Hybrid Services from Advanced Thermal Energy Storage Systems

This project has received funding from the European Union Horizon Europe Programme under grant agreement N. 101096789 (HYSTORE).

Renewable Electricity Supply Flexibility by Thermal Energy Storage








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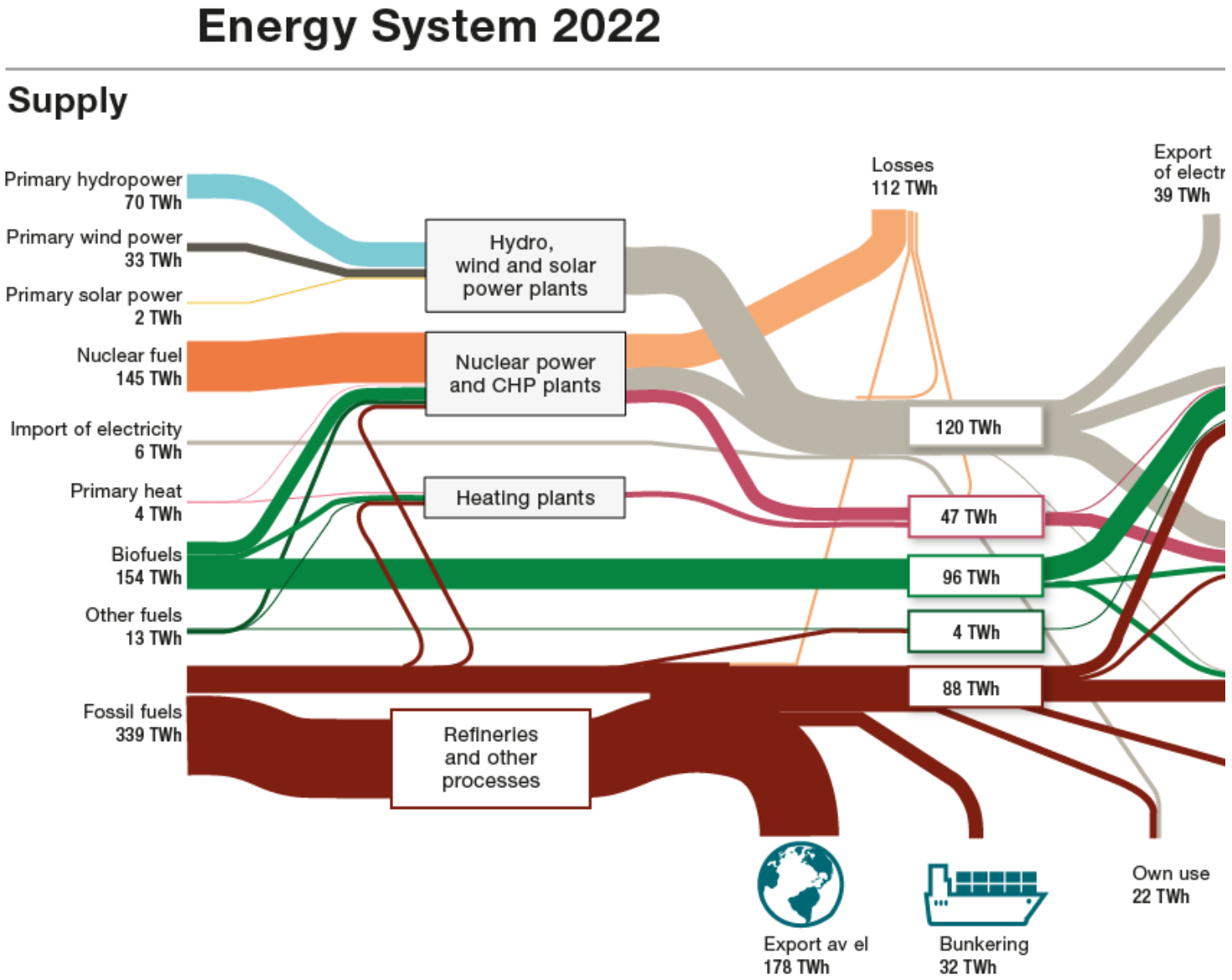
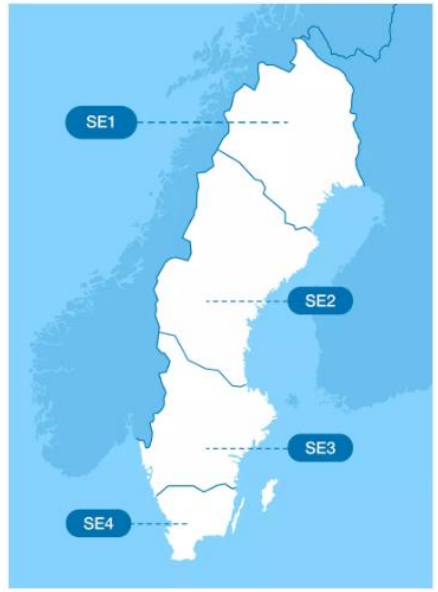
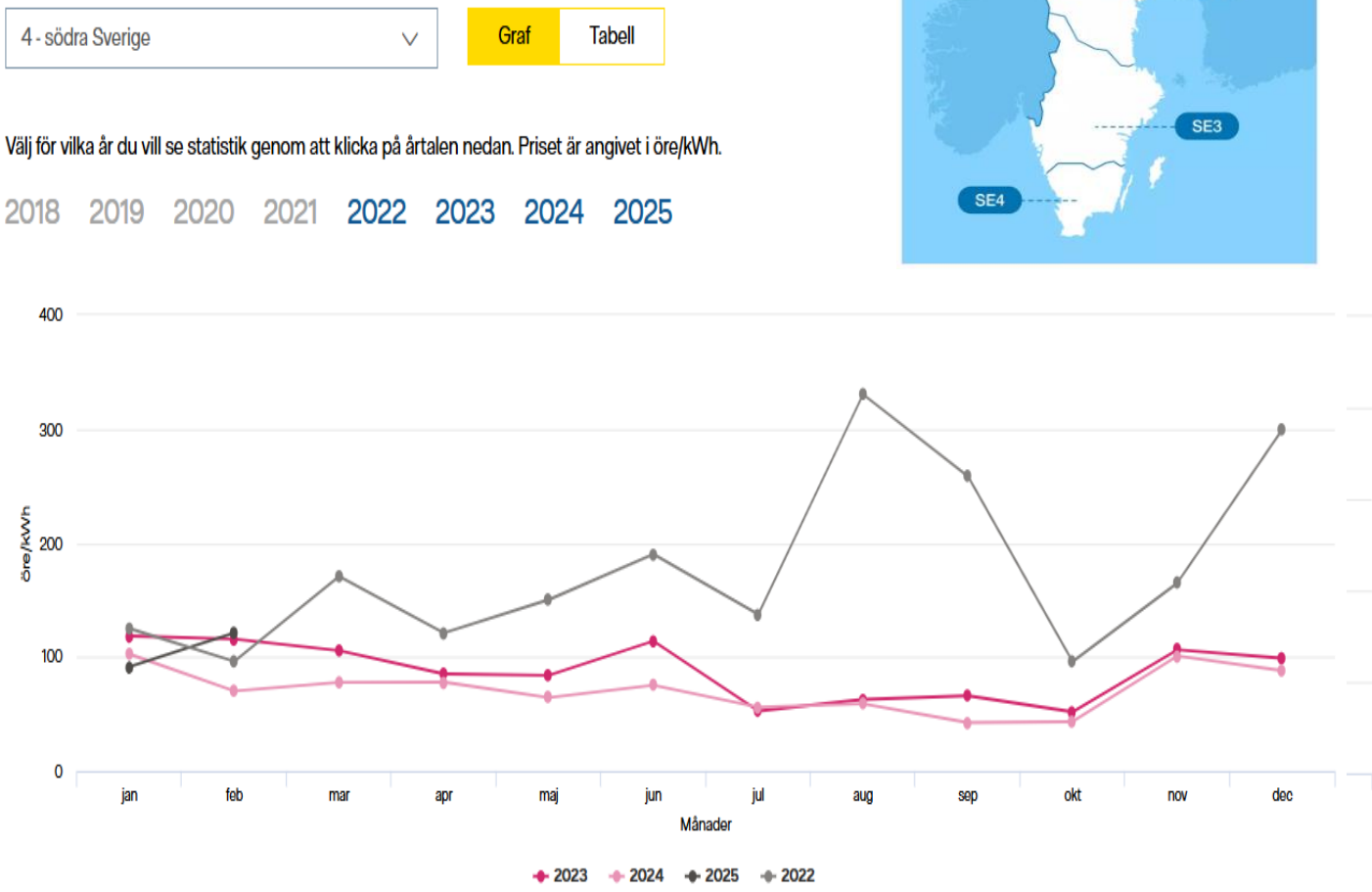
2025-03-26

