poll and discussion. After a brief recap of MACBETH goals, overall workplan and the role of MCS in decarbonising heavy-duty road transport done by the coordinator (Figure 3), the methodological background for the interviews and the workshop was explained. The team described how stakeholder groups had been selected, how the interview templates were co-designed with partners, and how the interviews were coded and aggregated by cluster. This was important to give transparency on the evidence base behind the slides that were shown.

The core of the workshop, its interactive part, was structured into four thematic blocks: (i) where electrification is really happening; (ii) what is blocking long-haul BET expansion and MCS adoption; (iii) opportunities to improve the MCS business case; and (iv) expectations about the future role of MCS versus CCS. Each block began with one or two synthesis slides that summarised the main findings from the interviews. These were followed by a Slido poll and open questions from three to five minutes to collect immediate reactions, concrete examples and counterexamples from the audience. The use of live polls allowed the team to test whether quantitative patterns from the interview sample coherent to the broader group.

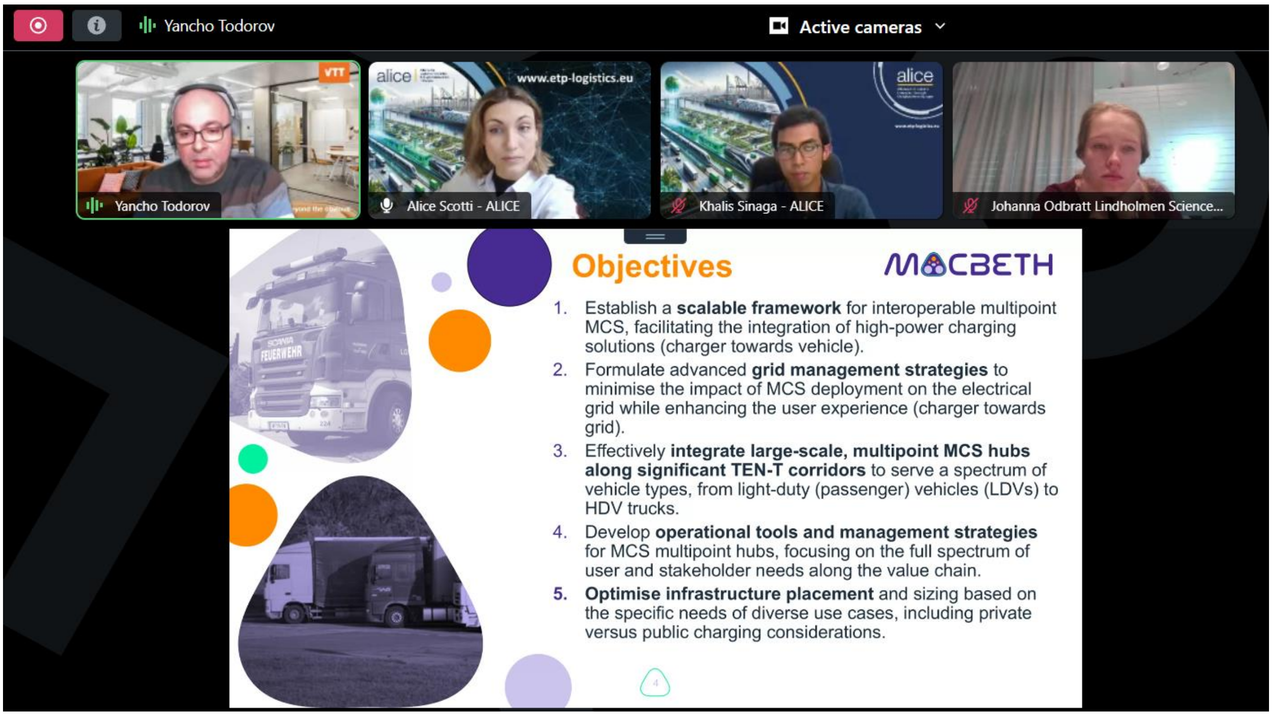

Figure 3: Screenshot of workshop introduction

The result of the validation workshop is presented in Chapter **Error! Reference source not found.**. are used in two ways in this deliverable. First, they are referenced in the analytical chapters as an additional layer of evidence that either confirms or nuances the interview-based requirements. Second, they highlight solution-oriented practices and optimistic examples (for instance from Nordic sites and early reservation schemes) that can inform the design of MACBETH demonstrations and the formulation of policy recommendations in later work packages. The results will also be disclosed on future in-person events to ensure continuation and holistic analysis of the needs to support MCS deployment.

4. STAKEHOLDER NEEDS AND REQUIREMENTS

The mapping of complex system involving multiple users and stakeholders, just like the one we are discussing, requires a comprehensive multi-level requirements definition. High-level requirements provide guidance for the creation of the system's primary functions, while low-level requirements inform the detailed design and specifications essential for implementing these functions and achieving system objectives.

User and stakeholder requirements are determined by those individuals responsible for establishing system goals or assessing the value and feasibility of achieving them. Users are the intended recipients of the system, whereas stakeholders are those who influence or are impacted by the system. Integrating user and stakeholder requirements into the development process ensures technical solutions and procedures are aligned with stakeholder interests, thereby preventing the creation of unnecessary solutions. Additionally, consideration of these requirements increases the likelihood that users and stakeholders will engage with or promote the use of solutions and processes that support the attainment of system objectives. User and stakeholder requirements are normally identified prior to solution requirements. Solution requirements describe what solutions or processes must do in order to satisfy user and stakeholder requirements, as well as conditions for how they must do it. Large projects often change over time and are shaped by more than just technical issues; social and political factors can have a big impact as well. This is especially important for electric vehicle adoption, where both commercial and passenger vehicles, as well as their charging infrastructure, depend on people's willingness to use new technology and on supportive rules and regulations. In this project, task 2.1 started by collecting the main high-level requirements, which help make sure the solutions designed match what users actually need, while low level (or system-level) requirements for the specific pilot demonstration sites were identified and consolidated in the subsequent task 2.2 System-level use cases and requirements for the pilot demonstration sites. Work packages WP3 to WP6 will use these inputs to develop practical use-cases and implementation strategies, while deployment pathways will be reviewed and improved in WP7.

4.1. Truck charging ecosystem mapping

4.2. As outlined in Chapter **Error! Reference source not found.** Stakeholder identification

The initial phase of the stakeholder identification process involved mapping the entire value chain associated with MCS deployment, from vehicle manufacturers and fleet operators to grid operators and public authorities. Attention was given to ensure that both established and emerging players were represented, capturing a balanced view of the sector's current dynamics. The team also considered regional diversity to reflect the varying regulatory and operational environments across different European markets.

, the initial phase of this research involved identifying the stakeholder groups relevant to the truck charging ecosystem, with a particular focus on long-haul applications. This process included analysing their roles and interests, followed by grouping them into categories based on the collected information. Results of this process are summarized below, as shown in Chapter **Error! Reference source not found. Error! Reference source not found.**.

The interviews revealed that some stakeholders play multiple roles in the deployment of truck charging infrastructure, especially larger enterprise or holding groups with diversified business line. In order to define the requirements and needs of the whole ecosystem, the interview result was aggregated based on similarities of the core activities and aspects of those organizations. For example, an increasing number of OEMs are developing their own EV routing tools and reservation systems, overlapping their services and products with those of eMSPs. The same applies to carriers and logistics companies, which might be the owners of logistics sites like warehouses or distribution centres and install charging stations at their premises. In case these charging facilities are opened to third parties, the LSP can decide to either operate the charging station themselves, becoming a CPO, or partner up with charging point operators to manage them.

As a result, stakeholders such as LSPs, carriers, and logistics site owners often play between user and operator roles, influencing both the demand for and provision of charging infrastructure. After identifying these multifaceted relationships, the team decided to cluster stakeholder groups into 6 categories, as explained below in chapter **Error! Reference source not found.**.

4.3. Stakeholder clusters identified

The first cluster taken into consideration is the one of demand-side users of MCS, as those whose primary objective is moving goods and thus require reliable charging solutions for their fleets. This category encompasses LSPs, meaning carriers, freight forwarders, shippers, retailers, and manufacturing companies with their own logistics department.

4.3.1. Cluster 1 - Demand-side users of MCS

Actors whose primary need is to move goods, hence, to charge electric trucks. The rationale behind this division is multiple: their business model, e.g. B2B (Business-to-Business) or B2C (Business-to-Consumer) and the ownership of physical assets i.e. their fleets or facilities like the depot or warehouses. Stakeholders within this clusters ranged from freight forwarders (which do not own physical assets but act as an intermediary within the logistics chain) to shippers and retailers (who can own vehicles or completely subcontract transport to external carriers while also managing logistics sites). Of course, the business models vary greatly and most of the times one organization is a subsidiary of a larger group controlling the whole supply chain; hence questions in the interview template were adapted to grasp these differences.

Stakeholders included:

i. LSPs / carriers
ii. Freight forwarders
iii. Shippers
iv. Retailers

This understanding of stakeholder roles guided the subsequent breakdown of charging site hosts and facility operators, ensuring the requirements captured reflect the full spectrum of practical use cases in the ecosystem and the variety of locations in which charging infrastructure can be deployed.

4.3.2. Cluster 2 - Site hosts and logistics facility operators

Actors who control the land and/or the facilities where truck stops during their missions. These can be either in en-route or at the destination and can represent their principal business line (e.g.terminal operators within ports) or part of the full set of services offered by different departments/subsidiaries. Note that modern logistics service providers are fundamentally integrated logistics and distribution companies, so the division between the first and second cluster is often thin.

Stakeholders included:

i. Owners or lessors of logistics sites
ii. Safe and Secure Truck Parking owners
iii. Gas stations / truck stops / service areas operators

Possible "dual-role" members:

i. LSPs / carriers that own depots and truck yards
ii. Retailers, freight forwarders and shippers that own Distribution Centres (DCs), terminals or warehouses

These stakeholders encompassed the majority of actors who can consider the provision of energy as an ancillary service to offer to their customers and therefore that can test MCS if the grid capacity on site permits it. These logistics site operators play a pivotal role in shaping the charging landscape, as their decisions regarding site access and business models directly influence the penetration of electric transport for logistics companies that do not have the resources, space or power availability to install chargers at their sites. As it will be explored more in detail in Chapter **Error! Reference source not found.**, co-funded infrastructure and third-party access to the so-called "semi-public" locations is a topic of increasing interest in the industry as it represents a solution to maximize utilization of the infrastructure and a reduction in charging costs.

4.3.3. Cluster 3 - Charging point operators

Actors that install and provide charging as a service. It is important to mention that the responsibility for operating charging infrastructure can rest with a variety of actors, be it the site owner, a logistics provider, or an independent CPO. The underlying infrastructure and business model may shift depending on the operator, but from the perspective of logistics companies seeking to electrify their fleets, the essential service - accessible, reliable charging - remains unchanged.

Stakeholders included:

i. CPOs

Actors that can also provide charging (overlapping with cluster 2):

i. Gas stations operators (running their own chargers at service areas)
ii. Energy suppliers (installing and/or operating public hubs or depot charging for clients)
iii. LSPs / logistics site owners (allowing private depot charging to third parties)

4.3.4. Cluster 4 - Energy system and grid actors

Actors responsible for ensuring electricity supply or providing the energy grid infrastructure (power lines with associated substations stations and connection points) to grid operators. These stakeholders also interact with a wider ecosystem that includes regulatory bodies and local/national authorities, whose policies and incentives can impact the deployment of the grid infrastructure needed to support the development of high-capacity charging parks.

Core members:

i. Grid operators (TSOs and DSOs)
ii. Grid hardware providers (transformers, substations, power lines manufacturers)
iii. Energy producers and suppliers (generation + supply)

Sometimes overlapping with cluster 3: Energy suppliers that also operate charging as a service

4.3.5. Cluster 5 - Technology and solution providers

Actors that design, supply, and support of technologies related to charging (vehicle, charging hardware and digital tools) but do not operate directly the charging points. This includes both physical and digital solution providers that enhance the efficiency of the charging ecosystem.

Core members:

i. Truck OEMs
ii. Charging hardware providers
iii. EMSPs and eRoaming operators
iv. Complementary charging technology providers
v. e.g. robotic plug-in, automation, payment terminals, access control, BESS control, fire detection, metering

Secondary: Consultancies (when they provide design and planning tools, VaaS or CaaS)

4.3.6. Cluster 6 - Governance, finance, standards and knowledge

Actors that shape the framework conditions and provide neutral expertise or capital within the charging ecosystem. This cluster includes authorities and advisory bodies such as EU and national industry associations, road authorities, public bodies, policymakers, regulators, certification and standards advisors, as well as consultancies acting as neutral advisors. Their primary focus is on setting high-level requirements, developing standards, providing regulatory support, and offering strategic guidance and knowledge support, rather than direct operation or ownership of charging infrastructure.

Authority and advisory bodies:

i. EU / National Industry Associations (note that industry associations findings are high-level requirements which were used to confirm background knowledge and update the interview templates of the relevant industry)
ii. Road Authorities
iii. Public bodies / policymakers / regulators
iv. Certification and standards advisors

Knowledge and support: Consultancies (as neutral advisors)

Table 2 illustrates the clustering approach, highlighting the main stakeholder categories and the connections between them:

● **Primary / typical role** in the context of MCS deployment.

○ **Possible / secondary role** depending on the specific business model or project, which explained in brackets ()

Stakeholder type	1. Demand-side users (LSPs)	2. Site hosts & facility operators	3. Charging point operators	4. Energy and grid actors	5. Tech & solution providers	6. Governance, finance, standards and knowledge
LSP / carriers	●	○ (own depots / yards)	○ (operate/open chargers)			
Freight forwarders	●	○ (own warehouses / plants)	○ (host/open charging)			
Shippers	●	○ (own warehouses / plants)	○ (host/open charging)			
Retailers	●	● (DCs, manufacturing plants)	○ (host/open charging)			
Owner of logistics sites	○ (use for own fleet)	●	○ (operate chargers for others)			
Safe and Secure Parking owners		●	○ (operate charging points themselves)			
Gas stations / truck stops		●	● (act as CPO)			
CPOs			●	○ (subsidiary of a utility company)	○ (backend / platform tech)	
EMSPs and eRoaming operators					● (software / platform provider)	
Complementary charging tech providers					● (robotics, payment, BESS, fire detection)	
Charging hardware providers					●	

Stakeholder type	1. Demand-side users (LSPs)	2. Site hosts & facility operators	3. Charging point operators	4. Energy and grid actors	5. Tech & solution providers	6. Governance, finance, standards and knowledge
Truck OEMs					● (both as physical and digital solutions)	
Grid operators DSOs and TSOs				●		
Grid hardware providers				●	●	
Energy producers and suppliers			● (act as CPO and offering/operating charging)	●		
EU / National Industry Associations	○ (represent the relevant industry)	○ (represent the relevant industry)	○ (represent the relevant industry)	○ (represent the relevant industry)	○ (represent the relevant industry)	●
Road Authorities						●
Public bodies / policymakers						●
Funding and financial institutions						●
Certification and standards advisors						●
Consultancies			○ (operate infrastructure for their clients)	○ (energy/grid advisory)	● (design, planning, modelling)	

Table 2: List of stakeholders identified and related cluste

4.4. Aggregated stakeholder requirements

The successful deployment of battery-electric trucks infrastructure hinges on the close collaboration of a wide range of stakeholders, each bringing unique expertise and perspectives to the table. As we have seen **Error! Reference source not found.**, these groups collectively shape the strategic and technical landscape needed to enable the transition to zero-emission freight transport. This chapter provides an overview of the main needs and requirements that must be addressed from each of the stakeholders' perspective to ensure the adoption and long-term viability of battery-electric trucks on longer routes, as well as, of course, the deployment and scale-up of MCS technology. The requirements have been collected through in-depth discussions with representatives from each group. These requirements are not intended to address user or stakeholder needs for demonstrations or pilots involving MCS, which will be detailed in Deliverable 2.2, but rather to identify what is necessary for MCS and electric trucks to be integrated into actual long-haul operations. It is essential that these requirements inform the design and development of use cases, ensuring that each use case delivers maximum relevance and value to logistics businesses and stakeholders.

As already mentioned in the **Error! Reference source not found.** (Chapter 3.4), the complexity of information collected and the number of engaged organizations required us to first compile a list of preliminary requirements, available in **Error! Reference source not found.**, to be then synthesized into core aggregated requirements below.

4.4.1. Demand-side/user aggregated requirements

ID	Aggregated requirement
UR1 – TCO and business case	The total cost of operating battery-electric trucks must be competitive with, or only moderately higher than, diesel, and support schemes should cover both vehicles and private infrastructure (including grid connections and civil works) so that logistics actors can build robust TCO models and justify investment.
UR2 – Cost transparency and modelling tools	Electricity prices, grid fees, taxes and tariff structures should be transparent and predictable over time, and suitable tools should be available to model TCO, asset lifetimes and risk under different charging events and logistics models.
UR3 – Fair and risk-sharing business models	Business models for semi-public and public MCS hubs should share costs and utilisation risks fairly between site owners, carriers and CPOs (depending on the partnership), optimize logistics performance and infrastructure utilization while providing clarity on residual values and contract durations.
UR4 – Service reliability and schedule keeping	Chargers must be reliable enough that planned charging sessions run as expected, without frequent derating, outages or blocking, so that delivery schedules and service levels can be maintained without excessive buffers or spare capacity.
UR5 – Integration with operations and driving/rest rules	Charging events must be integrated into real operations and current legislation, meaning charging must be compatible with driving and rest-time rules, compatibly with loading/unloading and yard processes, and designed so that drivers can take effective breaks while trucks charge.
UR6 – Predictable charging power and contingency	The power and energy used in planning must reflect the power that the CPO can deliver in each time window, with a committed power or energy “handshake” for booked sessions, and contingency options should be available for failures or delays at planned charging slots.

ID	Aggregated requirement
UR7 – Depot/grid readiness and energy management	Access to sufficient grid capacity at depots and private sites must be timely and affordable, with grid operators providing early, clear information, and depot energy management should coordinate building loads and truck charging, including options for on-site renewables, storage and flexibility services.
UR8 – Depot design, safety and scalability	Depot layouts must support safe and efficient access, protect equipment, comply with safety requirements, and should be designed to scale from overnight charging to higher power without full redesign.
UR9 – Corridor and public network coverage	A basic network of truck-compatible high-power chargers and future MCS hubs along main freight corridors and at key logistics nodes must be available, with locations and capacities aligned with real freight flows, cross-border routes and typical rest locations.
UR10 – Truck-compatible site geometry and layout	Public charging sites must be designed for long vehicle combinations, provide sufficient length, width, height and turning space, minimise manoeuvres (such as drive-through or angled bays) and separate truck flows from cars where needed. MCS hubs must follow standardized layout principles, including adequate bay length/width and drive-through height, safe cable and dispenser positioning relative to standardized inlet locations, the possibility to charge vehicles without decoupling where relevant, and clear circulation patterns and queue management so that MCS operations can be performed safely, quickly and with minimal manual handling and conflict between vehicles.
UR11 – Safety, security and amenities at hubs	Public charging sites must meet high safety and security standards (clear boundaries, lighting, monitoring, controlled access, emergency procedures) and must provide basic amenities such as covered parking, toilets, food and rest facilities with sufficient capacity for trucks.
UR12 – Digital planning and navigation for e-trucks	Transport management and planning tools must support electric trucks natively, estimating energy use with links with both depot and public charging; navigation systems should integrate detailed charging data (availability, realistic power, price and services) in a form usable also by SMEs and owner-drivers.
UR13 – Data, billing and price transparency	Real-time charger status data must be reliable, billing across networks should be consolidated and clear. Pricing (e.g. ad-hoc vs contract-based, energy vs time) should be transparent and distinguishable for planning and comparable.
UR14 – Booking and reservation systems	Booking and reservation systems for HDV charging should be optional but interoperable across networks, allow booking of site or pool rather than single satellites, include a committed power or energy amount, support anonymized data updates from the onboarding systems (e.g. SoC, ETA, O/D data) and booking transfer, and apply fair, standardised rules for no-shows, delays and fees. The system should be open, transparent, and neutrally governed.
UR15 – Semi-public site and access governance	Governance models should enable logistics companies and CPOs to co-develop and operate charging at private sites, allowing site owners to grant access to multiple carriers without becoming full CPOs, and provide fair prioritisation rules at shared sites.
UR16 – Roles, responsibilities and liability	Roles and responsibilities for safety, security, service quality and incident handling at depots and public hubs must be clearly defined, including who is responsible when a planned charging session cannot be delivered and how liability is allocated between actors.

ID	Aggregated requirement
UR17 – Supportive regulatory and incentive framework	The wider framework of incentives, taxation, road tolls, permitting, weight/length rules, rest-time guidance and AFIR implementation must support the economic and operational viability of electric HDVs and MCS-compatible models, with specific attention to smaller carriers.
UR18 – MCS deployment at private depots and logistics sites	The deployment of MCS at private depots and logistics sites must be technically and economically feasible where high-energy turnaround is needed, and should be modular so that a few MCS outlets can be added on top of existing CCS infrastructure, integrated with yard operations, energy management, grid constraints and safety rules, and, where desired, made accessible as semi-public infrastructure for selected external carriers without disrupting core operations.

Table 3: Aggregated user requirements

4.4.2. Logistics facility operators aggregated requirements

ID	Aggregated requirement
LSR01 - Business case, TCO and investment risk	Logistics site owners must be able to integrate charging and future MCS into a viable business model that does not undermine core terminal or warehouse activities.
LSR02 - Business case, TCO and investment risk	Charging and MCS investments at logistics sites should increase the long-term attractiveness and asset value of the property, rather than create unused or low-value infrastructure.
LSR03 - Business case, TCO and investment risk	Public support schemes and partnership models must share utilisation and technology risk between landlords, CPOs and investors, and should cover both charging infrastructure and required grid upgrades.
LSR04 - Operational planning, reliability and service quality	HDV charging and especially MCS at logistics facilities must fit real operations, aligning with loading and unloading processes, time-slot management and driving/rest rules.
LSR05 - Operational planning, reliability and service quality	High-power charging and MCS at logistics sites must deliver stable, predictable power over planned sessions so that yard schedules and service levels are not disrupted.
LSR06 - Operational planning, reliability and service quality	Charging areas must be integrated so that they do not create congestion, block docks, gates or rail interfaces, or compromise the primary function and safety zones of the site.
LSR07 - Depot and private-site charging	Depots, warehouses and logistics parks must be able to obtain and upgrade grid connections to support an evolving mix of CCS today and MCS tomorrow, with phased development aligned to BE-HDV uptake.
LSR08 - Depot and private-site charging	Greenfield logistics sites should be planned as “MCS-ready”, reserving technical space, cable routes and layout options for future high-power equipment without redesigning the entire yard.

ID	Aggregated requirement
LSR09 - Depot and private-site charging	For existing, space-constrained or grid-limited sites, practical upgrade options are needed, including the possibility to relocate part of the charging function to nearby yards with better grid access.
LSR10 - Depot and private-site charging	Grid capacity at multi-tenant logistics parks should be optimised across tenants through fair metering and contractual models that distinguish between tenant-only charging and semi-public access for subcontractors and external carriers.
LSR11 - Public and corridor charging/MCS hubs	Secure truck parks, logistics clusters near motorways and port areas should be recognised as priority candidates for public or semi-public HDV/MCS hubs when sufficient grid capacity and space are available.
LSR12 - Public and corridor charging/MCS hubs	Layouts at such hubs must combine secure parking, high-power CCS and selected MCS bays in a way that serves both local and through traffic, while keeping truck flows clearly separated from car and inbound/outbound traffic where relevant.
LSR13 - Public and corridor charging/MCS hubs	Operators of logistics-located hubs need clarity on whether chargers are fully public, port-community or semi-public, and on target user groups, so that access rules and prioritisation can be defined upfront.
LSR14 - Public and corridor charging/MCS hubs	MCS and very high-power infrastructure should be targeted to sites and use cases where short dwell times justify megawatt-level investment, while overnight and long-dwell charging at the same sites can rely on lower-power solutions.
LSR15 - Digitalisation, data and booking/ billing systems	Logistics facility operators hosting charging or MCS need digital systems that integrate parking, access control, yard or terminal operations and charging into a single operational view.
LSR16 - Digitalisation, data and booking/ billing systems	Back-end systems at logistics sites should interoperate with CPO platforms and support multiple vehicle types (cars, vans, trucks, future MCS), avoiding lock-in to proprietary or “dumb” charger solutions across a property portfolio.
LSR17 - Digitalisation, data and booking/billing systems	Combined booking of parking and charging at secure sites should be possible, allowing drivers and fleets to reserve both a safe rest slot and an energy slot in an integrated way.
LSR18 - Digitalisation, data and booking/billing systems	Metering, access control and reporting must distinguish tenants’ internal use from third-party trucks and support site- and portfolio-level monitoring of CCS vs MCS energy use and associated ESG indicators.
LSR19 - Governance, access models and partnerships	Ports, terminal owners, logistics landlords and secure parking operators must retain control over land use, safety, access rules and strategic energy planning

ID	Aggregated requirement
	while partnering with professional CPOs and investors for high-power and MCS operations.
LSR20 - Governance, access models and partnerships	Standard contractual or concession models should clearly allocate roles, responsibilities and liabilities between landlords, tenants, CPOs, grid operators and public authorities, including how safe-and-secure parking certification and evolving port energy systems interact with high-power and MCS charging.

