



PROJECT ACHIEVEMENTS

FROM CONCEPT TO LAB BENCH — THE V-ACCESS JOURNEY

How hybrid energy storage (supercapacitors + SMES) moved from a research idea to a validated marine power system technology, step by step, deliverable by deliverable.

MONTHS 1-8	
Chapter 1: Which ship has this problem?	
(KPI 1 Number of selected use cases – KPI 2 Number of use cases processed with preliminary design)	
<p>The project started with a fundamental question: for which vessels does a hybrid energy storage system actually make sense? The team ran a quantitative screening of seven vessel typologies, weighing factors like power demand variability, port dwell time, mission profile, and fuel consumption patterns. Three emerged as priority case studies: the electric ferry (high predictable power demand, short hops), the offshore support vessel with active heave compensation (OSV-AHC, extreme power spikes during crane operations), and the stern trawler (mixed mission profiles from harbour to offshore, diesel-heavy). Deliverable D1.1 catalogued all seven; D1.2 developed a full preliminary HESS design and sizing for each of the three, including lifetime, weight, volume and emission benefit quantification. Target: ≥ 2 use cases. Actual: 7 identified, 3 fully designed.</p>	
D1.1 (M8)	D1.2 (M16)

MONTHS 14-21	
Chapter 2: Can it actually fit on a ship?	
(KPI 3 Physical integration of the identified storage systems on vessel – KPI 4 Technical difficulty of physical integration in case ship)	
<p>Before any power electronics could be tested, V-ACCESS needed to answer a harder question: are supercapacitors and SMES physically and normatively compatible with</p>	



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the marine environment? WP2 tackled this head-on. D2.1 produced full environmental specifications (vibration, shock, temperature, humidity, EMC). D2.2 defined the naval architecture integration requirements. D2.3 — the centrepiece — built a complete virtual prototype of the test-case ferry in Cadmatic software, including structural integration layouts for both SC and SMES modules, and ran a compliance assessment against RINA, DNV and ABS class rules across five categories: vibration, acoustics, mechanical, electrical/EMC, and fire safety. The consortium’s conclusion, quoted directly: **“both solutions proved to be perfectly suitable for deployment on board the test-case ferry.”**

D2.1

D2.2

D2.3 (M21)

MONTHS 21-28

Chapter 3: The digital proof — CHIL simulation

(KPI 7 Efficiency of power converters – KPI 8 Accuracy of simulations of shipboard power systems including supercapacitors and SMESs – KPI 9 Number of components/devices simulated in the network)

Before putting anything on a physical bench, UniGE built a real-time digital twin of the entire system at its SHiL laboratory. The platform: an OPAL-RT OP4512 real-time simulator running at a 210 nanosecond time step, paired with an Imperix B-Box RCP 3.0 hardware controller. Five components were integrated simultaneously in this Controller Hardware-in-the-Loop (CHIL) environment: battery ESS (BESS), supercapacitor ESS (SCESS), SMES ESS (SMESS), bidirectional DC/DC power converters, and a dynamic vessel load profile. Simulation results were cross-checked against manufacturer datasheets from SKT (supercapacitors) and ASG (SMES). SC converters showed efficiency above 95%; SMES converters around 90% — both consistent with literature. The CHIL environment validated control strategies, identified tuning needs, and gave the team confidence to proceed to the physical lab. Target: ≥4 components in simulation. Achieved: 5.

D3.2

D3.4



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MONTHS 21-34

Chapter 4: Designing the DC power architecture

(KPI 5 Power levels managed by the DC power system – KPI 6 Per unit maximum and minimum voltage level of the network with duration in seconds)

Parallel to simulation, WP3 designed the full DC power system architecture for all three case study vessels. The electric ferry requires 2 MW; the offshore support vessel 3 MW for dynamic positioning; the stern trawler up to 4 MW peak during trawling operations. All designs comply with IEEE Std. 1709, the reference standard for DC marine power systems (1–35 kV range). D3.1 documented power flows, bus bar sizing, cable parameters and protection schemes. The lab demonstrator at ETEF was subsequently built around a 1050 V nominal DC bus — representative of the ferry case study — capable of running all key experiments. Voltage deviations during 100 kW load steps remained well within IEEE Std. 1709 limits in both simulation (D3.1) and laboratory testing (D3.5).

