



SAFE, SUSTAINABLE AND
MODULAR HYBRID SYSTEMS FOR
LONG-DURATION ENERGY
STORAGE AND GRID SERVICES

SMHYLES

NEWS

October 2026
Issue 01

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Welcome to the first edition of the SMHYLES LinkedIn Newsletter!

As Europe accelerates its transition towards renewable energy, one challenge remains at the heart of the energy system: how do we store clean energy when the sun isn't shining and the wind isn't blowing?

The SMHYLES project is developing next-generation Hybrid Energy Storage Systems (HESS) that combine long-duration batteries with high-power supercapacitors. By bringing together complementary storage technologies, SMHYLES aims to unlock greater renewable integration, improve grid flexibility, and support a cleaner and more resilient energy future.

In this newsletter series, we'll share project updates, research highlights, technological breakthroughs, and upcoming events from across the consortium.

Updates on the project

Authored by BayFOR

The SMHYLES project has successfully completed its first reporting period and is now entering an exciting new phase.

Several key project deliverables have been completed and are already available on the [project website](#). These include the HESS Business Cases Assessment, a report on Digital Twins for HESS Design, and the Techno-Economic Sizing Analysis.

At the same time, preparations for the demonstration sites are progressing steadily. These pilots will showcase SMHYLES technologies in real-world operating environments and validate their performance under practical conditions.

News & Events

Over the past months, SMHYLES partners have continued to present and discuss project developments at relevant conferences and events. As part of its [joint webinar activities](#), SMHYLES has organized a series of online events together with its sister projects, covering topics ranging from modular and sustainable energy storage and HESS business models to real-world applications and sustainability in energy storage systems.

Looking ahead, SMHYLES will also be represented at major upcoming events, including [BID 2026 in Stockholm](#) and [Enlit Europe 2026](#), providing further opportunities to share project results and engage with stakeholders from the energy and research communities.

As the project moves into its second half, attention is increasingly focused on demonstrating how hybrid energy storage can support Europe's transition towards a more flexible and sustainable energy system.



Unlocking the business potential of hybrid energy storage

Authored by RINA-C, COME

How can innovative hybrid energy storage systems support Europe's energy transition while creating viable business opportunities? The SMHYLES project has taken a major step forward by assessing market trends, regulatory drivers and real-world business cases for Hybrid Energy Storage Systems (HESS). The results show that HESS technologies can play a key role in increasing renewable energy integration, providing grid flexibility and enabling new energy services for communities, industries and island grids.

The SMHYLES project has completed a comprehensive assessment of the market opportunities and business potential of Hybrid Energy Storage Systems (HESS), providing a crucial bridge between technological innovation and future commercial deployment. HESS combine at least two electrically connected storage technologies with complementary characteristics, allowing the same system to address both energy-oriented needs, such as long-duration storage and load balancing, and power-oriented needs, such as rapid response and grid regulation. Compared with standalone storage solutions, a well-designed HESS can improve response time, operational flexibility, reliability and renewable energy utilization while supporting a broader range of services.

The assessment connects this technological potential with real operating environments and commercial pathways. It examines the European and African electricity and energy storage markets, the regulatory framework at EU and selected national levels, and the conditions that may enable or constrain HESS deployment. In Europe, opportunities are driven by decarbonization targets, electricity market reform and growing demand for balancing, congestion management, demand response and self-consumption optimization. In Africa, storage can support electricity access, renewable integration, mini-grids and the replacement of costly diesel generation, although infrastructure gaps, affordability, fragmented regulation, import dependence and limited local maintenance and recycling capabilities remain important challenges.

Building on these market and regulatory findings, the project defined several use cases across three demonstration sites using the IEC 62559 methodology, which provides a common structure for describing objectives, actors, scenarios, exchanged information, prerequisites and performance indicators. The following table summarizes all the use cases addressed, sorted by demonstration site, presenting their scopes and objectives.

