ESCALATE

Powering European Union Net Zero Future
by Escalating Zero Emission HDVs
and Logistic Intelligence

Image © Sunset on Semi Truck, Caleb Ruiter, Unsplash

Requirements and specifications of single and multi-energy stations

Project deliverable D4.1

MARKO ANTILA (VTT)

This project has received funding from
the European Union's Horizon Europe
research and innovation programme
under grant agreement No 101096598.

WWW.ESCALATE-EU.COM

Deliverable Administrative Information

Deliverable Administration					
Grant Agreement	101096598	**Project short name**	ESCALATE		
Deliverable no.	D4.1	**Name**	REQUIREMENTS AND SPECIFICATIONS OF SINGLE AND MULTI-ENERGY STATIONS		
Status	Final	**Due**	M09	**Date**	02/10/2023
Author(s)	MARKO ANTILA (VTT), ALEXANDER MLADEK (VIV), MIKKO JALONEN (KEM), MARKO PAAKKINEN (VTT), MEHRNAZ FARZAM FAR (VTT), CHRISTIAN KOLLIK (VIV) & HAYRI KAHVECIOĞLU (TEK)				
Related tasks	T4.1: Requirements and specifications for multi-energy stations				
Dissemination level	PU = Public				
Document history	**Version**	**Date**	**Submitted**	**Reviewed**	**Comments**
	V1.0	14/04/2023	MARKO ANTILA (VTT)	MARKO PAAKKINEN (VTT)	Content update
	V2.0	30/08/2023	MARKO ANTILA (VTT)	MIKKO PIHLATIE (VTT)	Partner circulation and company internal review
	V3.0	18/09/2023	MARKO ANTILA (VTT)	T.SCHNORBUS (FEV) & S. O GAMO (FEVFR)	Template and update contents
	V3.0	26/09/2023	MARKO ANTILA (VTT)	T. CHADEESINGH & C. MIKKELSEN (BLRD)	General review and approval
	V4.0	02/10/2023	MARKO ANTILA (VTT)	A. HARTAVI KARCI (USR)	Final submitted version
	V4.2	02/10/2024	MARKO ANTILA (VTT)	S. OUENOU GAMO (FEV FR)	Attainment of the objectives deleted

Legal Disclaimer

This project has received funding from the European Union's Horizon Europe research and innovation program under grant agreement No 101096598. The views represented in this document only reflect the author's views and not the European Commission's. The dissemination of this document reflects only the author's view, and the European Commission is not responsible for any use that may be made of the information it contains.

Contents

Project Executive Summary

ESCALATE, an EU funded Research and Innovation project, has been awarded funding under the HORIZON-CL5-2022-D5-01 call, highlighting its significance within the academic and scientific community. The primary objective of ESCALATE is to showcase and demonstrate the efficacy of high-efficiency zero-emission heavy-duty vehicle (z-HDV) powertrains, with a targeted increase of up to 10% in their overall efficiency. Specifically tailored for long-haul applications, these powertrains are designed to provide an impressive range of 750+ kilometres without the need for refuelling or recharging, while simultaneously ensuring consistent performance during daily operations over a period of six months or more under real-world conditions. To achieve these ambitious goals, ESCALATE focuses on the development of meticulously designed modular building blocks, which are intended to attain a Technology Readiness Level of 7 or 8. These modular components will serve as the foundation for three distinct types of z-HDVs, namely battery-HDV (b-HDV), fuel-cell-HDV (f-HDV), and range extender-HDV (r-HDV). The utilization of innovative business model innovations will be instrumental in optimizing the integration and utilization of these standardised and modular building blocks, further enhancing their efficiency and effectiveness. Moreover, the ESCALATE project aims to contribute valuable insights to the scientific community through the production of three comprehensive white papers. These papers will delve into various aspects of z-HDV technology, with one particular white paper focusing on defining a clear pathway to reduce well-to-wheel greenhouse gas emissions specifically from heavy-duty vehicles. The formulation of this pathway will be informed by rigorous analysis, utilizing both empirical results and policy assessments, thereby establishing a robust foundation for future efforts in reducing the environmental impact of HDVs. Through its multifaceted approach, ESCALATE strives to advance the knowledge and understanding of high-efficiency z-HDV powertrains, foster technological innovation, and contribute to the ongoing efforts of EU aimed at achieving sustainable and environmentally friendly transportation systems.

ESCALATE partners

List of participating countries:

- Belgium
- Denmark
- Germany
- Spain
- Estonia
- France
- Finland
- Greece
- Poland
- Portugal
- Austria
- Turkey
- UK

List of partners:

- FEV Europe Gmbh & FEV France (FEV) - Project Coordinator
- University of Surrey (USR) - Technical Coordinator
- Mercedes-Benz Turk As (MBT)
- Brussels Research and Innovation Center for Green Technologies (BRING)
- Teknologian Tutkimuskeskus Vtt Oy (VTT)
- Virtual Vehicle Research Gmbh (VIV)
- Aristotelio Panepistimio Thessalonikis (AUTH)
- Polis - Promotion of Operational Links with Integrated Services, Association Internationale (POLIS)
- Inegi - Instituto De Ciencia E Inovacao Em Engenharia Mecanica E Engenharia Industrial (INEGI)
- Deutsches Zentrum Fur Luft - Und Raumfahrt Ev (DLR)
- Rheinisch-Westfaelische Technische Hochschule Aachen (RWTH)
- BMC Otomotiv Sanayi Ve Ticaret Anonim Sirketi (BMC)
- Engie Energie Services (ENGIE)
- Commissariat A L Energie Atomique Et Aux Energies Alternatives (CEA)
- FEV TR Otomotiv Ve Enerji Arastirma ve Muhendislik Limited Sirketi (FEV TR)
- Ai4sec Ou (AI4SEC)
- Ballard Power Systems Europe As (BLRD)
- Kempower Oy (KEM)
- Hydrogen Europe (HEU)
- Ergtech Spolka Z Ograniczona Odpowiedzialnoscia (ERG)
- Pbx Gmbh (PBX)
- Primafrio Corporacion, S.A. (PRMF)
- Bsa Inno & Tech Gmbh (BSA)
- Oy Sisu Auto Ab (SISU)
- Valmet Automotive Ev Power Oy (VAL)
- Ortem Elektronik As (ORTEM)
- DHL Lojistik Hizmetleri As (DHL)
- Deutsches Institut Fuer Normung Ev (DIN)
- Kuljetus Ja Muutto O. Jylha Oy (TRJ)
- Oy M Rauanheimo Ab (RHM)
- TEKFEN Muhendislik As (TEK)
- FORD Otomotiv Sanayi Anonim Sirketi (FORD)
- Coventry University (CU)
- Electra Commercial Vehicles Limited (ELECT)
- Advanced Electric Machines Ltd (AEM)
- Reliability And Safety Technical Center (RSTER)
- Turkiye Bilimsel Ve Teknolojik Arastirma Kurumu (TUBITAK)

Social Media Links:

twitter.com/EscalateHEurope

linkedin.com/company/escalate-eu-project

For further information please visit **WWW.ESCALATE-EU.COM**

Deliverable executive summary

This deliverable defines initial infrastructure requirements and preliminary specifications for the single-energy stations (SES) and multi-energy stations (MES). The requirements and specifications will be finalized during the ESCALATE project in other tasks. Importantly, we have now identified the required parameters to be studied, and their exact values will be determined during the development work.

The focus of this deliverable is on the refuelling and charging of ESCALATE project pilot heavy-duty vehicles (HDV). Requirements and specifications of single and multi-energy stations of the pilot vehicles including the battery heavy-duty vehicles (be-HDV), fuel cell heavy-duty vehicles (fc-HDV), and hybrid vehicle using both fuel cells as range extenders and batteries (re-HDV) are defined in this deliverable.