D3.1

D3.5

MONTH 28 — DECEMBER 2024

Chapter 5: Is the HESS actually green?

(KPI 12 Assess the environmental impact of the HESS production – KPI 13 Assess the environmental impact of the HESS operation – KPI 14 Assess the efficiency improvement of the HESS)

An integrated techno-economic and environmental assessment of hybrid energy storage systems (HESS), combining battery energy storage systems with supercapacitors or superconducting magnetic energy storage, compared to conventional battery-only solutions, was carried out to quantify efficiency improvements and life cycle impact on climate change in marine applications. In all cases, the reference configuration consists of a stand-alone battery system, while hybrid configurations integrate auxiliary storage to manage peak power and reduce battery



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stress. The analysis covers three representative case studies — an electric ferry, an offshore support vessel with active heave compensation, and a trawler. The results show that hybridization, particularly with supercapacitors, consistently reduces climate change impacts due to lower operational energy losses, with reductions of about **13% for the electric ferry, up to 17% for the offshore vessel, and up to 31% for the trawler**. Full results in D4.2 and D4.3.

D4.2

D4.3 (M28)

MONTH 34 — NOVEMBER 2025

Chapter 6: How mature is the technology?

(KPI 15 Market readiness and next steps to increase TRL)

With simulation complete and physical testing beginning, WP4 conducted a formal Technology Readiness Level (TRL) assessment. Supercapacitor HESS: confirmed at **TRL 5** — technology validated in a relevant environment. This is a meaningful milestone: TRL 5 means the system works not just in a lab, but in conditions representative of real deployment. SMES HESS: also confirmed at **TRL 5** — technology validated in a relevant environment — following completion of laboratory testing at ETEF. The assessment is published in D4.4 and provides the maritime industry with a transparent maturity map for both technologies.

D4.4 (M34)

MONTH 24 — JANUARY 2025

Chapter 7: What could go wrong — and how do we prevent it?

(KPI 16 Risk assessment)

Supercapacitors store large amounts of energy at high voltages; SMES coils operate at cryogenic temperatures with powerful magnetic fields. Before regulators can accept these technologies on commercial vessels, every plausible hazard must be mapped,



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assessed and mitigated. WP5 completed a full HAZID (Hazard Identification) analysis in close collaboration with RINA, DNV and ABS. Hazards were systematically identified, ranked by likelihood and consequence, and assigned mitigation measures. The results cover electrical, thermal, mechanical, cryogenic and EMC hazard categories. D5.3 documents the complete analysis and has been shared with maritime regulatory bodies as a reference document for future class rule development. Zero open high-severity hazards.

D5.3 (M24)

MONTH 33 — OCTOBER 2025

Chapter 8: What the rules don't yet cover

(KPI 17 Rules gap analysis)

Even with a validated, safe system, commercial deployment is impossible without regulatory acceptance. V-ACCESS systematically compared existing maritime energy storage standards — originally written for batteries — against the specific characteristics of supercapacitors and SMES. The gaps are real and significant: more than eight distinct areas where current rules provide no adequate coverage. These span thermal management during fast charge/discharge cycles, cryogenic handling procedures for SMES, dynamic response requirements beyond what battery standards consider, and electromagnetic compatibility in dense marine electrical environments. D5.4 documents each gap with a proposed regulatory approach. The findings have been formally submitted to RINA, DNV and ABS, and are expected to inform the next revision cycle of their energy storage class rules.

D5.4 (M33)

MONTH 36 — JUNE 2025

Chapter 9: From simulation to the physical bench



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(KPI 10 Maximum power delivered by the supercapacitors and SMESs during lab testing of a marine power system – KPI 11 Voltage level of the DC network during lab testing in a marine power system)

The ETEF (Electric TEst Facility) in Trieste — operated by UniTS — became the stage for the physical verification of everything the project had designed and simulated. The 1050 V-zonal DC grid demonstrator was separately subjected to load steps of 20 kW, 50 kW and 100 kW. The supercapacitor HESS responded correctly at all power levels: peak power fully shaved, voltage transients within IEEE Std. 1709 limits, dynamic response matching CHIL predictions. The SMES system also ensured 20 kW–50 kW–100 kW power delivery, while the time duration depends on the automation intrinsic delay in configuring the subsystems. HESS and SMES demonstrated therefore their capability in feeding the onboard loads in the designed tests. Full results in D3.5.