Swedish Energy System



Swedish Electricity Supply





https://www.svk.se/en/national-grid/map-of-the-national-grid/,
https://www.vattenfall.se/elavtal/elpriser/rorligt-elpris/prishistorik/

Solar PV in Sweden

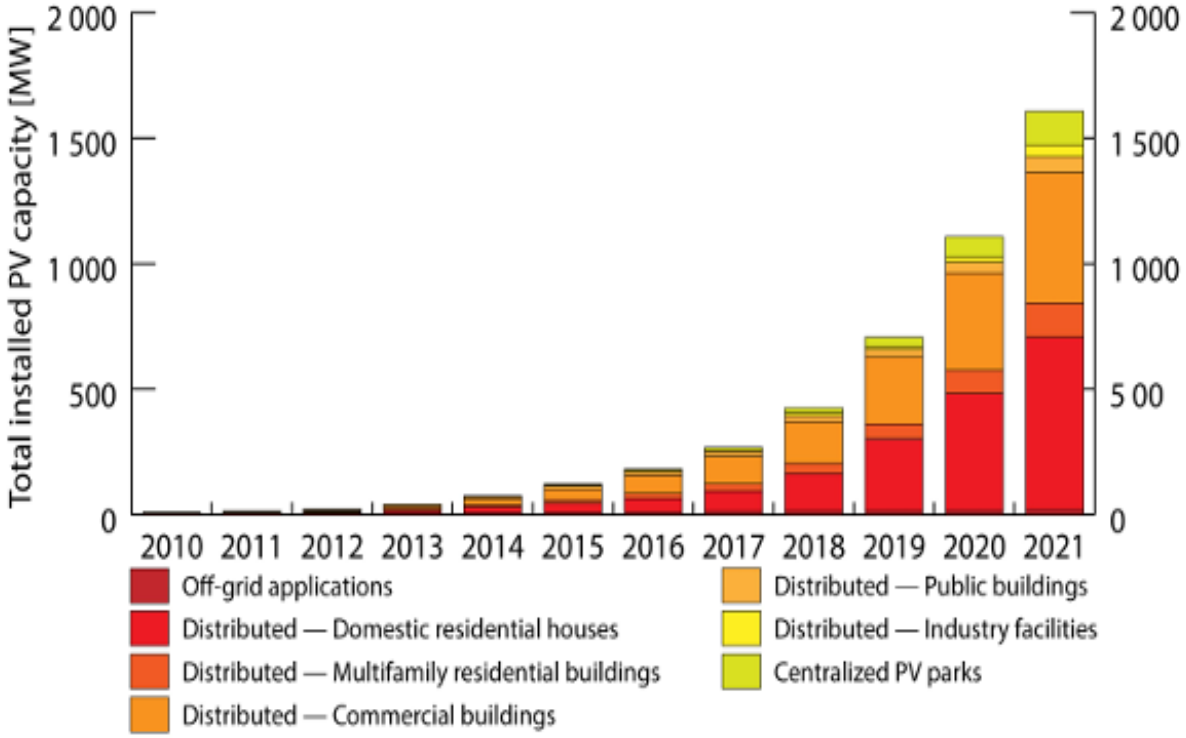


Figure 2: Total installed PV capacity in Sweden.