Table 4: Aggregated logistics operators requirements

4.4.3. Charging point operators aggregated requirements

ID	Aggregated requirement
CR1 – Site selection and permitting	HDV charging hubs must be located where there is sufficient existing or potential truck traffic, adequate land for truck-suitable layouts and a realistic path to recovering investments. Permitting, environmental assessment and distance rules should be clear, reasonably harmonised and flexible enough to allow CPOs to choose technically and economically feasible locations, with early clarity on any remediation needs.
CR2 – Grid access, capacity and reinforcement	CPOs must be able to obtain medium-voltage connections sized to current and medium-term demand within reasonable lead times, with transparent processes, contacts, timelines and curtailment conditions. Policy and regulation should explicitly support grid reinforcements and shared-connection solutions (for example cable pooling) at priority HDV locations, recognising that these are prerequisites for large MCS sites.
CR3 – Tariff structures and energy options	Tariff structures for capacity and energy must be compatible with the slow ramp-up of HDV utilisation and should avoid excessive fixed costs for unused capacity that make early hubs uneconomic. CPOs should be able to combine grid power with storage and renewables, and tariff and market design should enable new products (for example flexibility services or differentiated capacity products) that help recover high fixed costs.
CR4 – CCS/MCS standards and technology roadmap	MCS and CCS systems must be based on stable, fully specified and interoperable standards (connector, communication, ISO 15118-20, V2X) and clear OEM commitments, so CPOs can invest without repeated redesigns. CPOs should be able to plan coherent CCS/MCS roadmaps per site, deciding when to deploy hybrid sites, when to upgrade CCS bays and when to move to MCS-only hubs, without being forced into technology choices that do not match existing freight flows.
CR5 – Hardware performance, footprint and cost	High-power CCS and MCS hardware must deliver stable power at high current without frequent derating or restarts and must be compact enough not to erode truck parking capacity. Hardware prices, lifetime and upgrade paths should be predictable and competitive; given that MCS equipment is currently much more expensive than CCS, funding and regulation should avoid locking CPOs into premature high-cost deployments.
CR6 – HDV-oriented site design and geometry	HDV charging sites must follow clear design guidelines that work for long combinations, with sufficient bay length/width, turning radius, drive-through height and one-way circulation to minimise reversing and coupling/decoupling. Where LDVs and HDVs share sites, layouts

ID	Aggregated requirement
	must prevent conflicts and maintain safe truck circulation; in many contexts, truck-only zones or hubs should be preferred.
CR7 – Security, amenities and driver experience	Public truck charging hubs must provide secure perimeters, controlled access, good lighting, surveillance and clear safety procedures, aligned with expectations for safe and secure parking at night. CPOs or partners should ensure a minimum level of amenities (toilets, showers, food, rest space) sized to expected truck volumes, so that charging time can be aligned with mandatory rest and perceived as valuable by drivers and fleets.
CR8 – Flexible, mixed-use and scalable layouts	Site layouts should allow phased expansion and, where relevant, flexible mixed use, so that a given bay can serve different vehicle types over time and multiple dispensers/satellites per bay can be used to raise utilisation. Designs should support gradual scaling from initial CCS deployments to later MCS additions without requiring full redesign of civil works and traffic flows.
CR9 – Robust backend, CPMS and interoperability	CPOs must operate reliable backend and CPMS systems that manage dynamic load balancing across CCS and MCS, integrate with energy management and storage, and interoperate with multiple eMSPs, routing and planning tools. Protocols and platforms should be harmonised to support roaming, HDV-specific data fields and contract management, so fleets are not forced to adapt to bespoke solutions at each hub.
CR10 – Booking, reservation and access control	Reservation and capacity-booking systems for HDV charging must allow fleets to reserve time, bay type and guaranteed power or energy, and must be tightly integrated with load management so reserved capacity is actually delivered. Effective systems should typically book a site or group of chargers rather than a single plug, link to physical access control (for example licence plate or vehicle ID), handle delays and no-shows with clear rules, and, ideally, be based on open, interoperable standards usable across multiple CPO networks.
CR11 – Data sharing, transparency and pricing	CPMS and data platforms must publish reliable real-time information on station status, bay availability and realistic deliverable power, not just nameplate ratings. CPOs must provide clear, transparent information on energy prices and all additional fees, and should receive better data from fleets (for example SoC, expected energy, ETA, trailer configuration) in standardised and privacy-compliant ways, so that planning, booking and on-site operation can be optimised.
CR12 – Utilisation, business model and ROI	Public HDV and MCS hubs must be able to reach sustainable utilisation within a reasonable timeframe; otherwise early investments remain fragile and discourage further roll-out. Support schemes should cover not only chargers but also grid connections, transformers, civil works, storage, security and amenities, and CPOs should have access to mechanisms such as long-term capacity contracts with fleets to de-risk utilisation and improve ROI.
CR13 – Policy support and tariff innovation	Policy and support frameworks should recognise that HDV electrification will progress at different speeds across regions, allowing more flexible obligations and higher support intensity where fleets and grids are less mature. Tariff and market regulation should allow CPOs to offer pricing models beyond simple per-kWh (for example subscriptions, capacity/availability fees), while ensuring that funding rules do not artificially push MCS where robust CCS plus storage would deliver more value.
CR14 – Coherent, non-discriminatory regulatory framework	EU and national regulation must treat different HDV charging actors (independent CPOs, fleet-owned sites, gas-station operators, utilities) in a non-discriminatory way regarding grid access, obligations and support. AFIR implementation schedules and power/spacing requirements should reflect actual grid and permitting realities, and coordination between transport and energy policy must ensure that HDV charging targets are aligned with grid operators planning and investment cycles.

ID	Aggregated requirement
CR15 – Safety, secure parking	Rules on safe and secure truck parking should explicitly address electric HDV charging areas, so CPOs know which security and service levels are expected and can plan CAPEX/OPEX accordingly.
CR14 – MCS governance	Governance around MCS corridors and hubs should provide realistic roadmaps and clear expectations for security, operations and site classification, including where sites act as both charging hubs and safe and secure parking areas.

Table 5: Aggregated charging point operators requirements

4.4.4. Energy and grid requirements

ID	Aggregated requirement
GR1 – System demand growth and sector coupling	Grid operators must plan for transport electrification together with other fast-growing loads (heating, industry, data centres), using scenario-based planning so capacity is not consistently underbuilt at logistics nodes and corridors.
GR2 – Joint demand forecasting inputs	DSOs/TSOs need early, structured demand inputs from fleets, CPOs and site operators (commissioning dates, duty cycles, simultaneity, seasonal peaks) to locate and size reinforcements correctly and avoid repeated redesign.
GR3 – Capacity visibility for site selection	DSOs/TSOs should provide practical hosting-capacity visibility (maps or equivalent) plus forward-looking outlooks for priority areas, so developers can screen sites and reduce speculative requests.
GR4 – Anticipatory and staged investments	Regulation should enable anticipatory grid investments and staged connection pathways (connect now, upgrade later under a pre-agreed plan) with clear triggers and cost recovery, to match ramp-up realities.
GR5 – Spatial planning and land readiness	Grid and spatial planning must be coordinated so land, grid infrastructure (substations, transformers and lines) are reserved early for multi-megawatt hubs, reducing later permitting risk and delays.
GR6 – Standardised, digital connection processes	Connection processes should be digital by default, standardised in required inputs, milestone-based, and traceable end-to-end, to handle higher volumes and complexity of requests.
GR7 – Early pre-feasibility service	DSOs should offer an early, non-binding pre-feasibility check (capacity, likely reinforcements, indicative costs and timelines) before developers commit major CAPEX and permitting.
GR8 – Complexity-adapted assessment pathways	Connection processes must be adaptable by complexity (fast vs binding, LV vs MV/HV, hub+storage, industrial hybrid), with a coordinated DSO/TSO assessment to avoid duplicate studies and inconsistent assumptions.
GR9 – Clear timeline ownership and external dependencies	DSOs/TSOs should separate what they control (studies, grid works) from external bottlenecks (permits, land rights, supply chain) and state assumptions clearly in offers and schedules.
GR10 – Queue management and	Queue rules should be transparent, auditable, and readiness-based, with prioritisation criteria defined by regulators (chronological or public-interest) and applied by DSOs transparently.

ID	Aggregated requirement
regulator-defined prioritisation	
GR11 – Tariffs aligned with utilisation ramp-up	Network tariffs and contracted-power charges must work during low early utilisation (avoid punitive fixed costs), while still preventing capacity hoarding through clear milestone rules.
GR12 – Funding for strategic reinforcements	Dedicated funding should support grid reinforcements and upstream works needed for multi-megawatt charging hubs, especially where these are public-interest corridor assets.
GR13 – Flexible and non-firm connection products	DSOs should offer standard flexible/non-firm connection products with clear curtailment limits, notice times, and compensation principles, so constrained grids can still host early hubs.
GR14 – Interoperable control and curtailment interface	Curtailment and load-management interfaces must be interoperable and cyber-secure (standard protocols, defined telemetry and control signals) to avoid bespoke integrations and operational risk.
GR15 – Two-way operational data exchange	Grid operation increasingly requires two-way data exchange with hubs (day-ahead forecasts, real-time power telemetry) under clear technical requirements and service levels.
GR16 – Data governance and confidentiality	Data sharing must be privacy-compliant and protect commercially sensitive information, with clear rules on access, permitted uses, retention, and security responsibilities.
GR17 – Permitting coordination	Connection delivery should embed early coordination with municipalities and permitting bodies (standard documentation packs, safety concepts) to reduce delays beyond the DSO process itself.
GR18 – Supply chain resilience and standardisation	Grid hardware providers need earlier visibility on reinforcement pipelines and more standardised technical specifications, plus modular options (e.g., transportable substations) to reduce lead times and cost volatility.
GR19 – Grid-code, power quality, and cybersecurity compliance	Technical requirements must be clear for multi-megawatt hubs (grid-code compliance, protection schemes, ramp rates, reactive power, metering) and include cybersecurity expectations aligned with critical infrastructure.
GR20 – Energy supply contracts and carbon accounting	Energy suppliers should provide hub-suitable supply products (long-term indexed or hedged contracts), transparent cost breakdowns (energy vs network vs taxes), and clear GoO and carbon accounting compatible with corporate reporting.

Table 6: Aggregated energy and grid requirements

4.3.5. Technology and solution providers requirements

ID	Aggregated requirement
TSR01 – MCS standard finalisation and roadmap	The MCS standard must be finalised with a stable roadmap (mechanical, electrical, cooling, safety, communication) so OEMs and suppliers can industrialise products and avoid prolonged pilot-only deployments.

ID	Aggregated requirement
TSR02 – Conformance testing and certification	Harmonised conformance testing and certification must exist for vehicles, chargers and backend interfaces, recognised across markets, to prevent country-by-country implementation differences and delayed approvals.
TSR03 – End-to-end interoperability assurance	Interoperability must be validated end-to-end (vehicle ↔ charger ↔ backend ↔ roaming) through regular multi-OEM test events and shared defect learnings, because “standard-compliant” does not guarantee field compatibility.
TSR04 – CCS to MCS coexistence strategy	The transition must support CCS and MCS coexistence with clear rules (hybrid sites, dual inlets, retrofit strategies, timelines), so early infrastructure and vehicle choices do not become stranded.
TSR05 – Vehicle charging acceptance transparency	OEMs must provide reliable, usable charging acceptance information (power curve vs SoC/temperature, voltage windows, limits) and manage software changes transparently, so infrastructure sizing and performance guarantees match real vehicle behaviour.
TSR06 – High-power reliability and sustained performance	MCS charging must deliver stable high power with minimal derating, restarts and cooling-related failures under real duty cycles, since downtime and unstable performance destroy trust and utilisation.
TSR07 – Power sharing and “committed power” behaviour	Multi-outlet power allocation must be predictable and part of a contract including a “committed power or energy” concept per time window where reservations exist, so planning and SLAs remain valid when other vehicles plug in.
TSR08 – Footprint efficiency and modular scalability	Hardware must improve kilowatt-to-footprint ration and support modular scaling (more connectors per cabinet, phased upgrades), because space constraints and utilisation ramp-up make one-shot overbuilding uneconomic.
TSR09 – Robust HDV-grade design and maintainability	Chargers, connectors, cables and cabinets must be designed for HDV environments (high connect cycles, impacts, weather), with remote diagnostics and maintainability that sustain high uptime without permanent on-site staff.
TSR10 – Ergonomics and cable management	Connector handling and cable management must be driver-feasible and intuitive, with clear inlet positioning assumptions and reach envelopes, to prevent usability failures and mis-parking at both depot and public sites.
TSR11 – Automation readiness	Automated plug-in (robotics) must be supported via standardised mechanical/communication interfaces and defined integration envelopes, reducing bespoke engineering per vehicle, charger and site.
TSR12 – Hybrid hub energy architecture integration	Solutions must support hybrid hub architectures (CCS + MCS + destination charging) and integrate cleanly with site energy management and BESS control, enabling peak shaving and grid-constrained operation.
TSR13 – Grid constraint and curtailment compatibility	Charging systems must handle grid constraints (curtailment, non-firm limits) with defined behaviour and signalling to vehicles and planning tools, so charging outcomes remain predictable.
TSR14 – Standardised operational data set	A common HDV charging data model must be standardised (real deliverable power, connector/bay constraints, availability, reliability indicators), enabling consistent routing, booking and operational integration.

ID	Aggregated requirement
TSR15 – API interoperability and role clarity	Digital integration must rely on standard APIs and clear role boundaries (OEM tools, eMSPs, CPO platforms, third parties) to reduce fragmentation and repeated bespoke integration work for fleets.
TSR16 – Data quality and governance	Data quality must be measurable (definitions, update rates, accuracy) and governed (privacy, consent, commercial sensitivity) so optimisation and automation can be trusted at scale.
TSR17 – Booking, roaming and commercial interoperability	Booking and roaming must work across networks and tools (OEM and third-party), support pool-based assignment on arrival, and expose operational constraints (e.g., trailer-on compatibility), avoiding lock-in to proprietary ecosystems.
TSR18 – Commissioning and validation toolchain	Commissioning and validation processes must test real performance before go-live (interoperability, power sharing, cooling limits, telemetry correctness), reducing field failures and expensive troubleshooting.
TSR19 – Cybersecurity and safety-by-design	Cybersecurity and functional safety requirements must be built into charging, automation and data interfaces (authentication, encryption, incident handling), aligned with critical infrastructure expectations.
TSR20 – Industrialisation, cost-down and lifecycle support	Market scale-up requires credible demand signals, cost-down through industrialisation, clear upgrade paths, and strong after-sales support (spares, remote service, maintenance processes) to keep lifetime TCO acceptable.

Table 7: Aggregated technology and solution providers requirements

4.3.6. Governance, finance and standards

ID	Aggregated requirement
GFS1 – Policy stability and long-term signals	CO_2 pricing, tolls, taxes, exemptions and subsidy rules must be predictable over multiple years, with transition periods, so investors can commit to high-CAPEX HDV charging and grid works without policy-driven stranded assets.
GFS2 – Policy alignment with deployment reality	Vehicle uptake policy, AFIR implementation, grid reinforcement timelines, and corridor delivery plans must be aligned, with sequencing that avoids building assets far ahead of demand without compensating mechanisms.
GFS3 – Avoiding unintended fossil advantages	National measures that shift TCO should avoid creating unintended cost advantages for fossil solutions that slow ZE truck uptake and reduce utilisation of early charging infrastructure.
GFS4 – Cross-border regulatory consistency	Cross-border framework conditions (including weight/dimension allowances for battery trucks and corridor rules) should be consistent along key freight corridors to enable international operations and bankable networks.
GFS5 – Funding eligibility	Funding schemes must cover the full cost stack (chargers, civil works, grid connection and substations, safety and security, digital systems), not only dispenser hardware.

ID	Aggregated requirement
GFS6 – De-risking low utilisation phase	Early-stage financial instruments are needed to manage low utilisation risk (for example minimum-revenue or availability-type support), so projects can be financed before volumes ramp up.
GFS7 – Strategic location steering	Public support and tenders should steer build-out toward strategic locations and sufficient capacity (power and number of points), not only lowest-cost projects, to meet corridor needs and reduce underperforming sites.
GFS8 – Corridor governance and multi-actor coordination	Corridor planning must coordinate road authorities, regulators, DSOs/TSOs, municipalities and market actors, with clear roles, timelines, and escalation paths for delivery blockers.
GFS9 – Land access and concession bankability	Public land and service-area concessions must be structured for bankability (clear access rights, responsibilities, payback-compatible durations, and clauses that allow adding HDV charging without contractual conflicts).
GFS10 – Faster, predictable permitting	Permitting for hubs, substations and storage must be time-bound and predictable, supported by one-stop coordination for complex sites and early screening for showstoppers.
GFS11 – Clear safety rules and liability	Safety rules (including co-location and fire safety) must be clear and risk-based, and legal frameworks must clearly allocate liability and incident responsibilities across landlord, concessionaire and operator.
GFS12 – Stable standards roadmap for MCS and related systems	Standards and guidance for MCS and supporting systems must follow a stable roadmap, reducing ambiguity and enabling investment and industrialisation across the value chain.
GFS13 – Conformance testing and certification regime	Harmonised, independent conformance testing and certification should cover vehicle–charger interoperability and regression testing after updates, with recognition across countries.
GFS14 – Metering and billing compliance clarity	Clear metering accuracy and compliance requirements are needed for high-power and MCS so billing is auditable, trusted and enforceable across markets.
GFS15 – Transparent performance and data definitions	Common definitions are needed for key performance terms (online, available, reduced power, deliverable vs peak power) and for what data must be published in readable form.
GFS16 – Booking, roaming and access governance	Interoperable rules should govern booking, penalties, no-shows and “committed power or energy”, plus roaming, authentication and dispute handling, to avoid fragmentation into proprietary ecosystems.
GFS17 – Public monitoring and KPI enforcement	Authorities should define a shared KPI set and monitoring method for corridor readiness and service quality (uptime, delivered power, waiting time), and link it to enforcement or contractual remedies.
GFS18 – Cybersecurity and physical security baselines	Minimum cybersecurity and physical security requirements should be defined for charging infrastructure and backends, including incident response and measures against theft and vandalism.
GFS19 – Practical guidance, templates and standard clauses	Advisory bodies should publish practical toolkits (design guidance, permitting documentation packs, standard concession and contract clauses) to reduce transaction costs and accelerate replication.

ID	Aggregated requirement
GFS20 – Knowledge transfer and capability building	Structured knowledge-sharing, training and neutral decision-support tools should help municipalities, inspectors and corridor actors apply consistent methods and learn from early deployments (including failures).

Table 8: Aggregated governance, finance and standards requirements

5. RESULTS

5.1. Perspective on long-haul electrification

The first section of the interview explored the organization strategic viewpoint on long-haul trucking electrification. The perspective includes truck fleets owners as customers, truck manufacturers, charging infrastructure providers, equipment manufacturers, and road authorities, which together shape a comprehensive analysis on how relevant actors view electrification as the roadmap towards zero emission logistics. Some complementary technologies are also investigated, which may serve as a parallel or alternative solution besides the integration of BET into the existing logistics missions to reduce emissions.

5.1.1.Overview of the electrification of long-haul trucking

Electrification of long-haul missions is still in its early stages. This is the common answer received from the interviewee representing logistics service providers. While urban and regional applications have progressed significantly, long-haul remains challenging due to infrastructure gaps and cost barriers.

Across the sample of 14 carriers, shippers, retailers and freight forwarders, BE-HDVs typically represent a small share (on average 2%) of the total heavy-duty fleet, though with variations depending on the fleet size, type of goods transported and geographical coverage:

i. One medium-sized regional carrier operating in the Benelux area currently runs just a few battery-electric trucks, corresponding to roughly 3–4% of its tractor fleet. They have orders already placed to put more than 50 electric trucks in operation by 2026, approaching 30% of its own truck fleet. These are used mainly to transport FMCG, retail goods, palletized cargo on fixed regional routes and shuttles between distribution centres, not for open long-haul operations.
ii. Another medium-sized LSP owning around 130 HDVs is currently operating 2 BETs (one owned, one leased) in regional mission types.
iii. A logistics provider with a 300 fleet, handling national distribution, reports 11 electric vehicles in total, mostly vans plus a single heavy-duty truck. These 11 vehicles make up about 3.7 % of its total fleet. The electric truck is used for predictable, medium distance trips starting and ending at the same depot, while diesel remains dominant on longer and more variable routes.
iv. A large LSP (~750 trucks fleet in total) operating mainly FTL across whole Europe, deployed 8 BEVs (mostly in Germany, 1 in Italy), which are used solely for regional distribution.
v. Large food retailers (with around 400-500 trucks, mainly subcontracted) have very different strategies towards electrification: one has around 15-20 BE-HDVs committed (some delivered, some on order), which still represent only a few percent of the total number of contracted heavy vehicles serving its network. While the other started its electrification journey back in 2016 and already have more than 200 BEVs in operation. These trucks are deployed on regional flows to stores and warehouses within approximately 250 km of key distribution centres, especially in urban areas where noise and air quality are sensitive issues.
vi. Postal and parcel operators illustrated the difference between light- and heavy-duty segments: they already operate several thousand electric vans for last-mile delivery and have ambitious plan to reach > 80% electric by 2029/2030 in the Nordics and Benelux. In contrast, only a very small number of heavy-duty electric trucks (on the order of a few units) are in use out of a few hundred HDVs overall. Those trucks are used for short regional legs feeding parcel hubs rather than long-distance transport.
vii. A global FMCG shipper collaborates with carriers operating on the order of 40–50 battery-electric trucks across several European markets. However, when looking at all its road transport shipments, only a very small fraction of trips (around 2% in the country where adoption is most advanced) is currently carried out with BE-HDVs.

viii. A multinational shipper reports that electric truck pilots are currently confined to one or two leading markets where incentives and infrastructure are more favourable. In these countries, a limited number of BE-HDVs is operating on selected flows; in others, electrification has not yet started. On a European level, the BE-HDV share of its contracted fleet and volumes is still negligible.
ix. One interviewee (large LSP) notes that in a particular national segment (Sweden), around half of its own heavy-duty fleet is now electric, thanks to strong incentives and good grid access. However, this concerns mainly domestic, relatively short-haul operations (< 300 km). Cross-border and long-haul flows are still operated with conventional trucks.

Most of respondents (90%) have seen an increasing trend on BET penetration in their logistics missions and are planning to expand their BET fleet by 30-50% (on average) in the next 5 years. However, the development is uneven in Europe as more countries have seen more advanced adoption, such as the Nordics or Benelux.

Some exceptions are there of course, with 2 respondents stating they aim to electrify their entire fleet already within the next 3-4 years. In almost all cases as described above, respondents reported that more 80% of all their BE-HDVs are used for short-range or regional operations, typically with daily distances around 120–250 km, sometimes up to 300 km. Meanwhile, the longer distance missions (up to 350–500 km) are reportedly still in testing phase. The only exception is two large logistics providers who report that around 10% of their daily distance per trip with BETs is between 300-500 km/day. Unsurprisingly, they operate in the Benelux and Nordics, where the charging network for trucks is more developed.

In relation to long-haul routes in the strict sense (higher than 500 km cross-regional or cross-border), only few respondents from the demand side have seen the practical usage of BETs. The interviews indicate that:

i. The majority of LSPs are still not confident on the feasibility of HD-BEV adoption on longer missions. Several (10 out of 14) explicitly state that electrification of their long-haul routes is “not yet possible” under current infrastructure and vehicle constraints.
ii. Some actors see a medium-term opportunity to electrify “long regional” transport legs between major hubs (e.g. 300–400 km in one shift), but not yet the full long-haul network.