Demo Site	UC	Use case	Scope
Aqueous HESS demonstration	UC1	Load Leveling for Electric Vehicle (EV) Charging	ESS can be used to smooth out fluctuations in energy demand caused by charging electric vehicles, thereby reducing strain on the grid and optimizing the use of renewable energy resources.
	UC2b	Energy arbitrage	Electricity is purchased at low cost during off-peak periods, stored and then sold at a higher price during peak periods This use case overlap with UC3: Storage for energy-oriented services (intra day): Intra-day storage for local load balancing.
	UC5a	Self-consumption maximization	The stored energy of the HESS can be used during periods when production is lower than consumption, to maximize the use of generated renewable energy in the local grid and reducing reliance on non-renewable grid power, while also reducing overall cost.
Salt-based HESS demonstration	UC2a	Optimized Dispatch of Production and Storage Assets	Achieving an optimized dispatch of production and storage assets involves coordinating their operation to minimize energy costs and enhance renewable energy penetration in the grid. This use case overlap with UC3: Storage for energy-oriented services (intra day): Intra-day storage for local load balancing.
	UC4	Support for grid regulation services	ESS with proper frequency regulation capabilities, and with a long enough delivery period, can provide spinning reserve for dispatch solutions. In island systems, this allows to increase RES penetration by reducing the need to dispatch additional thermal units, or to curtail intermittent renewable sources, to ensure the spinning reserve criteria. Moreover, by being explored as grid forming units, the ESS bring additional stability to island systems and may avoid the need of additional dispatch of synchronous thermal units for system stability reasons, enabling larger RES integration or even dispatch solutions

		with 100% RES production.
	UC5a Self-consumption maximization	The stored energy of the HESS can be used during periods when production is lower than consumption, to maximize the use of generated renewable energy in the local grid and reducing reliance on non-renewable grid power, while also reducing overall cost.
HESS-Retrofitting	UC2a Optimized Dispatch of Production and Storage Assets	Achieving an optimized dispatch of production and storage assets involves coordinating their operation to minimize energy costs and enhance renewable energy penetration in the grid.
	UC3 Storage for energy-oriented services (intra day): Intra-day storage for local load balancing	This involves storing excess energy generated from intermittent renewable sources, which would be curtailed otherwise, and supplying it to the local grid, in the same day, when demand is high or during periods of low renewable energy generation, thereby maximizing the utilization of renewable resources in a daily basis.
	UC5a Self-consumption maximization	The stored energy of the HESS can be used during periods when production is lower than consumption, to maximize the use of generated renewable energy in the local grid and reducing reliance on non-renewable grid power, while also reducing overall cost.
	UC5b Storage extension: Intra week storage for local load balancing	By providing weekly flexibility, storage extension allows factories and businesses to balance their energy consumption over the course of the week, optimizing energy usage and reducing reliance on the grid during peak periods.

The use cases were translated into five business cases, each linking technical operation with services, stakeholders, required resources, expected benefits and implementation barriers.

BC1	Energy Community as Flexibility Aggregator	Energy Community as Flexibility Aggregator for Ancillary Service provision to System Operators and Balance Responsible Parties including network constraints management services, such as congestion management, and balancing services, such as frequency regulation.
BC2	Energy Community as an Energy Service Company (ESCO) offering energy management services	Energy Community as an Energy Service Company (ESCO) offering energy management services to community members, such as energy awareness and self-balancing at the community level.
BC3	Prosumer engagement	Prosumer engagement in Implicit Demand Response for local energy profile optimization (Time-of-Use optimization).
BC4	Hybrid power plants to increase RES in island grids	Hybrid power plants combine storage and RES as a single entity, being governed by specific rules to participate in the electricity dispatch of the power system. These can replace thermal generation in an island electricity system, provided that the grid connection requirements can compensate for the services lost from disconnecting the thermal generation.
BC5	Improved Energy Savings by self-consumption maximization due to storage extension	The Energy Storage system aims to store energy which would otherwise be curtailed and therefore saves money as less energy is needed from the grid.