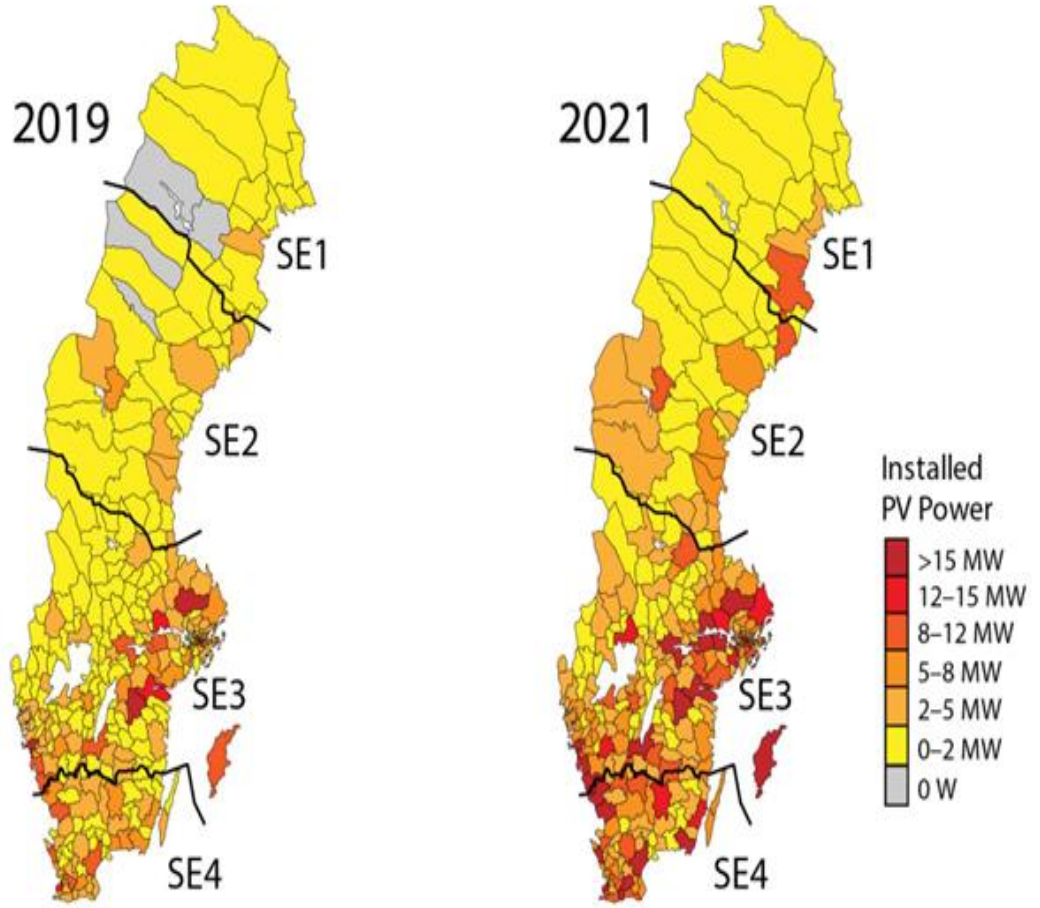


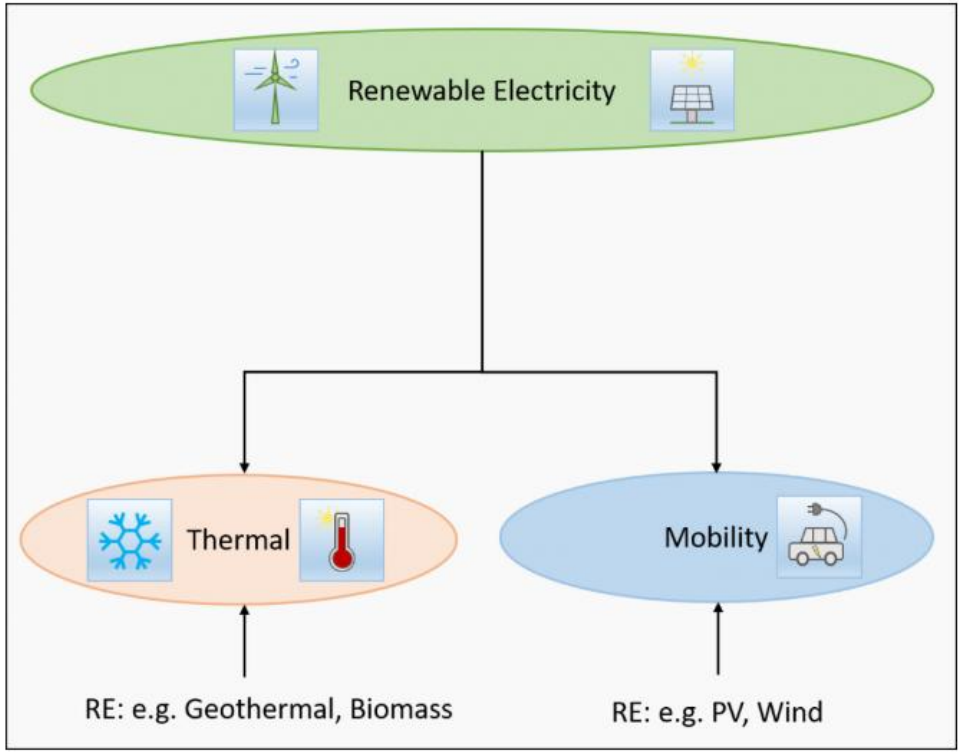
Figure 4: Total power of the PV systems in each of Sweden's municipalities. For some municipalities data from the green