In addition, a shipper which currently manages many intra-Europe routes believes that <u>the future of efficient and sustainable transport is intermodal, where BETs will serve the first and the last mile from the intermodal terminal</u>. This is aligned with one of the carrier’s strategies to enhance intermodal for long-haul mission. This case is relevant for routes characterized by high-shipping frequency, stable flows and regular schedules. From technology point of view, the trucks OEM depicted that the vehicle technology capable to fulfil longer route mission types is ready and close to market launch. Few OEMs have already set vehicle delivery dates for MCS-compatible BETs to the customers in 2026, with the earliest starting in March 2026. Others are still in testing phase to launch MCS-compatible BETs on commercial field, while keeping up with the MCS standardization progress. These companies keep conservative approach to assess the customer demand on the particular truck model with expectation to increase production rates in the next 1-2 years. Still, concern persists about fragmented standards, communication protocols, and the readiness of the MCS network.

CPOs agree that long-haul truck charging is still in a pre-commercial phase, with very low utilisation today. This creates a chicken-and-egg problem: OEMs cannot scale BETs production and efficiently reduce costs and fleet owners hesitate to invest in electric trucks due to lack of infrastructure and cost issues, while CPOs hesitate to build hubs because utilisation will remain low for years. There are notable best practices emerging from the Nordic region, such as the E-Charge project in Sweden and the ongoing development of a robust charging network, with 45–50 truck charging stations currently operational. Respondents indicate significant demand at one particular site, where 40–50 electric trucks regularly utilize the station during winter, and up to 90 charging sessions have been recorded within a 24-hour period.

5.1.2. Drivers towards electrification

As described **Error! Reference source not found.**, respondents representing logistics providers have different levels of electrification on their operations; some just started while others are implementing a clear and ambitious roadmap. Each organization has different motivations for electrifying their fleets and drivers are multi-layered and go beyond pure cost calculations. These include fulfillment of sustainability goals, raising awareness of logistics emission reduction from customers and any strategy to obtain incentives or subsidies. From demand-side, all respondents have expressed that their company is pursuing electrification as a core element of their emission reduction targets. The motivation behind this is, for example, for the customer to improve its public image, fulfilling country specific emission targets, or a global commitment for companies belonging to holdings. According to the emission type, the target is not only limited to Scope 1 emissions but also include Scope 3 emissions like operations from subcontracted fleets. However, it emerged that electrification is not always the main focus on emission reduction. Many shippers and large logistics groups frame electrification of road transport as one element of their decarbonisation strategies:

i. Several interviewees refer to Group-level targets such as net-zero by 2050, intermediate reductions by 2030 (e.g. −50%) and already achieved milestones of −20% emissions.
ii. Electric trucks are consistently described as a “major milestone” or “strategic lever” for decarbonising transport, alongside other options (biofuels, H2, efficiency).

Carriers that serve these shippers often align with these targets, viewing electrification as necessary to maintain long-term contracts and to remain part of decarbonized supply chains. In some cases there is no separate electrification target: shippers pursue CO_2 reduction through all available decarbonization levers. One possible cause is because for manufacturers, the main emission contributors are not on transport, instead on production processes or on facilities energy consumption. retailers, whose main operations are logistics, have set more ambitious targets. Two retailers are aiming to achieve fully zero-emission by 2030. The rest set 2030 as a milestone of 50-70% reductions. One retailer mentioned that outbound and intra-company fleets are easier to electrify. On contrary, inbound shipping, especially from other European countries have found difficulties.

<u>Customer pressure and market positioning</u>

This argument is confirmed by forwarders who reported growing interest from FMCG clients for BET solutions, driven by sustainability goals and reputation. Some clients already use biodiesel but see electrification as the future and want to learn operational implications. A recurring <u>driver is pressure from key customers:</u>

i. Several LSPs mention that large shippers now explicitly request low- or zero-emission transport options. In some cases, shippers have started to approach carriers to discuss electric trucking, reversing the earlier situation where LSPs had to “push” EV pilots to shippers.
ii. Some carriers and forwarders see electrification as a differentiator in tenders, allowing them to win business with sustainability-focused clients and to position themselves as early movers.

Retailers and FMCG companies highlight that electric trucks are also part of their brand and CSR narrative. Visible zero-emission deliveries in urban areas are considered important for reputation and alignment with consumer expectations.

From the truck OEM side, electrification is seen as critical for their future competitiveness and portfolio diversification, even if current uptake is slow. OEMs believe that keeping up with the technological evolvement on BET is essential, for example by participating in research or system demonstration projects like HoLa, Macbeth, FLEXMCS, ZEFES, REEL, and E-Charge or initiatives on standardization like CharIn. Another motive is also the regulatory pressure from the government of course. Compliance with CO_2

reduction targets is a major driver. OEMs cannot meet these targets with diesel efficiency improvements alone, making zero-emission vehicles essential.

Regulatory context and anticipated restrictions

Governments' policies and regulations must play an increasingly central role in accelerating electrification within the logistics sector. Certain countries are already imposing regulations that increase the cost competitiveness of BET compared to diesel trucks. There are mainly two approaches through which regulations can directly or indirectly influence electric trucks adoption: directly subsidize BETs investments and reduce their TCO or penalize diesel operations. For example, one of the interviewees mentioned that the Norwegian government was offering almost 60% support cost for BETs purchases[5], while in Sweden a maximum of 20% investment support of the total cost is provided[6] (which cannot exceed 40% of the additional cost compared to a similar conventional truck). On the contrary, a Belgian interviewee reported that from 1 January 2026, the Flemish Government decided that it will no longer be possible to apply for the ecology premium+ for the purchase of electric trucks.

Also, following the EU's Eurovignette Directive, a number of countries and regions have already introduced, or are preparing to introduce lower (Norway, Ireland and Czech Republic) or free toll (Germany, Austria and Belgium) road fees. Countries like the Netherlands, provide various incentives or specific Zero Emission Zones (ZEZ), which are helping improve the business case of BE-HDVs.

Operational and qualitative benefits

Alongside climate and regulatory drivers, interviewees representing mainly retailers and postal operators identified a set of operational and qualitative benefits: Lower noise and local emissions make electric trucks attractive for night-time urban deliveries and operations near residential areas.

On the latter case retailers and postal operators' logistics networks are mainly localized around regional distribution centres to fulfil the local stores or postal offices. In certain cities, low emission zones have been established for last-mile delivery to stores and within urban areas, requiring logistics carriers to transition to trucks with zero tailpipe emissions. Last-mile deliveries are typically handled by light or medium-duty vehicles, which can promote the wider adoption of electrification and encourage retailers to invest in on-site charging infrastructure. As a result, increased utilization of charging facilities may further reduce the total cost of ownership. Some operators report positive feedback from drivers, citing smoother driving and improved working conditions. This may help with recruitment and retention which are a huge issue in Europe, totalling to a shortage of more than 500 thousand drivers.

At the same time, many operators stress that these benefits are currently not enough on their own to compensate for higher TCO and infrastructure investments. They are seen as additional value in cases where an acceptable business case can already be built.

Strategic learning and risk management

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[5] https://www.electrive.com/2025/10/16/norway-to-phase-out-electric-vehicle-vat-exemption-from-2027/
[6] i.e. Klimatpremien for Trucks. https://www.energimyndigheten.se/49c994/globalassets/klimat/klimatpremien/vagledning-for-klimatpremie-tunga-lastbilar.pdf

Other drivers are the company strategy to be the market leader on electric transport and pioneer this technology to obtain a competitive advantage as early adopters.

Several carriers and shippers (8 in total) emphasise the value of learning and de-risking:

i. Early deployments with a limited number of trucks allow companies to build internal know-how on routing, charging, energy management and driver behaviour.
ii. Some actors explicitly describe their projects as “learning phases” to prepare for a future where electrification will no longer be optional.

In this sense, current BE-HDV projects in long-haul-capable fleets are often framed as a way to prepare for future regulation and market shifts.

The majority of CPOs (8 out of 9), especially those backed by OEM joint ventures or part of utility companies, are investing early to secure prime locations and build brand presence, even if ROI is uncertain. The company typically starts with regions with more advanced grid infrastructure and higher EV penetration. For example, mixed-use hubs (trucks + passenger cars) are common in Scandinavia and Western Europe to improve utilisation. Truck-only hubs are preferred in high-demand corridors or logistics clusters. Then the business model will be replicated to other European countries, like Eastern Europe where some projects have been postponed due to slow truck charging demand growth and grid constraints.

5.1.3.State of the art in the use of private charging infrastructure

As discussed in chapter **Error! Reference source not found.**, the great majority of logistics providers interviewed do not use BE-HDVs for routes longer than 300 km and recent electric trucks models enable a range autonomy of 600 km on a single charge, which make en-route charging unnecessary for shorter truck assignments. The charging strategies used by the interviewees of course reflect this pattern. Depot or private-site (meaning at warehouses, distribution centers or any logistics facility owned by the operator) charging is the dominant model:

1. <u>Overnight charging:</u>

90% (13 of 14) rely on overnight charging at private sites as the backbone of their BE-HDV operations. The chargers are located in the truck parking lots within the depot, or in the DC yards or also in intermodal terminals where trucks park between shifts. In one case the chargers are located under a “steel bridge” installed above the parking lot. Even when the shipper or retailer has no own chargers their contracted carriers charge overnight at their depots. Overall, a majority of overnight charging points are a mix of AC 7–22 kW and more commonly DC operating at 20–80 kW per truck even where nominal power is higher, because power is shared or limited by energy-management. However, next-generation Volvo trucks will reportedly remove AC charging capability, which will force investments in more advanced DC infrastructure for operators. Dwell times are typically full night or 6–10+ hours, often starting late afternoon or early evening and ending before morning departures.

2. <u>Charging during shifts</u>

These chargers have some flexibility for mid-day top-ups when trucks return to the base in a double-shift operating model. 80% (10 of 14) describe daytime depot/DC charging as an important complement to overnight, particularly during loading/unloading windows, between shuttle cycles, or during driver rest breaks. Chargers are either located at:

i. loading docks, and operating in the 250-400 kW range on average;
ii. parking areas at hubs, providing on average 400 kW of power;

These chargers target short dwell times (loading, breaks) and are sized to deliver energy within 30–120 minutes, depending on schedules. Key challenges are the following: warehouses have on average more than 100 docks, but building 100 chargers is impossible economically. High utilisation is critical. Operators must determine which docks to equip based on turnover.

Of course the number of sites featuring charging infrastructure and the number of chargers deployed varies greatly depending on the size of the electric fleet and grid access, for example:

- One postal operator reports more than 2,000 depot charging points (mostly AC) across its network, used for overnight charging of vans and trucks.
- A big retailer describes a steel structure above loading bays with six CCS outlets, enabling fast charging (e.g. 180 kW single, ~60 kW when shared) while trucks are being loaded.
- Several LSPs are rolling out multi-site depot charging networks (e.g. 10–12 plugs per large depot, supported by on-site batteries and PV), dimensioned around their regional routes.

In the context of private location, site owners have clearly seen the benefits of installing the infrastructure at their premises. The question is whether high power charging is necessary and can provide benefits to their operations or become a new business opportunity for them. Among site owners, <u>all operators interviewed have installed charging stations, however only 4 of them are interested in investing in high power charging</u>. Low utilization remains a challenge, hence MCS is unlikely to be deployed at loading docks, because utilization would be too low and it would limit the goods' flow. However, short-term parking areas near docks are promising as drivers often arrive 30 minutes early and could top-up there. Further detail on the specific interest towards the deployment of MCS in private sites is provided in Chapter 5.3.2.

5.2. Stakeholders challenges and needs

The stakeholder requirement has been defined in the previous chapter (**Error! Reference source not found.**), covering the six groups of actors that represent the truck charging ecosystem. From the perspective of long-haul electrification, all stakeholders agree that the development of charging infrastructure for trucks is slower than expected, while charging providers are struggling to manage costs due to low facility utilisation. Together, this creates an interdependent challenge between supply and demand side or referred many times by our interviewee as chicken-and-egg problem. Therefore, this issue should be addressed simultaneously from both the demand side (BET penetration) and the supply side (charging infrastructure).

5.2.1.Electrification of long-haul logistics routes

As highlighted on chapter 5.1.1., HD-BEVs mainly serve short to medium distance routes like regional shipment or feeder routes (below 300 km). The electrification of long-haul, as defined on the MACBETH project targeting over 500 km distance, is still low, with operators reporting certain aspect which still make BEVs less competitive than the existing diesel trucks. Operators often start with short-distance, high-volume routes to learn from operational experience before scaling up. Electrification is easier for sectors like FMCG, where volumes are high and distances are short.

The common obstacle is the <u>uneven truck charging infrastructure coverage in many regions</u>. Having in place private charging infrastructure makes electrification easier. A consultancy company highlights that "the first mover", a term refers to the fleet owners in their early electrification stage, rely primarily on depot charging because it is perceived as significantly cheaper than public charging. The company quoted an example of cost comparison in the Netherlands: depot charging is typically €0.20–€0.30 per kWh, while public charging is often above €0.30 and can reach €0.40 per kWh. For those carriers who do not have the investing power to install private chargers, using public charging and negotiating electricity rates to remain competitive is the only solution. In areas where public infrastructure is scarce, sometimes operators are forced to rely on passenger car chargers as contingency plan. This temporary solution is not scalable and unsuitable for heavy-duty use. Dedicated truck chargers will become increasingly important as demand ramps-up.

More specifically, a logistic carrier highlighted that the mission planning changes significantly compared to diesel where a different operational model need to be carried out. Electrification projects are not just about quoting a price. They involve close collaboration with carriers and shippers to adjust schedules and operational practices. Success depends on willingness to adapt at all levels of the organisation. New variables emerge as critical, such as the visibility over public charging, including availability, power, speed and waiting times. To accommodate this adaptation, charging events must be integrated into route planning. One of the carrier retailers mentioned that the current Transport Management System (TMS) does not support BETs driving range constraints, meaning that for missions more than the truck's full driving range (it was referred to around 300 km/day), the company does the charging plan manually. Another user, a postal operator, highlighted that ideally the planning tool should be able to align the charging location with driver's regulated break. This scenario ensures that the charging en-route took place with minimal detour. Charge planning is even more critical for small companies, because so far, charging decisions have been left to drivers, who choose where to stop. This approach is inefficient and has a lot of room for improvement. In the quest of cost efficiency, dispatchers or route planners are expected to manage charging plan because incorrect location choices can impact TCO and contractual obligations of CPO's premium. Freight forwarders report that every detail matters in EV planning: from warehouse opening times, delivery and pick-up windows, and seasonality of flows. For example, if 250 out of 500 annual loads occur within two months, electrifying that route becomes challenging.

Furthermore, uncertainty over TCO still hinders the adoption of BET, expressed by fleet owners. The issue is more evident for new variables other than conventional diesel truck, namely electricity price and BET residual value. Regarding the electricity price, a retailer highlighted that their quotations rely on a standard indexation system, the Swedish Carrier Association index, where transport tariffs are adjusted monthly based on fuel price changes, the purchasing price of the truck, and type of drivetrain/consumption. As charging price may fluctuate throughout the day and depending on the location, this operator calls for an electricity-based indexation which should become the norm for BETs. Another variable is the vehicle's cost and residual value, which are an important baseline for fleet's asset depreciation assumptions and therefore for investment decisions. Electric trucks cost about 2–2.5 times more than diesel trucks, and charging infrastructure adds further CapEx. This shifts expenses from operational to upfront, making financing and residual value critical factors. A major e-commerce player who owns a large fleet highlights that the unclear second-hand market for electric trucks and battery degradation risks make residual value unpredictable, complicating ROI calculations. Banks hesitate to finance purchases without long-term contracts guaranteeing utilisation. Similarly, insurances also remain uncertain because providers lack historical data, and uncertainty rarely results in lower premiums. This concern is higher for SMEs which typically own only few trucks, as they need to have visibility on which reselling value to expect after 6-7 years of operations.

Many respondents stress a cultural shift: drivers are used to "owning" their truck and taking it home; with BETs, the truck must remain at the depot for scheduled charging. This is expected to be a behavioural and HR challenge in the future.

5.2.2.Realization of charging infrastructure

The analysis of requirements from the demand-side has shown varying power level delivery needs to fulfil different logistics mission characteristics. The location and the timing of the charging event relative to the delivery trip is an influential variable: whether it is overnight (outside the working shift), en-route or during a truck stop. To fulfil this scenario, depot charging appears to be the easiest solution for missions' electrification. Therefore, deploying the charging infrastructure on logistics sites is seen as the first step to be followed in the electrification process. In addition, public charging infrastructure is an enabler of long-haul mission where MCS is valuable. Deploying infrastructure on these two types of locations imply specific challenges, especially related to the expected flow of vehicles and predictability on the energy demand, plus of course the cost of the investment.

Common challenges

The following are common problems faced by site-owners and CPOs alike when deploying charging infrastructure:

i. Grid connection establishment

Availability of adequate grid connection in the site is a primary requirement highlighted by most stakeholders. In fact, the process of establishing or upgrading grid connections has become the bottleneck of charging infrastructure deployment, as it takes long lead time. Our stakeholders reported that the leadtime ranges from 6 months to two years, but for high-power sites the timeline can stretch up to 5 years. In addition, one CPO reported that they often need to wait for months only to learn that their grid connection request will cost more than forecasted (some report up to over a million euro of grid connection fees), before moving on with a new request in another location. Another issue is in fact the lack of transparency on grid capacity mapping, showing clearly essential data such as potential locations with strong power connections or future grid expansion maps. While regulations like the Electricity Market Design Reform[7] aim to improve visibility into grid capacity across Europe, the reality is still opaque. A major e-commerce company who also builds depot charging facilities complained that without it, companies hedge their bets by bidding for capacity everywhere which leads to long queues. Therefore, the site owners urged TSOs and DSOs to provide clearer information. In certain countries, the DSO landscape is fragmented which creates complexity and slow approval as there is lack of standard new connection request procedure. For example, there are more than 800 DSOs in Germany alone.

Even when capacity exists, the power allocation works on "first come, first served" basis, creating pressure to reserve large capacities upfront, even if utilisation will be low initially. Whether it is a new grid connection for green field case, often for new public charging expansion, or grid power upgrade in case logistics site owner opting to install chargers on their premises. In relation to power allocation, some stakeholders argue that reservation is secondary to grid capacity issues. While the reservation system will be helpful to optimize utilization, it does not solve the fundamental bottleneck of grid connection delays.

From the grid operators' perspective, it is crucial to recognize that the main obstacle in installing sufficient high-power infrastructure is the lack of grid connectivity. The types of infrastructure covered by AFIR should specifically include grid equipment such as transformers, substations, and power lines, essential for supplying electricity to charging stations. Because AFIR mentions only the TEN-T corridor and not TEN-E, CEF funding does not apply to this grid equipment. As a result, the development of charging infrastructure and grid infrastructure may become misaligned in the future. Funding should be provided simultaneously to both CPOs and DSOs to ensure enough grid capacity will be available for charging stations, whether private or public, in the next 2-5 years when demand rapidly increases, by which time it will be too late to address shortages. To support this, dedicated electric infrastructure for charging is necessary; otherwise, capacity may be allocated to other business purposes, such as BESS investors purchasing land near transformers to sell ancillary services to the grid and engage in energy arbitrage.

[7] https://netzerocompare.com/policies/eu-electricity-market-design-reform-eu-emdr

ii. Permit and regulatory aspects

Beside grid connections, site owners must grant permit and follow regulatory procedure before operating their charger. Environmental checks, such as soil contamination assessments and fire safety regulations are major hurdles. These requirements differ significantly across region, forcing operators to adopt worst-case designs or over-engineer solutions to comply universally. For example, deploying charging infrastructure along the highway sites in Germany such as in service area requires strict design and safety requirements. While the government owns grid connections for on-highway sites, operators still face extensive compliance checks. Meanwhile, off-highway sites require operators to manage all the permits by themselves, including transformer approval. Another example, in Italy procedure varies in different regions with permitting and site scouting take 6 months to 2 years, heavily dependent on local DSOs.

While new regulations are being developed, one CPO highlighted that authorities may not be aware of the technical and spatial requirements for charging stations, which slows down approvals. For example, in some cities, they almost all need to educate the authorities about what charging infrastructure requires or the land needs involved. This lack of awareness adds complexity and delays to the permitting and site acquisition process. It underscores the importance of policy adaptation and capacity building at the authority level to support the rollout of charging infrastructure effectively.

iii. Cost

The major investment cost fraction of deploying charging hubs is securing the land, especially for green-field facilities. One of the CPOs mentioned that to ensure a positive business case, building charging hubs require long concession periods, often 20-30 years due to high upfront investment. Currently as in the early year's utilization remain low, short-term contracts are not viable. The company preferred to own the land rather than rent or lease unless the sites are highly favourable.

Grid upgrade cost is a major hurdle reported by the stakeholders as it should covered at the beginning of investment before the charging infrastructure even takes place. One of the stakeholders mentioned the significant expenses for CPOs, including connection fees, installation, and commissioning cost. The first component is connection fee which often charge based on the peak power requested, not just actual usage. One of the CPOs reported that this pricing scheme increases the financial risk on their business model as even if the utilization remains low, the cost will escalate because CPOs are charged based on the maximum capacity reserve. In addition, increasing grid power sometimes also requires equipment upgrade such as additional cabling, transformer replacement, electrical and civil works while installing the hardware. Stakeholders reported requests for 2.5 MW, 3 MW, and even up to 3.8–4 MW for charging sites. These high-power levels require substantial transformer capacity and grid readiness, as reported by one of the equipment manufacturers.

Meanwhile, the truck charging tariff basis is still being formulated as there are still different preferences from CPOs and customers. As energy price can fluctuate throughout the day, there are at least three approaches:

- Stable, fixed price €/ kWh per country.
- Spot price integration: In such cases, the communicated price will be: "X + spot price" €/ kWh, with X as a fixed cost.
- Dynamic pricing: Hourly electricity price and flexible tariff.

Integrating real-time electricity market prices can increase the cost competitiveness of public charging, as low midday prices in solar-rich regions could make public charging cheaper than depot charging. This factor will influence future demand and trigger higher utilization. However, the challenge is figuring out how to share the risk of price fluctuations between the energy supplier, CPO and customer. Users should be informed on the price before initiating a charging session, but how far in advance depends on the flexibility of the pricing model. Currently, spot price integration is a practical approach to accommodate fluctuating energy price. The user will be shown the €/kWh as a component of "*fixed + margin on spot price*". In the future, Dynamic pricing is seen to optimise utilisation and align with energy market conditions. However, it requires robust reservation systems and user predictability, such as arrival time, charging duration, energy needed.

Location-specific characteristics

- Public charging facilities

Site-owners who install charger on existing location, such as filling station operator, are faced with additional requirements that attach to public charging protocols. Two companies depicted that their strategy focuses on utilizing the asset, accommodating the new flow of electric vehicles. Depending on the type of existing infrastructure, site owner must adapt certain aspects such as layout, operation, and safety measure. For example, a highway operator depicted that the company is also building hydrogen refuelling in the service rest area. The country's safety regulation restricted hydrogen and electric charging to be deployed in the same area, which reduces flexibility and growth potential for electrification.

Space and layout constraints have been mentioned few times. The problem is especially relevant for brown-field case, such as gas station or highway service area. In relation to layout, existing facilities may not be initially designed for long vehicles. Traffic flow rerouting is needed, CPOs mentioned certain aspects including one-way vehicle circulation to avoid reversing trucks, longer charging bay (25-35 meter), and larger ramps to accommodate truck-trailer turning radius. These aspects are aligned with customer's voice; logistic carriers expect that drive-thru charging bay is an ideal and efficient setting. Moreover, others point out that many existing public sites have narrow charging bays and access ramps which makes it impossible for tractor-trailer to charge without decoupling.

One of the CPOs mentions that public sites are often designed without barriers which may raise concerns about security and driver safety. Therefore, the operator needs to install additional equipment such as surveillance cameras and adequate lighting. Moreover, some locations are a mixed-fleet facility or even combined with services for passenger cars. Traffic flow and pedestrian safety should be considered. For example, reducing the interaction between pedestrians and HDVs by redesigning the layout and placing the passenger cars parking area adjacent to the service area.

- Private locations

Many site owners remain hesitant about making major upgrades to high-power charging infrastructure. High upfront costs, limited grid capacity, and the current low demand due to the small number of BEVs are key factors making megawatt charging systems (MCS) less appealing right now. They are carefully weighing the expected operational improvements against the significant costs involved in upgrading electrical systems or expanding grid connections. As a result, most investments currently prioritize scalable solutions that can grow alongside fleet needs, rather than immediate, large-scale implementation. As reported by one of the retailers, grid reinforcement cost could reach up to €2–3 million just to support the first charger. Although subsequent chargers are more affordable, the initial upgrade poses a considerable barrier. This challenge makes phased electrification difficult, as it is hard to justify an investment of €2–3 million when only 3–5 trucks are expected to use the site in the early years.