The results demonstrate that HESS technologies can play a significant role in facilitating renewable energy integration, increasing grid flexibility, supporting local energy communities and creating new business opportunities across Europe. By aligning advanced storage technologies with real market needs and evolving energy policies, the assessment provides valuable guidance for future commercialization and large-scale deployment of the innovative solutions being developed within SMHYLES.

Seeing the future of energy storage, today

Authored by FBK

How SMHYLES is using digital twins to design smarter hybrid batteries

The SMHYLES team is tackling the energy storage challenge by developing Hybrid Energy Storage Systems (HESSs) that combine two very different technologies in one package: batteries that store large amounts of energy for long periods, and supercapacitors that can charge and discharge almost instantly. Together, they promise the best of both worlds – steady, long-duration power plus a rapid response to sudden spikes in supply or demand.

Before any of this hardware is built at full scale, the FBK team needed a way to test it virtually. That is the purpose of the first project's modelling activity, which introduces a set of “digital twins” – detailed computer models that mimic the real-world behavior of each storage component. These models let researchers simulate months or years of operation in a fraction of the time, well before a single battery cell is deployed on the ground.

Three technologies, one virtual laboratory

The developed tools reproduce the physics of three key components that make up SMHYLES' hybrid systems:

Vanadium Redox Flow Batteries (VRFBs) – aqueous batteries well suited to storing large amounts of energy over long periods. The model calculates the power flowing across the battery accounting for the losses associated to internal inefficiency, pumps and auxiliaries. It also takes into account operational limitations and the aging of some components like electrodes and electrolytes.

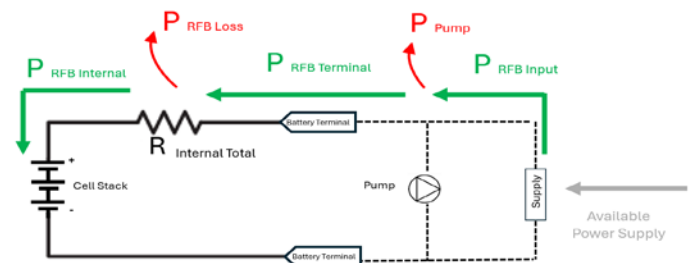


Figure – Equivalent electric model of the Vanadium Flow Battery charging process

Salt-based batteries (NaNiCl_2) – a high-temperature technology offering a robust, long-duration alternative. Here the typical electrical model works in tandem with a thermal model, able to capture the real battery operational window considering temperature and state of charge. This extension accounts for the different heating contributions, including

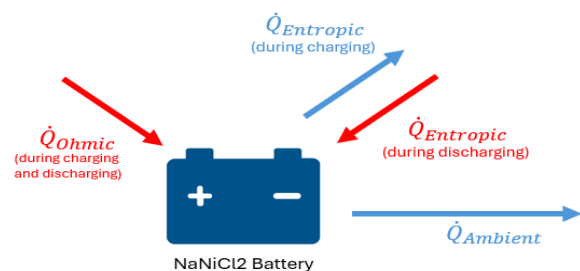


Figure – Scheme of the contributions to the salt-based battery thermal model

dissipation to the environment or the need to warm-up the system.

Supercapacitors (SCs) – devices that can absorb or release power almost instantaneously. Here internal power flow is calculated by an equivalent electrical circuit.

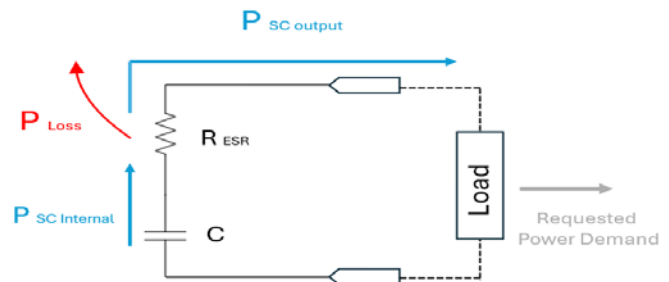


Figure – Equivalent electric model of the supercapacitor discharging process

Each model was built from the ground up and then checked against real measurements supplied by equipment manufacturers, confirming that the simulations track the actual charging and discharging behaviour, temperature swings and efficiency losses of the physical devices closely.

