i-STENTORE

Demonstrating the Future of Energy Storage Integration

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i-STENTORE: Pioneering the Integration of Innovative Energy Storage

Project Vision

To accelerate the integration of renewable energy and create a secure, clean energy future through advanced energy storage solutions.

Key Objectives

- **Enhance** the integration of renewable power sources.
- **Optimize** the performance of diverse energy storage technologies.
- **Develop** intelligent, interconnected storage systems.
- **Inform** strategic investments in energy storage infrastructure.
- **Explore** new and varied applications for energy storage.
- **Ensure** seamless compatibility across storage solutions.
- **Validate** real-world benefits and scalability throughout Europe.
- **Address** barriers hindering widespread energy storage adoption.
- **Stimulate** growth and investment in the energy storage sector.

Scope

i-STENTORE demonstrates and validates innovative energy storage across **6 practical sites** in Europe (5 demos, 1 Living Lab). The project covers a **versatile mix of technologies** applied to energy-intensive sectors like **industry, agriculture, and mobility**, addressing real-world energy challenges and engaging key stakeholders to showcase new business opportunities.

A Phased Methodology

The project follows a structured, step-by-step approach:

1. **Design & Planning:** Defining project requirements and designing the i-STENTORE framework.
2. **Implementation & Testing:** Deploying and rigorously testing solutions in real-world demonstration environments.
3. **Evaluation & Expansion:** Assessing performance, business viability, and potential for widespread adoption, informed by continuous learning.

Impact

- **Next-Generation Storage:** Demonstrating more sustainable, efficient, adaptable, and cost-effective storage.
- **Reliable & Green Energy:** Improving energy system efficiency and reducing environmental impact.
- **Tailored Storage Solutions:** Showcasing systems designed for specific needs.
- **Stronger European Industry:** Boosting the EU's role in the energy storage market.
- **Global Market Potential:** Creating opportunities for European technology leadership.
- **Viable Business Models:** Proving successful ways to integrate energy storage.
- **Seamless Renewable Integration:** Effectively linking clean energy with demand.
- **Flexible Grid Participation:** Enabling distributed storage to support grid stability.

DEMO 1 Slovenia	Molten Glass Thermal storage for an increased uptake of renewable electric energy.
DEMO 2 Portugal	*Madeira Island*. Pump Hydro Storage system combined with BESSs
DEMO 3 Spain	Virtual Energy Storage System for Renewable Energy Integration (VESS)
DEMO 4 Italy	Cooperative modular multi Hybrid Energy Storage Systems based on Hybrid SuperCap/Li-NMC batteries for Smart DC MGs of E-mobility Service
DEMO 5 Sweden	Green Steel Production Facility with energy storage capabilities based on Hydrogen and BESS technologies
LIVING LAB Greece	Agkistron Energy Park Sandbox

LIVING LAB
Agkistron Energy Park Sandbox

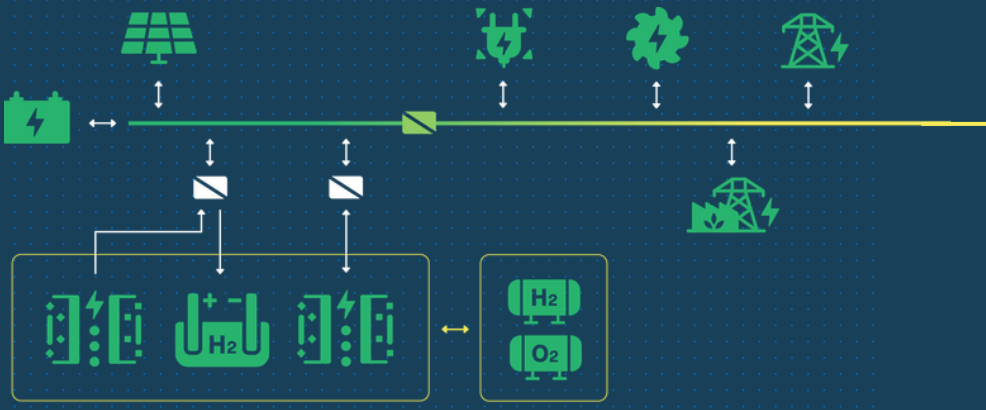
Location
Agkistron, Serres, Greece

Application & Integration
Hybrid renewable Living Lab integrating PV park, BESS systems, a Hybrid Hydrogen Energy Storage System (HHESS), biomass gasifier gen-set, EV charger and power electronics, interconnected with a local hydro plant and coordinated via SCADA for testing advanced energy management and scenario-based operation.