Raising safety and facility risk factors have also been reported by site owners when deploying chargers on their premises. To increase the charging utilization, private owners may open their facilities to external carriers. This comes with consequences of higher requirements, as soon as a private depot offers charging to outsiders even for a few hours, it is considered a commercial service. The facility must comply with public charging standards such as implementing communication protocols like ISO 15118 and meeting cybersecurity and interoperability requirements. These obligations can be complex for depot owners who are not experienced charge point operators (CPOs) and are often perceived as a significant burden.

A specific regulatory issue has been reported by site owners, stating that industrial clusters often have zoning that prohibits the installation of chargers inside certain areas. For example, logistics hubs may prohibit fueling stations under old rules, inadvertently creating barriers for charging stations. Moreover, site owners are faced with higher building insurance as liability factors increase. In fact, CFPA-E guideline No. 44:2025 provides detailed fire safety measures for charging infrastructure. Some relevant aspects include the distance between charging bay to storage areas of flammable goods, cabling, minimum fraction of roof protection, and mandatory features of fire extinguishers. Therefore, site owners need to carefully assess the implications of installing this infrastructure, especially if it involves major redesigning.

Limited space and layout modification have been mentioned few times by site-owners, especially those located on logistics clusters where truck parking spots are already scarce. One retailer depicted that they need to collaborate with other facility owners to place the charging infrastructure. Among the stakeholders who are interested in building or have been deploying charging in depots, they typically begin the electrification strategy for LDV or company's car. However, providing charging bay for HDV is not simply expanding the existing infrastructure as major relay outing often follows, such as accommodating turning radius, separate waiting bays, and clear vehicle flow to conflicts with loading and unloading operation.

5.2.3.Operation of charging infrastructure

As mentioned on the previous section **Error! Reference source not found.**., the risk of underutilization still haunts charging operators especially on investment in MCS given the higher cost of the grid connection. In fact, MCS refers to a set of standards of the vehicle, charger, and communication which is suitable to deliver both high (i.e. megawatt-level) and low power recharging. In order to increase the utilization, the challenge is how MCS can fit with various charging strategies to ensure a positive business case. MACBETH is developing multi-point charging hubs designed to serve both passenger vehicles and commercial fleets, adapting power delivery according to traffic conditions. To achieve this, the pilot sites will incorporate both MCS and CCS connectors, allowing flexibility for different vehicle types. This integrated approach introduces additional complexity for stakeholders, as it requires careful consideration of operational, technical, and regulatory factors affecting both light and heavy-duty vehicles. Given that high-power charging provided by MCS is essential primarily for HDVs with larger battery capacities (N2 and N3 categories), it is crucial to implement a clear strategy for prioritising charging access based on vehicle type. In this way, the hubs can optimise power allocation and ensure efficient utilisation of charging infrastructure to all users. Allowing light-duty vehicles to charge has been seen as strategy from some CPOs to fill the gap between station capacity on the early phase of truck electrification or in area with low commercial truck flow. As electric trucks roll-out grow, charging hubs exclusively for trucks will be more prominent. CPOs mentioned that they will need either technical mechanisms or substantial fines to ensure vehicles vacate the bay on time. Vandalism and theft are also mentioned as a non-negligible operational risk, especially theft of copper cables. While not yet systemic, incidents have high impact when they occur, pushing operators to consider more robust security measures, mentioned below:

- CTV Camera
- Call centre 24 hour which can be reached out by the driver (in-case no operator is present)
- Fences or gates for semi-public facilities

From the end-user point of view a mechanism (either physical or software) to block the charging bay should be implemented to ensure the accessibility of the bay only to those who reserved the charging slot.

Price transparency is another concern from user-side on using public charging. There has been a mixed view on pricing transparency. Some stakeholders advocate upfront fixed pricing, while others foresee dynamic pricing linked to spot market. While many carriers have established agreements with CPO, in the case of emergency charging, carriers wish to have visibility on ad-hoc pricing. This problem is even more critical for advance booking, as displaying accurate price remains a challenge due to spot market fluctuations. A few CPOs support fixed pricing for reservations, especially for long-haul corridors, arguing that it simplifies customer experience and reduces disputes over fluctuating rates. From LSPs side, dynamic pricing will complicate TCO calculations. Fixed pricing is seen as essential for early adoption and budgeting. On the other hand, energy providers prioritise market responsiveness which lean towards dynamic pricing scheme. If in the future dynamic pricing will be prominent, it requires real-time data exchange and advanced algorithms, which some stakeholders see as a barrier for near-term deployment.

The reliability of long-haul mission with BET cannot simply be achieved by increasing the density of truck charging facilities. Especially for time-sensitive logistics missions, operators need certainty that their fleets have enough power to complete the tour. Therefore, power allocation emerges as an important variable of reliability beside charging bay availability. This variable can be translated into estimated charging time which will help both users and charging hub operators to plan their operation. Its accuracy can be enhanced by providing certain data input such as vehicle's telematics, SoC, and estimated arrival.

Stakeholder from both demand and supply side, including logistics carrier, shippers, CPO, and charging infrastructure provider have mentioned that such route planning integration can be complement by charging reservation systems. However, one of the eMSP who have been providing route planning tools reported that currently no CPOs are accepting reservation for trucks yet. The company believes that a standalone reservation platform will not suffice. The real challenge is defining how to handle no-shows, late arrivals, or early arrivals. The system should be able to adapt to truck's ETA by considering some variables, such as charging slot extension with buffer time. This highlights a gap which will be further discussed in chapter 5.3.3.

5.2.4.Trucks and charging equipment innovation

One of the charging equipment suppliers suggests that MCS charging power can be controlled to lower the power to protect the battery. This can be managed either by the vehicle itself or by the CPO through intelligent systems. Different strategies can be applied, such as setting power to zero for long periods and then resuming charging without physically disconnecting the vehicle. This makes the process easier for the driver, who can have an uninterrupted rest while the truck and charger manage all requirements automatically. The approach depends on the situation. For example, a CPO may choose to limit power during periods of high electricity prices, while the truck may also decide to charge at low power throughout the night rather than at maximum power for one hour. Both strategies aim to optimize charging cost, battery health, and driver's welfare.

The technology providers highlights the importance of interoperability and smart software to manage different charging standards to realize this concept, such as CCS for LDVs and MCS for HDVs. For example, the manufacturer warned that modular or hybrid hubs (MCS + CCS + overnight charging) will require flexible transformer sizing to accommodate different power profiles. Beyond the equipment, there should be guidelines for shared hub governance and access prioritization that can be replicated by all charging operators. For example, a manufacturer suggests implementing automated load balancing and predictive algorithms to optimise energy distribution across mixed fleets.

On site spatial dimensions, reducing equipment has been one of the focuses of charging equipment manufacturer. One of the manufacturers describe their experience on installing infrastructure on sites with limited space such as along the highways or logistics hubs. They describe an important performance metric of their equipment, power delivery per square meter. Other manufacturers highlight the trade-off of cable length, which is an important design factor to accommodate diverging inlet position design. Some manufacturers offer hoses (a term referred by the interviewee as charger cable) from 5 to 20 metres to adapt to different site layouts. While longer hoses increase flexibility for site layouts, it causes issues such as power losses, temperature management (especially for liquid-cooled cables), and electrical behaviour (inductance/capacitance). In addition, longer hoses can easily clutter if not stored properly. One manufacturer offers a design concept to store the hoses inside the wall boxes or enclosures while not in use. Moreover, MCS cable are more expensive than CCS. Therefore, standardization of common inlet position among OEMs is more prominent for MCS to simplify cable management and site design.

Another crucial aspect concerns the ergonomics of cabling, as MCS cables are significantly heavier and thicker than CCS cables, rendering longer cable lengths impractical. This increased weight and bulkiness can create usability challenges for drivers when plugging in the charger, particularly in environments where flexibility and ease of handling are essential. To address these challenges, one manufacturer has proposed the use of spring-based mechanisms to assist drivers with cable management. While such solutions can be effective in private depot settings, they are more difficult to implement in public charging environments, where space and infrastructure constraints are greater. The MCS chargers by Kempower have this spring-based feature exactly to solve this issue, and are already deployed in several sites in Sweden.

In response to these limitations, further innovations are being developed, including the use of robotic arms to automate the connection process. Notably, one stakeholder is currently testing an autonomous plug connection system designed to pair seamlessly with autonomous driving trucks. These advancements represent the next step towards full electrification when vehicles will operate 24/7 and maximize efficiency by making better use of infrastructure, reducing costs (since trucks can charge during off-peak pricing), and improving overall operations.

5.2.5.Financing instrument and incentives

Some stakeholders have received existing funding schemes which are provided by EU, national, or regional government. The type of cost that can be covered varies, including vehicle, road toll exemptions, energy price subsidy, etc. In regard to cost structure, two different approaches are generally used: cover the CapEx or OpEx. While both aim to lower the TCO and alleviate the cost barrier to entry for electrification, the effectiveness of these two approaches is still a question mark.

Subsidy on vehicle purchasing cost, an incentive that has been rolling out for a while, was supposed to boost the growth of BET. Similar approaches had earlier been implemented on passenger vehicles on their first market introduction. However, some fleet owners thought that simply reducing the BET price will not help them to reach economic competitiveness. Expansion of zero-emission zones and ETS taxation schemes are strong drivers for electrification as well. These measures make diesel operations increasingly costly, tipping the balance toward EV adoption.

The effort on lowering the financial barrier of BET adoption can also be achieved through innovative partnership among stakeholders. A major e-commerce who wholly subcontracted their fleet described their strategy on how to reduce the financial risk of purchasing BET borne by the fleet operators. The company negotiate directly with OEMs and work with fleet management companies to secure the trucks. Once agreements are in place, the e-commerce subcontract the operators who will run the trucks and provide them with clarity on profit sharing for the required duration. As a result, the individual companies driving the trucks source them from fleet management companies, so neither the drivers nor the subcontractors need to invest their own money in acquiring electric trucks. Incentive on lowering OpEx is seen as breakthroughs, and it is not limited to lowering road tax or electricity charging price. Lower transport cost can be achieved through a more efficient logistics planning by aligning driving and rest regulation and increasing public charging network density. This approach removes financial barriers and supports adoption.

Depot charging will most likely be the dominant solution for fleet carriers and would require support, specifically for the establishment of the grid connection which is also subject to high costs. While there has been lots of funding mechanism on charging infrastructure, recently the focus has been shifted to MCS. A retailer reported that in fact the initial investment and procedure to follow are similar for MCS and CCS, such as establishment of the grid connection and the need for a Battery Storage System (BSS) to optimize site-power management. With the priority given to MCS, it is more challenging for private site-owner to fund depot-charging given its higher investment. Financial support for grid upgrades, civil works, and charger costs is seen as critical by all respondents. Some stakeholders note that even a 50% subsidy would not justify MCS at certain sites due to low expected utilisation.

In addition, smaller companies with fewer fleets are struggling to cope with charger utilization. To help them electrify the logistics mission, more incentive should be allocated for SMEs. One example is Klimatklivet for Non-public charging by Swedish Government. A small company is entitled to provide a maximum of 50% investment support, which is often the break-even point, but large enterprises can only receive 20% support under de minimis rules.

5.3. Opportunities

The transition towards electrified logistics and the deployment of MCS presents a variety of opportunities for stakeholders across the ecosystem. As technological advances and innovative business models converge, the sector is adapting to make the transition efficient, sustainable and economically viable.

This chapter will explore the opportunities observed in the ecosystem, including potential electrifiable routes from the end-user point of view, existing use cases for MCS infrastructure and trends towards charging infrastructure expansion, collaboration among stakeholders, and emerging complementary services.

5.3.1. Milestones towards long-haul electrification

As mentioned earlier on chapter 5.1.1, most of the logistics carriers interviewed are still on early electrification phase where typically the electrified missions are still limited to regular, predictable, and relatively short distance (< 300 km). As the truck driving range increases and public charging network expands, it opens opportunities for carriers to expand their BETs coverage to longer distance routes. The interview questions covered a specific section aimed at grasping the strategies pursued by logistics stakeholders who are more advanced in electrification to increase the electrification rate of their logistics missions. The following chapter elaborates on the milestones of the LSP's electrification strategies, starting from the routes with the greatest potential for development (and also the lowest complexity). Complexity here is measured by the number of nodes (stops) and the degree of coordination required between origin and destination. Below is a list of representative logistics missions described by respondents when asked "What type of logistics missions you BEV carry out?" and "What mission are still executed with diesel truck?" A visual representation of these can be found in Figure 4: Illustration of charging events on different logistics missions.

1. A to B (single Origin-Destination or O/D):
   These missions move goods from one origin to one destination. Depending on the type of stakeholder the origin, which is generally a private facility, can be a depot (in case of carriers and LSPs) or a warehouse/ distribution center/production facility (in case of retailers and shippers). these missions are often repetitive and well characterized in terms of load and distance (e.g. Full Truckload - FTL flows), which makes energy consumption predictable and allows charging to be organised at one or both ends of the route at private locations.

2. Milk-run/Last-mile (single origin and multiple destinations):

Another mission type mentioned by respondents is characterized by “closed-loop” patterns or milk-runs. In this case the truck repeatedly runs between several geographically clustered origins and destinations, with multiple stops on each shift. Industrial hotspots or logistics clusters are an ideal starting or end point due to concentrated flows. These types of missions are typically regional and city distribution and are especially relevant for e-commerce and couriers’ missions. In addition, facilities located around major ports are another prime candidate for electrification, as the port environment is also moving towards electrification (cold ironing) driven by national policies and incentives. Charging can be fulfilled at the depot/private site and be combined with opportunity charging while loading or unloading at the facilities named above.

3. Hub-and-Spoke (multiple O/D connected through a central hub)
   In these missions’ goods are transported from multiple origins to a central hub for sorting, then distributed to multiple destinations. These types of missions are likely Less-Than-Truckload (LTL) or cross-docking and have been mentioned by shippers and retailers as part of their inbound (supplier → production/warehouse) and outbound (production/warehouse → retailer) flows. Some actors reported working on double-shifts, covering up to 800 km, where the truck returns to the main hub or depot and change driver to resume the rest of the transport tasks for the day. During the break between driver’s shifts (mentioned as up to 2 hours), the truck can be charged at the depot at higher power levels. A research institute also pointed out that some regional trucks operate with multiple driving shifts each day, a fact supported by a retailer running milk-run tours with two shifts. Although logistics nodes are closer together, the constant flow of operations demands effective charging strategies, as loading and unloading schedules are tight and have limited time windows.

4. Cross-border/ multimodal (O/D across different countries and transport modes):
   In this mission type origin and destination are in different countries and can also be distant more than 500 km. According to a Swedish logistics company, international cross-border routes (also defined as line-haul) are being carried out with two drivers, which can either be both on board and switch at a specific location en-route. Like the other missions they can presumably begin and end at depots, while passing through a known charging location enabling en-route fast charging or, in some cases, overnight charging at truck parking and safe and secure parking facilities. International routes can also be covered through different transport modes of course (e.g., sea → rail → road). In these cases, they are managed by 3PL or 4PL providers which oversee the entire supply chain, acting as a single point of contact also for the road carriers. Often these flows will require an integrated port/terminal charging infrastructure for electric trucks handling the "first/last mile" of the international leg.

5. Ad-hoc/irregular routes (dynamic O/D)
   Unlike the other first four missions, these tasks do not follow a fixed schedule or a repetitive route through known locations. They are triggered by on-spot demands or one-off "special projects", usually requested through online freight exchange marketplaces. This step is the final towards the electrification of the entire network. In these irregular and unplanned routes charging infrastructure is unknown. This is where high-power charging play important role on enabling such missions through emergency top-ups (intended as not planned) at public stations. Of course, to be able to electrify the full network, information on available infrastructure, power and real-time booking capabilities should be available to the dispatcher and driver at all times.

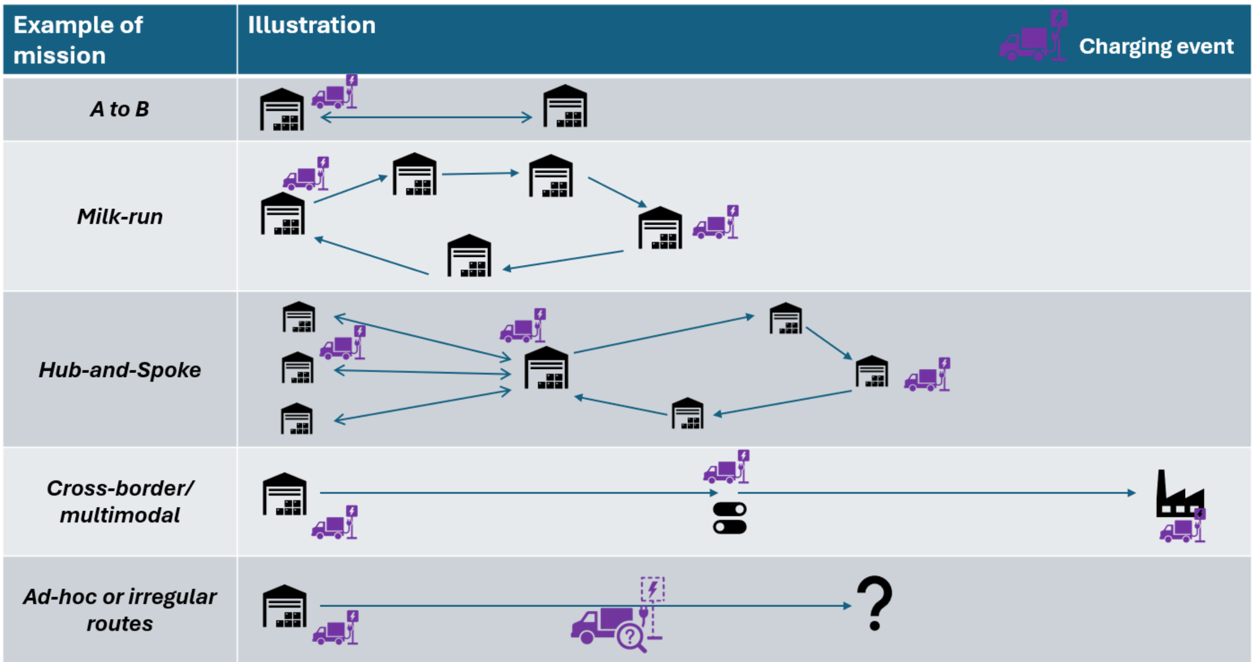


Figure 4: Illustration of charging events on different logistics missions

All routes, including long-haul ones, presumably begin and end at depots or at private logistics sites. But it is also true that SMEs (i.e. carriers with a few up to a dozen trucks), which represent the majority (89%) of road transport companies in Europe[8], do not have the financial capabilities to invest in charging infrastructure at their recovery site. Some respondents mentioned subcontracting the majority of their missions to small owners (referred to the "one person one truck" model), that are used to bring the truck home after their shift because it is their main vehicle. For these types of carriers high-power charging at their client's depot or at a public station before departing is the only solution.

5.3.2.Integration of MCS into different charging strategies

Based on the logistics missions described above, each charging location is described below to discuss its relevance to MCS deployment.

i. Depot charging (overnight and not):

The initial user requirements (UR1) highlight that competitive TCO relies mainly on overnight depot charging. One interviewee stated that depot charging is prioritized due to the lower cost: "We reschedule sessions, so vehicles charge at the right time and only up to the required state of charge to complete the tour and return to the depot, as depot charging is always cheaper." It shows that predictability of energy requirements for each BET is absolutely essential to determine how public charging infrastructure can enable a competitive TCO of electrified missions. The driver for MCS adoption at private sites is motivated by the lack of space for chargers to ensure overnight charging for big fleets. Two logistics providers who do not have space availability to install chargers at their premises are in

[8] IRU, Ti, UPPLY, The European Road Freight Rate Benchmark – Q4 2024, 03/02/2025. Available at: https://www.iru.org/intelligence/road-transport-intelligence/european-road-freight-rate-development-benchmark-q4-2024?token=db7b1f6edd6a521b50d83e1323359c37-1768507326-529f91e4

fact considering buying land or partnering up with parking operators or site owners to co-invest in infrastructure. Only one retailer mentioned that currently a 1.2 MW MCS has been installed at their private depot as part of a pilot study, with interest in being the front runner once the technology is prominent. Some carriers have limited grid capacity at their depots and may need third-party or semi-public charging locations.

ii. Destination charging:
Charging at destinations acts as a secondary location that supplements primary depot charging. To support this approach, private sites may permit access, becoming semi-public, to selected external carriers as needed, without disrupting core operations (UR18 – MCS deployment at private depots and logistics sites). This category of charging infrastructure offers untapped potential through idle charging slots, which can be made available to third parties through booking systems. Such utilization can enhance asset efficiency and help offset infrastructure costs, while providing convenient charging options for smaller carriers lacking their own depots. One eMSP noted that private owners have shown interest in joining broader charging networks. Additionally, a major retailer indicated willingness to co-invest in shared facilities, highlighting promising market prospects. Nevertheless, monetizing idle capacity requires site owners to undertake specific preparations. Primarily, an integrated power allocation and booking system is necessary to prevent scheduling conflicts. There are concerns among site owners regarding potential power distribution issues between internal fleets and external users, which could pose operational risks. From a regulatory perspective, many depot owners are reluctant to open sites to external carriers, as doing so reclassifies the facility from private to commercial. This shift necessitates compliance with public charging standards and protocols, including communication and interoperability requirements, leading to increased complexity and costs. Even offering access for few hours per day can impose these obligations, making it feel like a full business operation rather than a simple asset sharing arrangement.

As listed on the requirements list for logistics facility operators, infrastructure deployment on greenfield locations should prepare the site for future high-power equipment or called “MCS-ready” sites although investment may be postponed until utilization reach break-even point (LSR3 - Depot and private-site charging). MCS developments in these settings may begin in locations with higher utilization potential as mentioned in LSR4 *“… targeted to sites use cases where short dwell times justify megawatt-level investment, while overnight and long dwell time charging can rely on lower-power solutions”.*

iii. En-route charging:

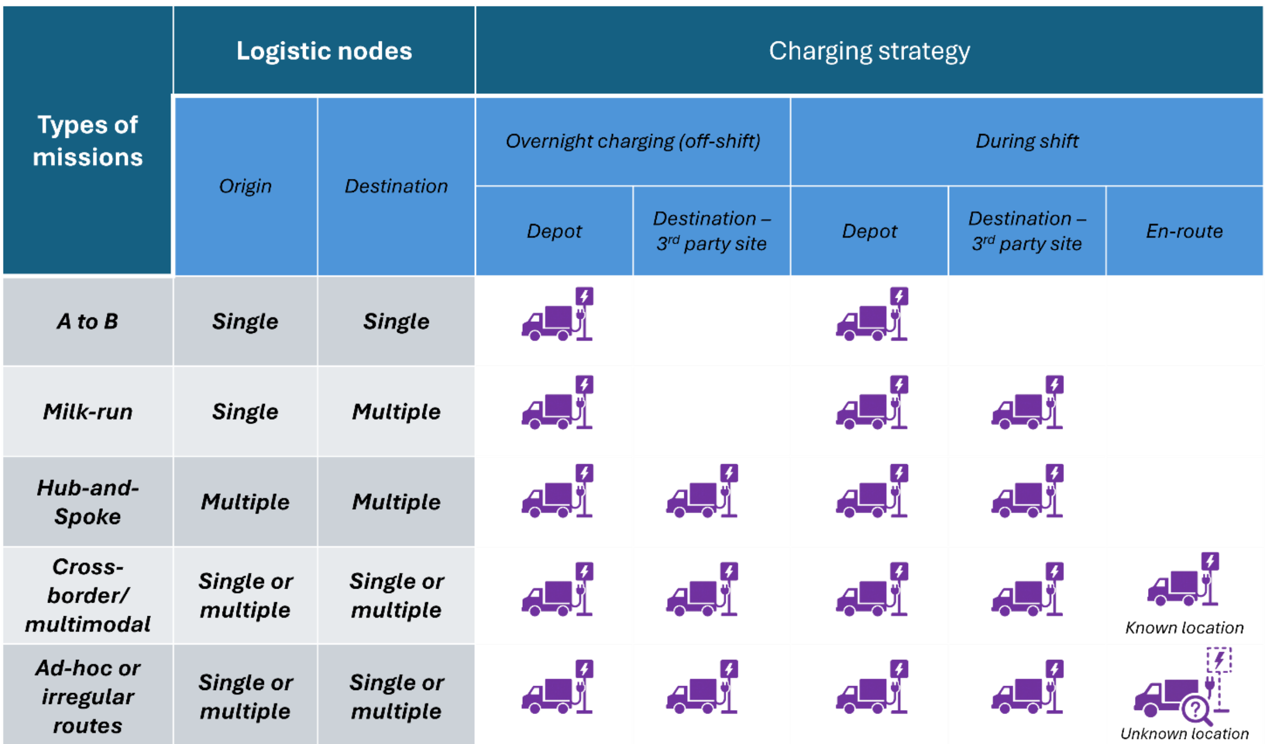
Charging along corridors, whether on public or semi-public locations, supports cross-border and long-range logistics operations. Users prefer reliable and predictable charging events that can be easily incorporated into their route planning. Requirements such as real-time charger status and transparent pricing (UR13) are important, and a reservation system should be available to ensure predictability and plan efficiently the missions (UR14).
The interviews’ analysis shows that there are infrastructure gaps that prevent fleet owners and carriers from electrifying certain logistics routes. The most promising sites for early MCS infrastructure deployment are logistics clusters and industrial hotspots (like the “Blue Banana”), identified in the user requirements for public corridor charging hubs (LSR4). According to CPOs responses, the choice on whether to deploy MCS at a specific location (being it a green field or brown field) is secondary to a number of different factors:

- Traffic flows and existing truck volumes are the dominant criteria. Several operators will only build where they already see or control sufficient flows, rather than extrapolating from diesel traffic patterns.