The general flow from the ESCALATE project objectives via requirements to specifications for this task was carried out first to define the requirements on the basis of the project objectives, and then set the specifications according to these requirements. Also, the general criteria framework from Task 2.1 and the requirements and specifications of the pilot vehicles in Task 3.1 were considered, whenever applicable.

The main labels for the requirements and specifications are hydrogen refuelling, electric HDV charging, safety, and waste heat recovery categories. The main requirements as well as the preliminary specifications for all those are presented in this deliverable. Furthermore, the standardization and guidelines for all these topics are addressed.

List of figures

List of tables

List of abbreviations and acronyms

Acronym	Meaning
BE-HDV	Battery-electric heavy-duty vehicle
BMS	Battery management system
CCS	Combined charging system, protocol and connections for DC charging
COP	Coefficient of performance
EMC	Electromagnetic compatibility
ESS	Energy storage system
EVSE	Electric vehicle supply equipment (charging station)
FC	Fuel cell
FC-HDV	Fuel cell heavy-duty vehicle
GA	Grant Agreement (includes the project plan and the initial objectives)
H_2	Hydrogen
HDV	Heavy-duty vehicle
HP	Heat pump
HRS	Hydrogen refuelling station
MCS	Megawatt charging system
MES	Multi-energy station
NVH	Noise, vibration, harshness
OCPP	Open charge point protocol, an open communication protocol to operate EVSEs
OEM	Original equipment manufacturer
PSU	Power supply unit (typically EVSE power supply unit)
PV	Photovoltaic module
RE-HDV	Range-extended heavy-duty vehicle
SES	Single-energy station
SOC	State of charge (battery)
SOH	State of health (battery)
TBD	To be decided, the placeholder for the parameter not yet defined
VCHP	Vapor compression heat pump
WG	Working group
WHR	Waste heat recovery
WP	Work package

1 Purpose of the deliverable

1.1 Intended audience

The primary audience of the deliverable consists of the ESCALATE project partners, containing all members participating in the consortium. Secondly, the audience includes representatives from the Commission Services responsible for overseeing the project. Lastly, the target group is the broad audience. It includes policymakers, stakeholders, researchers and industry professionals in the field of sustainable transportation and zero-emission technologies.

1.2 Structure of the deliverable and links with other work packages and deliverables

The initial requirements and preliminary specifications are prepared in cooperation with the WP2 (T2.1) and WP3 (T3.1) requirements definition work, as well as with project OEM partners. The interdependencies of those tasks are shown in Figure 1. Task 2.1 (Baseline assessment & criteria identification and economic, ethical & legal requirements) and task 3.1 (Requirements, specification and architectural design of cost-effective standardised modular and scalable powertrain components and E/E architecture) give the baseline and vehicle-related requirements and specifications for the T4.1 (Requirements and specifications for multi-energy stations). Task 2.1 has produced deliverable D2.1 (Hartavi Karci and Otuz, 2023), and Task 3.1 deliverable D3.1 (Mladek, 2023).

	2023								
	1	2	3	4	5	6	7	8	9
T2.1						D2.1			
T3.1						D3.1			
T4.1									D4.1

Figure 1. The interdependency of D4.1 and D2.1 + D3.1.

2 Introduction

Requirements and specifications of single energy stations (SES) and multi-energy stations (MES) of the pilot vehicles including the battery heavy-duty vehicles (be-HDV), fuel cell heavy-duty vehicles (fc-HDV), and hybrid vehicle using both fuel cells as range extenders and batteries (re-HDV) are defined in this deliverable. For battery pilot vehicles the electric vehicle supply equipment (EVSE, charging stations) has been defined, and for the fuel cell vehicles the hydrogen refuelling equipment.

Both requirements and deliverables are derived from the demands of the pilots. The general flow from the objectives via requirements to specifications is shown in Figure 2. The idea is first to define the requirements according to the project objectives, and then set the specifications according to these requirements. Also, the requirements and specifications of the vehicles in other project work packages (WPs) are considered, whenever applicable.

The work in T4.1. has been carried out in 3 working groups (WGs). WG1 has been in charge for the hydrogen related requirements and specification, WG2 for the charging related requirements, and WG3 for the waste heat recovery and safety related requirements.

The requirements have been collected internally to a database. In this database the most important requirements have been approved by the WGs. The approved requirements have been used for the definition of the specifications for the MES. These most important requirements as well as the main specifications are presented in this deliverable.

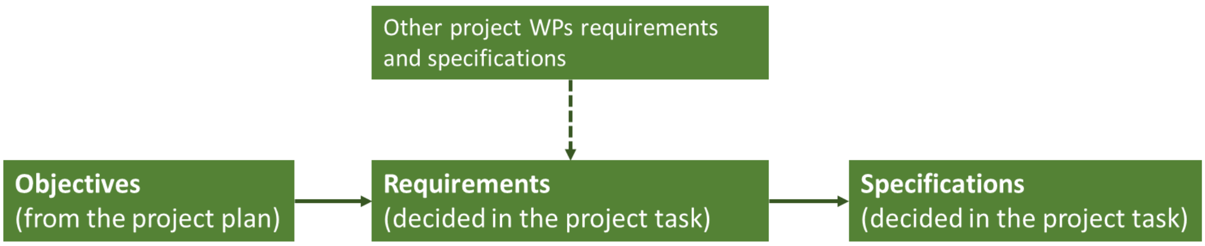

Figure 2. The flow from the project objectives to the specifications via the requirement phase.

3 Multi- and single energy stations for the pilots

The pilots in ESCALATE project need both the refuelling and charging infrastructure. The overview of the needed infrastructure is presented in Table 1. There are totally 5 heavy-duty vehicle (HDV) pilots: 2 hydrogen energy pilots using fuel cells (fc-HDV), 2 electric battery energy pilots (be-HDV), and 1 pilot combining both electric battery energy and a fuel cell as a range extender (re-HDV).

For Pilot 1 the role of the fuel cell is to operate as a range extender for the battery capacity. The need for the amount of H2 is moderate, as well as for the fuel pressure. Pilot 1 has a relatively large capacity battery. For this reason, the megawatt charging system (MCS) is the objective for the charging solution. Operating in Finland, Pilot 1 has one multi-energy station (MES) with MCS charging and hydrogen refuelling, and one or several single-energy stations (SES).

For the Pilot 2, the refuelling objectives are ambitious It will operate in France and in Türkiye. Station types are single-energy stations.

Pilot 3 is the battery-operated truck, travelling cross-border between Türkiye and Bulgaria. The regular combined charging system EVSEs are planned to be used for the charging of the vehicle batteries, as SESs. for this application.

Pilot 4 has its operational areas in Germany and in the UK. From multi-energy stations point of view this pilot is also using the regular CCS EVSEs, a similar approach of the Pilot 3, as SESs for this pilot.

The Pilot 5 operates solely in the virtual domain, so there are no requirements or specifications for a real refuelling station.

In addition to these direct refuelling and charging requirements there are safety and waste heat recovery (WHR) requirements, which are also considered. In general, there is many infrastructure-related requirements and specifications, but in WP4 and in T4.1 particularly, the focus is only both in the pilots and WHR, also taking some safety aspects into account at the same time. The economic aspects of MESs and SESs were not considered at this early phase of the project, but they will be addressed later in ESCALATE projects in upcoming tasks.

Table 1. The overview of the pilot objectives for the refuelling and charging.