D3.5 (M36)

MONTH 35 — DECEMBER 2026 · TODAY

Chapter 10: Building the next generation of HESS engineers

(KPI 18 Skills development – KPI 19 Project management progress)

V-ACCESS was never just about proving a technology — it was about creating the knowledge base and the people who will deploy it. D5.5 delivers a comprehensive training handbook structured as a 2-day equivalent course. It works at three levels simultaneously: theoretical (physics of supercapacitors and SMES, power electronics, system integration), practical (computer simulation exercises students can run on their own machines), and operational (what vessel crew and port engineers need to know for safe operation and maintenance). The handbook is designed to be adopted by maritime engineering programmes, shipyards, and classification society training arms. Meanwhile, the PSC has managed the entire project through a significant disruption — the M26 transport accident — navigating the Amendment AMD-01 process and keeping all partners aligned. The project is on track for a complete wrap-up at M40.

D5.5 (M35)

D7.3



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ALL 19 KPIS AT A GLANCE

KPI 1 — <input checked="" type="checkbox"/> ACHIEVED	
NUMBER OF SELECTED USE CASES	Vessel Selection
Target: ≥ 3 use cases. Result: 7 identified, 3 fully designed. D1.1 screened 7 vessel typologies; D1.2 developed complete HESS pre-design for electric ferry, OSV-AHC and stern trawler including lifetime, cost and emission quantification.	
D1.1	D1.2 (M8–M16)

KPI 2 — <input checked="" type="checkbox"/> ACHIEVED	
NUMBER OF USE CASES PROCESSED WITH PRELIMINARY DESIGN	Vessel Selection
Target: ≥ 3 use cases with complete preliminary design. Result: 3 achieved. ESS sizing methodology and HESS design framework applied to all three vessel types with quantified benefits.	
D1.2 (M16)	

KPI 3 — <input checked="" type="checkbox"/> ACHIEVED	
PHYSICAL INTEGRATION OF THE IDENTIFIED STORAGE SYSTEMS ON VESSEL	Physical Integration



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Full environmental specs (D2.1), naval architecture requirements (D2.2), and Cadmatic virtual prototype (D2.3) completed. Class rule compliance verified across 5 categories. Conclusion: “both solutions perfectly suitable.”

D2.1

D2.2

D2.3 (M21)

KPI 4 — ACHIEVED

TECHNICAL DIFFICULTY OF PHYSICAL INTEGRATION IN CASE SHIP

Physical Integration

Qualitative assessment completed positively in D2.3. Overall judgement consistently positive for both technologies.

D2.3 (M21)

KPI 5 — ACHIEVED

POWER LEVELS MANAGED BY THE DC POWER SYSTEM

DC Power System

Power levels designed for all 3 vessels (ferry 2 MW, OSV 3 MW, trawler 4 MW peak) in D3.1 and experimentally verified at 20, 50, 100 kW on the 1050 V DC bus demonstrator (D3.5).

D3.1

D3.5 (M36)



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KPI 6 — <input checked="" type="checkbox"/> ACHIEVED			
PER UNIT MAXIMUM AND MINIMUM VOLTAGE LEVEL OF THE NETWORK WITH DURATION IN SECONDS		DC Power System	
DC bus voltage maintained within IEEE Std. 1709 limits during 100 kW load steps in both SC and SMES control modes. Verified in simulation (D3.1) and laboratory (D3.5).			
D3.1		D3.5 (M36)	
KPI 7 — <input checked="" type="checkbox"/> ACHIEVED			
EFFICIENCY OF POWER CONVERTERS		CHIL Simulation	
SC converter >95%, SMES converter ~90% confirmed via CHIL simulation (OPAL-RT OP4512, 210 ns time step).			
D3.2		D3.4	
KPI 8 — <input checked="" type="checkbox"/> ACHIEVED			
ACCURACY OF SIMULATIONS OF SHIPBOARD POWER SYSTEMS INCLUDING SUPERCAPACITORS AND SMES		CHIL Simulation	
Multi-level validation (RMS, EMT, CHIL) completed. Consistency with manufacturer data (SKT, ASG) confirmed across all simulation levels.			
D3.2		D3.4	



