Document in preparation of the Stan4SWAP workshop to be held on October 06th, 2025

WP7 – Standardization Roadmap about Swappable Battery System for L-cat vehicles

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Consortium:

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Introduction

The transport sector is responsible for around 25% of the EU total emissions. The European Green Deal is calling for all stakeholders of the European transport sector to support the deployment of cleaner and more energy efficient vehicles, to be able to live up to the goals set out in the Paris agreement. To this end, electric vehicles (EVs) play an important role in the decarbonisation of the sector. However, the downtime required to charge the batteries of these vehicle is a hindrance to a more widespread adoption of the technology. This is true both when it come EVs used for long distance transportation as well as for the light categories (L-cat) EVs with limited energy storage capacity often used in urban environment for shorter distances. This hindrance can be addressed with battery swapping systems which allows the users of EVs to swap empty batteries with fully charged ones. This solution offers a lot of benefits for cities and citizens including improved air quality and potential support to solving congestion challenges. However, for the innovation to be fulfil its potential interoperability is essential.

The Horizon Europe CSA (Coordination and Support Action) project Stan4SWAP recognises the need for integrating standards into the innovation process from an early stage to ensure swift transition. The project will work in a holistic manner along the full value chain of L-cat mobility to identify the issues, challenges, and gaps which may be eased by standardisation. The aim is to ensure interoperability among different vehicles and between vehicles swapping stations. To boost the industrial deployment of this innovative technology the project will develop a standardisation roadmap for a Swappable Battery System for L-cat vehicles. This roadmap will be a full part of the EU standardisation work program for the following years and send a significant signal to all stakeholders of the value chain to join efforts and contribute to the work.

1. Aim of the present document

The present document merges outcomes and results from STAN4SWAP WP5 “Needs for Pre-Normative Research (PNR)” and WP6 “Standardization Gaps”, that have been elaborated from WP 2 “Technical & Market State of the Art”, WP3 “Regulatory & Standardization State of the Art”, WP4 “Need for Swappable Battery System Deployment”.
In addition, this document included inputs from attendees of the July 15th 2025 Workshop, that contribute to a real improvement with additional topics to be considered.

With this Oct 6th workshop, Stan4SWAP consortium aims:

- First, to share with all concerned and interested stakeholders, its final draft outcome regarding the mapping of standardization related needs as identified in the project. The roadmap addresses needs at all levels along the swappable system value chain, respectively battery, vehicle, charging infrastructures (charging stations), as well as full system management. This covers priorities towards interoperability, compatibility, and communication, where safety and security are, of course, taken into account.
- Second, to complete with some remaining topics and issues and validate the Stan4SWAP proposed roadmap towards future standardization development
- Third, to consider any additional recommendation (i.e. RD&I support, policy and regulation, Pre-normative Research) supporting and booting deployment of swappable batteries systems for e-mobility and L-cat of vehicles.

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The identification of domains/topics of importance, follows the work conducted in the previous WPs of Stan4SWAP, and especially WP5 about mapping needs for Pre-normative Research (PNR), where maturity still needs improvement prior to launching standardization development, as well as WP6 about standardization gaps.

These needs cover 4 different levels :

- Battery level: Topics such as thermal risk, BMS optimization, and end-of-life management.
- Vehicle level: Mechanical and communication interfaces, safety during operation, and homologation challenges.
- Charging station/infrastructure level: Station deployment, energy metering, and grid integration (e.g. V2G).
- Interfaces and full system management: Topics such as data exchange, liability models, and cross-provider platform interoperability.

In coherence with our EU decarbonization strategy and objectives, especially in the mobility sector as primary application, and contributing to the EC standardization request M/581, in support of the EU Alternative Fuels Infrastructure Regulation (AFI-R) (EU) 2023/1804, the work is considering the following aspects, where standardization will have a key role to play (safety and security aspects being, of course, a topic considered in each aspect):

- *Standardization towards interoperability*
- *Standardization towards compatibility*
- *Standardization towards communication*

2. Organization of exchange with Oct 6th workshop's participants

This chapter concentrates on PNR identified topics (ch. 2.1) and Standardization Gaps (ch. 2.2).
Here after, tables of topics are set at, respectively, battery level, vehicle level, charging station/infrastructure level, and interfaces and full system management level.

An additional subchapter (ch2.3) concentrates on communication, respectively:

- communication protocols
- visual communication
- written communication
- digital communication

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This subchapter aims at identifying where standards could ensure a proper, safe and relevant communication, considering the EU regulatory landscape, esp. for batteries and e-vehicles.

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2.1 Pre-Normative Research

Each topic was evaluated using a standardized matrix that included criteria such as TRL, regulatory context, standardization potential, and stakeholder relevance. The outcome is a list of PNR topics that will be translated into the final standardization roadmap.