- Logistics nodes at maximum 3 kilometres off TEN-T exits are often preferred over direct motorway locations, because they host clustered demand and can offer lower land costs. Long-haul operators are seen as willing to detour slightly if charging is cheaper and more reliable.
- Proximity to other power-intensive facilities: this location offers the potential to aggregate grid power requests, though it may also introduce competition for resources.
- Existing power generation facilities on site: co-location with RES is nice to have, while it implies the need to invest on battery energy storage.
- Availability of services and amenities in the surrounding area: existing amenities in the surroundings can enhance offerings to truck operators, while the site's established role as a truck stop increases visibility and driver familiarity.

Further expansion along TEN-T corridors and other major highways is seen as key to enabling cross-border and long-distance transport. Stakeholders, especially gas station operators, have started offering more truck charging options in service areas. However, developing these facilities is challenging due to complex landownership and concession agreements at highway rest stops. Meanwhile, CPOs are growing their networks near highway entry and exit ramps, just off the main roads to comply with AFIR and secure utilization.
Most of the CPOs replied that they are planning to retain the hybrid-hub concepts (CCS + MCS). As in requirement CR8 CPOs are advised to adopt flexible, mixed-use and scalable layouts to accommodate gradual expansion. Through this design approach, CPOs may postpone the MCS addition later without requiring full redesign and significant civil works.

As explained in chapter **Error! Reference source not found.**, the electrification strategy often begins with predictable and shorter routes. Along with the development of charging infrastructure, the BET fleets can cover more complex mission until full network electrification can be reached. Figure 5 illustrates the diversified charging strategy to fulfil the needs of different types of missions, which must be aligned with the grid capacity available along that specific route.



Types of missions	Logistic nodes		Charging strategy				
			Overnight charging (off-shift)		*During shift*		
	Origin	*Destination*	*Depot*	*Destination – 3rd party site*	*Depot*	*Destination – 3rd party site*	*En-route*
A to B	***Single***	***Single***					
Milk-run	***Single***	***Multiple***					
Hub-and-Spoke	***Multiple***	***Multiple***					
Cross-border/ multimodal	***Single or multiple***	***Single or multiple***					*Known location*
Ad-hoc or irregular routes	***Single or multiple***	***Single or multiple***					*Unknown location*

Figure 5: Types of logistics missions and related charging strategies

The figure illustrates that a hybrid charging strategy, combining both charging location and timing, offers the most efficient path to electrification and aligns well with stakeholder requirements. Point-to-point missions (A to B) rely primarily on depot charging, which serves as the baseline scenario. As the diagram descends, it shows that the more complex the logistics mission, the more sophisticated the charging needs to become:

- For carriers operating milk-run routes, destination charging becomes necessary to support the extended duty cycle.
- In a hub-and-spoke model, there is a possibility to charge overnight at the destination, especially in scenarios such as driver double-shifts, where the vehicle remains on-site between rotations.
- In cross-border operations, trucks need to recharge en-route, most likely at public hubs or semi-public facilities such as safe and secure parking areas.
- For highly flexible or ad-hoc missions, charging events become unplanned, requiring the route planner to dynamically locate available chargers along the route while taking into account the truck's state of charge (SoC), expected travel time, and remaining distance.

5.3.3. Reservation: How it enhances logistics efficiency

Truck charging reservation system will help to increase the reliability of public charging, especially for long-haul trucks arriving at new hubs. Without reservation, drivers will face unpredictability in availability and power level. For scheduled operation, pre-booking slots ensures alignment with driver rest times and optimise route planning. The benefit is extended beyond user-side, as energy supplier and charging operator have expressed the role of reservation on increasing the charging hub's utilization, with one stakeholder reported a potential improvement of 50%.

Early booking can offer advantages, especially if the energy management system at the charging location is sophisticated. Advanced reservation systems could include booking power and energy, not just time slots, to optimize energy procurement and cost. In addition, some CPOs see reservation as a way to monetise idle time by offering unused slots to third parties. Furthermore, the system will be integrated with queueing and dynamic pricing models.

For early reservation model, the system can adopt discrete model with static booking placed on a fixed time interval. For example, the CPOs provide discrete time interval like 15, 30, 45 or 60 minutes which can be reserve since X days in advance. To address problem of inaccurate arrival time, a discussion with eMSP agreed on 15 minutes as the base slot length with buffer time allocated before and after to booking to avoid overbooking. While this solution seems practical, another eMSP criticized this approach as unsustainable because as the demand of truck charging increase, the reservation should follow dynamic booking system as truck's actual arriving time is subject to change especially due to unpredictable traffic. Adding vehicle's telematics data is essential for scalability and efficiency.

To realize a dynamic booking system, the technology providers emphasised the need of data integration especially from vehicle side. The essential data include truck model, battery size, SoC, expected power demand, and even trailer details for accurate slot allocation. Future systems should pull this data directly from the truck on-board systems, reason why many OEMs are developing in-house EV-customized routing and booking systems. All together this information will allow synchronization between charging slot and power allocation. In the case of mixed-fleet hubs, it is essential also to determine which vehicle should be prioritized to charge with MCS.

5.3.4. Complementary services

Stakeholders described complementary services, intended as grid services and arbitrage, as a way to improve the economics of charging sites by turning energy management into an operational asset. In practice, the interest from logistics companies rarely start from ancillary service revenues themselves. The immediate driver for looking into this topic is cost and risk reduction as more predictable charging strategy reduces exposure to volatile electricity prices and grid constraints.

Several interviewees (8 out of 14) from the end-user cluster highlighted that a positive business case for battery electric trucks is strongly linked to combining charging infrastructure with onsite renewable generation, battery systems, and an energy management system. One logistics operator explained that the business case can work when smart charging is used, using solar production and storage systems to charge at the lowest energy price, supported by an energy management system that decides when and how charging should occur. BESS are reportedly an interesting part of the business case because they enable participation in grid balancing markets, creating additional revenue streams. This is particularly relevant as renewable penetration increases and grid fluctuations become more frequent. According to one respondent in markets like the Netherlands, companies can earn significant revenue from flexibility services, especially with high-power capabilities. In this context, stationary batteries were recognised as technically available, but still perceived as too expensive to be a default solution today. Beyond cost optimisation, some stakeholders acknowledged that flexibility and grid services could become a relevant revenue stream, but typically as a second step after owning and “controlling” electric operations. One operator stated that providing grid services is not a current goal, even though they already deployed sizeable battery systems, because they prioritise operational reliability and cost control first. They also noted that participation in such schemes can add permitting and technical requirements which can slow down implementation if rules and approvals are not clear. Logistics companies are waiting for regulatory clarity and smoother permitting for onsite battery storage and other flexibility assets, so that storage can be deployed as part of the charging strategy rather than treated as a “special” project. They also highlighted the need for grid operators to offer flexible connections and clearer processes to participate in flexibility and ancillary service markets, so that charging hubs can evolve.

From a CPO perspective, flexibility markets are viewed as a way to strengthen business cases for high-power charging hubs, especially given early low utilisation and high CAPEX. Battery storage is considered essential to compensate for weak grid connections and to participate in ancillary services. Some site layout concepts from 3 CPOs reflect a staged approach, where electrical equipment is designed in a compact way and physical space is reserved for future stationary batteries, once costs drop or market conditions make storage more attractive. No respondents is looking yet into second-life applications of used batteries to turn them into BESS.

Bidirectional charging and broader vehicle to grid (V2G) concepts were not a dominant theme in the interviews at this stage.This is not surprising as the majority of OEMs have reported that their vehicles are not yet V2G-capable. OEMs have not prioritised bidirectional functionality because compared to buses the value is less clear because trucks need to remain charged for next routes. According to an electricity producer and supplier, passenger cars already participate in V2G pilots, and the potential for trucks is significant due to their much larger batteries. However, this is expected only in the long term (5–10 years), mainly due to regulatory challenges (lack of clear policy on energy ownership and revenue distribution) rather than technical limitations, which are still mentioned i.e. concerns about battery degradation and warranty implications.

5.4. Future outlook

In the last section of the interview, stakeholders explained their vision on electrification pathways towards net-zero emissions target.

5.4.1. Alternative low-emission technologies

Most respondents agreed that other alternative technologies, such as hydrogen, biofuels, and battery swapping, will become complementary to electrification and stationary charging. Each technology has different characteristics that bring advantages for certain use cases. From the user side, a few are also considering other zero-emission vehicles as part of their fleet composition, though BET is widely seen as the backbone of decarbonisation.

Diverse opinions on the future of hydrogen have been expressed by the interviewee. Some respondents believe that the hydrogen refuelling station infrastructure is lacking behind electric charging networks, therefore its development will most likely be slower. Others have pointed out that fuel cell trucks are suitable in specific conditions where BET reached its payload and range limit. A logistic carrier mentioned FCEV as part of their hybrid approaches. Hydrogen is seen as a more reliable source of energy for long-haul missions in the future. This is aligned with the opinion from CPOs who view hydrogen as complementary. CPOs will remain focused on high-power charging as the primary solution for long-haul electrification.

None of the respondents have experience in battery swapping, while some are putting interest in how technology can bring sustainability. A remarkable statement from our respondents, battery swapping may disrupt MCS deployments because it provides quick energy recharge. However, most respondents found that to enable efficient battery swapping network, it requires collaboration between OEM to standardize battery pack configurations. Moreover, another issue emerges from environmental side, the battery end-life scenario. Therefore, it is less likely to be prominent in the context of electric trucking in Europe.

Meanwhile, biofuels have been adopted as transitional phase from the conventional diesel truck to electrification. Few respondents mentioned hydrotreated vegetable oil (HVO) as common biofuels currently used, other options include liquified biogas and biodiesel depending on the availability of the fuel on each region. The existence of biofuels depends on each organization's milestone to achieve zero-emission transport, ranging from 2030 to 2040. For example, a major retailer in Nordics aims to fully electrify their fleet by 2026, while offsetting the target for their subcontractor within 3-4 years. To gradually reduce the carbon footprint, the company combines electrification with LBG (liquefied biogas) since the country has substantial local biogas production from waste.

5.4.2. How the future of CCS and MCS looks like

In the final section of the interview, all participants were asked: "Will MCS become the dominant standard for truck charging, or will CCS continue to evolve and remain sufficient?" The most common replies are summarized in Figure 6:

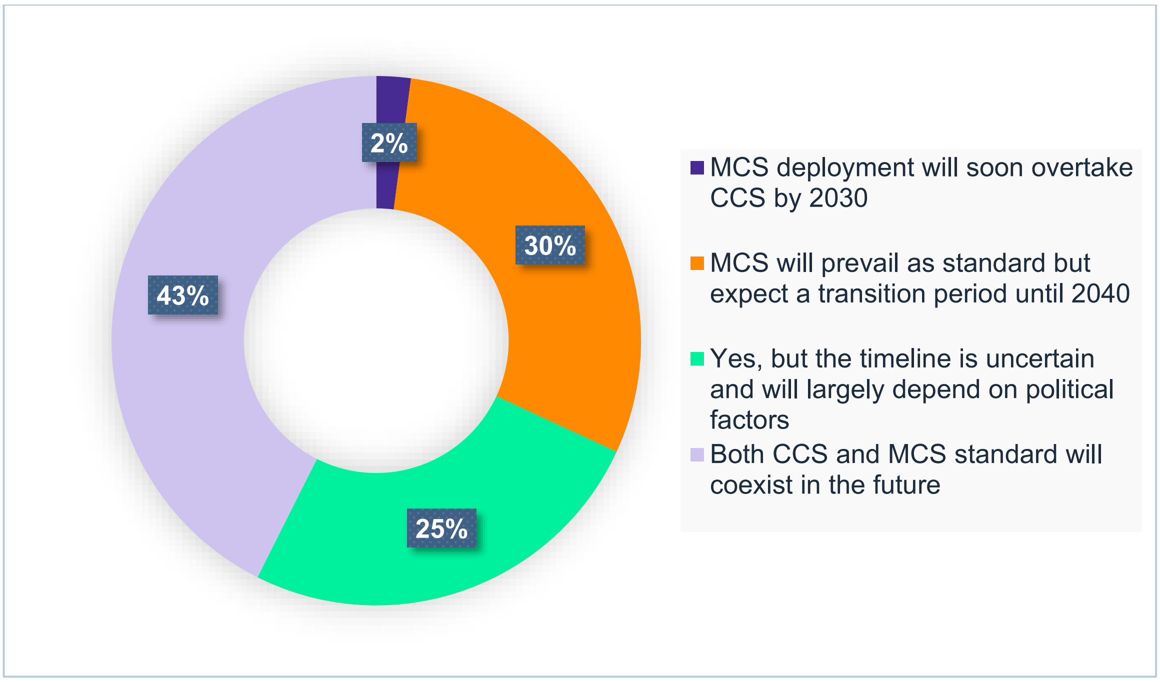


Figure 6: Respondents' replies on whether MCS is going to become the only standard for trucks

Truck OEMs believe that CCS and MCS will coexist in the near term. Future trucks will need both CCS and MCS connectors for several years. The main reason is that MCS infrastructure will not be fully deployed immediately, and CCS remains widely available. OEMs expect a transition phase where dual compatibility is essential for operational flexibility. Customers may prefer CCS for lower cost, slower charging when time allows, while MCS will be used for fast charging during short breaks. This dual approach helps fleets manage costs and adapt to varying infrastructure availability.

These arguments align with how CPOs see the market. Most CPOs emphasize that CCS will continue to play a key role for several years. Mixed-use sites are expected, with CCS serving existing fleets and regional traffic while MCS gradually scales up for long-haul needs. In addition, many trucks and passenger vehicles still rely on CCS, and OEMs will keep selling CCS-equipped trucks for several years. In relation to public charging, some CPOs adopt a cautious approach, maintaining CCS until market demand for MCS justifies investment. While few plan more aggressive plan to build MCS-only hubs in the future, such as “we strongly believe MCS is the right standard to support long haul trucking, while CCS is mostly a passenger vehicle technology, perhaps suitable for depot use cases”. How quickly CCS will be phased out depends on factors such as pricing and grid fee structures. Another factor is the location of charging hubs; CCS is expected to remain at regional hubs and depots, while MCS will dominate high-traffic corridors.

5.4.3. Innovations needed to scale-up MCS deployment

The response reflect that stakeholders do not perceive “innovation” limited to technical aspects. Many answers converged on a combined need for policy adjustments, business model evolutions, and practical system integration that reduces operational inefficiencies and the investment risk.

The first cluster of innovation is policy and market design, as several respondents believe competitiveness to diesel trucks will be influenced by regulatory cost drivers rather than equipment alone. One forwarder stressed the relevance of toll exemptions and the importance of weight and dimensions allowances to compensate payload loss due to battery weight. In certain routes, toll advantages combined with a smart charging strategy can make electric operations cheaper than diesel. Another operator placed less emphasis on new technical breakthroughs and more on policy signals that progressively restrict diesel access, such as expanding low emission zones, as a driver that can accelerate electrification and create predictable demand for charging infrastructure. CAPEX grants and operational support for grid costs are essential. Faster permitting and standardized protocols (such as ISO 15118-20 for MCS) are critical enablers. The question of how to allocate subsidies, whether towards vehicles, infrastructure, or lowering operational costs, is central to advancing electrification. Several stakeholders advocate fuel pricing policies that discourage the use of fossil fuels to accelerate the transition to electric vehicles. Extending subsidies to depot charging infrastructure is also mentioned, with public-private partnerships and co-financing models involving energy providers recommended as strategies to address high capital expenditure barriers. Furthermore, energy spot price fluctuation complicates TCO calculation of BET, especially when integrated with renewable sources. In this case, intermediate energy storage will allow operators to take advantage of the cheaper energy price on certain time-window. Ideally, the energy will be kept and released when needed, such that it stabilizes peak grid strain. However, supplying back energy to the grid system still face regulatory challenges and subject to additional cost (e.g., feed-back fees, double taxation when releasing energy abroad, etc.). Therefore, such stationary battery energy storage system (BESS) is more economically attractive than keeping the energy on vehicle's battery, implying that V2G/V2X is acknowledged as promising but still hindered by harmonization of standards across Europe.

A second cluster relates to business model innovation. Electrification requires changes to both business models and operations, not just transport modes. Charging hub cost structures are dominated by high fixed costs, unlike traditional fuel stations where revenue is tied to fuel volume. Megawatt charging involves significant upfront investment, and although operators still pay for electricity and grid fees, most costs depend on power capacity rather than energy delivered. Marginal operating costs are low, but economies of scale only emerge with increased truck demand. To ease early financial burdens, some suggest grid fee reforms like annual subscriptions, but current regulations only allow per-kilowatt-hour pricing.

A third cluster concerns technical and digital integration, where logistics companies asked for solutions that reduce complexity for dispatchers, drivers and site operators. One recurring risk mentioned is fragmentation of payment, booking and planning systems, where each provider develops a separate interface and workflow. Stakeholders warned that a similar fragmentation in booking and scheduling could add significant workload for dispatchers and become a barrier to adoption as utilisation grows.

In response, several interviewees described innovation needs around planning systems, interoperability and data integration, including smart energy management systems that can interoperate with transport management systems, routing and load optimisation tools, and emissions tracking and reporting. Stakeholders consistently highlight the need for high-voltage grid capacity and smart energy management systems to handle megawatt-level loads. This innovation can be complemented by energy storage and load balancing. Several stakeholders stress that MCS should also serve as a communication protocol, enabling seamless integration across brands and regions. MCS should not only be seen as high-power charging but as a communication standard that improves interoperability across brands and regions.

6. STAKEHOLDER VALIDATION WORKSHOP

This chapter elaborates how stakeholder respond to the interview findings and highlights additional insights captured from the interactive polls. It follows the four thematic blocks as presented during the workshop.

6.1. Insights from the interactive session

Block 1. Reactions to status of electrified mission type

The first block revisited the state of play of BE-HDV deployment and the main drivers behind electrification. Interview analysis had shown that BE-HDVs still represent a small share of fleets (roughly around 2% on average across the 14 interviewed logistics actors) and are mostly used in short-range or regional missions, typically in the 120–250 km range with clear return-to-base patterns. The workshop investigates this statistic through a question: "Which types of missions are currently feasible to run on BETs?"

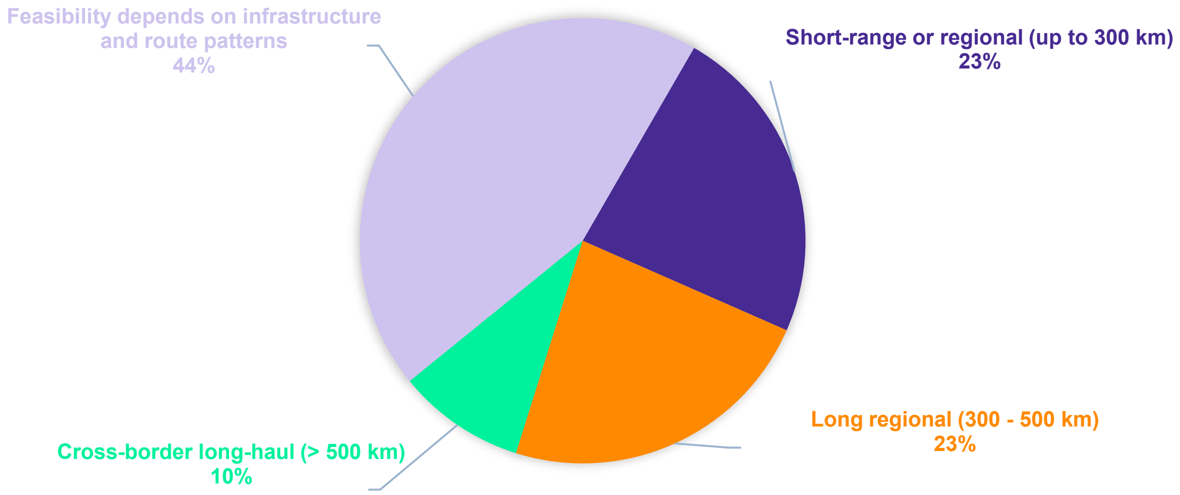


Figure 7: Types of missions currently feasible on BETs

The responses indicate varying levels of readiness for BET adoption, as illustrated in Figure 7. Approximately 23% indicated that short-range or regional missions up to 300 km are feasible, another 23% saw long regional missions between 300 and 500 km as feasible, only 9% selected cross-border long-haul missions above 500 km, and 44% answered that feasibility "depends on infrastructure and route patterns". This result is consistent with interviews findings, where several logistics actors reported that long-haul electrification is not systematically possible and remains highly dependent on mission type, route structure and available charging options.

The discussion continued with an elaboration of the milestones towards long-haul electrification, as formulated in chapter **Error! Reference source not found.**. Referring to the previous poll result indicating that feasibility "…depends on infrastructure and route patterns", it is confirmed that distance is not the sole factor contributing to the complexity of electrifying a specific mission. MCS is expected to serve as a breakthrough solution to overcome limited charging time within complex and time-sensitive truck assignments. Therefore, participants were asked to share their thoughts on the question: "In which types of missions will MCS bring significant value?". the responses, where similar inputs were identified and grouped accordingly.

summarizes the responses, where similar inputs were identified and grouped accordingly.

Mission type	Variable	Freq.	Remarks
Long-haul	Distance	8	*"…for long haul and various destination"* *"…supporting long haul in general (+600km)"*
Longer distance with few stops	Distance and number of stops	2	*"…multi stop"*
Limited truck stop time	Time	5	*"…regardless the distance"* *"…to match driver's break with charging event"*
Double shift driver		2	*"...where driving duration limit is less restricted"*
Autonomous vehicles		1	*"…autonomous 24/7 operations"*
Passing through strategic hub	Types of logistics nodes	3	*e.g. logistic centre, major port area*
Hub to Hub		1	
Heavy cargo/HCV	Weights and dimensions	2	*e.g. cement, mining;*
High energy demand transport		1	*"In the Nordics there are many potential HDV applications with high energy consumption"*
All routes		1	*"MCS plug is superior to CCS in terms of power and communication"*
None		1	*"The price of energy and vehicle is too expensive (TCO), while CCS 600kW will work better as it's already standardised"*

Table 9 Responses on which types of missions would benefit MCS application

The examples provided reflect different variables indicating the potential of MCS when viewed from the logistics mission-type perspective. While extending driving range remains a major factor, other considerations follow, such as the number of stops. Long distance and fewer stops may indicate that a truck has limited opportunities to charge at destination. Time is another relevant variable, particularly when truck stop duration is limited or when charging will be carried out during driver's mandatory break. Another potential use case is double-shift driving to cover longer distances or when the truck returns to base to exchange driver, though the latter is relevant when break duration is very restricted (lower than 1 hour). Some stakeholders also highlighted the types of facilities and areas where the truck passes through as important indicators, as these can signal high potential for MCS utilization in case of low truck turnaround time. Trucks' weight and dimensions were also mentioned, as heavier loads translate into higher energy demand. Specifically, high-capacity vehicles (HCV) were given as an example of very common use case in the Nordics, which are highly dependent on bulk industries (e.g. forestry, metal industry and mining).