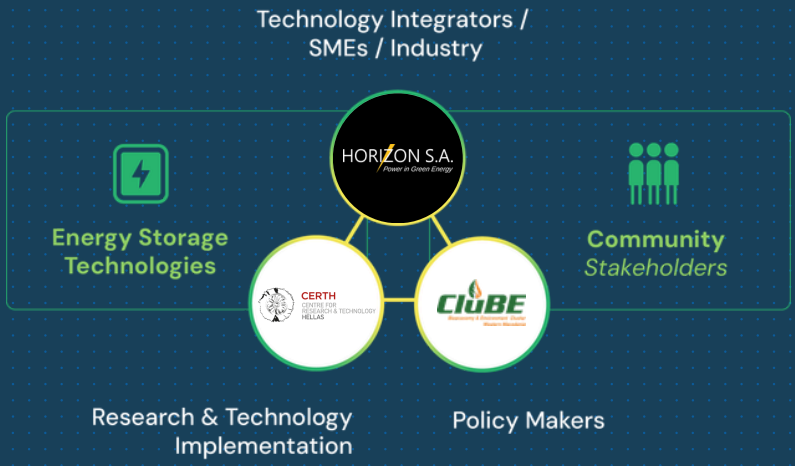
Key Functionalities & Services
- HHESS for mid- to long-term storage using electrolyzer, H_2 tanks, and PEM fuel cells.
- BESS for short-term balancing, peak shaving, and fast response support.
- PV park supplying local RES generation and reducing grid imports.
- Biomass gasifier gen-set as dispatchable, locally fueled backup/RES asset.
- EV charger enabling real-world smart-charging and e-mobility studies.
- SCADA-based EMS supervising all subsystems and demand-side management.

Expected Benefits & Impact
The Living Lab increases energy autonomy by combining PV, BESS, HHESS, biomass and hydro interconnection to minimize RES curtailment, enhance microgrid flexibility, and extend storage timescales from short-term to seasonal. Scenario-based operation using real EV, residential, office and agrifood load profiles supports optimization of control strategies, assessment of system durability, and evaluation of scalability and replicability in different regions and sectors.

Energy Storage Technologies
- **Battery:** Li-ion BESS
- **Hydrogen Storage:** HHESS (alkaline electrolyzer, compressed H_2 tank @30 bar, PEM fuel cells).
- **Virtual Energy Storage:** SCADA-based EMS, demand-side management and smart charging acting as virtual flexibility.



Living Lab Technology Sandbox



DEMO 1
Molten Glass Thermal Storage for an Increased Uptake of Renewable Electric Energy