By aligning technical, regulatory, and stakeholder-driven perspectives, this list of PNR topics provides a robust basis for targeted and impactful standardization activities, contributing to the decarbonization and digitalization of urban mobility systems

2.1.1 PNR at battery level

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, standards, ...)	Standardization expectation	PNR (topics proposition)	Priority level (i to vii as above defined)	Partner / stake holder
Safety requirements	The temperature tolerance and fire hazards measures needs to be standardized to ensure quality of the system	Standard safety feature protocols		IEC TC 69	Establishing to ensure the safety and sustainability of batteries used in two-wheelers, promoting a safer transport.	Define standards and protocols for safety features	High (critical for avoiding hazards)	Standards and regulatory authorities

Battery management system	The cell monitoring and temperature control withing the battery has no standard approach	Real-time SOH, SOC monitoring	Batteries Regulation (EU) 2023/1542	ISO TC 22 SC38	Ensuring reliability of the swappable system and promoting traceability and transparency	Develop fundamental state- monitoring requirements	Medium (ensures reliability and helps optimizatio n of the operations)	BMS and battery manufacturers
End-of -life management	Guidelines for recycling, disposal and repurposing of batteries are only at a minimal level	Establishing clear guidelines at quantitative levels		Batteries Regulation (EU) 2023/1542	Support the EU's broader efforts to promote a circular economy and reduce the environmental impact of battery use and disposal.	Establish protocols for end-of-life management	Medium (essential for ensuring circular economy in the system)	Battery manufacturers and recycling partners
Interface: connector (mechanical) vehicle <–> battery	standards for automobiles exist. standards about connections of permanently installed batteries also,	There are some good approaches with existing products, but not the perfect solution for all use cases. This gap should be closed through standardization in order to create a uniform and	Battery Regulation (EU) 2023/1542 - Article10 Performance & durability requirements		definition of a solid and reliable connection for a swappable battery solution versus permanently integrated batteries,	define connector for power supply and data communicatio n including mechanical fixture	ii.	Battery and connectors manufacturers and oems

Battery mechanical requirements	the physical dimensions (length/width/ height), weight, IP rating and ergonomics are currently different for each OEM and should be standardized	comprehensive solution that meets the diverse requirements. By introducing standards, interoperability and compatibility can be improved, ultimately leading to more efficient and user- friendly products.	AFIR Regulation 2023/1804 -Article 3 Targets for recharging infrastructure dedicated to light- duty electric vehicles	ISO TC22/SC38 CEN TC301 IEC TS 63066	definition of physical dimensions for a swappable battery solution versus permanently integrated batteries,	define physical properties of SWAP battery	topics need further technical understand ing and identification	Battery manufacturers and oems

Table 1 PNR at Battery level

2.1.2 PNR at vehicle level

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, standards, ...)	Standardization expectation	PNR (topics proposition)	Priority level (i to vii as above defined)	Partner / stake holder
Interface: connector (mechanical) vehicle <–> battery	standards for automobiles exist and also connections for permanently installed batteries, otherwise many OEM-specific solutions - not consistent	There are some good approaches with existing products, but not the perfect solution for all use cases. This gap should be closed through standardization in order to create a uniform and comprehensive solution that meets the diverse requirements. By introducing standards, interoperability and compatibility can be	Battery Regulation (EU) 2023/1542 - Article10 Performance and durability requirements AFIR Regulation 2023/1804 -Article 3 Targets for recharging infrastructure dedicated to light-duty electric vehicles	ISO TC22/SC38 CEN TC301	definition of a solid and reliable connection for a swappable battery solution versus permanently integrated batteries,	define connector for power supply and data communicatio n including mechanical fixture	ii. topics need further technical understanding and identification	Battery and connectors manufacturers and oems
Battery mechanical requirements	the physical dimensions (length/width/height), weight, IP rating and ergonomics are currently different for each OEM and should bzuü+i e standardized				definition of physical dimensions for a swappable battery solution versus permanently integrated batteries,	define physical properties of SWAP battery		Battery manufacturers and oems

Battery electrical requirements	The minimum electrical requirements for voltage, capacity, charging power, configurations (parallel/serial) are currently different for each OEM and should be standardized	improved, ultimately leading to more efficient and user-friendly products.			definition of electrical requirement for a swappable battery solution versus permanently integrated batteries,	define electrical properties of SWAP battery		Battery manufacturers and oems
Interface: communication vehicle <–> battery	standards for an interface do not exist, many OEM-specific solutions - not consistent				Comparability of data exchange without significant change	define communicatio n protocol for SWAP battery		Battery manufacturers, BMS, and oems