A few participants expressed more pronounced opinions. One participant stated that MCS would be beneficial for HD-BEVs missions in general, as it offers improved communication protocols and the ability to deliver higher power. In contrast, another participant argued that the TCO would not be competitive, and once CCS reaches higher power levels (around 600 kW), it would be sufficient.

<u>Block 2. Perceived barriers to long-haul BET expansion and MCS deployment</u>

The second block focused on the barriers to scaling up long-haul BE-HDVs and deploying MCS hubs. A summary of the interview results described in chapter **Error! Reference source not found.** was presented to participants by grouping the most critical bottlenecks into 8 major topics:

1. Grid capacity and energy availability
2. Land acquisition and space constraints
3. Regulatory and permitting

4. Economic and business case
5. Operational constraints
6. Technical challenges
7. Standards and Interoperability
8. Market and adoption uncertainty

A poll then asked participants to rank: “Which factors do you believe most limit the deployment of MCS hubs?” The results clearly confirmed the primacy of grid-related constraints. “Grid capacity and energy availability” obtained the highest average rank at 4.52 out of 5 and was consistently selected as the top barrier. “Business case and ROI limitations” came second with an average of 3.23, followed closely by “market and adoption uncertainty” at 3.19. “Permit and regulatory aspects” scored 2.58, “land acquisition and spatial constraints” 2.03, and “operational constraints of charging hubs” only 0.74. This ranking aligns closely with the interviews: stakeholders see grid access and economics as the critical foundations that must be in place before operational optimisation becomes a real concern.

Participants were then kindly invited to share their experiences and knowledge on best practices for addressing this multi-dimensional problem, even if only tackling one aspect of it.

- Buyer-incentive (CapEx): Bonus-malus scheme[9]
  The bonus-malus system was introduced in Sweden to boost electric-vehicle adoption. It contains two components: the “bonus”, which provides subsidies for the purchase of low-emission vehicles, and the “malus”, which imposes higher vehicle taxes on high-emitting vehicles, thereby making electric vehicles relatively more affordable. The scheme currently applies to small vehicles, including passenger cars, light buses, and small vans, while HDVs benefit from a different subsidy mechanism with similar limitations.

- Opex subsidies: Eurovignette
  To encourage the shift toward zero-emission logistics, the EU’s Eurovignette Directive[10] allows Member States to grant road-toll exemptions for battery-electric vehicles. The scheme is proposed to extend the full exemption for zero-emission heavy-duty vehicles (HDVs) until June 2031. Without this extension, fleet operators would begin paying toll fee, for example at least 25% of regular fee in Germany. Currently, only two countries offer a full exemption, and ten apply reduced rates. Wider implementation across Member States would help narrow the total cost-of-ownership gap between zero-emission and diesel trucks.

- Demand commitment from the transport sector:
  A stakeholder suggested establishing agreement with fleet owners to secure demand certainty, thereby justifying investments in charging infrastructure. This could take the form of guaranteed allocations of truck fleets to electric routes, minimum energy-consumption commitments per period, or similar arrangements. In return, users may benefit from secured power connections and predictable price indexation.

- Grid capacity mapping:

[9] https://clean-energy-islands.ec.europa.eu/countries/sweden/legal/res-transport/subsidy-bonus-malus-system
[10] https://alternative-fuels-observatory.ec.europa.eu/general-information/news/eu-backs-extended-toll-exemption-zero-emission-trucks

The lack of visibility on grid capacity was mentioned repeatedly during the interviews. Having an accessible and up-to-date database would help identify potential charging locations or facilities with high deployment potential. It also opens opportunities for cable pooling, enabling nearby facilities to share grid connections. A study by Atlas Public Policy (2024)[11] in the U.S. examined how hosting-capacity maps support EV-charging developers and equipment providers during infrastructure deployment, concluding *that "…saving EV charging developers and utilities significant time and costs by reducing the number of load study requests needed in areas with capacity constraints."* Although this does not fully resolve grid-connection bottlenecks, it enables the installation of more EV chargers at a lower cost and a faster pace.
The study highlights key information to be included in such maps, including location and voltage of distribution circuits, available capacity of distribution, visual indicators showing capacity ranges across regions, while data is expected to be updated at least every three months.

- Industry benchmark:
  Respondents also mentioned that frontrunners in the sector can serve as valuable references. For example, the European Organisation for Safe and Secure Truck Parking Areas (ESPORG) have launched the Voluntary Green Truck Parking Standard. This new standard builds upon the existing EU Safe and Secure Truck Parking Area (SSTPA) by adding a comprehensive sustainability dimension. It allows parking-area operators to establish, improve, demonstrate, and monitor their contribution to greener, more sustainable freight transport.
  The standard features four levels, each achieved by fulfilling a set of criteria. Initial criteria focus on operational aspects, such as real-time charging availability, charging-speed information, reservation systems, and adequate lighting. Higher-level criteria incorporate sustainability requirements, including installing solar roofs in parking areas and providing emission-intensity information.

Block 3. Opportunities to strengthen the MCS business case

The third block focused on solution-oriented practices, mainly on the opportunities from dynamic reservation systems and innovative solutions to ensure higher charging utilization, as described in Chapter **Error! Reference source not found.**. A rating poll explored whether stakeholders see energy and capacity management as a future bottleneck: "Do you believe that securing both the timeslot and the required energy will become a bigger challenge than the charging infrastructure itself?" The average score was 3.0 out of 5. Around 17% selected 1 (disagree), 22% selected 2, 22% selected 3, 26% selected 4 and 13% selected 5 (fully agree). This distribution suggests a balanced view. Many participants expect that ensuring the right capacity at the right time will become at least as challenging as deploying the physical hardware, while a significant minority still see infrastructure roll-out as the dominant issue.

On the pricing side, a poll asked: "Does it make sense to increase the charging cost for high-power charging, given the fleet dwelling time reduction it provides?" Here, 23% answered "Yes — faster charging justifies a higher price", 54% answered "Maybe — the price should be higher only during peak-demand periods", 12% answered "Maybe — other operational factors also influence the value", and 12% answered "No — pricing should only reflect kWh delivered". The majority view is therefore that high-power and MCS services can translate into higher tariffs, but that this should be linked to peak-demand periods and value delivered, rather

[11] Nicole Lepre, Moe Khatib and Lucy McKenzie (2024) Atlas Public Policy - HOSTING CAPACITY MAPS FOR EV CHARGING, Lessons Learned in Implementing Utility Hosting Capacity Maps to Support Electric Vehicle Charging. Available at: https://www.atlasevhub.com/wp-content/uploads/2024/12/Final-Report-Hosting-Capacity-Maps-for-EV-Charging-1.pdf

than simply attaching a permanent surcharge to power level. This aligns with interviews where users stressed that any premium for faster charging must be justified by actual time savings and reduced fleet size or improved reliability.

The open-text poll on “best practices already solving these issues” provided additional ideas. Participants mentioned OPEX subsidies and road-charging differentiation (e.g. Eurovignette-related measures), ESPORG’s safe and secure parking and “green parking” certification schemes, collaboration and demand-aggregation agreements with the transport sector, and buyer incentive programmes and bonus–malus systems aimed at equalising TCO between diesel and electric options. One respondent also pointed out that, for a given grid connection, MCS can use less land than an equivalent CCS configuration delivering the same total power, which improves the “kilowatt per footprint” ratio at constrained sites.

Block 4. Expectations regarding the future role of MCS and CCS

The final block looked at how participants see the long-term relationship between MCS and CCS and the impact of the two technologies on truck charging hubs design. Participants were first showed the results presented in Chapter **Error! Reference source not found.** on MCS vs CCS issues. The key poll question was: “If both CCS and MCS will remain in the market, which setup do you think will dominate truck charging hub design?” The results were very clear: 70% of respondents expect that “hybrid hubs providing both CCS and MCS, with flexible ratios” will dominate. A further 11% foresee “hubs with CCS as the primary option, offering MCS only on request”, and 19% foresee “hubs with MCS as the primary option, offering CCS only on request”. No respondent selected “dedicated hubs (MCS-only or CCS-only) serving different needs” as the likely dominant configuration. This outcome strongly supports the interview-based conclusion that CCS and MCS will coexist for a long time and that flexibility at site level will be crucial. Participants generally view MCS as essential for specific use cases with very high energy demand, tight schedules and short dwell times (for example two-driver operations, time-critical long-haul, operations that must align 45-minute breaks with charging), but do not expect it to replace CCS across completely. During the transition phase (mentioned by OEMs as lasting until approximately 2040) both plugs will be equipped on the latest truck models. CCS will likely remain as the main standard for rigid trucks and vans and used for overnight charging in private and public sites, especially as CCS hardware itself moves towards 800–1000 kW capabilities. Hubs must therefore be designed to host both technologies, with the relative shares adapting over time as fleets and use cases evolve.

When this poll result is combined with the earlier confidence rating (average 3.7/5 for MCS readiness by 2030), a consistent picture emerges. Stakeholders expect significant progress on MCS infrastructure within the next decade, but they see it as part of a broader, mixed-technology landscape rather than as a single dominant solution.

6.2. Next steps

To conclude the session, the team highlighted that the process of presenting and discussing results will remain ongoing, with a focus on engaging stakeholders at several major industry events and conferences over the coming year:

- In person at the ZEFES Symposium in Zeebrugge (25th February)
- In person at the ITS Congress in Istanbul (April 2026)
- In person at the Green Mobility Exchange in Amsterdam (May 2026)
- In person at the TRA 2026 in Budapest (May 2026)
- Online in September with US stakeholders

All interested parties were encouraged to participate and contribute to these in-person gatherings, which will serve as key platforms for knowledge exchange, collaboration and networking. Attendance at these events will offer stakeholders the opportunity to delve deeper into the findings, share insights, and help shape the next steps for the project.

7. CONCLUSIONS

The stakeholder interviews confirm that MCS is broadly perceived as a necessary enabler for electrifying the most demanding long haul freight segments, but also as a technology whose initial market is narrow and highly sensitive to business case conditions. The interviews reinforce that early adoption is constrained less by a single technical barrier and more by the interdependent effect of grid connection timelines, uncertain utilisation, operational integration challenges, and fragmented digital and commercial interfaces.

Across stakeholder groups, a consistent message is that viability depends on aligning high power charging with real operations. Actors are willing to consider MCS corridors and shared hubs when they can rely on predictable access, manageable waiting times, and booking and billing processes that do not add excessive administrative work. In parallel, many fleet operators continue to prioritise depot and private site charging where feasible, since control of charging conditions, energy sourcing, and dwell time reduces risk while offering lower and more predictable cost. The business case remains the central condition for scaling beyond pilots. Stakeholders emphasised that the cost of vehicles, infrastructure, grid connections, and energy must converge toward diesel competitiveness, and that uncertainty on electricity prices, grid fees, and long-term policy signals makes planning difficult. Policy measures that directly affect operating costs, such as toll exemptions and weight directives, were described as immediate levers to support competitiveness during the transition period.

On the supply side, the interviews highlight that charging hubs will need to evolve into energy managed assets. In the near term, stakeholders see the greatest value in managed charging combined with on-site renewables and battery storage, primarily to reduce energy costs and to mitigate grid constraints. Flexibility and grid services are seen as a future opportunity, but one that requires clearer market rules and permitting that do not compromise operational reliability.

The validation workshop confirmed that the vision of MACBETH is aligned with the current state of BE-HDV deployment and stakeholder expectations on MCS. The challenges on deploying and operating charging hubs highlighted how the two MACBETH demonstration site should focus on. Across clusters, participants recognised that long-haul electrification is still at an early stage, with more than 90% plan to expand the number of BET in the next five years to 30–50% of total fleets or even full electrification by 2030. Both situation, low electrified fleet penetration rate and strong near-term growth plans confirms that the project intervene at a critical moment, where lessons from early deployments can shape the wider European rollout.

High-power public charging was seen as essential to serve logistic missions with tight schedules, complex routing and limited dwell times, especially for long regional and cross-border corridors. In this context, MCS is perceived as a critical enabler for this energy-demanding long-haul, while CCS continues to cover wider application. For the MACBETH project, this highlights the importance of designing demonstration hubs that simulate energy allocation between CCS and MCS. Features such as advanced power management and reservation system will improve business cases viability even before truck charging demand is high. On spatial dimension, some critical site design emerged including truck-specific geometries, clear circulation patterns, integration with existing logistics flow, and high security levels, especially at nodes where charging event will be conducted during driver’s break.

A second set of takeaways concerns the digital and operational layer. The workshop confirmed strong interest in reservation and capacity-booking systems but also exposed the complexity of making it work at scale. Stakeholders stressed that simple time-slot bookings are not sufficient once truck volumes grow and that dynamic systems will be needed, integrating telematics data such as state of charge, ETA, planned stop duration and required energy.

For MACBETH, these findings confirm the importance of focusing pilot design and tool development on operational certainty, interoperability and proper grid planning. The deliverable provides a consolidated view of needs and challenges that will directly inform the definition of pilot requirements and the selection of deployment pathways to be validated in the Swedish and Belgian demonstration environments.

REFERENCES

References can be found at footnote in the related pages.

ANNEX I – INTERVIEW PROTOCOL

Notes for the interviewer

After filling in the general information on the interviewee, please proceed with the following:
Brief explanation of MACBETH project purpose and objectives, confidentiality of data.
Confirm stakeholder category and organizational role, level of expertise of the interviewee.
Ask to provide general information on their company.

The purpose of this section is to understand the interviewee's perspective on MCS deployment in logistics and gather insights on their role, experience and expectations. Given that we are engaging with a diverse set of stakeholders, the questions are designed to be flexible and applicable to different backgrounds. These questions are not meant to be technical but rather to frame the interviewee involvement and perspective on the transition towards BETs and the MCS charging ecosystem.

You should get insights into their current and future plans for infrastructure deployment, as well as experience in relation to grid connection requests for high-power charging infrastructure.

NB: in case the interviewee does not have any experience with MCS technology all questions related to that should be referred to CCS only. In each section questions are specifically divided based on the experience level in relation to MCS or truck charging.

To be presented at the beginning of the interview

(Show MACBETH_general presentation.pptx while presenting the project)

Thank you for participating in this semi-structured interview as part of the **MACBETH project (Megawatt Charging for Battery Electric Trucks)**, funded under Horizon Europe. MACBETH aims to support the deployment and scale-up of Megawatt Charging Systems (MCS) in logistics to electrify long-haul freight, through developing and showcasing multipoint MCS hubs combined with tools facilitating the scale-up. MACBETH intends to address many of the technical, social, and economic challenges of mass deployment of MCS by setting up two demonstration sites, one in Sweden and one in the Belgium to address various operational conditions, users' needs, and business cases.

To ensure that MACBETH innovations reflect real-world needs and operations of the complex charging ecosystem, we are aiming at identifying:
Current technical, operational, infrastructure, economic, and regulatory challenges
Stakeholder-specific needs and expectations for successful MCS adoption
Concrete use-cases and deployment scenarios for MCS

This interview forms part of **Task 2.1 "Identification of stakeholder needs and challenges towards deployment and use of MCS"**, which will gather insights from key actors across the logistics, energy, infrastructure, research and policy ecosystems.

Contributions will be anonymized and shared aggregated, directly informing the project's roadmap and policy recommendations for the rollout of MCS. The interview will follow a structured format and focus on challenges, needs, use-cases, and future outlook in relation to MCS technology.

NB: here, MCS (Megawatt Charging System) refers to a set of standards for the vehicle, for the cable, the communication, the charger. CCS on the other hand is the technology and standard that was developed for *light-duty vehicles; while it is suitable for heavy-duty ones, it is not considered optimal for long-haul mission types. However, MCS is suitable to deliver both high (i.e. megawatt-level) and low power recharging.*

ANNEX II – LSP INTERVIEW TEMPLATE

LSP template and example of template structure can be found below:

Introductory questions:

In which European countries or regions does your company operate?
How large is your fleet? Is your company currently operating battery-electric truck?
How many battery-electric trucks (BETs) do you currently operate? *(as a percentage of the total fleet)*
Do you also own/lease and operate logistics sites (warehouses, terminals, distribution centers)
If yes: Are renewable electricity production assets (PV panels and wind turbines) installed at your logistic sites?

What is your perspective on the current level of electrification in long-haul trucking and in deployment of high-power charging infrastructure? How well is the infrastructure coverage in your region?
What trends do you observe? Is the adoption of BETs in long-haul mission increasing?

If the LSP already operates battery-electric trucks (BEVs):
What motivated your company to start using BETs (e.g. sustainability goals, client demand, regulation)?
How many years has your company been operating BET?
Does your depot have an on-site charging infrastructure?
If it also own logistics sites: Did your company also deploy charging infrastructure at your logistics facilities or are they in the process of being installed?

If the LSP does not operate BEVs yet:
Has your company considered adopting battery-electric trucks?
If yes, what is your timeline and how significant the impact would be on your logistics missions?
If no, what are the main reasons?

Current challenges with MCS deployment (10 minutes)

Objective: Understand the barriers private charger deployment and use of MCS from an LSP perspective.

If the LSP already operates battery-electric trucks (BEVs):
If the LSP has installed private charging (on-site or depot):

What is the total charging capacity?
What were the main difficulties when installing the infrastructure?
Will the availability of grid capacity be a limiting factor in the future?
What do you perceive as the key economic risks of investing in on-site high-power charging?
Where does the EV charging stations locate at your facility, inside the gated area, along the perimeter, or outside the secured zone?
Is the charging point accessible to the public or reserved only for your clients?
If public:
How can non-clients/general customers reserve a charging spot? Do you collaborate with any eMSPs?
If yes: how far in advance can it be reserved?
If reserved for own fleet and/or clients:
What is the current saturation of the charging spots? Does the capacity meet actual demand?
What would be the impact on your operations if the charger were opened to the public?

(if not, skip to the following questions)
In relation to public charging infrastructure, what are the main limitations you experienced (e.g. speed, location, availability, design/layout, price/cost vs depot charging)?
Have you received complaints from your drivers about issues or disturbances when using public charging stations?
What logistic model adaptations (e.g., route changes, driver shifts) is necessary to integrate BETs compared to diesel operations?

If the LSP does not operate BEVs yet:

What barriers prevent the deployment of on-site charger at your premises (e.g. cost, land availability, grid connection, uncertainty of ROI)?
Do you anticipate space or grid power limitations at your depots or rest points?
How concerned are you about the availability and standardization of trucks public charging infrastructure?

Stakeholder needs in relation to MCS (10 minutes)

Objective: Capture concrete stakeholder requirements, expectations, and supporting conditions.

If the LSP already operates BEVs:
How do you integrate the charging operation in your route planning?
Do drivers decide the break/charging location themselves or the planner/dispatcher?
If by the planner/ dispatcher: How far in advance do they typically plan charging schedules?
Are the charging options indicated in the routing software? Is this an in-house develop or external software?
If by the drivers: How far in advance do you typically plan charging schedules?
Which tools or software, are they using to find location?
Which information coming from the public charger would help you plan your route efficiently? (e.g. real-time charger availability, price-transparency, expected waiting/charging time, etc.)
Which payment methods do you use at public charging stations?
Which aspects of the layout are critical in designing a convenient public charging station? (e.g. space, turning radius, waiting bay, vehicle flow)
Macbeth aims to develop and test mixed-use/flexible charging hubs serving both passenger cars and trucks in the same lanes/bays depending on traffic flows pattern (e.g. weekdays vs weekend). What do you think about this concept and how will it impact the station layout, accessibility, energy prices, safety and reliability of charging?

If the LSP does not operate BEVs yet:

What would make BEVs and depot charging infrastructure investments more attractive or feasible for your company (e.g. subsidies, tax benefits, pilot projects, clearer ROI)?

Would you consider participating in shared infrastructure models or public-private partnerships? Are willing to pay a premium for MCS use?

Use-Cases and opportunities (10 minutes)

Objective: Identify practical MCS deployment scenarios and areas with immediate potential.

If the LSP already operates battery-electric trucks (BEVs):
What kind of logistics mission are carried out by BEVs?
How many percent of your BEV logistic trips are regular/planned (vs spot request)?
Do you assign the BEV and diesel trucks to the different logistics mission? (short-distance, long-haul)
What is the maximum **distance (km) covered** on a single trip? *Including diesel truck*
Can you indicate (for BEVs missions):
What is the maximum **distance (km) covered** on a single trip? Is it a daily trip?
What kind of **goods** are transported?
Typically, **where drivers usually stop during driver break and charge?** (e.g.,gas station, secured parking, depot, customer site)?
What **charging infrastructure** is typically used (power level, type of charger)?

If the LSP does not operate BEVs yet:
What types of missions do your diesel trucks usually carry out *(*follow LSP definitions)*?
Are your transport operations mostly regular/planned or dynamic/flexible?
Which of your current missions do you consider **most suitable for electrification** in the future?
How would electrification affect this mission? (e.g. maximum payload, route, schedule, driving break, etc.)
For this mission candidate, please specify:
What is the **departure and destination location**?
What is the **distance (km),** is it a **daily trip**?
What types of **products** are typically transported?
What is the **level of flexibility or time sensitivity** of these trips?
Would these missions end at your **own depot** or external customer locations?
Where do your drivers typically stop for breaks or loading/unloading? How long does this stop typically lasts?
Do any of customer sites currently have charging infrastructure? Have you investigated it?

Future outlook and wrap-up (10 minutes)

Objective: Identify practical MCS deployment scenarios and future areas of research.

For all stakeholders
What are the biggest uncertainties you see for the future of high-power charging systems?
How do you see the role of other alternative technologies toward logistics decarbonisation? Will it eventually substitute or complement the MCS? E.g. hydrogen, biofuels, battery swapping, ERS, etc.
What innovations or developments (technical, policy, business model) are critical to support scale-up?
Do you have any plan to expand your BEV fleets within the next 5 years?
If yes,
By how much (%) relative to current levels?
Any specific types of mission? especially long haul or any time-sensitive missions that requires en-route ultra-fast charging
By when does your company believe to realise the full transition to Zero Emission Vehicles (ZEVs)?
Would you be interested in participating in the validation workshop for interview results?

ANNEX III – PRELIMINARY REQUIREMENTS

Cluster 1 - List of preliminary requirements from demand-side users:

ID	Category	Requirement
BC1	Business case, TCO and investment risk	The total cost of operating battery-electric trucks, including vehicles, infrastructure, grid connections and energy, must be competitive with or only moderately higher than diesel to enable scaling beyond pilots.
BC2	Business case, TCO and investment risk	Electricity prices, grid fees and taxes should be transparent over time to obtain reliable TCO calculations for long-term contracts and investments.
BC3	Business case, TCO and investment risk	Tools and guidance should be available to help us model TCO for different charging set-ups and logistics models, including vehicle downtime, grid upgrades and on-site storage.
BC4	Business case, TCO and investment risk	Support schemes should cover not only vehicles but also charging infrastructure, grid connections and upstream works, since these often represent the largest site costs.
BC5	Business case, TCO and investment risk	Policy signals on CO_2 pricing, road tolls and fuel taxation should be predictable over the long term to justify early electrification and high-power infrastructure investments.
BC6	Business case, TCO and investment risk	Business models for shared or semi-public hubs should distribute costs and risks fairly between site owners, carriers, shippers, energy companies and CPOs while respecting logistics constraints.
BC7	Business case, TCO and investment risk	The treatment of residual values and contract durations for trucks and infrastructure should be clear to reduce uncertainty about asset lifetime and technology evolution.
OP1	Operational planning, reliability and service quality	Charging solutions must allow us to maintain delivery schedules and service levels without adding buffers that make routes commercially unattractive.
OP2	Operational planning, reliability and service quality	High-power charging must be aligned with how our trucks are actually used (for example shuttle loops, night distribution, regional routes) rather than only idealised use cases.
OP3	Operational planning, reliability and service quality	MCS and fast charging must be compatible with driving and rest-time rules so that drivers can charge during breaks and rests without breaching Regulation 561/2006.
OP4	Operational planning, reliability and service quality	Vehicles and chargers must reach a high level of reliability, since unplanned downtime, derating or blocked chargers quickly undermines the business case and service quality.
OP5	Operational planning, reliability and service quality	Contingency solutions, such as alternative sites or mobile chargers, should be defined in case planned charging points are unavailable.