Pilot	H2 refuelling	Charging	Station types	Stations‘ locations
1: re-HDV	x	MCS	MES, SES	Finland
2: fc-HDV	x		SES	France, Türkiye
3: be-HDV		CCS	SES	Türkiye, Bulgaria
4: be-HDV refrigerator		CCS	SES	Germany, the UK
5: fc-HDV refrigerator	(x)		-	virtual: Switzerland, France, Spain

3.1 Refuelling objectives for pilots

The refuelling infrastructure objectives are summarized in Table 2. Pilots 2 and 5 are hydrogen fuel cell trucks, and Pilot 1 has a hydrogen range extender. Pilot 5 will be realised only as a model. Since there will be no virtual single-energy hydrogen refuelling station, no objectives, requirements, nor specifications for it are defined.

Table 2. The hydrogen refueling pilots.

Pilot	Vehicle provider/ operator	H2 Fuelling providers	Fuelling characteristics	Fuelling objectives and information	Fuelling locations
1 re-HDV	SISU/ Tr Jylhä	*TBD*	• 70 kg H2 at 350 bar	• H2 refuelling once per roundtrip. • Time reserved for H2 refilling per round trip = 20 min • Minimum 400 km range recovery in 45 min for charging + H2 refilling • H2 infra in Lahti area along the core TEN-T corridor, in place from 2025	Finland: • Vuosaari (Helsinki) • (Lahti) • (Jyväskylä)
2 fc-HDV	BMC/DHL	ENGIE, TEKFEN	• H2 tanks at 700 bar (65-80 kg H2)	• High speed protocols applied at ENGIE station : 170g/s (capacity station 4t/day) • Mobile HRS for TEKFEN: refuelling in 15-25 min (capacity station 120 kg/day)	France, Türkiye
5 fc-HDV refri-gerator	FORD/-	-	• up to 80 kg H2 at 700 bar	• **Only virtual**	virtual: • Switzerland • France • Spain

3.2 Refuelling objectives for pilots

The charging infrastructure is summarized in Table 3. Pilot 1 will use megawatt charging system (MCS) while the other Pilots will use conventional fast DC combined charging system (CCS).

Table 3. The charging pilots.

Pilot	Vehicle provider/ operator	Charging providers	Charging characteristics	Charging objectives and information	Charging locations
1 re-HDV	SISU/ Tr Jylhä	Kempower	• MCS charging	MCS 700 kW, 800 km with a single charge (with a range extender)	Finland: • Vuosaari (MCS, Helsinki) • Lahti, optional (MCS/ CCS) • Jyväskylä (CCS)
3 be-HDV	MBT/DHL	Any available	• Fast CCS charging	*TBD*	Türkiye: • Istanbul Bulgaria: • Sofia
4 be-HDV refrigerator	ELECTRA/ ELECTRA	Any available	• Fast CCS charging	Dependent on the battery requirements – Electra currently use CATL, but BRING will be providing the batteries for this project, specifications currently not known.	Germany: • Flensburg Worth (Karlsruhe) UK: • Dundee Southampton

3.3 Charging waste heat recovery for charging stations

To lower the ecological footprint of charging stations and at the same time, increase the overall efficiency of the complete system, a sound concept of waste heat recovery (WHR) should be implemented, especially when multiple charging stations are in operation at a particular charging site. Considering a 5 % - 7 % heat loss during fast charging, heat losses of 50 kW - 70 kW will occur for a 1 MW charging station. This heat, commonly is being dissipated to the surrounding through convective cooling without taping into its potential, energetically speaking. In this project, one of the goals is to use this potential through WHR strategies and therefore some feasible concepts are being presented hereafter.

When talking about WHR the heat losses can be classified into three categories: High temperature (above 400 °C), medium temperature (100 °C - 400 °C), and low temperature grade heat (below 100 °C). For each category, different types of WHR systems can be employed. Since the power electronics within a power charger in general should not be exposed to temperatures higher than 60 °C, we are faced with WHR at the lower spectrum of low-grade heat. Low grade heat tends to be the hardest to recover cost effectively and typical examples of recovering low grade waste heat would be ventilation or hot water systems. There has been some research conducted in recent years to recover low grade waste heat through different thermodynamic processes, like heat pumps (vapor compression or absorption heat pumps), low heat power cycles (Organic Rankine Cycle), absorption (Zeolith, Silica Gel, etc.), and thermoelectric and thermomagnetic generators. Due to the ease of implementation, reliability, and marketability only vapor compression heat pumps (VCHP) are being considered for this project.

Vapor Compression heat pump (VCHP) is a classical heat pump (HP) design proven at industrial scale where available heat (e.g., waste heat) is collected within the evaporator, brought to a higher temperature level through the refrigerant compressor and dissipated within the condenser, where the heat dissipated represents the benefit for the heat pump cycle (e.g., hot water, radiator heating, floor heating). A very basic view of coupling a heat pump system architecture with a charging station to leverage the incurring waste heat to a more usable temperature level for a given use case is being shown in the Figure 3. In this example, the heat sink is a general one (often of a water pool or similar type), but in practical MES and SES applications the heat sink will be selected according to the site specific properties, and this only illustrates the concept.

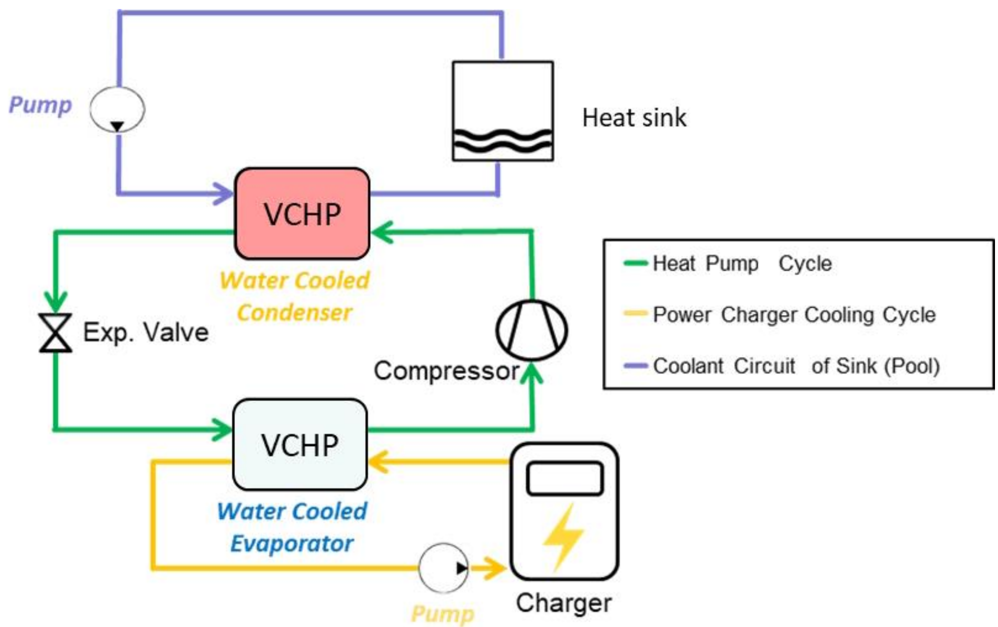

Figure 3. Basic concept of WHR with a heat pump system.

Using waste heat collected from the power charger as a heat source for the heat pump system brings a significant increase in COP (coefficient of performance) of the HP system, therefore reducing the necessary electrical power to heat up, for example, an existing water pool. Table 4 lists several possible WHR use cases, that could be investigated further.