Why pairing batteries with supercapacitors pays off

Batteries are excellent at storing energy, but they cannot always follow every fast fluctuation in solar generation or consumer demand – internal limits force them to “throttle” their charging or discharging rate. This is precisely the gap supercapacitors are designed to fill. The diagram below summarises the concept at the heart of the work: a battery handles the slow, long-term energy balance, while a supercapacitor smooths out the second-to-minute scale fluctuations that the battery alone would have to reject.

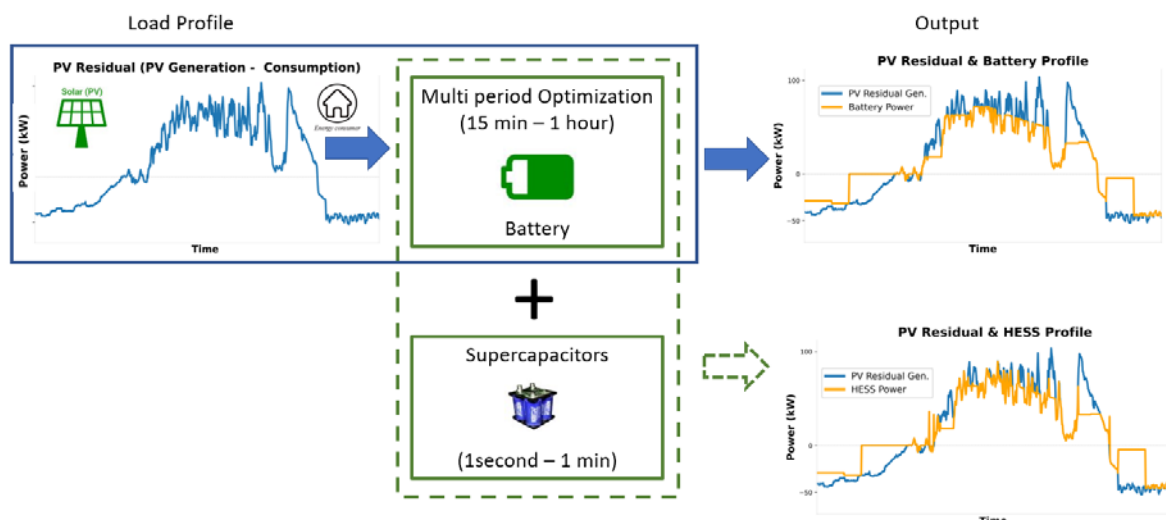
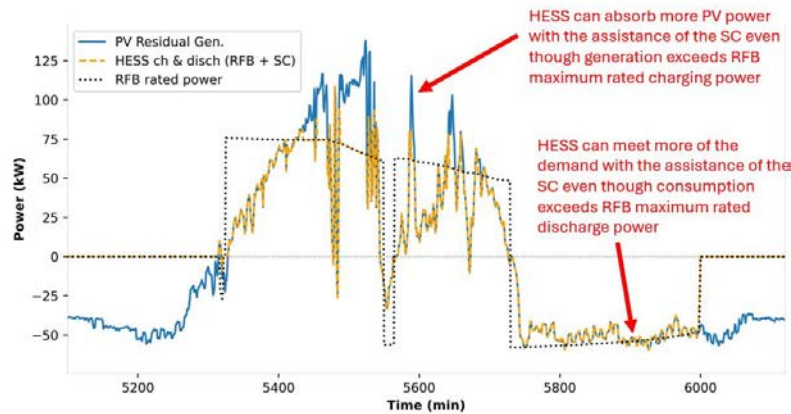


Figure – Battery and supercapacitor work on different timescales, and combining them (bottom path) captures more of the fluctuating solar-minus-demand profile than the battery alone (top path).