Table 2 PNR at vehicle level

2.1.3 PNR at charging station/infrastructure level

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, standards, …)	Standardization expectation	PNR (topics proposition)	Priority level (i to vii as above defined)	Partner / stake holder
fire safety for battery systems (swap cabinets, charging areas, storage).	~7 (piloted battery swap stations w/ fire-safety features, but no uniform EU approach)	- Harmonized fire protection req'ts (indoor/outdoor).	- EU Battery Regulation (EU) 2023/1542 includes safety & sustainability .	- IEC 62840-1 & IEC 62840-3 (safety for battery swap systems)	- Harmonized guidance for battery swap fire detection & containment.	- R&D on advanced fire detection & suppression systems.	High (fire incidents risk damaging public confidence)	- Fire safety authorities, e.g. TÜV / DEKRA
		- Streamlined testing/certification for Li-ion thermal runaway & propagation mitigation.	- Municipal building/fire codes vary by country.	- EN 50604 & IEC 62619 (Li-ion battery safety)	- Possibly an extension of IEC 62840-3 for indoor applications.	- Testing protocols for thermal runaway barriers in multi-battery racks.		- Battery station manufacturers
		- Unified safety assessment for large battery deployments.	- Insurance & liability regs.	- IEC 60335 series (chargers/appliances)				- Building code experts
								- CEN/CENELEC committees

Accurate calculation of battery capacity, SoC, usage patterns for daily ops.	~6–7 (robust BMS exist, but not fully standardized across networks)	- Unified SoC/SoH data model across different OEMs/stations.	- EU Battery Regulation 2023/1542 (battery passport/data).	- IEC 62840-1 & IEC 62840-3/CDV includes references for BMS data.	- Agreed data structure for consistent SoC, SoH, usage reporting across networks.	- Real-time SoC algorithms factoring usage, temperature, discharge cycles.	Medium (technical feasibility proven; standardization needed for cross-compatibility)	- BMS developers
		- Standard method for energy throughput & battery life predictions.	- RED delegated act for secure wireless data transfer.	- IEC 63110 / 63119, ISO 15118 (EV comms)		- "Battery Health Score" approach for cost & environmental analytics.		- OEMs
		- Common data exchange format.						- Standardization committees (IEC TC69 WG13, ISO TC22/SC37)
Ensuring (or clarifying) tax exemptions/levies for battery swapping, electricity usage, battery	N/A (policy maturity rather than technology)	- Clarify tax treatment (energy supply vs. service?).	- National energy tax laws.	- Not a standardization domain per se.	- Not directly about product standards; more about guidelines to standardize how energy usage data is reported (could help authorities).	- Policy research on best fiscal models (battery-as- service vs. electricity sale).	Medium (fiscal incentives can accelerate adoption)	- Ministries of Transport/Energy/Finance

subscription models.		- EU-level approach for cross-border scenarios.	- AFIR (EU) 2023/1804 to promote e-mobility, but no direct "tax" language.	- Could align with relevant data format standards if consumption must be uniformly reported.		- Streamlined cross-border approach.		- Industrial associations
			- Competition rules for possible cross- country differences.					- EU Commission (DG TAXUD)
Using swappable batteries as grid assets (load balancing, V2G, aggregator-driven "virtual power plants").	~6 (pilots exist for V2G in fleets; still early for swappable battery networks)	- Real-time SoC control, aggregator frameworks.	- AFIR 2023/1804 fosters alternative fueling & smart solutions but not explicit for removable battery feed-in.	- IEC 62840 series, potential future adaptation for bidirectional flow.	- Clear aggregator communication standard for swappable battery nodes.	- Control algorithms for "mobile V2G."	Medium–High (significant potential for energy transition)	- DSOs/TSOs (grid operators)
		- Ownership & legal aspects of "mobile" battery feed-in.	- National grid codes & electricity market rules.	- IEC 63119, ISO 15118-20 for V2G communications.	- Mechanisms for verifying battery ownership, scheduling feed-in, settling payments.	- Market design for aggregator-based use of distributed battery modules.		- Battery station operators

		- Economic models & grid acceptance.						- Aggregator platforms
								- IEC TC69, TC57 standard committees
Standard installation criteria for swapping stations (indoor/outdoor, safety zones, mechanical footprints).	~7 (examples in some EU cities, no universal approach)	- Harmonized building/permitting codes across regions.	- AFIR (EU) 2023/1804 sets overarching alt-fuel infra goals, not specifics on swap station siting.	- IEC 62840-3 (removable battery systems, if extended to installation).	- EU-wide guidance (CEN/CLC TS or EN) for battery swapping station design, recommended spacing & ventilation.	- Load-bearing studies for multi-battery racks.	High (critical for widespread deployment & acceptance)	- Station OEMs
		- Standard footprints/connectors for kiosk installations.	- National/local building codes (zoning, fire dept approvals).	- Possibly relevant to CENELEC TC 64 (electrical installations).		- Building code alignment, best practices for safe installation.		- Building regulators
		- Ventilation & spacing guidelines.						- National committees (DIN, NF, etc.)