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KPI 9 — <input checked="" type="checkbox"/> ACHIEVED	
NUMBER OF COMPONENTS/DEVICES SIMULATED IN THE NETWORK	CHIL Simulation
<p>Target: ≥ 4 components in real-time simulation. Result: 5 integrated — BESS, SCESS, SMES, DC/DC converters, dynamic vessel load profile. Target exceeded.</p>	
D3.2	D3.4

KPI 10 — <input checked="" type="checkbox"/> ACHIEVED	
MAXIMUM POWER DELIVERED BY THE SUPERCAPACITORS AND SMES DURING LAB TESTING OF A MARINE POWER SYSTEM	Lab Testing
<p>SC fully verified at 100 kW. SMES also ensured 20–50–100 kW power delivery. Both HESS and SMES demonstrated capability in feeding onboard loads across all designed test conditions.</p>	
D3.5 (M36)	

KPI 11 — <input checked="" type="checkbox"/> ACHIEVED	
VOLTAGE LEVEL OF THE DC NETWORK DURING LAB TESTING IN A MARINE POWER SYSTEM	Lab Testing
<p>IEEE Std. 1709 voltage compliance confirmed for both SC and SMES experiments at ETFE (1050 V DC bus). Voltage transients within limits across all load step tests.</p>	
D3.5 (M36)	



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KPI 12 — <input checked="" type="checkbox"/> ACHIEVED	
ASSESS THE ENVIRONMENTAL IMPACT OF THE HESS PRODUCTION	LCA & Environment
Full LCA completed. Manufacturing carbon footprint of HESS quantified vs battery-only ESS across all vessel types. Higher manufacturing impact largely offset by operational savings over vessel lifetime.	
D4.2 (M28)	
KPI 13 — <input checked="" type="checkbox"/> ACHIEVED	
ASSESS THE ENVIRONMENTAL IMPACT OF THE HESS OPERATION	LCA & Environment
Best-performing configurations reduced operational climate impacts: Ferry -15%, Offshore support vessel -19%, Stern trawler -36% (kg CO ₂ eq vs battery-only baseline).	
D4.2 (M28)	
KPI 14 — <input checked="" type="checkbox"/> ACHIEVED	
ASSESS THE EFFICIENCY IMPROVEMENT OF THE HESS	LCA & Environment
HESS reduces energy losses vs battery-only ESS due to improved charge/discharge management. Confirmed across all three vessel types in LCA and system-level simulation.	
D4.2	D.4.3 (M28)



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KPI 15 — <input checked="" type="checkbox"/> ACHIEVED	
MARKET READINESS AND NEXT STEPS TO INCREASE TRL	LCA & Environment
SC HESS: TRL 5 confirmed. SMES HESS: TRL 5 confirmed. Both technologies validated in a relevant marine environment. Full assessment published in D4.4.	
D4.4 (M34)	
KPI 16 — <input checked="" type="checkbox"/> ACHIEVED	
RISK ASSESSMENT	Market & Regulations
Full HAZID analysis completed. All hazards identified, classified and mitigated. Conducted with RINA, DNV, ABS. Zero open high-severity items. Report shared with regulatory bodies.	
D5.3 (M24)	
KPI 17 — <input checked="" type="checkbox"/> ACHIEVED	
RULES GAP ANALYSIS	Market & Regulations
8+ regulatory gaps identified covering thermal management, cryogenic procedures, dynamic response and EMC. Formally submitted to RINA, DNV and ABS to inform next rule revision cycle.	
D5.4 (M33)	



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KPI 18 — <input checked="" type="checkbox"/> ACHIEVED	
SKILLS DEVELOPMENT	Market & Regulations
2-day equivalent training course produced: theoretical, simulation-practical and operational sections. Targets students, engineers and vessel crew at different technical depths.	
D5.5 (M35)	

KPI 19 — <input checked="" type="checkbox"/> ACHIEVED	
PROJECT MANAGEMENT PROGRESS	Project Management
Regular PSC meetings throughout the project. AMD-01 successfully navigated and approved by the EC. All WPs progressing per amended Annex I. Final review at M40.	
D7.1	D7.2
	D7.3