Table 4. Possible Uses Cases for Waste Heat Recovery

Use Case	Temperature Level (°C)	Heat Pump needed (y/n)
Tap Water Heating	70 °C	y
Water Pool Heating	70 °C - 90 °C	y
Low Temp. Floor heating	30 °C - 35 °C	n
Ground Heating	30 °C - 35 °C	n
Feed into district heating system	120 °C - 70 °C	y

4 Categories and priorities of the requirements

The requirements are divided into 6 categories, as presented in the Table 5. Furthermore, these requirements are prioritized to 4 levels, as shown in Table 6.

The requirements are used as basis of the specifications of MESs and SESs. At minimum the "must"-level requirements will be converted into specifications, and lower priority ones, if found necessary. Mostly only "must" and "should" level requirements are adapted as the specifications.

Table 5. The requirement and specification categories.

Category	Description	Examples
Performance	The performance of the components and the complete station	Required charging power, availability
Safety	The safety of the components and the complete station	Fulfils standard x
Functionality	How the station and its components should operate	What kind of charging connectors should be available, how to initiate the charging, at which side the connector should be, installability and serviceability requirements, requirements from the location of stations
Connectivity	How the components should be connected to the back end, and each other, and how the complete station is connected	OCPP, integration to the logistic company backends & billing
User experience (UX)	What the user expects from the station	How the station should be available, accessibility and usability, how the station can be accessed and used (also by the partly disabled or similar persons)
Sustainability	What are the sustainability requirements for the components and the station	For charging/refuelling stations for vehicles, sustainability requirements typically include using renewable energy sources for power, and integrating eco-friendly materials and designs that minimize environmental impact during operation

Table 6. The requirement and specification priorities.

Priority	Description
Must	An essential requirement, that must be fulfilled. The highest category.
Should	A relatively essential requirement. The second highest category.
Could	A requirement that is somewhat important. The third category.
Would	A non-essential requirement, nice-to-have, if possible. The lowest category.
Dropped	A requirement that is listed, but then dropped from the list. Can be kept on the list for the future reference.

5 Standards and regulations

5.1 Relevant hydrogen refuelling standards and regulations

Hydrogen refuelling stations (HRS) are covered with several standards and regulations. The most important ones for ESCALATE refuelling stations are the gaseous hydrogen refuelling standards

- Directive 2014/94/EU (EU, 2014b) (Deployment of alternative fuels infrastructure. Setting technical specifications for alternative fuels refueling stations. Recommends the follow through with ISO/TS 20100 standards)
- ISO/TR 15916:2015 (Basic considerations for the safety of hydrogen systems)
- ISO 17268:2020 (Gaseous hydrogen land vehicle refuelling connection devices)
- ISO 17127:2020 (Gaseous hydrogen land vehicle refuelling connection devices)
- ISO 19880-1:2020 (Gaseous hydrogen — Fuelling stations — Part 1: General requirements)
- ISO 19880-3:2018 (Gaseous hydrogen — Fuelling stations — Part 3: Valves)
- ISO 19880-5:2019 (Gaseous hydrogen — Fuelling stations — Part 5: Dispenser hoses and hose assemblies)
- ISO 19880-8:2019 (Gaseous hydrogen — Fuelling stations — Part 8: Fuel quality control)
- ISO 19880-8:2019/Amd 1:2021 (Gaseous hydrogen — Fuelling stations — Part 8: Fuel quality control — Amendment 1: Alignment with Grade D of ISO 14687)
- ISO 17533:2020 (Gaseous hydrogen - Cylinders and tubes for stationary storage)
- ASME B31.12 (Hydrogen Piping and Pipelines)
- IEC 60079-10-1 (Classification of areas – Explosive gas atmospheres)
- IEC 60079-29-2 (Gas detectors – Selection, installation, use and maintenance of detectors for flammable gases and oxygen)
- SAE J2600 (Hydrogen Coupling)
- SAE J2601 (Fueling Protocol for Light/Heavy Duty Vehicles & Forklifts)
- SAE J2799 (FCEV to Station Communications)

5.2 Relevant charging standards and regulations

For charging and EVSE there are several related standards. Basic conductive charging standards are in EN IEC 61851 standards group: 61851-1 has general requirement (EN IEC 61851-1, 2017), 61851-21 EMC requirements (EN IEC 61851-21-2, 2021), and 61851-23 requirements for charging stations (EN IEC 61851-23, 2014).

For megawatt charging CharIN organisation has released the white paper discussing the requirements (CharIN, 2022). Actual MCS standards for EU are currently under preparation.

CCS communication specifications are given in EN ISO standard series, in 15118-1 the general information (EN ISO 15118-1, 2019), in 15118-2 the protocol (EN ISO 15118-2, 2016), and in 15118-3 physical and data link requirements (EN ISO 15118-3, 2016).

The connectors for CCS charging are specified in standards EN IEC 62196-1 (2022) and EN IEC 62196-3 (2022). The thermally managed connector specifications are in the standard IEC TS 62196-3-1:2020.

There are also some standards to be published soon, such as a pre-release version of IEC 61851-23 (IEC 61851-23:2023 PRV, 2023)

5.3 Relevant multi-energy and safety standards

Hydrogen refuelling and charging form together potentially hazardous conditions. Such explosive atmospheres are considered in EU directive (EU, 2014a) and Ex (ATEX) standards. The most important standards in this group are general requirements (EN IEC 60079-0, 2018), classification of areas (EN IEC 60079-10-1, 2021), and design of electrical installations (EN IEC 60079-14, 2014). The ISO 19880 standard is widely used globally and recommends minimum design characteristics for safe and effective refuelling stations.

Safety for conductive charging system is covered in EN ISO 17409 (EN ISO 17409, 2020).

Hydrogen fuel quality: Requirements for hydrogen for road vehicles. This standard specifies the requirements for hydrogen fuel for road vehicles, including purity, moisture content, and other properties. (ISO 14687-2:2020).

6 Common NVH requirements and specifications for all MESs and SESs

There are common NVH (noise and vibration harshness) requirements and specifications for all multi- and single energy station for the pilots.

6.1 Common NVH requirements for all pilot MESs and SESs

The common requirements for all pilot MESs and SESs are presented in Table 7. The requirements contain the noise requirements.

Table 7. The general requirements for all pilots MESs and SESs.

Requirement title	Requirement	Category	Priority	Comments
Noise outside	Max 60 dB (A) @ 1 m	User experience (UX)	Must	KPI-16. Sound pressure values.
Noise inside cabin	Max 40 dB (A)	User experience	Must	KPI-16. Sound pressure values.

6.2 Common NVH preliminary specifications for all pilot MESs and SESs

The common preliminary specifications for all pilot MESs and SESs are presented in Table 8. The specifications contain the noise levels outside and inside the truck cabin. The measurement possibilities inside the cabin include a microphone at the position of a driver's head, dummy head, or binaural microphone at the driver's head. Binaural microphones are recommended for validation of the values, but other methods are also acceptable. The noise inside that cabin is related also to pilot vehicle noise insulation specifications. 20 dB insertion loss is assumed as a baseline. If the sound insulation properties of the truck cabin are considerably less, the noise level may exceed the target value.

Table 8. The general specifications for all pilots MESs and SESs

Specification title	Specification	Category	Comments
Noise outside	Less than 60 dB SPL (A) @ 1 m, measured at the front of the power supply cabin	User experience (UX)	KPI-16. Sound pressure values, measured in the free field.
Noise inside cabin	Less than 40 dB SPL (A), measured at the driver head location	User experience	KPI-16. Sound pressure values, measured with a suitable test setup. Depends also on the cabin sound insulation properties defined for the vehicles.