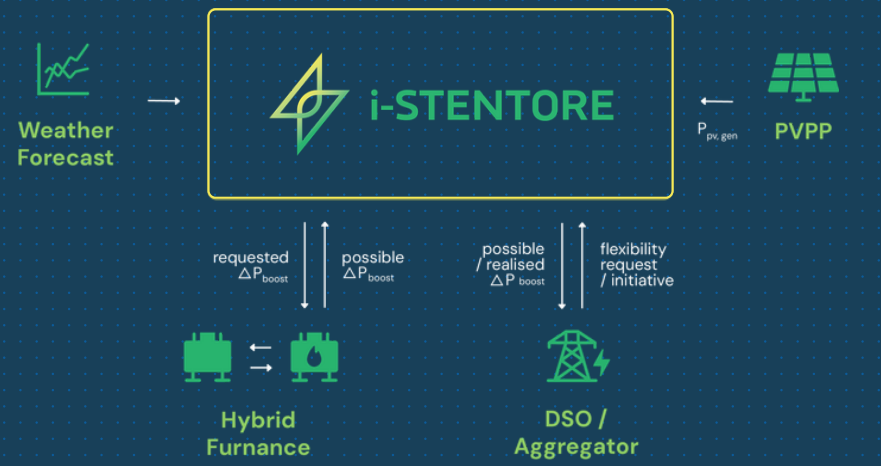
Location
Hrastnik, Slovenia

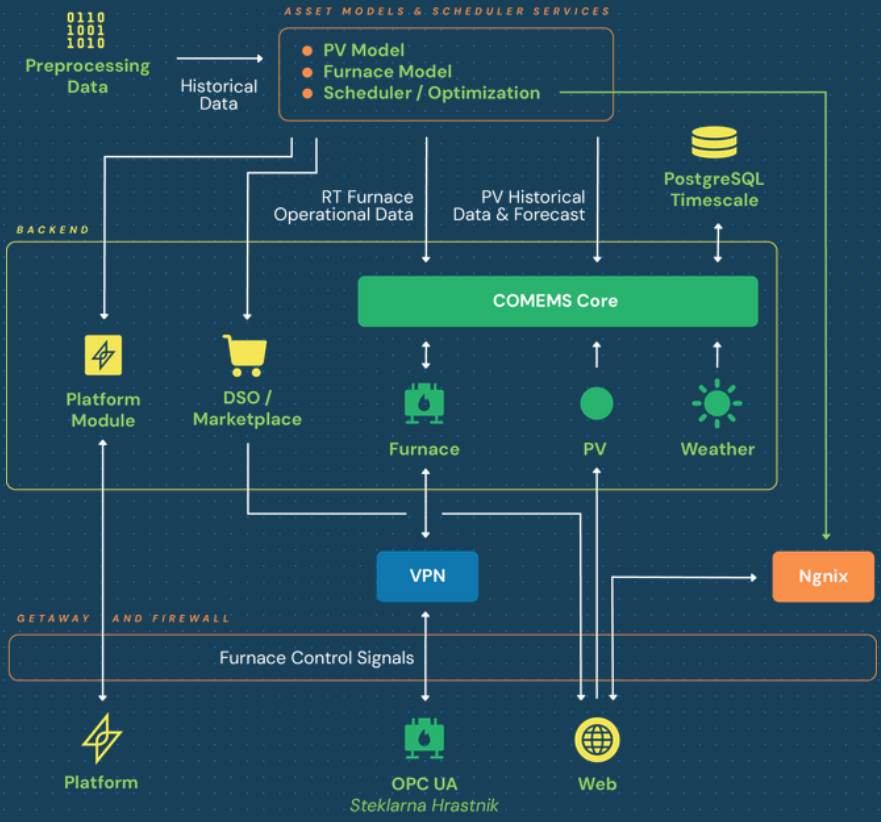
Application & Integration
Hrastnik1860 is an i-STENTORE demonstrator where a hybrid furnace is paired with rooftop PV through COMS flexibility platform to align glass melting with renewable energy availability using coordinated electric boosting.

Key Functionalities & Services
- Aligning glass melting with RES availability through coordinated electric boosting.
- Maximizes onsite PV utilization, reducing energy costs and curtailment.
- Optimising energy costs by utilising data from wholesale market
- Provide ancillary services to the DSO, such as peak shaving and grid balancing support.

Expected Benefits & Impact
Enables flexibility and by utilizing hybrid electrical-thermal storage, reduces gas use and associated emissions, and aligns electric boosting with renewable energy availability to lower CO_2 footprint.

Energy Storage Technologies
- Thermal Storage (Molten Glass)


Weather Forecast
i-STENTORE
P pv, gen
PVPP
requested ΔP boost
possible ΔP boost
possible / realised ΔP boost
flexibility request / initiative
Hybrid Furnance
DSO / Aggregator


0110
1001
1010
Preprocessing Data
Historical Data
ASSET MODELS & SCHEDULER SERVICES
PV Model
Furnace Model
Scheduler / Optimization
PostgreSQL Timescale
RT Furnace Operational Data
PV Historical Data & Forecast
BACKEND
COMEMS Core
Platform Module
DSO / Marketplace
Furnace
PV
Weather
VPN
Ngnix
GETAWAY AND FIREWALL
Furnace Control Signals
Platform
OPC UA
Steklarna Hrastnik
Web

