Swappable Container Waterborne Transport Battery

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Reducing the Cost of Large Batteries for Waterborne Transport

D2.1

Design Recommendations Battery

23 December 2024

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GLOSSARY OF TERMS

Term	Definition
Alert	An alert consists of a Warning, Alarm, or Fault
Battery System	The highest-level building block within the energy storage system
BMS	Battery management system
Building Block	An arbitrarily sized electrical or physical unit of the system. There can be multiple tiers of building blocks nested in one another.
Cell group	Group of paralleled cells
EaaS	Energy as a Service
Electrical Building Block	An arbitrarily sized standalone electrical component in the system. There can be multiple tiers of electrical building blocks nested within each other.
EMS	Energy management system
FiFi	Firefighting
Installation Unit	The building block used during installation
LRU	Line Replaceable Unit.
Mechanical Building Block	An arbitrarily sized, standalone mechanical component in the system. There can be multiple tiers of mechanical building blocks nested within each other.
OEM	Original Equipment Manufacture
PCS	Power Conversion System
PMS	Power management system
Service Unit	The building block that can be serviced in the field
SOC	State of charge
SOH	State of health
String	Number of serialized cell groups operating at battery system voltage
System Bus	Communication bus from the battery system to the customer / EMS.

DOCUMENT PROPERTIES

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0.2	14-Jul-2021	2nd Version Submitted, updated Executive Summary
1.0	23-Dec-2024	Updated version with requirements prioritised

"This document reflects only the author's view and the Agency is not responsible for any use that may be made of the information it contains".

PROJECT SUMMARY

The transport sector contributes to almost a quarter of Europe's greenhouse gas (GHG) emissions. Compared to other sectors, such as agriculture or energy industries, it is the only sector with emissions higher than that of 1990. Waterborne transport emissions represent around 13% of the overall EU greenhouse gas emissions from the transport sector. Moreover, waterborne transport emissions could increase between 50% and 250% by 2050 under a businessas-usual scenario, undermining the objectives of the Paris agreement. The challenge for a large-scale adoption and implementation of batteries for waterborne transport is mainly related to the high costs of the battery systems and cells.

The Current Direct project addresses these challenges by proposing an innovative lithium-ion cell optimized for waterborne transport, using novel manufacturing techniques allowing for a consistent cost reduction compared to the current market prices. Additionally, a swappable containerized energy storage system optimized for cost and operation in the waterborne transport industry will be developed. The overarching aim of the Current Direct project is to develop and demonstrate an innovative interchangeable waterborne transport battery system and EaaS Platform in an operational environment at the Port of Amsterdam at TRL7 that facilitates fast charging of vessels, fleet optimization and novel business models. The Current Direct project is dedicated to (i) significantly reduce the total cost of waterborne transport batteries, (ii) cut GHG emissions of the marine transport sector through electrification of vessel fleets, (iii) increase the energy density of waterborne battery cells and (iv) trigger investments for innovation, job and knowledge creation in the European marine transport and battery sector.

The Current Direct EcoSystem is shown in Figure 1.

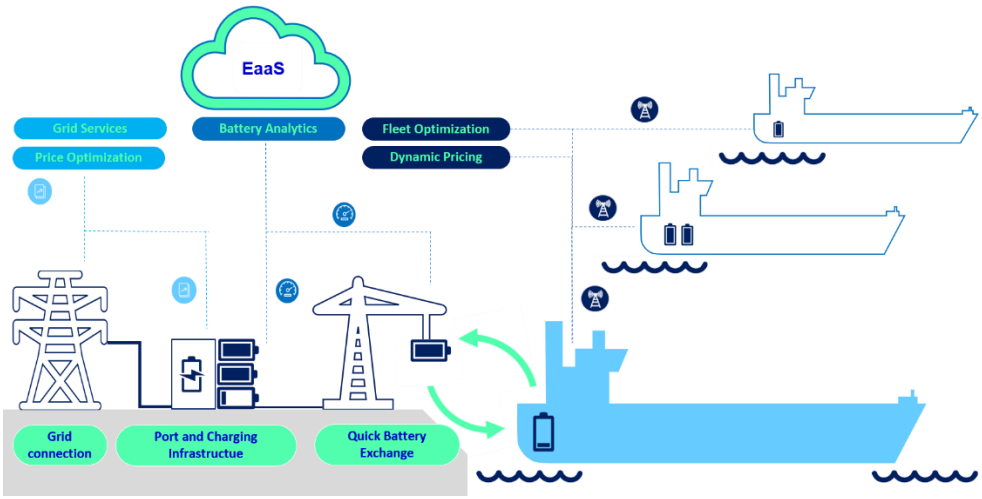

Figure 1. Current Direct EcoSystem

1. EXECUTIVE SUMMARY

Design Recommendations for the Current Direct Waterborne Transport Battery describes verifiable, independent performance and safety requirements. Certain requirements are specified as Performance Indicators (PIs). The requirements will synthesize inputs from suppliers, operators, classification societies, governments, and recyclers.

The requirement specification has been divided into requirements that need to be in place for the demonstration unit timetable and requirements for commercialization. At this stage, the deliverable mainly contains requirements related to the demonstration unit. The specification requirement work is ongoing and will continue to follow the project schedule.

Further work is required to evaluate and refine the specified requirements and there is ongoing work to develop a better understanding of Standard and Regulatory Requirements.