7 Pilot 1 multi-energy station (MES) and single-energy stations (SESs)

Pilot 1 multi-energy station (MES) comprises of the hydrogen refuelling and charging stations. Furthermore, Pilot 1 single-energy stations (SESs) are charging stations (EVSEs). Geographically, MES refuelling and charging are preferably close to each other, but the exact composition will be defined later in the project and is not currently part of the requirements or specifications.

Both requirements (demand) and specifications (the realization) are presented for Pilot 1 MES and SESs in this chapter.

7.1 Pilot 1 MES and SESs objectives

Objectives for the Pilot 1 MES and SESs are presented in Tables 9 and 10. They are the baseline for the definition of the requirements for such stations. The objectives originate partly from the project plan, and partly from the specifications of the pilot vehicles.

Table 9. The hydrogen refueling objectives for Pilot 1 including planned locations.

Vehicle provider/ operator	H2 Fuelling providers	Fuelling characteristics	Fuelling objectives and information	Planned refuelling locations
SISU/ Tr Jylhä	Will be decided later during the project	70 kg H_2 at 350 bar	• H2 refuelling once per roundtrip • Time reserved for H2 refilling per round trip = 20 min • Minimum 400 km range recovery in 45 min for charging + H2 refilling • H2 infra in Lahti area along the core TEN-T corridor, in place from 2025	Finland: • Vuosaari (Helsinki) • (Lahti) • (Jyväskylä)

Table 10. The charging objectives for Pilot 1 including planned locations.

Vehicle provider/ operator	Charging providers	Charging characteristics	Charging objectives and information	Planned charging locations
SISU/ Tr Jylhä	Kempower	MCS charging	• KPI-15 & KPI-20: 1 MW charging • MCS 700 kW, 800 km with a single charge (with a range extender, modeling result • Prerequisite from D3.1: battery capacity 700 kWh	Finland: • Vuosaari (Helsinki) • Lahti • Jyväskylä • Kokkola

7.2 Pilot 1 MES and SESs location requirements

There is requirement for one MES for Pilot 1, and for one or several additional SESs. The requirements are presented in the Table 11.

Table 11. The location requirements for Pilot 1.

Requirement title	Requirement	Stations	Category	Priority	Comments
MES location	A suitable location to make Pilot 1 long haul operation possible (Case 1.3)	Pilot 1 MES	Performance	Must	Vuosaari, Finland, planned for this
SES locations	Suitable locations to make Pilot 1 operations possible, for all cases	Pilot 1 SESs	Performance	Must	Possible locations in Finland Lahti, Jyväskylä, Kokkola

7.3 Pilot 1 hydrogen refuelling requirements

Pilot 1 hydrogen refuelling requirements are shown in Table 12.

Table 12. The hydrogen refuelling requirements for Pilot 1.

Requirement title	Requirement	Charging station	Category	Priority	Comments
Data connectivity protocol	Dynamic refuelling Protocol require to fulfil H_2 filling duration.	All pilot 1 MESs	Connectivity	Must	Protocol from PRHYDE EU project and SAE J2601 can be taken as example
Needed hydrogen amount	80 kg	Vuosaari, Finland	Performance	Must	Needed to drive the long haul mission
Time reserved for H2 refilling per round trip	20 min	Vuosaari, Finland	Performance	Should	
Needed hydrogen amount	80 kg	Lahti, Finland	Performance	Could	If refuelling station in Lahti will be realised
Time reserved for H2 refilling per round trip	20 min	Lahti, Finland	Performance	Could	If refuelling station in Lahti will be realized
Hydrogen quality	Hydrogen purity must be sufficient	All pilot 1 MESs	Sustainability	Must	

7.4 Pilot 1 charging requirements

Charging requirements for Pilot 1 are presented in Table 13.

Table 13. The charging requirements for Pilot 1.
JT = Jylhä terminal, Vuosaari, Finland. JK = Jyväskylä, Finland. KO = Kokkola, Finland.

Requirement title	Requirement	Charging station	Category	Priority	Comments
Charging time	45 min	JT	Performance	Must	KPI-21, up to 90 % SOC
Charging efficiency	80 %	JT	Performance	Must	KPI-21
Charging power, average	840 kW	JT	Performance	Must	Over the 0 % - 90 % charging cycle, computed from other requirements
Charging power, peak	1 MW	JT	Performance	Must	Must be available during some part of the charging cycle, KPI-20
Charging voltage, min	500 VDC	JT	Performance	Must	Battery configuration limit
Charging voltage, max	810 VDC	JT	Performance	Must	Battery configuration limit
Data connectivity protocol for EVSE	MCS	JT	Connectivity	Should	If not MCS protocol available, then MCS power levels but CCS protocol possible
Adjustability of the charging power	From the lowest vehicle request to 1 MW	JT	Connectivity	Should	
EVSE effects on the grid	Values of THD and reactive power must be under defined limits	JT	Connectivity	Should	
Charging cable handling	Easy to reach and connect to vehicle	JT	Functionality	Must	
Charger efficiency	Min. 90 %	JT	Performance	Must	KPI-18, with the cable
Charging power, average	90 kW	JK	Performance	Should	
Charging voltage, min	500 VDC	JK	Performance	Must	
Charging voltage, max	810 VDC	JK	Performance	Must	
Data connectivity protocol for EVSE	CCS	JK	Connectivity	Should	
Charging maximum duration	8 h	JK	Performance	Must	Over the 0 % - 90 % charging cycle, computed from other requirements
Charging power, average	90 kW	KO	Performance	Should	
Charging voltage, min	500 VDC	KO	Performance	Must	
Charging voltage, max	810 VDC	KO	Performance	Must	
Data connectivity protocol for EVSE	CCS	KO	Connectivity	Should	
Charging maximum duration	8 h	KO	Performance	Must	Over the 0 % - 90 % charging cycle, computed from other requirements

7.5 Pilot 1 MES and SESs safety and WHR requirements

The safety and WHR requirements for all Pilot 1 MES and all SESs are presented in Table 14. Due to the early phase of the development, the WHR requirements are in general level. Related to that, only general specifications for the WHR are given at this stage of development and research work.

Table 15 lists the initial parameters to be studied during the concepting and designing the WHR for Pilot 1, MES. During the studies, PSU (EVSE power supply), the charging cable, and the other relevant components will be addressed separately.

Table 14. The safety and WHR requirements for Pilot 1.

Requirement title	Requirement	Stations	Category	Priority	Comments
Safety	According to the standards	All Pilot 1 MESs and SESs	Safety	Must	Must fulfil the relevant standards
Fire and explosion protection	The system shall be designed to prevent fires and explosions.	MES and SESs	Safety	Must	This includes using explosion-proof equipment, providing adequate ventilation, and training personnel in safety procedures.
Electrical safety	The system shall be designed to prevent electrical hazards.	MES and SESs	Safety	Must	This includes using explosion-proof electrical equipment, grounding all equipment properly, and avoiding the use of open flames near hydrogen.
System monitoring	Sufficient monitoring	MES refuelling	Safety	Must	This allows for early intervention to prevent accidents.
WHR performance	Sufficient WHR	MES charging	Performance	Should	According to the relevant standard(s)

Table 15. The general WHR parameters for Pilot 1 MES station.

Parameters of actively cooled components	MES Station
Type of Coolant [e.g., air, water/glycol, thermal oil]	TBD
Maximum estimated Heat Dissipation (kW)	~50 kW -70kW (estimate)
Temp. Level of Dissipation (°C)	40°C -70°C (estimate)
T_max of coolant at Inlet (°C)	TBD
Maximum Δ_T across component (K)	TBD
T_max of Component (°C)	TBD
Maximum mass flow rate of coolant (kg/s)	~2 -3.5 (estimate for water/glycol)
Minimum mass flow rate of coolant (kg/s)	TBD

7.6 Pilot 1 MES and SESs preliminary location specifications

Currently, 2 main locations for Pilot 1 refuelling and charging are selected, as shown in Table 16. There are also additional locations available for SESs, both charging and refuelling, including Lahti area, but they are not specified in this deliverable.