DEMO 2
Pump hydro Storage System Combined with BESSs

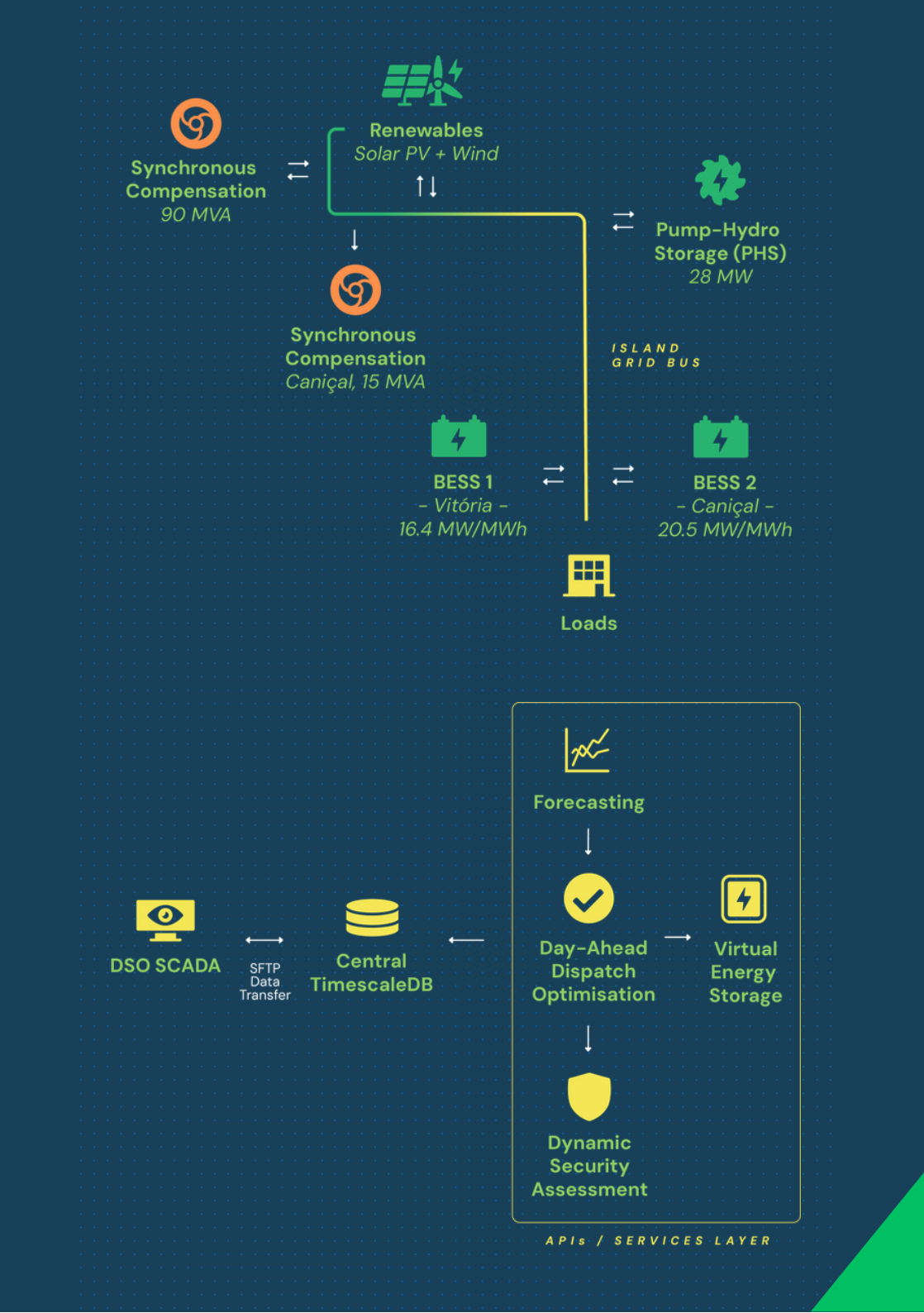
Location
Madeira Island, Portugal

Application & Integration
Hybrid island-grid demo integrating pumped-hydro, Li-ion BESS and synchronous condensers with i-STENTORE data/forecasting, day-ahead dispatch and stability services.

Key Functionalities & Services
- Day-ahead optimal dispatch of hydro cascade + BESS to cut curtailment and fuel.
- Dynamic security assessment (including RoCoF/nadir constraints and synchronous condensers support).
- Data pipeline (SCADA-to-SFTP-to-central Timescale DB) + APIs feeding platform services.
- VM-based integration/deployment and operator visualisation/dashboards.

Expected Benefits & Impact
Higher RES hosting and lower diesel generation via coordinated storage dispatch; improved frequency stability (RoCoF/nadir) leveraging synchronous condensers; better planning via forecasts and predicted operational KPIs.