The team put this idea to the test with real photovoltaic (PV) generation and consumption data. In a first set of simulations aimed at maximising self-consumption of solar power, adding a supercapacitor to a redox flow battery reduced wasted (curtailed) solar energy by around 3.3%

and left 0.2% less demand unmet, compared with using the battery alone. For the salt-based battery, the supercapacitor cut curtailment by 2.4% and unmet demand by 0.7%. These may sound like small percentages, but at scale, over a full year of operation, they translate into a meaningful amount of energy that would otherwise be wasted or bought from the grid.



Turning smart timing into savings

Beyond self-consumption, the FBK team also developed an optimisation tool – based on a genetic algorithm – that decides, hour by hour, when a HESS should charge or discharge to take advantage of variable electricity prices, a strategy known as energy arbitrage. Tested against nine days of real price and generation data, simply adding a battery already cut electricity costs by 5.7–14.4% compared with having no storage at all. Layering a supercapacitor on top brought a further 1.4–7.8% reduction, by helping the battery follow its optimal charging schedule more precisely even when solar generation swings rapidly from minute to minute.

What comes next

This work lays the technical groundwork for the next stage of the project, which will use these same digital twins to determine the optimal size of each HESS component in several use cases across utility and industrial applications. By validating the models today, the project ensures that tomorrow's physical installations are backed by design choices tested over and over in the virtual world first – a faster, cheaper and safer route to unlock the flexible, resilient energy storage that the clean energy transition needs.

If you are interested, you can find more in [Deliverable D2.2 “Digital twins for HESSs design”](#)

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- Buchajczyk, Marcin, et al. "Techno-economic analysis and sizing of RFB and supercapacitor-based HESS for an EV charging station." 2024 AEIT International Annual Conference (AEIT). IEEE, 2024.
- Buchajczyk, Marcin, et al. "Dual-timeframe optimization of hybrid salt-based battery-supercapacitor systems—A techno-economic sizing framework." Journal of Energy Storage 154 (2026): 121347.
- Deliverable D2.2 "Digital twins for HESSs design", SMHYLES Project, GA #101138029

Test rig for vanadium recycling

Authored by Fraunhofer ICT

From spent electrolyte to new battery: Closing the vanadium loop with a cascading electrolysis stack

Vanadium redox flow batteries are a cornerstone of long-duration energy storage – but what happens to the electrolyte at end of life? In the EU project SMHYLES, Fraunhofer ICT and partners have taken a major step toward a truly circular vanadium economy by developing a cascading electrolysis stack that converts spent vanadium electrolyte back into a fresh, battery-ready product.

The result: a 4-cell prototype that achieves up to 30 % conversion in a single pass, guided by multi-physics simulations, integrated into a pilot-scale recycling plant at TRL 4. The recycled electrolyte has already been cycled for over 70 charge-discharge cycles with no signs of degradation.

Closing the Vanadium Loop: A Cascading Electrolysis Stack for Electrolyte Recycling

The Challenge

Vanadium redox flow batteries (VRFBs) store energy in liquid electrolyte – which means spent electrolyte can be reprocessed rather than discarded. In the predecessor project HyFlow, Fraunhofer ICT developed a process to extract vanadium from used electrolyte via liquid-liquid extraction. The remaining gap was converting the resulting V(IV) precursor into a balanced V(III)/V(IV) mixture ready for reuse in a battery. Task 3.1 of SMHYLES was set up to close this gap.