Table 16. The preliminary location specifications for Pilot 1.

Requirement title	Specification	Stations	Category	Priority	Comments
MES location	Vuosaari, Finland	Pilot 1 MES (hydrogen refuelling and charging)	Performance	Must	Vuosaari, Finland, selected for this
SES location 1	Jyväskylä, Finland	Pilot 1 SES (charging)	Performance	Must	Jyväskylä selected for this
SES location 2	Kokkola, Finland	Pilot 1 SES (charging)	Performance	Must	

7.7 Pilot 1 preliminary hydrogen refuelling specifications

Preliminary refuelling specifications for Pilot 1 are shown in Table 17.

Table 17. The hydrogen refuelling specifications for Pilot 1.

Specification title	Specification	Charging station	Category	Comments
Data connectivity protocol	Protocol from PRHYDE EU project and SAE J2601	Vuosaari, Finland	Connectivity	
Needed hydrogen amount	80 kg	Vuosaari, Finland	Performance	Needed to drive the long haul mission, increase from the objectives
Minimum flow of hydrogen in refuelling	3.6 kg/min	Vuosaari, Finland	Performance	
Hydrogen quality	Pure hydrogen (hydrogen purity ≥ 99.99%	Vuosaari, Finland	Sustainability	Options: Pure hydrogen (hydrogen purity ≥ 99.99%), high pure hydrogen (hydrogen purity ≥ 99.999%), and ultrapure hydrogen (hydrogen purity ≥ 99.9999%) Standard ISO 14687.

7.8 Pilot 1 preliminary charging specifications

Charging specifications for Pilot 1 are presented in Table 18. The MCS charging requirements translate directly to the specifications, for average charging power of 700 kW. From this requirement also the specifications for the needed grid power and charger efficiency can be deducted.

Table 18. The preliminary charging specifications for Pilot 1.
JT = Jylhä terminal, Vuosaari, Finland. JK = Jyväskylä, Finland. KO = Kokkola, Finland.

Specification title	Specification	Station location	Category	Comments
Charging power, average	840 kW	JT	Performance	
Charging power, peak	1 MW	JT	Performance	
Grid power, average	950 kW	JT	Performance	Computed from other specifications
Grid power, peak	1.1 MW	JT	Performance	Computed from other specifications
Charging voltage, min	500 VDC	JT	Performance	
Charging voltage, max	810 VDC	JT	Performance	
Charger efficiency	90 %	JT	Performance	KPI-18
Data connectivity protocol for EVSE	MCS	JT	Connectivity	If not MCS protocol available, then MCS power levels but CCS protocol
Grid connection type	Local transformer	JT	Connectivity	To ensure sufficient power
Adjustability of the charging power	From the lowest vehicle request to 1 MW	JT	Connectivity	
Grid power quality, THD caused by EVSE	less than 5 % @ nominal load	JT	Connectivity	
Grid power quality power factor (PF), effected by EVSE	Greater than 0.98	JT	Connectivity	
Dispenser maximum dimensions	Easy to reach and connect to vehicle, cable short enough for good efficiency	JT	Functionality	Cooling requirements for MCS increase rapidly with increasing charging cable length
Data connectivity protocol for EVSE	MCS	JT	Connectivity	If not MCS protocol available, then MCS power levels but with CCS protocol
Charging power, average	90 kW	JK	Performance	
Grid supply power, average	100 kW	JK	Performance	
Charging voltage, min	500 VDC	JK	Performance	
Charging voltage, max	810 VDC	JK	Performance	
Data connectivity protocol for EVSE	CCS	JK	Connectivity	
Charging power, average	90 kW	KO	Performance	
Grid supply power, average	100 kW	KO	Performance	
Charging voltage, min	500 VDC	KO	Performance	
Charging voltage, max	810 VDC	KO	Performance	
Data connectivity protocol for EVSE	CCS	KO	Connectivity	

7.9 Pilot 1 MES and SESs preliminary safety and WHR specifications

The safety and WHR specifications for Pilot 1 MESs and SESs are shown in Table 19.

Table 19. The preliminary safety and WHR specifications for Pilot 1.

Specification title	Specification	Station location	Category	Comments
Safety	According to the standards: 61851-23-3, IEC 63379, 15118-xx (diff PLC), J3271 (MCS standard, connector)	All Pilot 1 MES & SESs	Safety	
Leak detection and prevention	The system shall be designed to detect leaks and to take action to prevent them. ISO 61851-23-3, IEC 63379	All MES and SESs	Safety	This includes using leak detectors, inspecting equipment regularly, and maintaining proper operating procedures.
Emergency Shutdown System	Integrated emergency shutdown system (ESS), compliant with ISO 26262 and SAE J2954 standards.	All charging stations	Safety	Equipped with ESS for immediate safety measures in case of emergencies during charging.
Thermal Management	ISO 26262 or Manufacturer's Standard	Pilot 1 MES	Performance	Compliance with ISO 26262 or adherence to the manufacturer's specific standards for thermal management
System monitoring	The system shall be equipped with monitoring systems to detect and report any abnormalities.	MES refuelling	Safety	This allows for early intervention to prevent accidents.

8 Pilot 2 single-energy hydrogen refuelling stations (SESs)

Pilot 2 single-energy stations (SESs) are a hydrogen refuelling stations. Both requirements (demand) and specifications (the realization) are presented for Pilot 2 SESs.

8.1 Pilot 2 SESs objectives

The objectives for the Pilot 2 SESs are presented in Table 20. They form the baseline for the definition of the requirements for such SESs.

Table 20. The hydrogen refueling objectives for Pilot 2 SESs including planned locations.

Vehicle provider/ operator	H_2 Fueling providers	Fueling characteristics	Fueling objectives and information	Planned refueling locations
BMC/DHL	ENGIE, TEKFEN	70 kg H2 at 700 bar	• High speed protocols applied at ENGIE station: 170g/s (capacity station 4t/day) • Mobile HRS for TEKFEN: refuelling in 15-25 min (capacity station 120 kg/day)	France, Türkiye

8.2 Pilot 2 SESs location requirements

2 main locations for Pilot 2 refuelling are selected, as shown in Table 21.

Table 21. The location requirements for Pilot 2.

Requirement title	Requirement	Refuelling stations	Category	Priority	Comments
SES location 1	Istanbul, Türkiye	Pilot 2 SES (refuelling)	Performance	Must	İstanbul, Türkiye
SES location 2	*Around Paris, Gennevilliers*	Pilot 2 SES (refuelling)	Performance	Must	France

8.3 Pilot 2 hydrogen refuelling requirements.

Refuelling specifications for Pilot 2 are presented in Table 22 .

Table 22. The hydrogen refuelling requirements for Pilot 2.

Requirement title	Requirement	Refuelling station	Category	Priority	Comments
Data connectivity protocol	Dynamic refuelling Protocol require to fulfil H_2 filling duration.	All pilot 2 SESs	Connectivity	Must	Protocol from PRHYDE EU project and SAE J2601 will be taken as example
Needed hydrogen amount	65 kg - 80 kg	All pilot 2 SESs	Performance	Must	Needed to drive the long-haul mission
Time reserved for H_2 refilling per round trip	20 min	SES 1 (TEK)	Performance	Should	Needed to supply hydrogen in fast refuelling
Hydrogen quality	Hydrogen purity must be sufficient	All pilot 2 SESs	Sustainability	Should	

8.4 Pilot 2 SESs safety requirements

The safety requirements for all Pilot 2 SESs are presented in Table 23.