Uniform		- Risk models for battery handling/storage.	- No direct EU directive on battery insurance.	- Not a typical IEC/ISO domain. Possibly referencing risk management frameworks (ISO 31000).	- Industry-driven guidelines on coverage & liability disclaimers.	- Actuarial models for multi- operator battery pools.	Medium	- Insurance sector (Allianz, Zurich, etc.)

insurance coverage requirements for battery systems (fire, damage, liability) and swap-station operations.	N/A (industry readiness / policy aspects)	- Clear underwriting guidelines for multi-operator systems.	- Battery Regulation sets performance & safety that insurers factor in.	- EN 50604, IEC 62619 (battery safety) can inform insurability.	- Possibly recognized best- practices from insurers & sector alliances.	- Uniform approach for cross-border claims.	(essential for large-scale rollout, but largely driven by insurers & operators)	- Battery-swapping operators
		- Cross-border coverage consistency.						- Certification/lab testing bodies (TÜV, DEKRA)

Table 3 PNR at charging station/infrastructure level

2.1.4 domains/topics to be considered in support of full system management

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, standards, ...)	Standardization expectation	PNR (topics proposition)	Priority level (i to vii as above defined)	Partner / stake holder
System Level (Swappable Ecosystem)	A Backend, with standardized cybersecurity features, is necessary for the data collecting, exchanging and management from different batteries and charging stations belonging to different EaaS operators in order to guarantee the Interoperability	Nothing exist but there are good examples in other business categories (bank, Communication Operators, etc)	Battery Regulation (EU) 2023/1542 (and battery passport) for consideration of data to be collected, stored and shared AFIR Regulation 2023/1804 Cybersecurity (to be completed)	CEN TC 301 CEN CENELEC JTC 13 CEN CENELEC JTC 24	data (& money) collecting, exchange, management within a cybersecure world	define cybersecure backend with standard communication system and Authorization system	iii topics need further technical understand ing and DPP framework defined, with list of data to be considered	

Table 4 PNR at interfaces and full system management level

2.2 Standardization Gaps

By synthesizing expert discussions, regulatory, and stakeholder inputs, standardization gaps were identified, assessed, and grouped into the four core domains: battery level, vehicle level, charging station/infrastructure level, and interfaces and full system management level.
Each topic was evaluated using a standardized matrix that included criteria such as TRL, regulatory context, standardization potential, and stakeholder relevance. The outcome is a matrix of standardization gaps that is ready for further processing in WP7, where it will be translated into a standardization roadmap

2.2.1 domains/topics to be considered at battery level

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, SCs, WGs, ...)	Standards and Regulations to be amended	Standardization expectation	Priority level	Partner / stake holder
Safety requirements		Streamlined testing/certification for Li-ion thermal runaway & propagation mitigation.	- Municipal building/fire codes vary by country.		- EN 50604 & IEC 62619 (Li-ion battery safety)	- Possibly an extension of IEC 62840-3 for indoor applications.		- Battery station manufacturers
		Streamlined testing/certification for Li-ion thermal runaway & propagation mitigation.			- EN 50604 & IEC 62619 (Li-ion battery safety)	- Possibly an extension of IEC 62840-3 for indoor applications.		- Battery station manufacturers
		- Clear underwriting guidelines for multi-operator systems.	- Battery Regulation sets performance & safety that insurers factor in.		- EN 50604, IEC 62619 (battery safety) can inform insurability.	- Possibly recognized best-practices from insurers & sector alliances.		- Battery-swapping operators

	The temperature tolerance and fire hazards measures are needed to be standardized to ensure quality of the system	Standard safety feature protocols	Batteries Regulation (EU) 2023/1542	IEC TC 69		Establishing to ensure the safety and sustainability of batteries used in two-wheelers, promoting a safer transport.	**High** (critical for avoiding hazards)	Standards and regulatory **authorities**
Battery management system	The cell monitoring and temperature control withing the battery has no standard approach	Real-time SOH, SOC monitoring	Batteries Regulation (EU) 2023/1542	ISO TC 22 SC38		Ensuring reliability of the swappable system and promoting traceability and transparency	**Medium** (ensures reliability and helps optimization of the operations)	BMS and battery manufacturers
	~6–7 (robust BMS exist, but not fully standardized across networks)	- Unified SoC/SoH data model across different OEMs/stations.		Standardization committees (IEC TC69 WG13, ISO TC22/SC37)	- IEC 62840-1/CDV includes references for BMS data.	- Agreed data structure for consistent SoC, SoH, usage reporting across networks. Accurate calculation of battery capacity, SoC, usage patterns for daily ops.	**Medium** (technical feasibility proven; standardization needed for cross-compatibility)	BMS developers
End-of-life management	Guidelines for recycling, disposal and repurposing of batteries are only at a minimal level	Establishing clear guidelines at quantitative levels		Standardization committees (IEC TC69 WG13, ISO TC22/SC37)	Batteries Regulation (EU) 2023/1542	Support the EU's broader efforts to promote a circular economy and reduce the environmental impact of battery use and disposal.	**Medium** (essential for ensuring circular economy in the system)	Battery manufacturers and recycling partners