2. SPECIFIC OBJECTIVES FOR WORK PACKAGE 2

2.1. Introduction

This WP will define the requirements for the two Current Direct technology pillars: the Waterborne Transport Battery and the EaaS platform. This WP will also assess the current state of the Waterborne Transport market to provide inputs for WP6 regarding classification societies, national maritime authorities, independent standards bodies, and de facto commercial standards. It will synthesize the power and energy requirements, operating profiles, and installed propulsion topologies of various vessel types across Europe's inland waterways and coastal shipping routes. While this work package will generate deliverables D2.1, D2.2 and D2.3 in month M3 to provide a solid baseline for the Phase II Development work, the requirements and specifications will be updated throughout the Development phase until the tasks they feed into reach a design freeze.

Specific Objectives:

- Identify and engage relevant stakeholders to define market technical and financial needs
- Define operational requirements for the Waterborne Battery & supporting vessel infrastructure
- Define business requirements for the EaaS platform
- Define the current state of certification and regulatory frameworks for waterborne transport batteries and analyze opportunities for standardization
- Assess current vessel integration and port electrical infrastructure for battery charging
- Specify design requirements to maximize recyclability of the Current Direct solutions

2.2. Capture Methodology Introduction and Description

The owner for work package 2 is Foreship. For gathering information and requirements, a kick-off meeting was held with all the consortium members on January 15th, 2021. The process and the methodology were described and agreed upon during the meeting. The workflow, schedule and Owners of the different sub-categories were communicated. The common platform for gathering the requirements is Box. Revision handling of documents is done in Box, using a manual methodology.

The main principles of the process for gathering requirements are described in Figure 2.

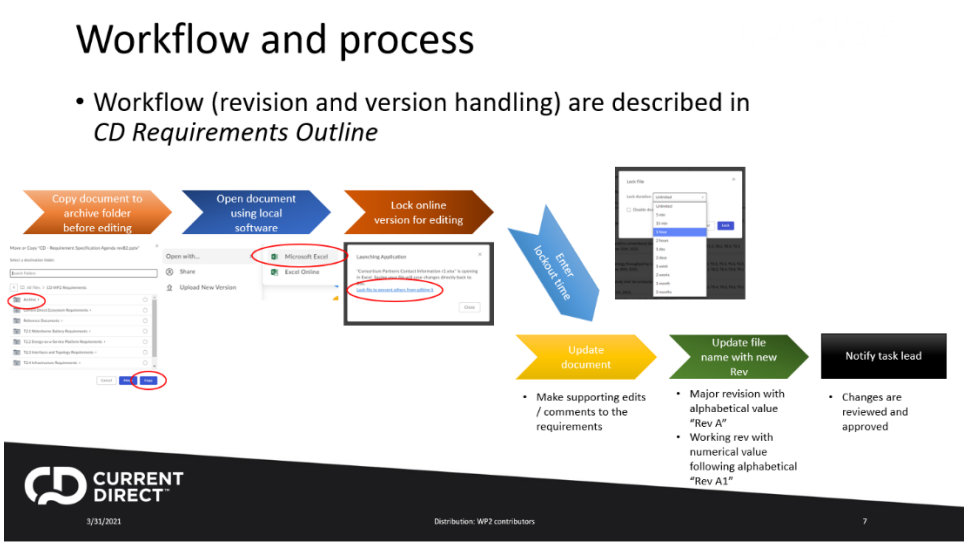

Figure 2. Workflow and Process for Gathering Requirements

2.3. Requirement Structure and Information Gathering Principles

2.3.1. Current Direct Requirements Structure Outline Document Description

This document outlines Current Direct's requirements hierarchy, document lead, content descriptions, file locations, member access rights, and editing rule. The document is saved under the common folder available to all members.

2.3.2. Technical and Financial Requirements

The requirements are broken up into two categories: technical requirements, and financial requirements. Technical requirements are saved at the file locations indicated in the Requirements Hierarchy section below. Financial requirements are located in the member's folder providing the component or service so financial privacy can be maintained.

2.4. Requirements Hierarchy and Relationship

Figure 3 below outlines Current Direct's requirements hierarchy. The Ecosystem is the highest-level document from which all other requirements are derived.

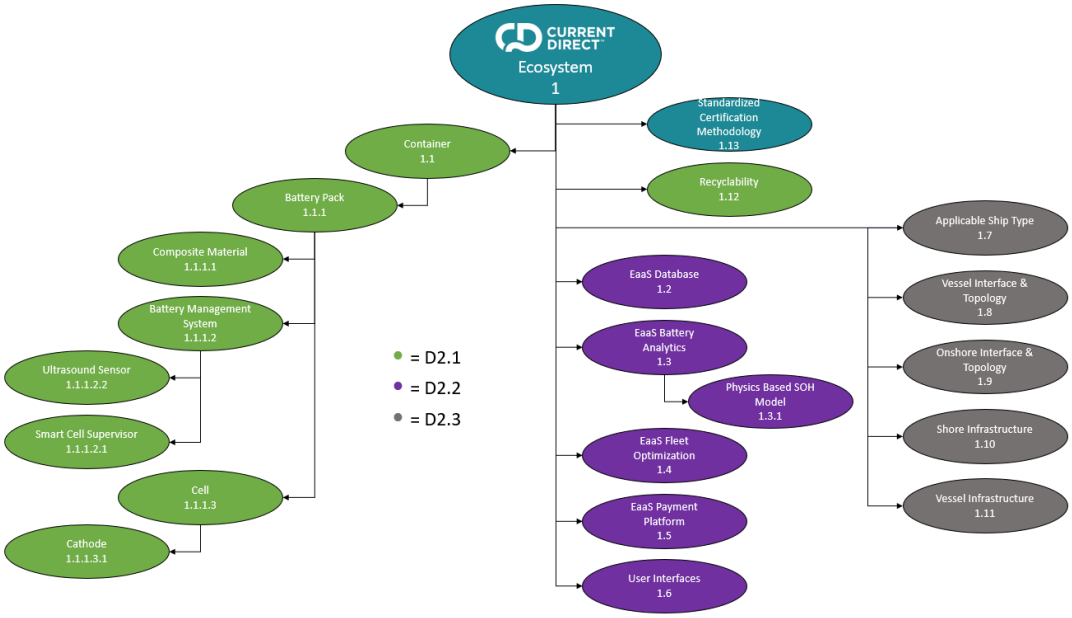

Figure 3. Requirements Hierarchy

Requirement documents are also related to one another independent of the serial hierarchy. This means that a requirement document in one branch of the system can drive or refer to one from a separate branch. An example would be the container interfaces which determine aspects of both the vessel and onshore systems.