Table 23. The safety requirements for Pilot 2.

Requirement title	Requirement	Refuelling stations	Category	Priority	Comments
Safety	According to the standards	All Pilot 2 SESs	Safety	Must	Must fulfil the relevant standards
Hydrogen quality	The hydrogen used in the system shall be of a high quality and shall meet the requirements of the relevant standards.	All Pilot 2 SESs	Safety	Medium	This ensures that the system operates efficiently and that the fuel cells are not damaged.
System monitoring	Sufficient monitoring	MES refuelling	Safety	Must	This allows for early intervention to prevent accidents.

8.5 Pilot 2 SESs preliminary location specifications

Preliminary location specifications are presented in Table 24.

Table 24. The location requirements for Pilot 2.

Requirement title	Specification	Refuelling stations	Category	Comments
SES 1 location	Location in France	Pilot 2 SES 1	Performance	
SES 2 location	Location in Türkiye	Pilot 2 SES 2	Performance	

8.6 Pilot 2 preliminary hydrogen refuelling specifications.

Pilot 2 preliminary hydrogen refuelling specifications are in Table 25.

Table 25. The hydrogen refuelling specifications for Pilot 2.

Specification title	Specification	Refuelling station	Category	Comments
Data connectivity protocol	Protocol from PRHYDE EU project and SAE J2601	All pilot 2 SESs	Connectivity	
Needed hydrogen amount	*TBD*	All pilot 2 SESs	Performance	Needed to drive the long-haul mission
Minimum flow of hydrogen in refuelling	*TBD*	All pilot 2 SESs	Performance	
Hydrogen quality	Pure hydrogen (hydrogen purity ≥ 99.99%	All pilot 2 SESs	Sustainability	Options: Pure hydrogen (hydrogen purity ≥ 99.99%), high pure hydrogen (hydrogen purity ≥ 99.999%), and ultrapure hydrogen (hydrogen purity ≥ 99.9999%) Standard ISO 14687.

8.7 Pilot 2 SESs preliminary safety specifications

The safety specifications for all Pilot 2 SESs are presented in Table 23.

Table 26. The safety requirements for Pilot 2.

Requirement title	Specification	Refuelling station	Category	Comments
Safety	*TBD*	All Pilot 2 SESs	Safety	Must fulfil the relevant standards
Thermal Management	ISO 26262 or Manufacturer's Standard	All Pilot 2 SESs	Safety	Compliance with ISO 26262 or adherence to the manufacturer's specific standards for thermal management
System monitoring	The system shall be equipped with monitoring systems to detect and report any abnormalities.	MES refuelling	Safety	This allows for early intervention to prevent accidents.

9 Pilot 3 single-energy charging stations (SESs)

Pilot 3 single-energy stations (SESs) are charging stations. Both requirements (demand) and specifications (the realization) are presented for Pilot 3 SESs.

9.1 Pilot 3 SES objectives

In Table 27 the objectives for the Pilot 3 SESs are presented. They form the baseline for the definition of the requirements for such SES.

Table 27. The charging objectives for Pilot 3.

Vehicle provider/ operator	Charging providers	Charging characteristics	Charging objectives and information	Charging locations
MBT/DHL	Any available	Fast CCS charging	*TBD*	Türkiye: • Istanbul Bulgaria: • Sofia

9.2 Pilot 3 SESs location requirements

Pilot 3 location requirements will be defined later in the project. Preliminary locations requirements are in Table 6

Table 28. The location requirements for Pilot 3.

Requirement title	Requirement	Charging stations	Category	Priority	Comments
SES locations	Suitable locations to make Pilot 3 operations possible	Pilot 3 SESs	Performance	Must	Possible locations Türkiye: • Istanbul Bulgaria: • Sofia

9.3 Pilot 3 charging requirements

Charging requirements for Pilot 3 are presented in Table 29.

Table 29. The charging requirements for Pilot 3.

Requirement title	Requirement	Charging station	Category	Priority
Charging power, average	*TBD*	All Pilot 3 SESs	User experience (UX)	Should
Charging maximum duration	*TBD*	All Pilot 3 SESs	Performance	
Charging voltage, min	*TBD*	All Pilot 3 SESs	Performance	Must
Charging voltage, max	*TBD*	All Pilot 3 SESs	Performance	
Data connectivity protocol for EVSE	CCS	All Pilot 3 SESs	Connectivity	

9.4 Pilot 3 SESs safety requirements

The safety requirements for all Pilot 3 SESs are presented in Table 30.

Table 30. The safety requirements for Pilot 3.

Requirement title	Requirement	Charging stations	Category	Priority	Comments
Safety	According to the standards	All Pilot 3 SESs	Safety	Must	Must fulfil the relevant standards

9.5 Pilot 3 SESs preliminary location specifications

Pilot 3 preliminary SES locations are shown in Table 31.

Table 31. The preliminary location specifications for Pilot 3.

Requirement title	Specification	Charging stations	Category	Priority	Comments
SES location 1	Istanbul	Pilot 3 SES (charging)	Performance	Must	Türkiye
SES location 2	Sofia	Pilot 3 SES (charging)	Performance	Must	Bulgaria

9.6 Pilot 3 preliminary charging specifications

Charging specifications for Pilot 3 are presented in Table 32. The CCS charging requirements translate directly to the specifications. From this requirement also the specifications for the needed grid power and charger efficiency can be deducted.

Table 32. The charging specifications for Pilot 3.

Specification title	Specification	Category
Charger efficiency	92 %	Performance
Charging power, average	*TBD*	Performance
Charging power, peak	*TBD*	Performance
Grid power, average	*TBD*	Performance
Grid power, peak	*TBD*	Performance
Charging voltage, min	500 VDC	Performance
Charging voltage, max	810 VDC	Performance
Data connectivity protocol for EVSE	CCS	Connectivity
Charging maximal duration	*Part of vehicle performance assessment listed in WP2 catalogue of assessment criteria (D2.1)*	Performance

9.7 Pilot 3 SESs preliminary safety specifications

Pilot 3 preliminary safety specifications are given in Table 33.

Table 33. The preliminary safety specifications for Pilot 3.

Specification title	Specification	Station location	Category	Comments
Safety	According to the standards: 61851-23-3, IEC 63379, 15118-xx (diff PLC), J3271 (MCS standard, connector),	All Pilot 3 SESs	Safety	
Emergency Shutdown System	Integrated emergency shutdown system (ESS), compliant with ISO 26262 and SAE J2954 standards.	All Pilot 3 SESs	Safety	Equipped with ESS for immediate safety measures in case of emergencies during charging.

10 Pilot 4 single-energy charging stations (SESs)

Pilot 4 single-energy stations (SES) are charging stations. Both requirements (demand) and specifications (the realization) are presented for Pilot 4 SESs.

10.1 Pilot 4 SES objectives

In Table 34 the objectives for the Pilot 4 SES are presented. They form the baseline for the definition of the requirements for such SES.

Table 34. The charging objectives for Pilot 4.

Vehicle provider/ operator	Charging providers	Charging characteristics	Charging objectives and information	Charging locations
ELECTRA/ ELECTRA	Any available	Fast CCS charging	*TBD*	Germany: • Flensburg Worth (Karlsruhe) UK: • Dundee Southampton

10.2 Pilot 4 SESs location requirements

The SES location requirements for Pilot 4 are presented in Table 35.

Table 35. The location requirements for Pilot 4.