Energy Storage Technologies
- Battery (Li-ion): Two Li-ion BESS on Madeira island (Funchal area) - Vitória BESS with 15 MW/16.4 MWh and Caniçal BESS with 18.7 MW/16.1 MWh
- Pumped Hydro Storage: Pumped-hydro storage available (>60 MW in demo scope; hydro plants with pumping capabilities).
- Virtual Energy Storage (software): Day-ahead dispatch optimisation + forecasting/services acting as “virtual storage” by coordinating flexibility.
- Synchronous condensers (for grid support): Included as key grid stability enabler (15 MVA + 60 MVA).
- VRFB: Not implemented in Madeira as initially planned (due to supplier issues). However, a lab-scale prototype was built and electrolyte testing performed.


Renewables
Solar PV + Wind
Synchronous Compensation
90 MVA
Synchronous Compensation
Caniçal, 15 MVA
Pump-Hydro Storage (PHS)
28 MW
ISLAND GRID BUS
BESS 1
- Vitória -
16.4 MW/MWh
BESS 2
- Caniçal -
20.5 MW/MWh
Loads
Forecasting
Day-Ahead Dispatch Optimisation
Virtual Energy Storage
Dynamic Security Assessment
APIs / SERVICES LAYER
DSO SCADA
SFTP Data Transfer
Central TimescaleDB

DEMO 3
Virtual Energy Storage System for Renewable Energy Integration (VESS)

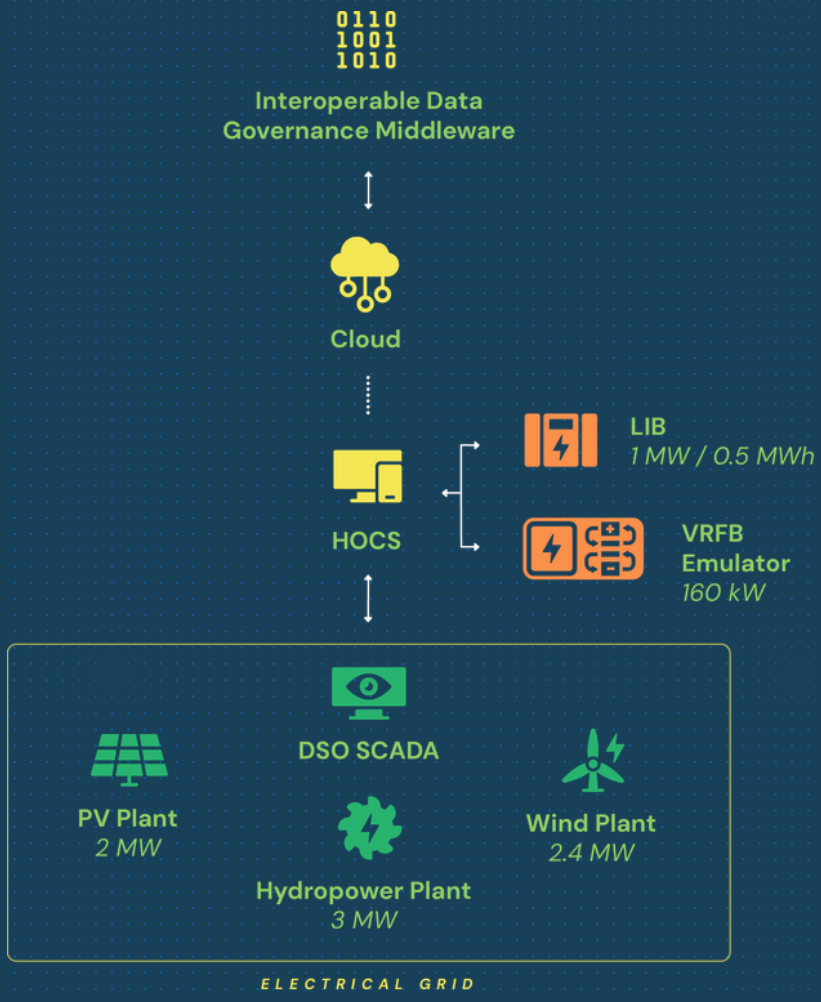
Location
Albuñol (Granada, Spain)

Application & Integration
Integrates Li-ion BESS and a VRFB emulator with PV, wind, and hydro plants in a distribution grid. Operates as a Virtual Energy Storage System (VESS) using multi-layer control for coordinated operation.