electricity system has been used instead of grid operators' data due to confidentiality reasons.

IEA PVPS- Solar PV in Sweden

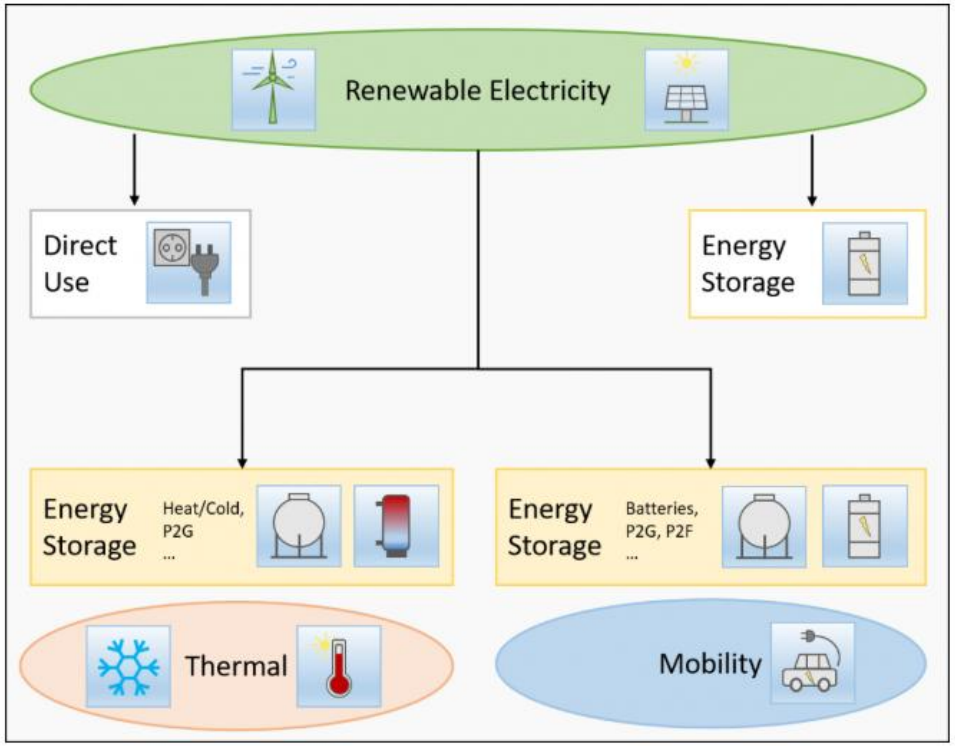
Flexible Sector Coupling (FSC)?