OP6	Operational planning, reliability and service quality	Charging events should handle seasonal peaks in demand without excessive queuing or forcing us to buy extra trucks solely for peak weeks.
OP7	Operational planning, reliability and service quality	Charging events should support multi-drop and return-to-base operations where trucks have limited idle time at each node.
OP8	Operational planning, reliability and service quality	The charging and refueling infrastructure for trucks must be predictable, reliable and accessible at all times so that flows of goods and passengers remain efficient and compliant with transport legislation and service expectations.
OP9	Operational planning, reliability and service quality	The power and energy used for planning must reflect what the charger can actually deliver during the booked or expected time window, and CPOs must indicate realistic “committed power” rather than only hardware peak ratings.
DP1	Depot and private-site charging	Depot and private-site charging is the enabler of efficient electrification, since most current and planned use cases are return-to-base or hub-to-hub services.
DP2	Depot and private-site charging	Access to sufficient grid capacity at depots and warehouses must be timely and affordable so that connection lead times and reinforcement costs fit fleet roll-out plans.
DP3	Depot and private-site charging	Grid operators must provide early, clear information on available capacity, needed upgrades and alternatives so we can select suitable sites and design charging events accordingly.
DP4	Depot and private-site charging	Smart energy management at our sites should coordinate building loads, cold storage, warehouse equipment and truck charging to stay within contracted capacity while supporting high-power or MCS charging.
DP5	Depot and private-site charging	Depot layouts must allow trucks to reach chargers safely and efficiently, with enough maneuvering space for long combinations and without blocking docks, internal roads or emergency routes.
DP6	Depot and private-site charging	Guidance should exist on how to position CCS and future MCS chargers on logistics so that operations remain safe, scalable and compatible with different power levels.
DP7	Depot and private-site charging	Chargers, cables and cabinets in busy yards must be physically protected and robustly sited so that normal shunting does not frequently damage equipment.
DP8	Depot and private-site charging	Depot charging systems should allow us to combine slow/overnight charging with occasional high-power or MCS top-ups at the same site and to scale power up over time as fleets grow.
DP9	Depot and private-site charging	Options to integrate on-site renewables and stationary storage with depot charging should be available, together with tariffs or flexibility products that reward optimized consumption and flexibility.
DP10	Depot and private-site charging	Safety, permitting and insurance requirements for high-power truck charging and on-site storage must be clear and practical so that site owners and insurers accept such infrastructure.

DP11	Depot and private-site charging	Grid connection procedures for depot and private-site charging should be standardized, digital and efficient to minimize administrative burden and connection lead times.
PC1	Public and corridor charging / MCS hubs	A basic network of reliable high-power truck chargers along main freight corridors must be available so that long-haul and cross-border trips are feasible without diesel back-up.
PC2	Public and corridor charging / MCS hubs	Public charging sites must be fully suitable for heavy-duty vehicles, providing sufficient space, safe access and turning/parking areas that match truck and combination dimensions.
PC3	Public and corridor charging / MCS hubs	MCS hubs must be located and sized according to real freight flows and rest areas rather than only land or grid cost considerations, to ensure meaningful utilization.
PC4	Public and corridor charging / MCS hubs	When chargers are co-located with passenger car charging, truck-dedicated lanes or clearly separated zones must be provided to avoid blocking, queuing and safety issues.
PC5	Public and corridor charging / MCS hubs	MCS hubs must support several trucks charging simultaneously and, where possible, allow charging without decoupling the trailer to meet tight time windows.
PC6	Public and corridor charging / MCS hubs	The value proposition for using public MCS instead of depot charging should be clear, given that public fast-charging prices are typically higher than internal electricity costs.
PC7	Public and corridor charging / MCS hubs	Tariff structures at public hubs should be transparent and predictable, covering energy, time-based fees, idle fees and reservation fees for integration into contracts and planning tools.
PC8	Public and corridor charging / MCS hubs	Truck charging sites must be designed for HDV dimensions and manoeuvring based on existing mass and dimension rules and practical layout guidance for bay size and turning radii.
PC9	Public and corridor charging / MCS hubs	Covered sites must offer drive-through heights that are sufficient for heavy trucks and coaches, typically around 5 metres of clearance.
PC10	Public and corridor charging / MCS hubs	Layouts such as angled or 90-degree drive-through parking should be used where appropriate to minimise complex manoeuvres, keep traffic flowing and allow safe evacuation routes.
PC11	Public and corridor charging / MCS hubs	Early-phase hybrid sites for HDVs and LDVs should include a clear plan to transition towards HDV-optimised layouts and MCS equipment as electric truck volumes grow.
PC12	Public and corridor charging / MCS hubs	Public charging sites must meet high standards for safety and security, including defined boundaries, good lighting, monitoring, controlled access and procedures for incidents and emergencies.
PC13	Public and corridor charging / MCS hubs	Public charging and refuelling sites must provide a minimum level of basic amenities for truck and coach drivers, such as weather-protected parking, toilets, food and resting facilities, with sufficient capacity for multiple vehicles.

DG1	Digitalisation, data and booking / billing systems	Transport management and planning tools must support electric trucks natively, including range, charging time, payload effects and depot/public charging options.
DG2	Digitalisation, data and booking / billing systems	Digital interfaces and APIs should be harmonised so that information from different CPOs and EMSPs can be integrated into a single view for planners and drivers.
DG3	Digitalisation, data and booking / billing systems	Real-time information on charger status (online/offline, reduced power, occupied, reserved, access rules) must be reliable to avoid unnecessary detours and waiting times.
DG4	Digitalisation, data and booking / billing systems	Billing solutions across public and semi-public networks should be consolidated so that carriers and shippers receive simplified invoices and can allocate costs per vehicle, route or client.
DG5	Digitalisation, data and booking / billing systems	Booking and reservation systems for high-power and MCS hubs should be able to prioritise contracted users and critical missions, while still allowing ad-hoc use and avoiding long idle times.
DG6	Digitalisation, data and booking / billing systems	Ownership and use of operational data on routes, charging and energy use must be governed by clear rules, especially where hubs are operated by third parties.
DG7	Digitalisation, data and booking / billing systems	Route-planning tools must be able to estimate cumulative energy use along trips, taking account of route profile, payload, traffic, weather and arrival times, and link this to charging options.
DG8	Digitalisation, data and booking / billing systems	Planning and navigation tools should use detailed charging data (location, connectors, availability, realistic power or energy per session, price and services) and be available in basic form to SMEs and owner-drivers.
DG9	Digitalisation, data and booking / billing systems	Booking systems should remain optional and market-driven, yet interoperable across networks and based on shared data sets agreed between CPOs and operators.
DG10	Digitalisation, data and booking / billing systems	Booking systems should allow reservation of a group of suitable chargers at a site or in a pool, with specific connector assignment provided on arrival to reduce conflicts.
DG11	Digitalisation, data and booking / billing systems	Bookings should include at least the site or group of sites, booking start and end, time slots and reservation tariff, and may also include charging tariff and user preferences.
DG12	Digitalisation, data and booking / billing systems	Booking processes must include a committed power or energy amount for the booked window based on what the CPO can actually provide, and must specify remedies if this commitment cannot be met.
DG13	Digitalisation, data and booking / billing systems	Continuous information exchange between vehicle or fleet systems and the booked location must support updates on estimated time of arrival and state of charge while minimising in-drive driver interaction.
DG14	Digitalisation, data and booking / billing systems	Standardised practices for no-shows, late arrivals, buffer times and related fees should be defined to manage delays caused by traffic or weather fairly.

DG15	Digitalisation, data and booking / billing systems	Booking systems should allow transfer of a reservation to another vehicle or user in case of delays or operational changes and, where relevant, to book combined resources such as tractors and e-trailers.
DG16	Digitalisation, data and booking / billing systems	Booking and reservation protocols should be standardised and interoperable across networks and open to different providers, including third-party booking platforms.
GV1	Governance, access models and partnerships	Cooperation models should enable site owners, carriers, shippers and energy companies to jointly develop and operate charging infrastructure with clearly defined roles.
GV2	Governance, access models and partnerships	Legal and contractual frameworks should allow shippers or retailers to host charging on their premises and give access to several carriers without being forced to become full CPOs.
GV3	Governance, access models and partnerships	Rules for prioritisation at shared hubs should be fair and transparent so that charging supports agreed logistics performance for all users.
GV4	Governance, access models and partnerships	Allocation of liability and responsibilities for safety, security and service levels at shared hubs must be clear, including who is responsible when a truck cannot charge as planned.
GV5	Governance, access models and partnerships	Corridor planning between countries should be coordinated so that long-haul services are not hindered by uneven national progress or fragmented schemes.
PO1	Policy, incentives and wider framework conditions	Policy measures must reduce the operating cost gap between electric and diesel trucks, for example through differentiated tolls, CO_2-based charging or targeted support for zero-emission services.
PO2	Policy, incentives and wider framework conditions	Support schemes should recognise the specific challenges of smaller carriers and subcontractors that work for large shippers but have limited financing capacity.
PO3	Policy, incentives and wider framework conditions	Regulations on vehicle weights and dimensions must allow electric trucks to compensate for battery weight without significant payload loss, especially for cross-border routes.
PO4	Policy, incentives and wider framework conditions	Planning rules and permitting procedures for charging infrastructure, including MCS hubs, must be faster and less uncertain, particularly in industrial areas and along TEN-T corridors.
PO5	Policy, incentives and wider framework conditions	Guidance should clarify how corporate decarbonisation targets and reporting frameworks treat public versus private charging so that strategies can be designed accordingly.
PO6	Policy, incentives and wider framework conditions	European-level guidance should clarify how charging time interacts with driving and rest-time rules, so drivers can move vehicles to and from chargers without undermining rest periods during the transition phase.
PO7	Policy, incentives and wider framework conditions	Public charging pools that require reservation or are gated/fenced must still be recognised as public infrastructure if professional users can access them under transparent conditions.

PO8	Policy, incentives and wider framework conditions	Regulations should require CPOs to publish clear information on value-added services (reservation, parking, amenities, occupancy) and their fees in a transparent and comparable way.
PO9	Policy, incentives and wider framework conditions	A clear distinction should be made between ad-hoc pricing and contract-based pricing in regulation and data, so that short-term prices and long-term conditions can be understood and compared.

Table 1010: Preliminary requirements from demand-side users

Cluster 2 - List of preliminary requirements for logistics site operators:

ID	Category	Requirement
BC1	Business case, TCO and investment risk	Logistics facility operators must be able to recover investments in charging, grid upgrades and yard works through rent, service fees or long-term contracts so that energy infrastructure does not undermine the core property business.
BC2	Business case, TCO and investment risk	They must have sufficient visibility on tenants' or terminal operators' electrification plans (number of trucks, duty cycles, time on site) to size charging infrastructure and grid capacity with a reasonable level of risk.
BC3	Business case, TCO and investment risk	Charging and energy solutions should increase asset attractiveness and long-term property value (occupancy, lease level, re-letting potential), not only generate kilowatt-hour revenues.
BC4	Business case, TCO and investment risk	For large truck parks, safe and secure parking areas or brownfield redevelopments, operators must be able to combine user fees with public support or CPO partnerships, because parking and heavy civil works alone rarely pay back.
BC5	Business case, TCO and investment risk	When acting also as CPO, landlords should be able to ring-fence energy investments and risks from the wider real-estate portfolio through appropriate corporate and contract structures.
OP6	Operational planning, reliability and service quality	Charging locations on sites must be compatible with warehouse, terminal and gate operations so that trucks can charge without blocking docks, internal roads, safety zones or other critical flows.
OP7	Operational planning, reliability and service quality	Facility operators should be able to design and operate different charging "zones" (overnight, dwell-time, fast-turn) that match actual logistics processes at the site.
OP8	Operational planning, reliability and service quality	Charging infrastructure at facilities must be sufficiently reliable so that repeated outages, derating or repairs do not disrupt terminal operations or damage the reputation of the site.
OP9	Operational planning, reliability and service quality	At complex ports and terminals, there must be clear operational rules for which users can access which chargers, in which time windows, with appropriate queue management to avoid congestion inside the facility.
OP10	Operational planning, reliability and service quality	Charging sessions at facilities should be planned to align as much as possible with drivers' rest periods and loading/unloading times, limiting extra manoeuvres and unproductive waiting.

DP11	Depot and private-site charging	Logistics parks, terminals and distribution centres must be able to obtain or upgrade grid connections to a level compatible with expected truck and building loads within workable lead times.
DP12	Depot and private-site charging	When multiple buildings share a medium-voltage connection, landlords should be able to manage energy at cluster level and allocate available capacity dynamically between tenants and charging.
DP13	Depot and private-site charging	Grid operators should not remove contracted capacity too quickly when EV uptake is still low, so that sites can reserve headroom for future truck charging without losing it during the ramp-up phase.
DP14	Depot and private-site charging	Rules and permitting conditions for on-site battery storage and other flexibility assets must be clear and proportionate so that facility operators can use storage to support weak grids and provide peak power for trucks.
DP15	Depot and private-site charging	New and refurbished sites should include future-proof provisions (space for transformers, cable trays, ducts, foundations) so that upgrading from car/DC charging to MCS for trucks does not require demolishing large parts of the yard.
PC16	Public and corridor charging / MCS hubs	Port authorities, terminal owners and logistics park developers should be able to designate parts of their estate as public or semi-public truck charging hubs while keeping other areas private and secure.
PC17	Public and corridor charging / MCS hubs	Safe and secure parking operators must be able to integrate charging with existing parking services, giving priority to booked trucks, maintaining safe night-time access and avoiding uncontrolled use by non-customers.
PC18	Public and corridor charging / MCS hubs	Ports and large hubs should be able to develop multi-modal high-power nodes where the same reinforced grid connection can serve truck MCS, shore power, barge charging and other electrified equipment under clear technical and regulatory conditions.
PC19	Public and corridor charging / MCS hubs	Motorway service areas and fuel stations that add truck MCS must have clear design and safety guidelines so that new chargers coexist safely with fuel infrastructure, retail activities and existing traffic patterns.
PC20	Public and corridor charging / MCS hubs	Corridor and AFIR planning should take into account real spatial constraints at logistics nodes and service areas (brownfields, urban edges, safety distances), not only theoretical distances along motorways.
DG21	Digitalisation, data and booking / billing systems	Terminal and yard management systems should be able to integrate with charging and parking booking systems so that dock assignments, gate slots and charging reservations are coordinated in a single operational picture.
DG22	Digitalisation, data and booking / billing systems	Logistics facilities need robust digital access control (e.g. licence-plate recognition, QR/RFID) that links trucks, bookings, parking and charging sessions for both security and operational management.
DG23	Digitalisation, data and booking / billing systems	Site owners should receive aggregated, privacy-compliant data from CPOs on charging use, truck dwell times and flows at their sites so that they can plan future capacity and investments.

DG24	Digitalisation, data and booking / billing systems	Where landlords operate charging themselves, they must have simple and consistent driver interfaces and remote monitoring tools so that sites can be supported without permanent on-site technical staff.
GV25	Governance, access models and partnerships	Port authorities and logistics landlords must be able to keep control over land use, safety and access rules while partnering with specialised CPOs that invest in and operate the charging infrastructure.
GV26	Governance, access models and partnerships	Concession and tender models for logistics facilities should allow bundling of parking, charging and possibly retail or other services, so that the combined package forms a viable business case.
GV27	Governance, access models and partnerships	Multi-tenant logistics parks need transparent rules for allocating charging capacity and costs between tenants and mechanisms to integrate new tenants without fundamentally restructuring existing infrastructure.
GV28	Governance, access models and partnerships	Contracts must clearly specify roles and liabilities between facility owners, CPOs, tenants, carriers and grid operators in case of incidents, grid outages, equipment failure or damage to vehicles and cargo.
GV29	Governance, access models and partnerships	When facility operators provide limited charging only to their own tenants, regulation should treat them proportionately and not impose the full obligations of public CPOs.
GV30	Governance, access models and partnerships	For safe and secure truck parking sites, any additional security and service requirements linked to electric truck charging should be matched by suitable funding, pricing flexibility or incentives so that higher standards remain economically sustainable.

Table 1111: Preliminary requirements for logistics site operators

Cluster 3 - List of preliminary requirements for charging point operators:

ID	Category	Requirement
ST1	Site selection, land and permitting	CPOs must be able to secure land in locations with sufficient truck flows, adequate size for HDV layout and acceptable lease/purchase conditions over a period long enough to recover investments.
ST2	Site selection, land and permitting	CPOs need access to sites both on or near main corridors and in logistics/industrial clusters, since early volumes often concentrate around hubs rather than directly on the TEN-T.
ST3	Site selection, land and permitting	Permitting rules (environmental, fire safety, building) must be clear, reasonably harmonised and predictable in time, so that CPOs can estimate time-to-operation when planning and committing to customers or funding bodies.
ST4	Site selection, land and permitting	Local authorities should be familiar with HDV charging needs (land use, footprint, security) to avoid long delays caused by lack of understanding and repeated clarifications.
ST5	Site selection, land and permitting	In regions with sparse infrastructure and complex geography, distance requirements between highway sites should be applied with flexibility so that CPOs

		can select technically and economically feasible locations instead of theoretically ideal but impossible spots.
ST6	Site selection, land and permitting	Environmental assessments (soil contamination, water protection) need to be manageable in cost and time; CPOs need to know as early as possible if any site clean-up or remediation is required, so they can avoid investing time and resources in projects that may later become unviable.
GC1	Grid connection, capacity and energy management	CPOs must obtain medium-voltage connections sized to current and medium-term demand within reasonable lead times (typically less than 2–3 years), with clear roadmaps for later upgrades.
GC2	Grid connection, capacity and energy management	CPOs need transparent procedures, contacts and timelines from DSOs/TSOs for connection requests, upgrades and curtailment conditions, including clarity on when capacity will actually be physically available.
GC3	Grid connection, capacity and energy management	The tariff structure for contracted power must be compatible with HDV utilisation ramp-up; otherwise fixed costs for use-it-or-lose-it capacity can make public charging uneconomic for years.
GC4	Grid connection, capacity and energy management	CPOs need the option and incentives to combine grid power with battery storage and renewables to compensate weak grid connections, provide peak power for MCS and participate in flexibility markets.
GC5	Grid connection, capacity and energy management	Regulatory frameworks should allow and encourage cable pooling or similar shared-connection models with adjacent large energy users to optimise grid capacity and reduce connection bottlenecks.
GC6	Grid connection, capacity and energy management	Policy should provide funding and incentives not only for CPO infrastructure but also for grid reinforcements that are prerequisite to large MCS installations, especially in less-developed regions.
HW1	Hardware, standards and technology roadmap (CCS/MCS)	CPOs require stable, fully specified MCS standards (connector, communication, ISO 15118-20, V2X) and alignment with OEMs before committing to large-scale MCS procurement.
HW2	Hardware, standards and technology roadmap (CCS/MCS)	CPOs need guidance and internal strategies for how CCS and MCS will coexist over time, including when to deploy hybrid sites, when to retrofit CCS bays and when to build MCS-only hubs, to avoid idle stranded assets.
HW3	Hardware, standards and technology roadmap (CCS/MCS)	Connectors, cables and communication protocols must deliver stable power at high current without repeated failures, restarts or derating. MCS is expected to outperform CCS in continuous high-power operation, but this must be confirmed in practice.
HW4	Hardware, standards and technology roadmap (CCS/MCS)	Power units, dispensers and cooling systems for MCS must be compact enough to limit the loss of parking capacity; current designs risk reducing usable parking space significantly at some sites.
HW5	Hardware, standards and technology roadmap (CCS/MCS)	CPOs need competitive hardware prices, stable supply chains and clarity on lifetime and upgrade paths; MCS hardware is currently significantly more expensive than CCS (more than 2 times), increasing the investment risk.

HW6	Hardware, standards and technology roadmap (CCS/MCS)	Funding and regulation should not require CPOs to deploy MCS where flows and use cases do not require it, but should let the market select power levels and standards based on real demand.
SD1	Site design, geometry, safety and amenities	CPOs require clear, shared design guidelines for HDV station layouts (bay length/width, turning radii, drive-through height, one-directional flow, protection barriers) that work for long combinations and minimise complex reversing or coupling/decoupling.
SD2	Site design, geometry, safety and amenities	Where stations are shared between LDVs and HDVs, layouts must prevent conflicts and maintain safe circulation for long trucks; in many contexts, CPOs prefer truck-only designs.
SD3	Site design, geometry, safety and amenities	CPOs need to integrate secure parking, charging bays and driver rest areas in a coherent design, aligning charging sessions with mandatory rest breaks and avoiding unnecessary vehicle movements during rest time.
SD4	Site design, geometry, safety and amenities	Sites must provide fencing, controlled access, good lighting, surveillance and clear safety procedures, both to deter theft and vandalism and to meet expectations for safe and secure parking at night.
SD5	Site design, geometry, safety and amenities	CPOs or their partners must provide or ensure access to minimum amenities for drivers (toilets, showers, food, rest space) sized to expected truck volumes, either on-site or via adjacent facilities.
SD6	Site design, geometry, safety and amenities	Site design must protect dispensers, cables and cabinets from accidental damage by trucks and from vandalism, without making bays hard to use.
SD7	Site design, geometry, safety and amenities	In flexible, multi-point mixed-use hubs, bay and satellites layouts should allow a single physical bay to be used by different vehicle types over time (e.g. trucks and cars), with trucks given priority when reserved, and should support multiple satellites per bay where space permits to increase utilisation.
BE1	Backend systems, booking, data and interoperability	CPOs need reliable backend systems to manage power allocation, dynamic load balancing across CCS and MCS, session control and integration with energy management and storage.
BE2	Backend systems, booking, data and interoperability	Backend platforms must interoperate with multiple eMSPs and routing or planning tools, supporting roaming, different contract models and future HDV-specific data standards.
BE3	Backend systems, booking, data and interoperability	For HDVs, CPOs require booking and capacity-reservation systems that allow fleets to reserve time, bay type and guaranteed power or energy, and that demonstrably increase utilisation without adding excessive complexity.
BE4	Backend systems, booking, data and interoperability	To optimise booking and operation, CPOs need better data from trucks and fleet systems, such as state of charge, battery capacity, expected energy need, ETA, route and trailer configuration, shared in privacy-compliant and standardised ways.
BE5	Backend systems, booking, data and interoperability	CPOs must provide clear energy prices per kWh and any additional fees and ensure that, even when an eMSP is the customer interface, the overall price structure is understandable for fleet planning.

BE6	Backend systems, booking, data and interoperability	CPMS must publish reliable real-time data on station status, bay availability and realistic deliverable power, so that route planning and booking are based on what can actually be delivered in a given time slot.
BE7	Backend systems, booking, data and interoperability	Reservation systems for HDV charging must be tightly integrated with dynamic load management so that reserved sessions receive the power and energy committed at booking, and walk-in users cannot compromise booked capacity.
BE8	Backend systems, booking, data and interoperability	Effective reservation systems should be linked to physical access control (for example via licence-plate or vehicle ID at gated sites) so that the right vehicle occupies the right bay and no-shows or mis-parked vehicles can be identified and managed.
BE9	Backend systems, booking, data and interoperability	User interfaces at chargers should be simple, robust and consistent across sites, relying on clear buttons and minimal steps rather than complex touchscreens, so that truck drivers can operate chargers
BE10	Backend systems, booking, data and interoperability	CPOs would benefit from common, open reservation platforms and booking standards (for example based on OCPI booking modules) that allow third-party truck drivers and fleets to reserve charging across multiple CPO networks instead of using proprietary systems per operator.
EC1	Economics, business models and risk	Public HDV sites must reach sufficient utilisation within a reasonable time; current very low usage in many regions makes business cases fragile and discourages early investment, especially for MCS.
EC2	Economics, business models and risk	CPOs need predictable long-term incentives (CAPEX grants, tax relief, flexibility revenues) and clear AFIR and national plans, to reduce regulatory risk and justify upfront investment in high-power infrastructure.
EC3	Economics, business models and risk	Support schemes should address not only chargers but also associated costs (grid connections, transformers, civil works, storage, security, amenities), otherwise the economics of full truck-ready sites remain weak.
EC4	Economics, business models and risk	CPOs must be able to base network roll-out on actual and committed truck flows, not only on theoretical diesel routes or purely top-down plans, to avoid underutilised stations and stranded investments.
EC5	Economics, business models and risk	Financiers increasingly require evidence of contracted or existing flows to fund stations; CPOs therefore need mechanisms such as long-term capacity contracts with fleets to de-risk utilisation and improve bankability.
EC6	Economics, business models and risk	In less advanced markets, CPOs need differentiated support and more flexible obligations, recognising that HDV fleets, grid capacity and utilisation will lag behind more mature regions.
EC7	Economics, business models and risk	Funding rules that tie subsidies strictly to MCS or specific power levels can push CPOs to deploy technology that does not fit current flows, creating underused MCS assets where robust CCS plus storage sites would deliver more value.
EC8	Economics, business models and risk	Tariff and market regulation should allow CPOs to offer pricing models beyond pure per-kWh tariffs, such as subscriptions or capacity/availability fees, to better recover high fixed costs of HDV and MCS hubs while keeping energy prices competitive.