Key Functionalities & Services
- Energy Arbitrage in Day-Ahead Market: Optimizing dispatch based on price/generation forecasts.
- mFRR Participation: Providing upward/downward reserve services to the TSO via scheduled activation.
- DSO Flexibility Services: Real-time voltage regulation and congestion management support.

Expected Benefits & Impact
Demonstrates VESS viability for grid support and market participation. Enhances renewable integration and grid resilience while optimizing business cases for storage and generation assets.

Energy Storage Technologies
- Lithium-ion Battery (1 MW/0.5 MWh)
- Vanadium Redox Flow Battery Emulator (160 kW)
- Virtual Energy Storage System


0110
1001
1010
Interoperable Data
Governance Middleware
Cloud
HOCS
LIB
1 MW / 0.5 MWh
VRFB
Emulator
160 kW
DSO SCADA
PV Plant
2 MW
Wind Plant
2.4 MW
Hydropower Plant
3 MW
ELECTRICAL GRID

DEMO 4
Cooperative Modular Multi Hybrid Energy Storage Systems based on Hybrid SuperCap /Li-NMC Batteries for Smart DC MGs of E-mobility Service

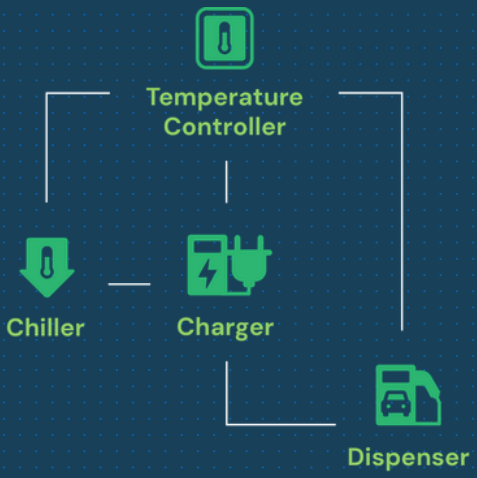
Location
Mercogliano, Italy.

Application & Integration
Integrating a hybrid storage system (LTO+NMC) into an e-mobility hub. It combines PV, ultra-fast charging, and V2G to optimize energy management in bus depots.

Key Functionalities & Services
- Ultra-fast 320kW charging supported by hybrid batteries for heavy-duty electric buses.
- Bidirectional Vehicle-to-Grid (V2G) services to support grid stability.
- Fillee mobile units for flexible charging with 18kWh second-life batteries.
- Predictive EMS control to minimize grid peaks and maximize battery cycle life.

Expected Benefits & Impact
80% reduction in grid peaks, increased local renewable self-consumption, and extended battery lifespan through intelligent hybrid management.

Energy Storage Technologies
- Battery: (NMC, LTO, Li-ion 2nd life).
- Virtual Energy Storage: (EMS software-defined storage management and V2G logic).


Temperature
Controller
Chiller
Charger
Dispenser

DEMO 5
Cooperative Modular Multi Hybrid Energy Storage Systems based on Hybrid SuperCap /Li-NMC Batteries for Smart DC MGs of E-mobility Service

Location
Hofors, Sweden

Application & Integration
This demo integrates a 20 MW PEM electrolyzer and 1 MW grid-forming BESS at the Ovako steel plant. It synchronizes green hydrogen production, heavy-duty fueling, and district heating into a single, flexible industrial energy hub controlled by a digital management platform.

Key Functionalities & Services
- Grid Resilience and Stability: Black-start and intentional islanding during outages. Inertia emulation and frequency/voltage regulation.
- Green Fueling: High-capacity hydrogen station for heavy-duty vehicles.
- Heat Recovery: 2 MW of waste heat for 1,000+ local households.
- System Optimization: Digital modeling to maximize efficiency and decarbonization.

Expected Benefits & Impact
Proves the business case for carbon-neutral steel while enhancing grid resilience. It reduces emissions, extends asset lifecycles through optimized electrical response, and provides a scalable model for stabilizing weather-dependent energy systems.

Energy Storage Technologies
- Green Hydrogen (HESS)
- Utility-Scale BESS
- Grid-Forming Inverters
- Thermal Storage
- H2 Fueling Station

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