3. ECOSYSTEM KPI'S

3.1. Introduction

Current Direct KPI and lifecycle considerations are gathered in a separate document called Ecosystem requirement, where KPI's are described. The Ecosystem KPI's are presented in Table 1.

Table 1. Ecosystem KPI's

Requirement Category	Description	KPI ID [A]	Target
Key Performance Indicators	Cost Reduction	A1.1.1	20% cost reduction over current commercial marine cells at volume production
		A1.1.2	Achieve ≥8,000 cycles at 80% Depth of Discharge before reaching 70% State of Health.
		A1.1.3	Cost 500 €/kWh for the waterborne transport battery container.
		A1.1.4	Have a cost per unit energy throughput 1/2 that compared to today's waterborne battery transport battery systems.
		A1.1.5	Have an OPEX ≤ compared to conventional diesel fuel.
	Increased Energy	A1.2.1	Cell level density ≥500 Wh/L
		A1.2.2	Pack level energy density ≥200 Wh/L
		A1.2.3	Have an installed capacity ≥ 2MWh in a 20' container.
	Environmental	A1.3.1	Reduce GHG emissions ≥1.5MT per discharge cycles when compared to tradition diesel propulsion.
		A1.3.2	Have ≥90% of the total waterborne battery container mass can be recycles
		A1.3.3	Reduce recycling processing cost by 30% when compared to today's containerized waterborne transport battery systems
	Market Acceleration	A1.4.1	Have a State of Health uncertainty of ≤2%
		A1.4.2	Accommodate ≥15% of today's and ≥85% of tomorrow's inland waterway and coastal shipping vessels
		A1.4.3	Support a container swap in ≤5 minutes
		A1.4.4	Have an EaaS operating cost ≤ the operating cost of diesel propulsion

Requirement Category	Description	KPI ID [A]	Target
		A1.4.5	Develop standardized certification methodology for marine battery systems.
		A1.4.6	Develop standardized certification methodology for vessels that adopt containerized energy storage systems through Current Direct's ecosystem.
		A1.4.7	Reduce battery system approval time by 30%
		A1.4.8	Reduce battery system approval cost by 75%
		A1.4.9	Be scalable to ≥ 6,000 users.
		A1.4.10	Be capable of supporting ≥ 23,000 deployed containers.
	Project	A1.5.1	Demonstrate the Current Direct Energy-as-a-Service platform through simulation
		A1.5.2	Establish a working demonstrator ecosystem featuring a waterborne battery container, supporting infrastructure, and the EaaS platform to a vessel in operation
		A1.5.3	Develop a demonstrator ecosystem with Technology Readiness Level (TRL) 7.
		A1.5.4	Create a demonstrator report every 3 months of operation
		A1.5.5	Create 1 Product Brochure
		A1.5.6	Create ≥ 3 Press Releases
		A1.5.7	Host ≥ 2 International Presentations
		A1.5.8	Host ≥ 1 Workshop

4. DESIGN RECOMMENDATION AND REQUIREMENTS

4.1. General

Design Recommendations for the Current Direct Waterborne Transport Battery will clearly describe verifiable, independent performance, safety, and cost requirements. Certain requirements will be specified as Performance Indicators (PIs). The requirements will synthesize inputs from suppliers, operators, classification societies, governments, and recyclers. They are the output of T2.1 and T2.5.

Design requirements shall also be considered according to both the demonstration unit and the wider commercialization beyond the end of the funded project.

4.1.1. Requirement Definition

Requirements are divided by category, identifier, description, type, and target.

- Requirement category - Category name for organization only (i.e., Physical Characteristics)
- Requirement ID – Unique identifier for each requirement. ID does not change once assigned. Each requirement document has its own unique ID which prevents requirement ID's being duplicated used across documents.
- Description - Requirement description for organization only (i.e., Size).
- Type – There are three different types of requirements
- Reference; information only
- Shall; the product must comply
- Should; compliance is preferred, but not required
- Target – Pass / Fail limits where applicable, design constraints, design standards

4.2. T2.1 Analysis and Specification of the Waterborne Battery

Lead: LCD; Contributors: Foreship, Wärtsilä, Lloyd's, EDP, Blackstone, Umicore, LCH

This task will use the input collected through engagement in T9.3 with stakeholders throughout the Waterborne Battery value chain including governments who award routes, ship owners, naval architects, shipyards, ports, electrical integrators, classification societies, national maritime authorities, and firefighters to develop a comprehensive set of technical requirements for the Current Direct battery. Requirements D2.1 will be synthesized and refined to provide a set of design specifications for WP3 and WP4. As the project progresses the requirements will be updated based on lessons learned and continued stakeholder input. Many requirements gathered in this task will feed WP7 including power and mechanical interfaces of the battery container to the ship and shoreside infrastructure (T7.1, T2.3, and T2.4), communications interfaces to the ship and shore (T7.2), and safety and performance standards (T7.3, T7.4). Moreover, a set of performance PIs will

be defined that constitutes a demonstration framework against which the operational performance of the battery container will be evaluated during the demonstration activities in WP6 (T6.1 and T6.6). The gathered PIs will further serve as a base for the validation of the business case in WP8 (T8.3).