PO1	Policy, regulation and governance	EU and national frameworks should work toward more harmonised requirements for permits, environmental assessments, fire safety and technical approvals, to reduce administrative overhead across multiple countries and municipalities.
PO2	Policy, regulation and governance	Better coordination is needed between transport policy and energy policy so that HDV charging targets are actually compatible with grid planning and DSO investment cycles.
PO3	Policy, regulation and governance	Regulation on safe and secure truck parking should be clarified for electric truck charging areas, so CPOs know which security level is expected and can plan CAPEX and OPEX accordingly.
PO4	Policy, regulation and governance	Rules must ensure that different actors (pure CPOs, fleet-owned sites, gas station operators, utilities) can participate in HDV charging without discriminatory grid access or regulatory advantages for any one model.
PO5	Policy, regulation and governance	CPOs require AFIR implementation schedules and power/spacing requirements that reflect grid and permitting reality, especially for very high-power MCS corridors.

Table 1212: Preliminary requirements for charging point operators

Cluster 4 – List of preliminary energy and grid requirements:

ID	Category	Requirement
EG1	Grid planning and forecasting	Grid development plans must explicitly include transport electrification together with other fast-growing loads (heating, data centres, industrial electrification) to avoid systematic under-sizing of capacity at corridors and logistics nodes.
EG2	Grid planning and forecasting	Demand forecasts for truck charging should be built with input from fleets, CPOs and site operators, including duty cycles, simultaneity, seasonal peaks and expected commissioning dates.
EG3	Grid planning and forecasting	TSOs and DSOs should publish forward-looking capacity outlooks for priority corridors and logistics clusters, including indicative reinforcement timelines for MV and HV levels.
EG4	Grid planning and forecasting	Anticipatory investments should be permitted and incentivised under defined trigger conditions, with clear cost-recovery rules to build capacity ahead of confirmed demand where evidence is strong.
EG5	Grid planning and forecasting	Spatial and grid planning must be coordinated so land, servitudes and corridors for substations/lines are reserved early for multi-megawatt hubs.
EG6	Grid planning and forecasting	Grid planning should support staged capacity pathways for hubs, enabling initial connections with a pre-approved route to later upgrades without restarting the full assessment process.
CP1	Connection process and timelines	Connection processes should be digital by default, with standardised data requirements, clear milestones, and trackable status updates visible to applicants and partners.

CP2	Connection process and timelines	DSOs should provide an early, non-binding pre-feasibility check (capacity, likely reinforcement needs, indicative costs and timelines) before developers invest in full site development.
CP3	Connection process and timelines	Processes must clearly distinguish non-binding vs binding requests and define required documentation at each step to reduce iterative rework and incomplete submissions.
CP4	Connection process and timelines	For complex hubs (MCS-scale, hub + storage, hybrid industrial sites), TSOs and DSOs should offer a coordinated single technical assessment pathway to avoid duplicated studies and misaligned assumptions.
CP5	Connection process and timelines	Connection offers should separate controllable timeline components (studies, grid works) from external dependencies (permits, land rights, supply chain) and state assumptions explicitly.
CP6	Connection process and timelines	Connection agreements should include upgrade and staging options (partial energisation first, full capacity later) where this accelerates opening and reduces stranded civil works.
QM1	Queue management and prioritisation	Queue rules should be transparent, auditable and consistent, with clear entry criteria defining when a request is “ready” for technical assessment.
QM2	Queue management and prioritisation	DSOs should provide queue visibility (position, expected assessment start, key blocking constraints) updated at defined intervals.
QM3	Queue management and prioritisation	Applicants should face milestone-based obligations (e.g., land secured, permits submitted, financing progress) to prevent speculative reservations that block capacity.
QM4	Queue management and prioritisation	Prioritisation criteria (chronological or public-interest) must be defined by regulators and applied by DSOs without discretionary decision-making, in line with non-discrimination principles.
TC1	Tariffs and cost recovery	Tariffs for contracted power should be compatible with utilisation ramp-up, avoiding early-year fixed charges that make first-mover hubs uneconomic.
TC2	Tariffs and cost recovery	Cost allocation principles for reinforcements (grid-side vs customer-side works, shared assets) should be predictable and comparable across regions, with transparent rules.
TC3	Tariffs and cost recovery	Connection offers should provide a clear, bankable cost breakdown (studies, equipment, civil works, land rights, commissioning, monitoring) to support financing and funding applications.
TC4	Tariffs and cost recovery	Dedicated funding mechanisms should exist for grid reinforcements that are prerequisites to corridor and other public-interest multi-megawatt hubs.
TC5	Tariffs and cost recovery	Rules should avoid “use-it-or-lose-it” outcomes that penalise reserving future headroom during low early utilisation, while still preventing capacity hoarding.
FM1	Flexibility and congestion management	DSOs should offer standard flexible or non-firm connection products for hubs, including defined curtailment limits, notice times and compensation rules where applicable.

FM2	Flexibility and congestion management	Flexibility contracts should specify what is controlled (power cap, energy cap, ramp rate), how signals are sent, and how compliance is measured and settled.
FM3	Flexibility and congestion management	Curtailment and load-management interfaces should be interoperable and cyber-secure, using standard protocols rather than bespoke one-off solutions.
FM4	Flexibility and congestion management	Regulatory frameworks should clarify when and how DSOs can procure flexibility from hubs (including managed charging and storage) while preserving neutrality and market principles.
FM5	Flexibility and congestion management	Hubs should have clear pathways to participate in flexibility and ancillary service markets (directly or via aggregators), with standard metering, baselines and settlement rules.
DT1	Data and digital tools	TSOs and DSOs should publish hosting-capacity information at practical geographic resolution (substation/feeder where feasible) with clear caveats and update frequency.
DT2	Data and digital tools	Digital platforms should support two-way data exchange for grid operation, including day-ahead hourly demand forecasts and real-time power telemetry where required.
DT3	Data and digital tools	DSOs should expose structured APIs for connection status, capacity offers, curtailment events and planned outages to support project delivery and operational planning.
DT4	Data and digital tools	Data governance must be privacy-compliant and proportionate, with clear rules on access, permitted uses, retention and protection of commercially sensitive information.
DT5	Data and digital tools	Key definitions should be harmonised (firm vs flexible capacity, committed power, curtailment event, outage) to improve comparability and cross-border coordination.
PS1	Permitting and supply chain bottlenecks	Permitting requirements for lines, substations and associated works supporting hubs should be clearer and more standardised to reduce interpretation risk and rework.
PS2	Permitting and supply chain bottlenecks	Early engagement with municipalities and permitting bodies should be integrated into the connection process via standard documentation packs and pre-agreed safety concepts.
PS3	Permitting and supply chain bottlenecks	Land rights, servitudes and spatial acts must be addressed early with a clear responsibility split between grid operators, site owners and developers.
PS4	Permitting and supply chain bottlenecks	Permitting for on-site storage and other flexibility assets should be risk-based and proportionate, with predictable requirements and timelines.
PS5	Permitting and supply chain bottlenecks	Supply-chain risks (transformers, switchgear, cabling) should be mitigated through standardised specifications, framework procurement and the option of temporary/modular equipment.

TS1	Technical integration and grid stability	Connection agreements must specify applicable grid codes and national operating instructions, including power quality limits, protection schemes and commissioning tests.
TS2	Technical integration and grid stability	Requirements should define acceptable ramp rates and simultaneous start behaviour for multi-bay charging to avoid local voltage dips and nuisance trips.
TS3	Technical integration and grid stability	Reactive power and power factor obligations should be explicit for large hubs, including whether voltage support is required under defined conditions.
TS4	Technical integration and grid stability	Cybersecurity requirements for hub-to-grid communication should be defined (authentication, encryption, incident response), aligned with critical infrastructure expectations.
HS1	Hardware supply chain and standardisation	Hardware providers need earlier visibility on reinforcement programmes (volumes, timelines, technical envelopes) so manufacturing capacity and workforce can scale.
HS2	Hardware supply chain and standardisation	Technical specifications for key assets (transformers, switchgear, modular substations) should be harmonised where possible to reduce engineering and procurement delays.
HS3	Hardware supply chain and standardisation	Modular and transportable substation concepts should be supported with standard interfaces to accelerate deployment at constrained motorway and logistics-node sites.
HS4	Hardware supply chain and standardisation	Sustainability requirements for grid equipment (including insulating gases) should be integrated into specifications without creating new permitting uncertainty or unmanageable compliance burdens.
EM1	Energy supply and market interface	Energy suppliers should offer contract structures suitable for hubs (long-term fixed or indexed supply, hedging options) aligned with multi-year fleet and CPO contracts.
EM2	Energy supply and market interface	Price structures should transparently separate energy cost, network charges, taxes and flexibility revenues to enable predictable hub pricing for transport customers.
EM3	Energy supply and market interface	Guarantees of origin and carbon accounting for electricity supplied to hubs should be clear, auditable and compatible with corporate reporting needs.
EM4	Energy supply and market interface	Retail and balancing arrangements should accommodate large, peaky hub loads without punitive imbalance exposure when deviations are within agreed operational limits and data-sharing rules.
GC1	Governance and coordination	Corridor-level coordination must align transport planning, grid planning and permitting into publishable “where and when” capacity guidance that reduces investor uncertainty.
GC2	Governance and coordination	Roles and liabilities between TSOs, DSOs, site owners, CPOs and energy suppliers should be contractually clear, including responsibilities during curtailment, outages and incident response.

Table 1313: Preliminary energy and grid requirements

Cluster 5 – List of preliminary requirements for technology and solution providers:

ID	Category	Requirement
SI1	Standards, conformance and interoperability	The MCS standard (mechanical, electrical, cooling, safety, and communication stack) must be finalised with a stable roadmap so OEMs and suppliers can industrialise products beyond pilot stage.
SI2	Standards, conformance and interoperability	Standard interpretation must be aligned across OEMs and charger suppliers, including clear conformance tests, to avoid CCS-like interoperability issues caused by “different interpretations” of protocols.
SI3	Standards, conformance and interoperability	MCS standardisation should remain a multi-stakeholder process (OEMs, CPOs, suppliers, digital actors) to ensure a jointly accepted and functioning standard.
SI4	Standards, conformance and interoperability	Cross-border harmonisation should reduce country-by-country deviations in technical approvals and implementation details that drive fragmentation and extra integration work.
SI5	Standards, conformance and interoperability	Interoperability must cover end-to-end communication (vehicle ↔ charger ↔ backend) and reliability in real operations, not only laboratory charging.
SI6	Standards, conformance and interoperability	The industry must standardise how “realistic deliverable power” is represented (power availability vs peak rating) so routing, booking and charging guarantees can be trusted.
SI7	Standards, conformance and interoperability	Standardised interface requirements are needed for automated connection systems (mechanical + electrical + communication compatibility end-to-end) so robotics can scale without custom engineering per site.
SI8	Standards, conformance and interoperability	Standardised data fields for planning and operations (connector type, bay constraints, trailer compatibility, realistic power) must be consistent across providers to avoid dispatcher “multi-system” complexity.
VR1	Vehicle architecture and charging capability roadmap	OEMs must provide clear CCS–MCS coexistence roadmaps (dual-inlet strategies, retrofit options, timelines) to avoid stranded investments for fleets and hubs.
VR2	Vehicle architecture and charging capability roadmap	OEMs should publish realistic power-acceptance behaviour (power vs SoC, temperature, battery limits) so infrastructure sizing and “committed power” contracts match what vehicles can actually take.
VR3	Vehicle architecture and charging capability roadmap	Vehicle battery strategy must be aligned with MCS charging specifications, since higher charging power increases battery-side cost and constraints.
VR4	Vehicle architecture and charging capability roadmap	OEMs and suppliers must provide practical guidance to customers that are still learning CCS, to avoid MCS adding unmanaged complexity for private-site deployment.
VR5	Vehicle architecture and charging capability roadmap	OEMs should support route simulation / energy estimation tools and make them usable for fleet planning as operations expand beyond depot-only charging.

VR6	Vehicle architecture and charging capability roadmap	OEM charging-interface decisions (e.g., removal of AC capability) must be communicated early with transition guidance so depots can plan DC upgrades without surprises.
VR7	Vehicle architecture and charging capability roadmap	Vehicle designs should support charging during regulated rest periods without extra driver workload, including clear operational rules for when trailer decoupling is or is not required.
HW1	Charger hardware design and reliability	MCS hardware must deliver stable high-current operation with minimal failures, restarts, noise issues, or derating under real duty cycles.
HW2	Charger hardware design and reliability	Hardware providers must prioritise footprint reduction and space-efficient satellite/dispenser designs because every centimetre affects site capacity and utilisation.
HW3	Charger hardware design and reliability	Distributed architectures (shared power cabinets feeding multiple satellites) should be supported to maximise utilisation and avoid "standalone truck chargers" that oversize grid needs.
HW4	Charger hardware design and reliability	Chargers, connectors and cables must be durable and ergonomic for HDV use, including physical robustness for frequent handling and harsh environments.
HW5	Charger hardware design and reliability	Reliability and remote diagnostics must be designed-in (monitoring, fault isolation, maintainability) to keep uptime high without constant on-site technical staff.
HW6	Charger hardware design and reliability	Multi-connector designs and higher connector-per-cabinet ratios should be enabled to improve utilisation and reduce idle capacity at mixed CCS/MCS sites.
HW7	Charger hardware design and reliability	Hardware should support controllable charging power (including low power on MCS) to enable overnight or dwell-time strategies without changing connectors or requiring disconnect/reconnect actions.
PM1	Power management and hybrid hub architecture	Hybrid hub concepts (MCS + CCS + destination/overnight charging) must be modular and upgradeable so sites can evolve with fleet uptake rather than overbuilding day one.
PM2	Power management and hybrid hub architecture	Power sharing and dynamic load allocation must adapt to each vehicle's acceptance in real time to maximise delivered energy per hour and avoid bottlenecks.
PM3	Power management and hybrid hub architecture	Integration with stationary storage and site energy strategies should be supported at control level (interfaces and control logic), since BESS is used to mitigate grid limits and optimise cost.
PM4	Power management and hybrid hub architecture	Hardware designs should minimise space loss from transformers, cabinets and cabling, since footprint drives both CAPEX and operational capacity at hubs.
DT1	Digital planning, telematics and APIs	Digital tools must integrate OEM telematics (SoC, position, ETA) and operational context (next tour) to reschedule charging and avoid unnecessary charging to high SoC when not needed.
DT2	Digital planning, telematics and APIs	Planning systems must merge depot control and public opportunity charging into one optimisation loop, including re-optimisation when delays occur.

DT3	Digital planning, telematics and APIs	Depot charging control should support OCPP-based steering via broker connections, with the ability to push calculated charging profiles to chargers.
DT4	Digital planning, telematics and APIs	Tools should ingest public CPO datasets and translate them into operational instructions for drivers (specific bay/charger guidance), not just “site-level” recommendations.
DT5	Digital planning, telematics and APIs	API integration must minimise bespoke work. When customisation is needed for large customers, suppliers should provide standard integration patterns and versioning to limit fragmentation.
DT6	Digital planning, telematics and APIs	Data exchange should move beyond static location info, using dynamic optimisation inputs (traffic, temperature, historical consumption) to make charging outcomes predictable.
RB1	Booking, roaming and commercial interfaces	Reservation systems should integrate with routing and telematics, and must expose operationally critical constraints such as “charge with trailer attached vs must detach.”
RB2	Booking, roaming and commercial interfaces	Booking should work with “pooling” logic where the system can assign a specific charger/bay on arrival, reducing conflicts and re-planning workload.
RB3	Booking, roaming and commercial interfaces	Roaming and commercial models should support both ad-hoc access and long-term contract structures in parallel, without forcing one rigid customer journey.
RB4	Booking, roaming and commercial interfaces	Digital tools must support cost-based network prioritisation (roaming agreements, preferred CPOs, contract rates) so dispatchers can optimise on €/kWh and total mission cost.
RB5	Booking, roaming and commercial interfaces	Depots that open semi-public access need reservation and access features to sell unused time slots safely, increasing utilisation without disrupting the host fleet.
AT1	Automation and complementary technologies	Automated connection solutions must be integrated as a first-class design requirement (not an afterthought), with clear mechanical envelopes and interoperability across MCS/CCS.
AT2	Automation and complementary technologies	Automation should reduce operational friction at high-power sites (less manual handling, fewer connection errors), while maintaining safety and secure access control.
AT3	Automation and complementary technologies	Suppliers should define clear integration responsibilities and interfaces when combining chargers with third-party systems (robotics, payment terminals, access control) to avoid “end-to-end” integration risk sitting with one actor.
CS1	Cost, supply chain and lifecycle support	MCS hardware cost must decline through industrialisation and design optimisation, since current first-generation products are still treated as pilots and adoption depends on cost reduction.
CS2	Cost, supply chain and lifecycle support	Suppliers should provide clear upgrade paths (CCS-to-MCS, hybridisation, connector additions) to reduce stranded-asset risk for early deployments.
CS3	Cost, supply chain and lifecycle support	Technology roadmaps should avoid forcing MCS everywhere. Systems should support right-sized solutions (robust CCS plus modular upgrades) based on real use cases and maturity.

CS4	Cost, supply chain and lifecycle support	OEMs and suppliers must support customers with deployment know-how (site design implications, operational constraints, integration complexity) to accelerate scale-up beyond controlled pilots.

Table 1414: Preliminary requirements for technology and solution providers

Cluster 6 – List of preliminary requirements for governance, finance and standards:

ID	Category	Requirement
PF1	Policy stability and fiscal signals	CO_2 pricing, road tolls, fuel taxation, and ZEV exemptions must be predictable over a multi-year horizon so private actors can commit to high-capex HDV charging projects.
PF2	Policy stability and fiscal signals	Policy changes that affect TCO (taxes, toll exemptions, subsidies) should avoid sudden reversals and include transition periods to prevent stranded investments.
PF3	Policy stability and fiscal signals	Vehicle uptake and infrastructure policy must be aligned so that charging assets are not built years ahead of demand without compensating mechanisms.
PF4	Policy stability and fiscal signals	National policies should avoid creating cost advantages for fossil options that unintentionally worsen the TCO of electric trucks during early rollout.
PF5	Policy stability and fiscal signals	Cross-border rules on weights and dimensions must allow compensation for battery weight with minimal payload loss, and be consistent across key freight corridors.
PF6	Policy stability and fiscal signals	Public-sector and regulated frameworks should clearly define how “renewable electricity use” is counted across public vs private charging for reporting and compliance.
FD1	Funding and financial instruments	Funding schemes must cover the full cost stack (civil works, grid works, substations, safety/security, digital systems), not only chargers.
FD2	Funding and financial instruments	Public support should be designed to steer build-out toward strategic locations and adequate site capacity (power and number of points), not only lowest-cost projects.
FD3	Funding and financial instruments	Early-phase mechanisms are needed to manage low utilisation risk (e.g., minimum revenue support, availability payments, or similar de-risking instruments).
FD4	Funding and financial instruments	Public funding must be compatible across EU and national schemes, with clear eligibility and predictable timing to support investment decisions.
FD5	Funding and financial instruments	Financial rules should support long-asset-life investments (depreciation, tax treatment, guarantees) that match the payback profile of MCS hubs.
FD6	Funding and financial instruments	Grid reinforcement costs that enable AFIR-compliant HDV corridors should be treated as eligible “enabling investments,” not left fully to first movers.

CG1	Corridor governance and sequencing	Corridor planning must coordinate road authorities, DSOs/TSOs, and ministries to sequence grid upgrades and site delivery against AFIR timelines.
CG2	Corridor governance and sequencing	Authorities should use demand and network studies to pre-identify and reserve viable HDV charging locations and power needs along the corridor.
CG3	Land access and public assets	Public land and rest areas should be made available under conditions that allow bankable investments (clear access rights, duration, and responsibilities).
CG4	Concessions and service-area contracts	Concession and sub-concession frameworks must allow adding HDV charging without triggering prohibited competition or breaching exclusivity clauses.
CG5	Concessions and service-area contracts	Concession durations must be compatible with the CAPEX payback of HDV charging. Short caps can make MCS investments non-viable.
CG6	Concessions and service-area contracts	Tenders should clearly allocate responsibilities for grid connection delivery, site works, operations, and service quality KPIs between landlord and operator.
CG7	Spatial constraints and expansion	Corridor plans must account for space constraints at service areas (truck parking, queuing, safety distances) and include a pathway for site expansion over time.
PR1	Permitting and planning procedures	Permitting for charging hubs (including substations and storage) must be faster, time-bound, and predictable, with clear required documentation and decision steps.
PR2	Permitting and planning procedures	Authorities should provide a "one-stop" coordination process for complex sites involving road works, grid works, and multiple permits.
PR3	Fire safety and co-location rules	Fire safety rules for HDV charging and co-located energy carriers (e.g., hydrogen and electricity) must be risk-based and avoid unnecessary prohibitions that reduce site feasibility.
PR4	Environmental and technical assessments	Environmental and grid-impact assessments must be proportionate, with early screening to identify showstoppers (land contamination, protected zones) before heavy project spend.
PR5	Road safety and traffic management	Clear road-authority guidance is needed for safe traffic flow and works management when retrofitting charging into busy service areas and rest areas.
PR6	Liability and incident handling	Legal frameworks must clearly define liability and incident responsibilities across landlord, concessionaire, CPO, and other parties for outages, damage, and safety events.
ST1	MCS standards roadmap	MCS standards (connector, comms, safety, conformance) must be stable and delivered on a clear roadmap to reduce stranded-asset risk.
ST2	Conformance and interoperability certification	Independent, harmonised testing and certification must exist for vehicle–charger interoperability, including regression testing after major software/firmware updates.

ST3	Metering and billing compliance	Clear metering accuracy and compliance rules are needed for high-power DC and MCS charging so billing is auditable and trusted.
ST4	Definitions for performance reporting	Standard definitions are needed for “available,” “online,” “reduced power,” “derating,” and “deliverable vs peak power,” so KPIs are comparable and enforceable.
ST5	Booking and reservation standardisation	Interoperable standards should define how booking windows, penalties, and “committed power/energy” are expressed and exchanged across providers.
ST6	Data publication requirements	Regulation should require publication of comparable, machine-readable data (location, access rules, bay type, real-time status, realistic power, price components).
ST7	Authentication and roaming governance	Harmonised approaches are needed for authentication (including plug-and-charge where applicable), roaming governance, and dispute handling across networks.
ST8	Automation and novel solutions	Standardisation and safety validation pathways are needed for automated connection (robotic plug-in) and other enabling technologies used at HDV sites.
DT1	Price transparency and comparability	Requirements should ensure tariff transparency (kWh, time, parking, reservation, idle fees) and clear separation of ad-hoc vs contract-based prices.
DT2	Real-time operational transparency	Reliability requirements should cover real-time data quality on occupancy, reservations, downtime, and reduced-power operation to support planning and compliance.
DT3	Data governance and privacy	Clear rules must govern ownership and use of operational and fleet data shared for planning and booking, with privacy-compliant exchange and neutral governance.
DT4	Public monitoring and KPIs	Authorities should define a common KPI set and reporting method for corridor readiness and service quality (uptime, delivered power, waiting times, utilisation).
DT5	Interoperability as default	Rules should prevent fragmentation into many proprietary apps and promote interoperable access via roaming and third-party platforms.
SR1	Cybersecurity baseline	Minimum cybersecurity requirements must be defined for charging infrastructure and backends, including incident response and coordinated vulnerability handling.
SR2	Anti-theft and vandalism measures	Coordinated measures are needed against cable theft and vandalism, including design guidance, enforcement, and insurance alignment.
SR3	Physical security for sites	Security requirements for HDV charging sites should align with safe and secure parking expectations (lighting, surveillance, controlled access, emergency procedures).
SR4	Operational resilience	Minimum resilience requirements should address site-level contingencies (fallback procedures, safe shutdown, fault isolation) for critical corridor nodes.

KN1	Practical guidance and templates	Authorities and advisory bodies should publish practical guidance for HDV charging site design, permitting packs, and standard contract clauses for concessions/PPPs.
KN2	Capacity building for authorities	Municipalities, inspectors, and road operators need training and reference material on HDV charging needs to reduce delays caused by lack of familiarity.
KN3	Neutral planning and decision-support tools	Neutral tools are needed to support corridor planning, location screening, and impact assessment using consistent assumptions and transparent methods.
KN4	Knowledge sharing and lessons learned	A structured mechanism should exist to share lessons from pilots and early deployments (including failures) to accelerate standard practice.
KN5	Demand-side awareness and communication	Public communication and coordination efforts should support demand growth and user trust as part of the wider rollout strategy.

Table 15: Preliminary requirements for governance, finance and standards