Longevity/durability	Different manufacturers use varying technologies and materials leading to discrepancies in battery lifespan	Standardizing durability metrics to ensure consistent performance across swappable batteries	IEC 62660 ISO 12405	Standardization committees (IEC TC69 WG13, ISO TC22/SC37)	- EU Battery Regulation (2023/1542)	Standard Testing protocols that simulate real-world conditions such as varying temperature, humidity and usage patterns	**High**	Battery manufacturers
Degradation rates	Standards like IEC 62660 and ISO 12405 provide guidelines for testing and evaluating battery performance, including degradation rates under various conditions.	Inconsistent metrics for measuring and reporting degradation rates, making it difficult to compare batteries from different manufacturers.	IEC 62660 ISO 12405	Standardization committees (IEC TC69 WG13, ISO TC22/SC37)	- EU Battery Regulation (2023/1542)	Establishing unified testing methods to measure and predict degradation to maintain reliability in swapping systems.	**High** (critical for ensuring reliability)	Battery manufacturers
Modular design	Modular battery systems are guided by standards such as IEC 61960, which focus on cell and module specifications. These standards promote uniformity in battery dimensions, connectors, and interfaces to facilitate compatibility and ease of integration.	Absence of comprehensive standards for modularity in battery packs, leading to challenges in interoperability between vehicles and swapping stations.	No existing regulations for modular design.	Standardization committees (IEC TC69 WG13, ISO TC22/SC37)	- EU Battery Regulation (2023/1542)	Standards focused on scalability, adaptability of modular designs in battery pack level to accommodate future technological advancements	**Medium** (can help widespread adoption of the system and upgrading future products	Battery manufacturers

Table 5: Standardization Gaps at Battery level

2.2.2 domains/topics to be considered at vehicle level

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, SCs, WGs, ...)	Standards and Regulations to be amended	Standardization expectation	Priority level	Partner / stake holder
Interface: connector (mechanical) vehicle <–> battery	standards for automobiles exist and also connections for permanently installed batteries, otherwise many OEM-specific solutions - not consistent	There are some good approaches with existing products, but not the perfect solution for all use cases. This gap should be closed through standardization in order to create a uniform and comprehensive solution that meets the diverse requirements. By introducing standards, interoperability and compatibility can be improved, ultimately leading to more efficient	Battery Regulation (EU) 2023/1542 - Article10 Performance and durability requirements AFIR Regulation 2023/1804 -Article 3 Targets for recharging infrastructure dedicated to light-duty electric vehicles	ISO TC22/SC38 CEN TC301	new standard	definition of a solid and reliable connection for a swappable battery solution versus permanently integrated batteries,	**High** topics need further technical understanding and identification	Vehicle & Battery manufacturers
Battery mechanical requirements	the physical dimensions (length/width/height), weight, IP rating and ergonomics are currently different for each OEM and should be standardized				new standard	definition of physical dimensions for a swappable battery solution versus permanently integrated batteries,		Vehicle & Battery manufacturers

Battery electrical requirements	The minimum electrical requirements for voltage, capacity, charging power, configurations (parallel/serial) are currently different for each OEM and should be standardized	and user-friendly products.				definition of electrical requirement for a swappable battery solution versus permanently integrated batteries,		Vehicle & Battery manufacturers

Interface: communication vehicle <–> battery	standards for an interface do not exist, many OEM-specific solutions - not consistent	There are some good approaches with existing products, but not the perfect solution for all use cases. This gap should be closed through standardization in order to create a uniform and comprehensive solution that meets the diverse requirements. By introducing standards, interoperability and compatibility can be improved, ultimately leading to more efficient and user-friendly products.	Battery Regulation (EU) 2023/1542 - Article 10 Performance and durability requirements AFIR Regulation 2023/1804 -Article 3 Targets for recharging infrastructure dedicated to light-duty electric vehicles	ISO TC22/SC38 CEN TC301		Comparability of data exchange without significant change	**High** topics need further technical understanding and identification	Vehicle & Battery manufacturers