4.2.1. Container (1.1)

The requirements for the container is presented in Table 2.

Table 2. Container

Requirement Category	Description	Requirement ID [B]	Type	Target
General Information	Objective	B1.2.1	Reference	To develop a fully independent containerized energy storage system with a standard 20' ISO envelope.
Physical Characteristics	Weight	B4.1.1	Shall	Weigh ≤25000 kg
	Size	B4.2.1	Shall	Be designed according to ISO 20' container dimensional standards
		B4.2.2	Should	Be designed according to ISO 20' high cube container dimensional standards
Functional Behavior	Battery Capacity	B5.1.1	Shall	Contain battery capacity of ≥2MWh
	Onboard Charging	B5.4.1	Should	Support independent onboard charging from shore power while installed on a vessel
Safety	Emergency Stop	B6.3.1	Shall	Include an externally hardwired mordancy stop interface
		B6.3.2	Shall	An independent emergency stop external of the container
	Exhaust Vent	B6.4.1	Shall	Have dedicated ventilation exhaust system for ESS
		B6.4.2	Shall	Be activated upon detection of Fire / Smoke in the battery compartment or thermal runaway gas detection.
	Fifi System - Internal	B6.5.1	Shall	Include Fifi system
		B6.5.2	Shall	FiFi system to be self-contained & independent from vessel/shore infrastructure
	Fifi System - External	B6.6.1	Should	Support external fifi system if deployed

Requirement Category	Description	Requirement ID [B]	Type	Target
	Fire/Smoke Detection	B6.7.1	Shall	Incorporate fire/smoke detection system.
		B6.7.2	Shall	Be independent from vessel/shore
		B6.7.4	Shall	Communicate status of the fire/smoke detection system to the vessel
		B6.7.5	Shall	Comply to FSS-code
	Gas Detection	B6.8.1	Shall	Incorporate a gas detection system to detect a thermal runaway event.
		B6.8.4	Shall	Communicate the status of the gas detection system to the vessel
		B6.8.5	Shall	Position detectors to give responsive of detection of gas release.
		B6.8.6	Shall	Be independent from vessel/shore
		B6.8.7	Shall	Equipment in ESS space not suitable for hazardous area installation shall be shut down if gas is detected
	Temperature Monitoring	B6.9.1	Shall	Be monitored independently from the battery system
	Door Monitoring	B6.11.1	Shall	Doors/hatches into container shall be monitored
Structure	Fire Class	B7.1.1	Shall	Maintain structural design integrity during thermal runaway event
	Structural Integrity	B7.2.1	Shall	Strength to be minimum according to ISO 1496-1 standard for containers
Electrical System	Cables	B8.3.1	Shall	Have current carrying capacity per IEC 60092-352
		B8.3.2	Should	Have minimum banding radius per IEC 60092-352

Requirement Category	Description	Requirement ID [B]	Type	Target
		B8.3.3	Shall	Have minimum bending radius to be as per manufacturers recommendations
		B8.3.4	Shall	Have cables suitable for a hazardous area for all equipment powered after activation of the gas detection system
		B8.3.5	Shall	Have installation per relevant rules/regulations and IEC 60092-352
	UPS	B8.4.1	Shall	Have UPS to be installed for auxiliary power supply.
		B8.4.4	Should	Be in a separate space from ESS
		B8.4.5	Shall	Provide UPS status to a telematics system.
	Distribution Board	B8.8.1	Should	Have breakers for auxiliary power
		B8.8.2	Should	Have breakers easily accessible
	External Auxiliary Power Supply	B8.9.1	Should	Have external power supply for auxiliary equipment during long term storage
	IECex / ATEX	B8.10.1	Shall	Equipment in ESS space that will remain switched on after detection of gas shall have suitable Ex-certification.
		B8.10.2	Shall	All equipment located at ceilin g level in the EES space shall b e suitable for zone 2 installatio n.
		B8.10.3	Shall	Temperature class and gas gro up for the ex rated zone 2 equi pment shall as a minimum be T2 and IIC.
		B8.10.4	Shall	Meet IEC 60079

Requirement Category	Description	Requirement ID [B]	Type	Target
Electrical Interfaces	Power Connection	B9.1.1	Shall	Be designed to minimize the need for human interaction
		B9.1.2	Shall	Have galvanic power connection
		B9.1.5	Shall	Allow for defined container movement
		B9.1.6	Should	Allow stacked containers to be electrically connected in parallel
		B9.1.7	Should	Allow stacked containers to be electrically connected independently
Mechanical Interfaces	Locking Connections	B10.1.1	Shall	Support mechanically swapping the container within 5mins
		B10.1.2	Should	Be self-locating
		B10.1.5	Shall	Be designed to minimize the need for human interaction
		B10.1.6	Shall	Minimize container movement
		B10.1.7	Shall	Allow containers to be securing stacked
		B10.1.8	Shall	Allow the container to be lifted
Communication Interfaces	Antennas	B11.1.1	Shall	Include a GSM antenna
		B11.1.2	Shall	Include a GPS antenna
		B11.1.3	Shall	Include a wifi antenna
	Communication Connection	B11.2.1	Shall	Be designed to minimize the need for human interaction
		B11.2.2	Shall	Have galvanic power connection
		B11.2.5	Shall	Allow for defined container movement
		B11.2.6	Should	Allow stacked containers to be electrically connected in parallel
		B11.2.7	Should	Allow stacked containers to be electrically connected independently.