Requirement title	Requirement	Charging stations	Category	Priority	Comments
SES locations	Suitable locations to make Pilot 4 operations possible	Pilot 4 SESs	Performance	Must	Possible locations: Germany: • Flensburg • Worth (Karlsruhe) UK: • Dundee • Southampton

10.3 Pilot 4 charging requirements

Charging requirements for Pilot 4 are presented in Table 36.

Table 36. The charging requirements for Pilot 4.

Requirement title	Requirement	Charging station	Category	Priority
Charging power, average	100 kW	All	User experience (UX)	Should
Charging maximum duration	12 h	All	Performance	
Charging voltage, min	*TBD*	All	Performance	Must
Charging voltage, max	*TBD*	All	Performance	
Data connectivity protocol for EVSE	CCS	All	Connectivity	

10.4 Pilot 4 SES safety requirements

The safety requirements for the all Pilot 4 single-energy stations (SESs) are presented in Table 37.

Table 37. The safety requirements for Pilot 4.

Requirement title	Requirement	Charging station	Category	Priority	Comments
Safety	According to the standards	All Pilot 4 SESs	Safety	Must	Must fulfil the relevant standards

10.5 Pilot 4 SESs preliminary location specifications

The preliminary location specifications for Pilot 4 are shown in Table 38.

Table 38. The preliminary location specifications for Pilot 4.

Requirement title	Specification	Charging stations	Category
SES location 1	Southampton, the UK	Pilot 4 SES (charging)	Performance
SES location 2	Dundee, the UK	Pilot 4 SES (charging)	Performance
SES location 3	Flensburg, Germany	Pilot 4 SES (charging)	Performance
SES location 4	Worth (Karlsruhe), Germany	Pilot 4 SES (charging)	Performance

10.6 Pilot 4 preliminary charging specifications

Charging specifications for Pilot 4 are presented in Table 39. The CCS charging requirements translate directly to the specifications. From this requirement also the specifications for the needed grid power and charger efficiency can be deducted. Some parameters are a part of vehicle performance assessment listed in WP2 D2.1 Catalogue of assessment criteria (Hartavi Karci and Otuz, 2023).

Table 39. The charging specifications for Pilot 4.

Specification title	Specification	Station location	Category
Charger efficiency	92 %	All	Performance
Charging power, average	*100 kW*	All	Performance
Charging power, peak	*TBD*	All	Performance
Grid power, average	*110 kW*	All	Performance
Grid power, peak	*TBD*	All	Performance
Charging voltage, min	*TBD*	All	Performance
Charging voltage, max	*TBD*	All	Performance
Data connectivity protocol for EVSE	CCS	All	Connectivity
Charging maximal duration	12 h	All	Performance

10.7 Pilot 4 SES preliminary safety specifications

Pilot 4 preliminary safety specifications are shown in Table 40.

Table 40. The preliminary safety specifications for Pilot 4.

Specification title	Specification	Station location	Category	Comments
Safety	According to the standards: 61851-23-3, IEC 63379, 15118-xx (diff PLC), J3271 (MCS standard, connector)	All Pilot 4 SESs	Safety	
Emergency Shutdown System	Integrated emergency shutdown system (ESS), compliant with ISO 26262 and SAE J2954 standards.	All Pilot 4 SESs	Safety	Equipped with ESS for immediate safety measures in case of emergencies during charging.

11 Conclusions

The focus of this deliverable was on the refuelling and charging of ESCALATE project heavy-duty vehicle (HDV) pilots. Requirements and specifications of single and multi-energy stations of the pilot vehicles including the battery heavy-duty vehicles (be-HDV), fuel cell heavy-duty vehicles (fc-HDV), and hybrid vehicle using both fuel cells as range extenders and batteries (re-HDV), were defined in this deliverable.

First the objectives for the T4.1 were collected both from the project plan in Grant Agreement (GA) and from the prior work in ESCALATE work packages and T4.1. After that, the three working groups reviewed the requirements, which were then transformed into preliminary specifications for this document.

The requirements and specifications are labelled as hydrogen refuelling, electric HDV charging, safety, and waste heat recovery categories. The main requirements as well as the preliminary specifications for all those are presented in this deliverable. Furthermore, the standardization and guidelines for all these topics were addressed.

Not all the requirements and specifications were given numerical values at this initial stage of the project, but importantly the need for them was identified. The specification activity will continue in order to enrich the level of performance of our expectations on this project.

12 References

CharIN (2022) CharIN Whitepaper Megawatt Charging System (MCS) Recommendations and requirements for MCS related standards bodies and solution suppliers. Standard MCS WP 2022-11-24 v 1.0. CharIN. Available at: https://www.charin.global/technology/mcs/ (Accessed: 26 November 2021).

EN IEC 60079-0 (2018) Explosive atmospheres - Part 0: Equipment - General requirements. Standard EN IEC 60079-0:2018. CENELEC.

EN IEC 60079-10-1 (2021) Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres. Standard EN IEC 60079-10-1:2021. CENELEC.

EN IEC 60079-14 (2014) Explosive atmospheres. Part 14: Electrical installations design, selection and erection. Standard EN IEC 60079-14:2014. CENELEC.

EN IEC 61851-1 (2017) Electric vehicle conductive charging system - Part 1: General requirements. Standard EN IEC 61851-1:2017. CENELEC.

EN IEC 61851-21-2 (2021) Electric vehicle conductive charging system - Part 21-2: Electric vehicle requirements for conductive connection to an AC/DC supply - EMC requirements for off board electric vehicle charging systems. Standard EN IEC 61851-21-2:2021. CENELEC.

EN IEC 61851-23 (2014) Electric vehicle conductive charging system - Part 23: DC electric vehicle charging station. Standard EN IEC 61851-23:2014. CENELEC.

EN IEC 62196-1 (2022) Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 1: General requirements. Standard EN IEC 62196-1:2022. CENELEC.

EN IEC 62196-3 (2022) Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers. Standard EN IEC 62196-3:2022. CENELEC.

EN ISO 15118-1 (2019) Road vehicles. Vehicle to grid communication interface. Part 1: General information and use-case definition. Standard EN ISO 15118-1:2019. CENELEC.

EN ISO 15118-2 (2016) Road vehicles — Vehicle-to-Grid Communication Interface — Part 2: Network and application protocol requirements. Standard EN ISO 15118-2:2016. CENELEC.

EN ISO 15118-3 (2016) Road vehicles. Vehicle to grid Communication interface. Part 3: Physical and data link layer requirements. Standard EN ISO 15118-3:2016. CENELEC.

EN ISO 17409 (2020) Electrically propelled road vehicles. Conductive power transfer. Safety requirements. Standard EN ISO 17409:2020. CENELEC.

EU (2014a) Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres with EEA relevance.

EU (2014b) Directive 2014/94/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to deployment of alternative fuels infrastructure.

Hartavi Karci, A. and Otuz, O. (2023) Catalogue of Assessment Criteria. ESCALATE project deliverable D2.1.

IEC 61851-23:2023 PRV (2023) Electric vehicle conductive charging system - Part 23: DC electric vehicle supply equipment. Standard IEC 61851-23:2023 PRV. IEC. Available at: https://webstore.iec.ch/publication/87434 (Accessed: 21 August 2023).

IEC TS 62196-3-1:2020 (2020) Plugs, socket-outlets, vehicle connectors and vehicle inlets - Conductive charging of electric vehicles - Part 3-1: Vehicle connector, vehicle inlet and cable assembly for DC charging intended to be used with a thermal management system. IEC TS 62196-3-1:2020. IEC. Available at: https://webstore.iec.ch/publication/59654 (Accessed: 21 August 2023).

Mladek, A. (2023) Requirements and Architectural Design of Cost-effective Standardised Modular and Scalable Powertrain Components. ESCALATE project deliverable D3.1.