The Approach

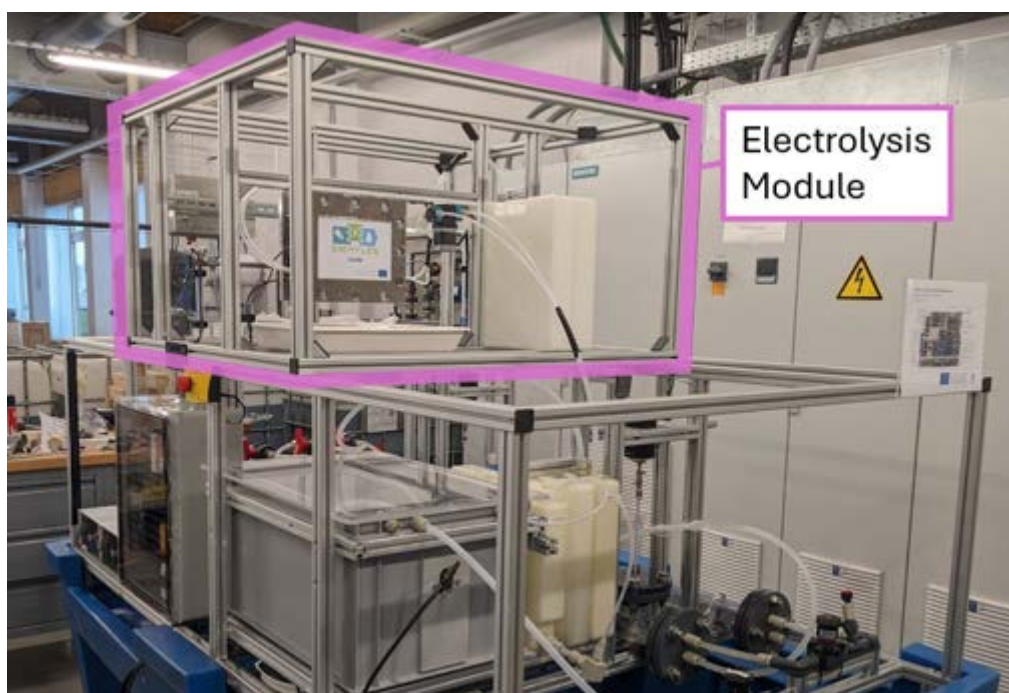
The idea: use a VRFB stack in electrolyser mode – an external power source drives the partial reduction of V(IV) to the target 50/50 V(III)/V(IV) mixture. A cascading cell configuration (all cells hydraulically in series) maximizes conversion in a single pass, enabling integration into a semi-continuous recycling process. Two electrode designs were built and compared: flow-through (carbon felt, flat bipolar plates) and flow-by (carbon cloth, interdigitated channels). FBK supported the development with coupled CFD and electrochemical simulations in COMSOL Multiphysics.

Key Results

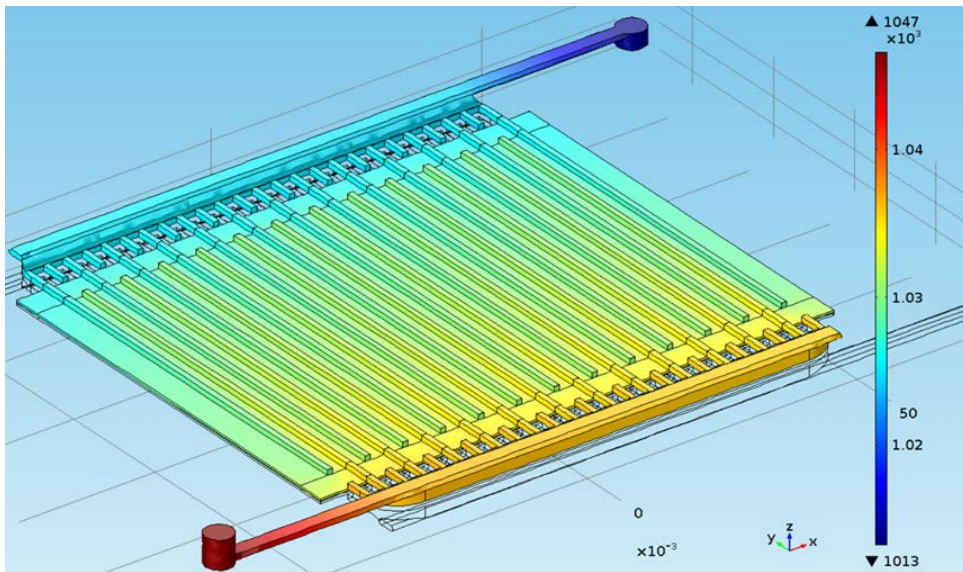
- Flow-by outperforms flow-through roughly half the pressure drop and lower, more consistent resistance. The flow-by design was selected for plant integration.
- A 4-cell prototype achieved up to 30 % single-pass V(IV) conversion; extrapolation shows 8-9 cells are needed to reach the 50 % target.
- A novel EPR method was developed for real-time, in-line conversion measurement at the stack outlet, enabling process control.
- The stack was integrated as a modular "Electrolysis Module" onto the existing extraction pilot plant (TRL 4). The recycled electrolyte showed stable cycling over 70+ cycles with no degradation; physical parameters were within spec, though efficiencies still trail commercial electrolyte due to residual impurities.