Requirement Category	Description	Requirement ID [B]	Type	Target
Hvac	Temperature Regulation	B14.1.1	Shall	Be capable of controlling the temperature of the container per operating mode specifications in all operating environment conditions.
	Humidity	B14.9.1	Shall	Be capable of controlling the humidity of the container per operating mode specifications in all operating environment conditions.
	Thermal Insulation	B14.10.1	Shall	The container shall be sufficiently thermally insulated to support all operating mode specifications in all operating environment conditions
Service	Service Access	B16.1.1	Shall	Service access to be provided for equipment inside the container
Reliability	Useful Life	B17.1.1	Shall	Support 20-year life
		B17.1.2	Should	Support 40-year life
	Storage Life	B17.2.1	Shall	Support 20-year life
		B17.2.2	Should	Support 40-year life

4.2.2. Battery Pack (1.1.1)

Requirement for Battery Pack are presented in Table 3.

Table 3. Battery Pack

Requirement Category	Description	Requirement ID [C]	Type	Target
General Information	Objective	C1.2.1	Reference	The development of an energy-focused battery system with the goal of reducing costs and maximizing the amount of energy contained within a 20' shipping container.

Requirement Category	Description	Requirement ID [C]	Type	Target
Regulatory Certifications	Class Societies	C3.1.9	Shall	IACS
	Flag State	C3.2.1	Shall	NMA
		C3.2.3	Should	UK Maritime & Coastguard Agency
	Other Regulatory Certifications	C3.3.1	Shall	UN DOT 38.3
		C3.3.2	Shall	RoHS ES-TRIN
Connectors and Cables	External Connectors	C5.1.3	Shall	The main power connectors shall have an integrated safety interlock (HVIL), securing that connection/disconnection only can be performed when the battery contactor is open.
		C5.1.19	Shall	Mated IP rating achieves at least IP44
	External Cables	C5.2.1	Shall	Support maximum operational charge/discharge currents at maximum operating temperature.
	Wire Routing	C5.3.1	Shall	Route and secure all wire harnesses safely per IEC standard 61914.
Performance	Maximum Battery Charge Voltage	C6.1.1	Shall	Support up to 1100 VDC
		C6.1.2	Should	Support up to 1250 VDC
	Ingress Protection	C6.11.1	Shall	Prevent an arc under max voltage when subjected to spray conditions IPX4 for these water and glycol.
		C6.11.2	Should	Prevent an arc under max voltage when subjected to spray conditions IPX6 for these water, glycol, and saltwater.
		C6.11.3	Shall	Prevent an arc under max voltage when subjected to dust conditions IP4X.

Requirement Category	Description	Requirement ID [C]	Type	Target
		C6.11.4	Should	Prevent an arc under max voltage when subjected to dust conditions IP5X.
Functional Behavior	BMS	C7.1.1	Shall	Have an integrated BMS
Safety	Venting	C8.1.1	Shall	The ventilation of a cell pre- or post-thermal event shall not result in an explosion
		C8.1.2	Shall	Include a method to evacuate the gasses exterior of the vessel/container.
		C8.1.3	Shall	Be designed to minimize vented gas leakage into the battery compartment.
	Switch Disconnect	C8.4.1	Shall	The battery system's main power contactors or circuit-breakers shall disconnect both poles.
	Creepage and Clearance	C8.6.1	Shall	Pass creepage and clearance for 3820 VDC; Pollution Degree 3.
		C8.6.2	Should	Pass creepage and clearance for 3820 VDC; Pollution Degree 4.
	Coolant Leak	C8.9.1	Shall	Battery modules shall be designed such that the risk of a cooling liquid leakage inside the module is minimized and do not lead to hazardous creepage currents, electrolysis, short circuit, electric arcing, earth faults or other hazards.
		C8.9.3	Shall	Battery systems shall be designed such that the risk of cooling liquid leakage in the battery system is minimized

Requirement Category	Description	Requirement ID [C]	Type	Target
				and do not lead to hazardous creeping currents, electrolysis, short circuit, electric arcing, earth faults or other hazards.
	Cell Support	C8.11.1	Shall	Use cells that have passed IEC 62619
		C8.11.3	Shall	Use cells that have passed UN DOT 38.3
	Pressure Relief	C8.12.1	Shall	For sealed batteries, a safety pressure valve or other means of explosion protection (weak point) shall be included in the battery design.
	E-Stop	C8.14.1	Shall	The battery system shall be equipped with an independent emergency shutdown for disconnection of the battery system.
	High Voltage Insulation Resistance	C9.2.1	Shall	Support >= 2.25 MΩ at 3820V for 1 min on each terminal, Modules and SCU
		C9.3.1	Shall	Support > 3820 VDC
	Signal/Control Voltage Insulation Resistance	C9.4.1	Shall	Support >= 1 MΩ at 707V for 1 min between all signal and control power nets and chassis
	DC Signal/Control Voltage Dielectric Breakdown Voltage	C9.5.1	Shall	Support > 707 VDC for 12-60V control power circuits
	AC Signal/Control Voltage Dielectric	C9.6.1	Shall	Support 1500VAC or 2120VDC for 60-300VAC/VDC control power circuits