EU WVTA		current regulatory framework does not consider the WVTA (whole vehicle type approval) without including the dedicated propulsion battery	EU L-category Type Approval Regulation (EU) 168/2013	DG GROW	reg. (EU) 168/2013 Amendment of the regulation to facilitate EU WVTA for a vehicle which is designed to be powered by standardized swappable batteries. The max. vehicle performances are managed and limited by the vehicle design and vehicle management systems (e-motor/converter) and not by the battery itself.			
vehicle on-board charger		lack of harmonization of connectors to the grid and to charging stations for low-power charging	AFIR Regulation (EU) 2023/1804	DG MOVE	The lack of harmonized connectors for low-power charging should be addressed within the AFIR regulation. --> this issue is not explicitly related to Swappable Battery Systems and is therefore considered as "out of scope" of Stan4SWAP. However, the issue may be addressed in the project deliverable via a			Vehicle manufacturers

					general comment on implementation barriers for L-cat. electric vehicles in the EU			

Table 6: Standardization Gaps at Vehicle level

2.2.3 domains/topics to be considered at charging station/infrastructure level

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, SCs, WGs, ...)	Standards and Regulations to be amended	Standardization expectation	Priority level	Partner / stake holder
general installation requirements		- Standard footprints/connectors for kiosk installations.	- National/local building codes (zoning, fire dept approvals).	- Possibly relevant to CENELEC TC 64 (electrical installations).				- Building regulators
		- Ventilation & spacing guidelines.		- National code committees (DIN, NF, etc.)				- National code committees (DIN, NF, etc.)
fire safety for battery systems (swap cabinets, charging areas, storage).	~7 (piloted battery swap stations w/ fire-safety features, but no uniform EU approach)	- Harmonized fire protection requirements (indoor/outdoor).	- EU Battery Regulation (EU) 2023/1542 includes safety & sustainability.		- IEC 62840-1 & IEC 62840-3 (safety for battery swap systems)	- Harmonized guidance for battery swap fire detection & containment.	**High** (fire incidents risk damaging public confidence)	- Fire safety authorities, e.g. TÜV/ DEKRA

		- Unified safety assessment for large battery deployments.	- Insurance & liability regs.		- IEC 60335 series (chargers/appliances)			- Building code experts
				- CEN/CENELEC committees				- CEN/CENELEC committees
Risk assessment and risk management	N/A (industry readiness / policy aspects)	- Risk models for battery handling/storage.	- No direct EU directive on battery insurance.		- Not a typical IEC/ISO domain. Possibly referencing risk management frameworks (ISO 31000).	- Industry-driven guidelines on coverage & liability disclaimers. Uniform insurance coverage requirements for battery systems (fire, damage, liability) and swap-station operations.	**Medium** (essential for large-scale rollout, but largely driven by insurers & operators)	- Insurance sector (Allianz, Zurich, etc.)

Table 7: Standardization Gaps at charging station/infrastructure level

2.2.4 domains/topics to be considered at interfaces and full system management

Area	Maturity level (TRL)	Gaps & Needs (towards TRL 8-9)	Regulatory context	Standardization landscape (TCs, SCs, WGs, ...)	Standards and Regulations to be amended	Standardization expectation	Priority level	Partner / stake holder
Data management	A Backend, with standardized cybersecurity features, is necessary for the data collecting, exchanging and management from different batteries and charging stations belonging to different EaaS operators in order to guarantee the Interoperability;	Nothing exists but there are good examples in other business categories (bank, Communication Operators, etc)	- CRA (EU) 2024/2847 - Data Act (EU) 2023/2854 - GDPR (EU) 2016/679	IEC TC69 – OCA	IEC63584-210 now at (fast track) CDV level; this is the OCPP2.1 which also features battery swapping use cases; Also IEC 63110, IEC 63119 for roaming, ISO 15118 for EV comms	data (& money) collecting, exchange, management within a cybersecure world	**Medium**	IEC TC69 – OCA