Outlook

Next steps include scaling to 8-9 cells, reducing extraction impurities, and permanently implementing spectroscopic quality control. Beyond recycling, the cascade design is equally applicable to primary electrolyte production.



Vanadium electrolyte recycling system with extraction pilot plant and attached "Electrolysis Module".
Electrolysis stack mounted in the middle of the module.



3D color map representing pressure drop in interdigitated configuration

Design of an intrinsically safe supercapacitor

Authored by C2C

Over the first two years, C2C-NewCap achieved the SMHYLES goals in developing safe, modular, and sustainable high-power energy storage technologies. C2C focused on redesigning the module architecture to reduce manufacturing complexity, lower costs, and extend the supercapacitor lifespan.

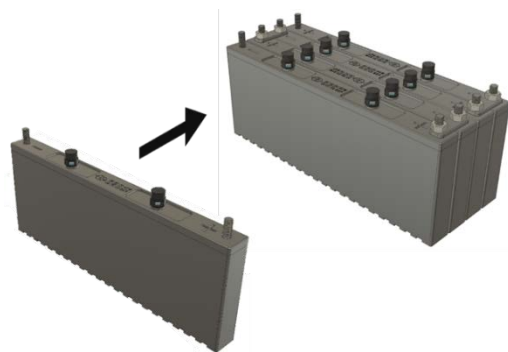
Key Progress & Technical Highlight:

- **Transition to Monoblock Design (G6 Concept):** shift from individual machined single-cell units to an injection-moulded monoblock architecture. This new design integrates cell compartments internally, improving module assembly while increasing overall system modularity and scalability.
- **Significant Material & Cost Reductions:** By eliminating extensive external connectors and optimising component housing, the new monoblock design achieved a ~40% and ~43% reduction in total plastic weight and metal hardware, respectively, per 27 V module. This material optimisation drove a 42% overall reduction in module manufacturing costs.

- **Pressure Relief & Safety Features:** Combined non-flammable Nickel-Carbon (Ni-C) aqueous chemistry with an integrated gas channel and relief valve system, eliminating fire and pressure risks.
- **Continuous Voltage Balancing:** A custom Voltage Balancing System (VBS) designed in-house that actively operates across any SoC range, maximising energy delivery and component longevity. Unlike conventional passive systems that only activate during overvoltage.

With the monoblock architecture and VBS validated, C2C is moving forward with the construction of the Supercapacitor prototypes for Demonstrator #1 (Porto) and Demonstrator #2 (Graciosa Island).

Here's a picture of the new design:



Impressum

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Disclaimer

About SMHYLES



SMHYLES is a Horizon Europe project developing innovative Hybrid Energy Storage Systems that combine batteries and supercapacitors to support renewable energy integration and grid flexibility.

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Grant agreement ID: 101138029