Requirement Category	Description	Requirement ID [C]	Type	Target
	Breakdown Voltage			
Testing Requirements	Drop Test	C10.1.1	Shall	Drop full module on its edge and corner from 5cm height with no fire or explosion.
	Altitude	C10.2.1	Shall	UN DOT 38.3, T.1 - Altitude Simulation
	Thermal Shock	C10.3.1	Shall	UN DOT 38.3, T.2 - Thermal Test
	Vibration	C10.4.1	Shall	UN DOT 38.3, T.3 - Vibration
	Shock / Impact	C10.5.1	Shall	UN DOT 38.4, T.4 - Shock
	External Short Circuit Test	C10.6.1	Shall	UN DOT 38.3, T.5 - External Short Circuit
	Overcharge	C10.8.1	Shall	UN DOT 38.3, T.7 - Overcharge
		C10.8.2	Shall	Overcharge with voltage per IEC 62619 8.2.2
		C10.8.3	Shall	Overcharge with current per IEC 62619 8.2.3
		C10.10.2	Shall	Module to module thermal propagation protection
	Functional Performance Test	C10.11.1	Shall	Demonstrate all functions
	Electrical Power Supply Failure Test	C10.12.1	Shall	Experience at least 3 interruptions in 5 minutes with no permanent or temporary malfunctions.
	Power Supply variation Test	C10.13.1	Shall	Comply with class requirements
	Vibration Test	C10.14.1	Shall	Comply with class requirements
	Dry Heat Test	C10.15.1	Shall	70 ± 2°C for 16 hours, 50% RH
	Damp Heat	C10.16.1	Shall	80-100% relative humidity cycle, 22-57°C, pass hi-pot test within 1 hour
		C10.16.2	Shall	95% relative humidity, 55°C, 2 cycles of 12+12 hours

Requirement Category	Description	Requirement ID [C]	Type	Target
	Ingress Protection Test	C10.22.1	Shall	Test to a designed IP rating of the system per IEC 60529.
	Overheating	C10.26.1	Shall	Test overheating control per IEC 62619 8.2.4
	Sensor Failures	C10.27.1	Shall	Test detection of all failure modes of the sensors
	Function and Failure Response Testing	C10.30.1	Shall	Test normal operation and failure response of the BMS
	Independent Safety Function Test	C10.31.1	Shall	Test emergency disconnection function
		C10.31.2	Shall	Test independent temperature and or voltage-based disconnection
		C10.31.3	Shall	Test HVIL
	Dielectric Strength	C10.32.1	Shall	Comply with class requirements
	Pressure Test of Coolant Piping	C10.34.1	Shall	Comply with class requirements
Noise Immunity	EMC/EMI/ESD	C11.1.1	Shall	Comply with class requirements
	Standby Ambient Temperature Range	C12.3.1	Shall	−20°C to +25°C for up to 1 year +25°C to +40°C for up to 3 months +40°C to +60°C for up to 1 week
Material Selection	Asbestos Declaration	C13.1.1	Shall	Be 100% free of asbestos.
	Flammability	C13.2.1	Shall	The battery system shall be made of a flame-retardant material according to IEC 60092-101.
	Lead	C13.4.1	Shall	Shall meet ROHS standard
	Material Restrictions	C13.6.1	Shall	Meet ECHA regulations.

Requirement Category	Description	Requirement ID [C]	Type	Target
		C14.1.1	Shall	Support 10-year life
		C14.2.1	Shall	Support 10-year life
Labelling	Product Identification	C17.1.1	Shall	Include markings that identify the product including part number, serial number, service contact information
	Warning/Hazard	C17.3.1	Shall	Include appropriate warning/hazard markings

4.2.3. Composite Material (1.1.1.1)

Requirements for composite material are presented in Table 4.

Table 4. Composite Material

Requirement Category	Description	Category ID [D]	Type	Target
General Information	Objective	D1.2.1	Reference	To develop a novel material that combines properties of multiple components used in today's state of the art marine battery systems. This newly created composite will simplify the design and reduce both material and assembly costs.
Physical Characteristics	Mounting Features	D4.6.1	Shall	Incorporate features to allow for alignment with adjacent cell frames
Performance	Thermometric Properties	D5.5.1	Shall	Maintain all required material properties with up to 700°C surface temperature.
Reliability	Useful Life	D9.1.1	Shall	Support 10-year life
		D9.1.2	Should	Support 20-year life
	Shelf Life	D9.2.1	Shall	Support 10-year life
		D9.2.2	Should	Support 20-year life

4.2.4. Battery Management System (1.1.1.2)

The requirements for the battery management system is presented in Table 5.

Table 5. Battery Management System

Requirement Category	Description	Requirement ID [E]	Type	Target
General Information	Objective	E1.2.1	Reference	The development of a battery management system to protecting the battery from operating outside a safe operating window and calculating / reporting data with the goal of reducing cost and maximizing the amount of energy contained within a 20' shipping container.
Performance	State of Charge	E4.1.1	Shall	Estimate and provide the battery's State of Charge (SOC)
		E4.1.3	Shall	Provide accurate SOC prediction within ± 5%.
		E4.1.4	Should	Provide accurate SOC prediction within ± 2%.
	State of Health	E4.2.1	Shall	Estimate and provide the battery's State of Health (SOH)
		E4.2.5	Shall	SOH uncertainty is ≤ 4%
		E4.2.6	Should	SOH uncertainty is ≤ 2%
	Available Power	E4.3.1	Shall	Provide available battery power
	Balancing	E4.4.1	Shall	Provide cell and module balancing.
	Location	E4.7.1	Shall	Be able to acquire its location information (GPS coordinates) without the use of vessel infrastructure
	Internet connection	E4.8.1	Shall	Support wireless connection to the internet via GSM
		E4.8.2	Shall	Support wireless connection to the internet via WIFI
Functional Behavior	Measurements	E5.1.1	Shall	Measure the current on each electrical building block operating at the system level voltage.