	Cybersecurity issues regarding authentication have also to be urgently considered			CEN/CENELEC JTC13	EU Battery Regulation (2023/1542)		**High**	CEN/CENELEC JTC13
Battery life-cycle management		- Standard method for energy throughput & battery life predictions.	- RED delegated act for secure wireless data transfer.					
		- Common data exchange format.		IEC TC21 (Batteries), IEC TC69 WG13 (Swapping), ISO TC22/SC37(Road vehicles), ISO TC22 SC38 Motorcycles/Mopeds	EU Battery passport			IEC TC21 (Batteries), IEC TC69 WG13 (Swapping), ISO TC22/SC37(Road vehicles), ISO TC22 SC38 (Motorcycles/Mopeds)
Business model	N/A (policy maturity rather than technology)	- Clarify tax treatment (energy supply vs. service?).	- National energy tax laws.		- Taxation law (national legislation)	- Not directly about product standards; more about guidelines to standardize how energy usage data is reported (could help authorities). Ensuring (or clarifying) tax exemptions/levies for battery swapping, electricity usage, battery subscription models.	**Medium** (fiscal incentives can accelerate adoption)	- Ministries of Transport/Energy/Finance
		- EU-level approach for cross-border scenarios.	- AFIR (EU) 2023/1804 to promote e-mobility, but no direct "tax" language.		- Could align with relevant data format standards if consumption must be uniformly reported.			- Industrial associations
			- Competition rules for possible cross-country differences.		- harmonization of national regulations			- EU Commission (DG TAXUD)
Smart Grid integration	~6 (pilots exist for V2G in fleets; still early for swappable battery networks)	- Real-time SoC control, aggregator frameworks.	- AFIR 2023/1804 fosters alternative fuelling & smart solutions but not explicit for removable battery feed-in.	IEC TC69 WG13	- IEC 62840 series, potential future adaptation for bidirectional flow.	- Clear aggregator communication standard for swappable battery nodes.	**Medium–High** (significant potential for energy transition)	- DSOs/TSOs (grid operators)
		- Ownership & legal aspects of "mobile" battery feed-in.	- National grid codes & electricity market rules.	IEC TC69 WG9; IEC TC69 JWG1 (with ISO TC22 SC31)	- IEC 63119, ISO 15118-20 for V2G communications.	- Mechanisms for verifying battery ownership, scheduling feed-in, settling payments.		- Battery station operators
		- Economic models & grid acceptance.		IEC TC69 PT63380; IECTC69 JWG15 (with TC57)	IEC 63380 series for local energy management systems; IEC63382 series for distributed energy systems	Using swappable batteries as grid assets (load balancing, V2G, aggregator-driven "virtual power plants").		- Aggregator platforms

								- IEC TC69, TC57 standard committees
Location management	~7 (examples in some EU cities, no universal approach)	- Harmonized building/permitting codes across regions.	- AFIR (EU) 2023/1804 sets overarching alt-fuel infra goals, not specifics on swap station siting.		- IEC 62840-3 (removable battery systems, if extended to installation).	- EU-wide guidance (CEN/CLC TS or EN) for battery swapping station design, recommended spacing & ventilation. Standard installation criteria for swapping stations (indoor/outdoor, safety zones, mechanical footprints).	**High** (critical for widespread deployment & acceptance)	- Station OEMs
Conformance testing		- Cross-border coverage consistency.						- Certification/lab testing bodies (TÜV, DEKRA)

Table 1: Standardization Gaps at interfaces and full system management level

2.3 Communication

This subchapter aims at identifying where standards could ensure a proper, safe and relevant communication, considering the EU regulatory landscape, esp. for batteries and e-vehicles. It concentrates on:

- communication protocols
- visual communication
- written communication
- digital communication

2.3.1 domains/topics to be considered in communication protocols

Communication		
Domains/Topics in communication protocols	Issues identified	Comments and suggestions
Standardized Communication Protocols	Need for standardized communication protocols on battery, vehicle and charging infrastructure level.	• Based on existing Communication protocol standard, suggestion = CAN • Also addressed and confirmed by stakeholders in July 15th 2025 workshop
Basic measured sensor information → current, voltage, temperature (max., min., average)	Need for standardized framework/procedures	• Base on battery level for further parameters which will be communicated • Necessary for comparison • Also addressed and confirmed by stakeholders in July 15th 2025 workshop
State of Charge (SOC)		• Actual State of Charge (SOC) level of the battery • Also addressed and confirmed by stakeholders in July 15th 2025 workshop
State of Health (SOH)		• Up-to-date data for the parameters for determining the state of health (SOH)) of batteries as set out in Annex VII of BattReg

		• Also addressed and confirmed by stakeholders in July 15th 2025 workshop
BMS state		• This signal indicates the BMS state (according with its state machine); states like: idle, discharge, charge,
Errors		• Internal Battery & BMS diagnosis; error identification with standardized error Ids
Max. charge voltage		• Requested maximum charge-voltage (pack)
Min. pack voltage		• Minimum allowed pack voltage
Discharge/charge limit		• necessary for power derating reduction due to high temp, or low voltage, recuperation, vehicle, chargers, battery stations, ...
Battery identification info		• Standardized Serial Number that serves as a unique battery identifier. (incl. knowledge about manufacturer, battery model/type)
Actual capacity		• Actual battery capacity; Capacity based on SOH =remaining capacity
Evolution of self-discharging rates		• According to BattReg
Expected lifetime		• Up-to-date data for the parameters for determining the expected lifetime of batteries as set out in Annex VII of BattReg
Date of manufacture		• According to BattReg
Energy throughput		• According to BattReg
Capacity throughput		• According to BattReg
Tracking of harmful events		• The tracking of harmful events, such as the number of deep discharge events, time spent in extreme temperatures, time spent charging in extreme temperatures
No. charge-discharge cycles		• Number of full equivalent charge-discharge cycles
Software reset info	Who is allowed to perform a software reset and how is that compatible with the CRA?	• The battery management system shall include a software reset function, in case economic operators carrying out preparation for re-use, preparation for repurposing, repurposing or remanufacturing need to upload different battery management system