Technology Collaboration Programme by iea

Task 35 seccoflex



Sector Coupling



Flexible Sector Coupling

https://iea-es.org/task-35/

Renewable Electricity Supply Flexibility with Thermal Energy Storage (TES)

An FSC Case Study →

HYSTORE
Hybrid Services from Advanced Thermal Energy Storage Systems

Hybrid Services from Advanced Thermal Energy Storage Systems

HYSTORE: Hybrid services from advanced thermal energy storage systems

HYSTORE project web
HYSTORE @EGI-KTH

Nº	Name	Acronym	Country	Type
1-Coord.	ARC	ARC	ES	SME
2	Consiglio Nazionale delle Ricerche	CNR	IT	RTO
3	KTH Royal Institute of Technology	KTH	SE	UNI
4	Rubitherm GmbH	RUBI	DE	SME
5	Austrian Institute of Technology	AIT	AT	RTO
6	OCHSNER	OCHS	AT	SME
7	PINK GmbH	PINK	AT	SME
8	Sorption Technologies	SOR	DE	SME
9	Inovalab	INOVA	IT	LE
10	STAM	STAM	IT	SME
11	Maston AB	MAST	SE	SME
12	Dublin City University	DCU	IE	UNI
13	EURAC	EUR	IT	RTO
14	R2M solutions s.r.l	R2M	IT	SME
15	University College Dublin	UCD	IE	UNI
16	Central de reserves Montserrat	CRM	ES	SME
17	RAAL	RAAL	RO	SME
18	European Innovation Marketplace	EIM	BE	NGO

HYSTORE IN A NUTSHELL

- Technological advancement of thermal energy storage (TES) with **up to +150% energy density and -50% CAPEX compared to state-of-art (SoA)**
- Significant **lower design and installation effort** thanks to pre-defined and standardized guidelines
- **allow TES to be coupled and integrated with grid-level aggregators** that can be federated in the context of both single buildings and local energy communities
- **4 use case application** in different climates both for DHC (District Heating/Cooling) connected and non DHC-connected buildings with high-impact and replication potential.
- LCOS in line with EU targets from IRENA annual reports and SET-plan.

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PCM: Phase Change Materials
TCM: Thermochemical heat storage materials