Requirement Category	Description	Requirement ID [E]	Type	Target
		E5.1.2	Shall	Measure the voltage of each electrical building block.
		E5.1.3	Shall	Measure voltage for each cell group
		E5.1.4	Shall	Measure cell or module temperature
	Alert System	E5.5.2	Shall	Provide an alert for any abnormal condition in the battery system.
		E5.5.3	Shall	Activation of protective safety functions shall give an alert.
		E5.5.4	Shall	Abnormal conditions that can develop into safety hazards shall be alarmed before reaching the hazardous level. Sensors and other components used for such alarms shall be separate from emergency shutdown or other protective safety functions.
		E5.5.8	Shall	Provide an alert for high cell or module temperature.
		E5.5.9	Shall	Provide an alert for over and under-voltage.
		E5.5.10	Shall	Provide an alert for battery disconnection.
		E5.5.11	Shall	Provide an alert for tripping of battery breakers/contactors.
		E5.5.12	Shall	Provide an alert for communication alarm.
		E5.5.13	Shall	Provide an alert for liquid cooling leakage.
		E5.5.14	Shall	Provide unbalanced cell voltage.
		E5.5.15	Shall	Provide insulation monitoring
	Diagnostics	E5.7.1	Shall	Provide local diagnostics.
		E5.7.2	Shall	Provide remote diagnostics.

Requirement Category	Description	Requirement ID [E]	Type	Target
	Over-Current	E5.10.1	Shall	Protect against over-current by disconnection of the battery system
	Over-Voltage	E5.11.1	Shall	Protect against over-voltage by disconnection of the battery system
	Under-Voltage	E5.12.1	Shall	Protect against under-voltage by disconnection of the battery system
	Over-Temperature	E5.13.1	Shall	Protect against over-temperature by disconnection of the battery system
Communication	System Bus	E6.1.3	Shall	Communicate the voltage and discharge/charge current limits.
Safety	Over Charge Protection	E8.1.1	Shall	Incorporate redundant analogue and digital safety with configurable limits
	Failure Modes	E8.9.1	Shall	Any faults isolate only the electrical building block it originated in, allowing continued operation of the system at the highest-level electrical block.
	E-Stop	E8.12.1	Shall	The battery system shall be equipped with an independent emergency shutdown for disconnection of the battery system.
Tools	Remote Monitoring	E10.1.1	Shall	Include remote monitoring
		E10.1.3	Shall	Provide real-time location tracking
Reliability	Useful Life	C14.1.1	Shall	Support 10-year life
		C14.1.2	Should	Support 20-year life
	Shelf Life	C14.2.1	Shall	Support 10-year life
		C14.2.2	Should	Support 20-year life

4.2.5. Smart Cell Supervisor (1.1.1.2.1)

The requirements for smart cell supervisors are presented in Table 6.

Table 6. Smart Cell Supervisor

Requirement Category	Description	Requirement ID [F]	Type	Target
General Information	Objective	F1.2.1	Reference	The development of a Single Cell Supervisor component with a coupled first-line controller as part of a battery management system with the goal for reducing costs, maximizing safety and amount of energy contained within a 20' shipping container
Functional Behavior	Measurements	F5.1.1	Shall	Measure voltage (V) for each cell or group.
		F5.1.2	Shall	Measure temperature (T) of each cell group.
	Balancing	F5.2.1	Shall	Passively balance each cell group
		F5.2.2	Should	Actively balance each cell group
	Data and commands	F5.3.1	Shall	Perform local measurement data conversion
		F5.3.3	Should	Store cell group historical data locally.

4.2.6. In situ SOC and SOH means of measurements (1.1.1.2.2)

The requirements for In situ SOC and SOH sensors is presented in Table 7.

Table 7. In situ SOC and SOH means of measurements

Requirement Category	Description	Requirement ID [AD]	Type	Target
General Information	Objective	AD1.2.1	Reference	Comparative Study – In situ SOC and SOH means of measurements with the goal for reducing costs,

				maximizing safety, and increasing battery utilization throughout its operating life
Functional Behavior	State of Charge	AD5.1.1	Shall	Calculate and provide the battery's State of Charge (SOC)
		AD5.1.2	Shall	Have SOC calculation at the lowest level installation unit.
		AD5.1.3	Shall	Provide accurate SOC prediction within ± 5%.
		AD5.1.4	Should	Provide accurate SOC prediction within ± 1%.
	State of Health	AD5.2.1	Shall	Determine the SOH for the lowest level installation unit.
		AD5.2.2	Should	Determine the SOH for each cell
		AD5.2.3	Shall	SOH uncertainty is ≤ 4%
		AD5.2.4	Should	SOH uncertainty is ≤ 2%
	Thermal Runaway Detection	AD5.6.1	Shall	Detect the onset of a thermal runaway due to internal gas generation early enough to prevent it from occurring

4.2.7. Cell (1.1.1.3)

The requirements for battery cells are presented in Table 8.

Table 8. Cell

Requirement Category	Description	Requirement ID [G]	Type	Target
General Information	Objective	G1.2.1	Reference	To develop a cell using a novel cell with electrodes, which contain no PFAS for the marine industry to reduce cost and increase energy density.
Regulatory	Certifications	G3.1.1	Shall	Meet UN DOT 38.3 requirements
		G3.1.2	Shall	Meet IEC 62619
		G3.1.3	Shall	Meet IEC 62620
	Capacity	G5.7.1	Shall	≥ 59 Ah
	Energy Density	G5.8.1	Shall	≥ 500 Wh/L
		G5.8.2	Should	≥ 560 Wh/L
	Specific Energy	G5.9.1	Shall	≥ 200 Wh/kg
		G5.9.2	Should	≥ 230 Wh/kg
	Cycle Life	G5.10.1	Shall	≥8,000 cycles at 80% DOD before reaching 70% SOH
		G5.10.2	Shall	Be capable of being consistently cycled until reaching 80% BOL capacity without cell fallout.
	Calendar Life	G5.11.1	Shall	≥10 years at 25°C at 50% SOC before reaching 80% of BOL capacity
		G5.11.2	Should	≥15 years at 25°C at 50% SOC before reaching 80% of BOL capacity
Testing Requirements	Cell Test Certifications	G6.1.1	Shall	Meet IEC 61233 Cell Test Certification Requirements