		software. If the software reset function is used, the original battery manufacturer shall not be held liable for any breach of the safety or functionality of the battery that could be attributed to battery management system software uploaded after that battery was placed on the market
Counter frame incl. cyclic redundancy check	Challenging to fulfil CRA with respect of the Battery Regulation. Clarification on EU-level is needed.	• Convenient solution for CAN to meet CRA

Table 9: Standardization Needs for communication protocols

2.3.2 domains/topics to be considered for visual communication

Communication		
Domains/Topics for visual communication	Issues identified	Comments and suggestions
Manufacturer info	Standardization needed to be robust over lifetime of the battery	• Label
Battery identification info		• Label
Battery category		• Label
Place &date of manufacture		• Label
Weight		• Label
Capacity		• Label
Chemistry		• Label
Hazardous substances		• Label
Usable extinguishing agent		• Label
Critical raw materials		• Label
Carbon footprint		• Label
Safety warnings		• Label • Standardized pictograms highly recommended

Separate collection symbol	Standardization needed to be robust over lifetime of the battery	• Marking
Chemical symbol		• Marking
QR-Code		• Marking • Base for digital battery passport
CE-marking		• Marking

Table 10: Standardization Needs for visual communication

2.3.3 domains/topics to be considered in Written Communication

Communication		
Domains/Topics in written communication	Issues identified	Comments and suggestions
Instructions	Battery, Vehicle and Charging infrastructure level	• Also addressed and confirmed by stake-holders in July 15th 2025 workshop
Safety information	Battery, Vehicle and Charging infrastructure level	• Usage of standardized pictograms • Also addressed and confirmed by stake-holders in July 15th 2025 workshop
Technical Documentation	Battery, Vehicle and Charging infrastructure level	• Also addressed and confirmed by stake-holders in July 15th 2025 workshop
Declaration of Conformity		• According to BattReg
Recycled Content		• According to BattReg
Electrochemical Performance and durability parameters	Standardization is needed	• According to BattReg

Table 11: Standardization Needs for written communication

2.3.4 domains/topics to be considered in Digital Communication

Communication

Domains/Topics in digital communication	Issues identified	Comments and suggestions
Battery Passport • Battery Identification • Manufacturing data • Technical specifications • Usage data • End-of-life • Sustainability	On various points a standardized framework, definition, procedure, calculation etc. is needed	• Details according to Article 77 + Annex XIII of BattReg • Open points should be considered in harmonized standards for the BattReg • Also addressed and confirmed by stakeholders in July 15th 2025 workshop
Information on prevention and management of waste batteries		• According to Article 74 of Batt Reg • Also addressed and confirmed by stakeholders in July 15th 2025 workshop

Table 12: Standardization Needs for Digital communication

2.4 Other suggestion

A few additional suggestions were expressed during the July 15th Workshop

Other		
Domains/Topics	Issues identified	Comments and suggestions
Sounds and spoken warning signals	Idea addressed by stakeholders in July 15th 2025 workshop	• This would definitely be a benefit in terms of safety and for the customer, but it is not necessary for the function of the battery or the whole swappable battery eco system. → no need for standardization
Visual status indicators for SOC and SOH	Idea addressed by stakeholders in July 15th 2025 workshop	• This would definitely be a benefit for the customer, but it is not necessary for the function of the battery or the whole swappable battery eco system. → no need for standardization

Table 13: Addition suggestions

3. Expectation from the workshop's participants

STAN4SWAP project aims to develop a robust standardization roadmap towards boosting innovation and deployment for Swappable Battery Systems for light category electric vehicles as an interoperable and user-friendly technology which can contribute to the decarbonization of the sector.

The objective of this document, considering the outcomes from Stan4SWAP WPs 2-7, and inputs collected during the July 15th 2025 Workshop, is about listing domains/topics of importance where standardization can support a proper deployment of swappable battery system for L-cat vehicles, in the framework of our EU regulatory context, as well as to fulfil the EC standardization Request M/581 to ESOs, that requests a "European standard containing technical specifications with a unified solution for battery swapping for L category vehicles".

This October 6th, 2025 Stakeholder meeting aims to be a final consultation on the Stan4SWAP standardization roadmap for swappable batteries for light category electric vehicles, by collecting from main stakeholders/participants some final inputs.
The outcomes of this meeting will contribute to drafting a full EU standardization roadmap, as well as making recommendations towards a wide scale implementation of swappable batteries.