Requirement Category	Description	Requirement ID [G]	Type	Target
		G6.1.2	Shall	Meet IEC 62620 Cell Test Certification Requirements
	Shock	G6.2.1	Shall	UN DOT 38.4, T.4 - Shock
	Vibration	G6.3.1	Shall	UN DOT 38.3, T.3 - Vibration
	Altitude	G6.4.1	Shall	UN DOT 38.3, T.1 - Altitude Simulation
	Thermal Shock	G6.5.1	Shall	UN DOT 38.3, T.2 - Thermal Test
	Short Circuit	G6.6.1	Shall	UN DOT 38.3, T.5 - External Short Circuit
	Impact / Crush	G6.7.1	Shall	UN DOT 38.3, T.6 - Impact / Crush
	Overcharge	G6.8.1	Shall	UN DOT 38.3, T.7 - Overcharge
	Forced Discharge	G6.9.1	Shall	UN DOT 38.3 T.8, - Forced Discharge

4.2.8. Cathode (1.1.1.3.1)

The requirements for cathode are presented in Table 9.

Table 9. Cathode

Requirement Category	Description	Requirement ID [H]	Type	Target
General Information	Objective	H1.2.1	Shall	Develop a cathode material optimized for Current Direct application requirements.
	Cas Registry Number	H1.3.1	Shall	CAS No- 182442-95-1
Full Cell Performance	Reversible Discharge Capacity	H6.1.1	Shall	>150 mAh/g
		H6.1.2	Should	>185 mAh/g

4.3. T2.5 Analysis and Specification of Recyclability

Lead: Umicore; Contributors: Spear, Blackstone, VUB

This task will generate a set of design guides D2.1 for the Current Direct Waterborne Transport Battery Container. It will include the impacts of all non-cell material selections, disassembly techniques, and the scale of minimum disassembly units permissible for planned recycling processes. A key focus of the task will be designing for safe disassembly, recycling, and disposal of the Current Direct battery containers at their end of life. This will be an input to the Safety assessment in T7.4. This task will include participation in the preliminary and critical design reviews of the Current Direct battery in T4.1 to ensure that at end-of-life future cost of recycling and non-reusable waste is minimized.

4.3.1. Recyclability (1.12)

Requirements for recyclability are presented in Table 10.

Table 10. Recyclability

Requirement Category	Description	Requirement ID [Q]	Type	Target
General Information	Objective	Q1.1.1	Shall	Provide design guidelines to achieve an easily recyclable containerized battery system.
Regulatory	Standards	Q3.1.1	Shall	Meet EU Batteries Directive (2006/66/EC)
		Q3.2.1	Should	UN 38.3 Conformity
Performance	Recyclability	Q4.1.1	Shall	Have ≥90% of total waterborne battery container mass be recyclable
		Q4.1.2	Shall	Reduce recycling processing cost 30% when compared to today's containerized waterborne transport battery systems

Requirement Category	Description	Requirement ID [Q]	Type	Target
Safety	Safety Impairing Event Notification	Q5.1.1	Should	Log and notify short circuits or short-term high current loads outside of design recommendations
		Q5.1.2	Should	Log and notify reduced insulation resistance of the complete system
		Q5.1.3	Should	Log and notify system overheating > 70 °C
		Q5.1.4	Should	Log and notify deep discharge below the lower control limit of the BMS
		Q5.1.5	Should	Log and notify overcharge exceeding the upper control limit of the BMS
		Q5.1.12	Should	Log and notify the damaged cooling circuit
		Q5.1.13	Should	Log and notify any apparent abnormal events
Design Requirements Impacting Dismantling	State of Charge	Q6.1.1	Shall	Design to allow easy & safe discharging
		Q6.1.2	Shall	Store EoL battery at State of Charge (SoC)<30 %
	Modularity / Separability	Q6.2.1	Should	Allow maximum modularity of the components
		Q6.2.2	Should	Allow maximum acceptability of the components
		Q6.2.3	Should	Allow standardization among similar and other major applications
		Q6.2.4	Should	Allow separation of cooling components
		Q6.2.5	Should	Use of a maximum number of non-permanent electrical cell connections

Requirement Category	Description	Requirement ID [Q]	Type	Target
	Component Uniformity	Q6.3.1	Should	Maximum the use of similar fasteners/connectors
	Material Selection	Q6.4.1	Should	Use of similar plastic/polymer materials
		Q6.4.2	Should	Use of similar alloying elements for metals used.
		Q6.4.3	Should	Avoid/minimize the use of Glues / Adhesives / thermal pastes
		Q6.4.4	Should	Minimize organic material
	Weight	Q6.5.1	Should	Have ergonomic design for manually handled units.
		Q6.5.2	Should	Limit manually handled unit weights to ≤ 20kg
		Q6.5.3	Should	Follow ADR regulation
	Voltage	Q6.6.1	Should	Include voltage labelling
Design requirements impacting Recycling	Size	Q7.1.1	Should	Minimize and standardize module
	Chemical composition	Q7.2.1	Should	Minimize impurities
		Q7.2.2	Should	Avoid/minimize the use of heavy metals

5. Conclusion & Next steps

The requirement specification developed has been divided into requirements that need to be in place for the demonstration unit timetable and requirements for commercialization. At this stage, the deliverable mainly contains requirements related to the demonstration unit. The specification requirement work is ongoing and will continues to follow the project schedule.

Additional internal/external workshops have been planned to further define and refine requirements for the demonstration unit. These will be followed by the requirements towards commercialization.

Furthermore, a requirements relational database is under development. This database will provide intelligence, analytics and insights that will drive future phases of the project.

Market research and workshops will be conducted to develop further understanding of applicable ship types and required shore infrastructure for the service of Current Direct.