Overall Concept of HYSTORE

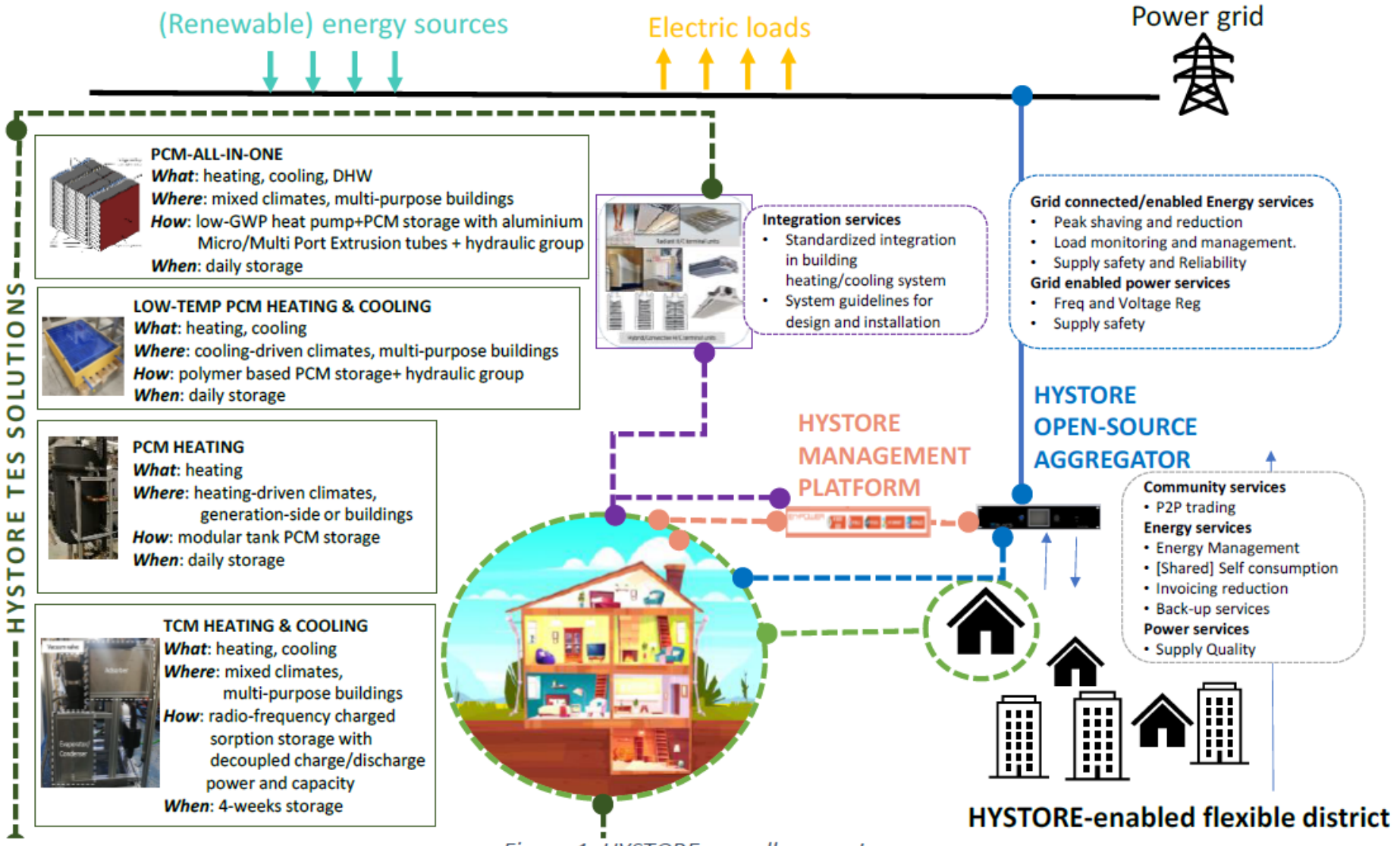

Figure 1: HYSTORE overall concept

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Material, Component and System-scale PCM-TES Design, Operation and Optimization with Heat Pumps

STO1: to design, manufacture and characterize modular and plug-and-play thermal energy storage solutions for daily to monthly storage with different functions (heating, cooling, DHW). **Targeted WPs: WP2, WP3**

STO2: to develop and deploy optimised control strategies from TES controller level, aggregation and community-levels for efficient TES operation and energy services provision. **Targeted WPs: WP3, WP4**

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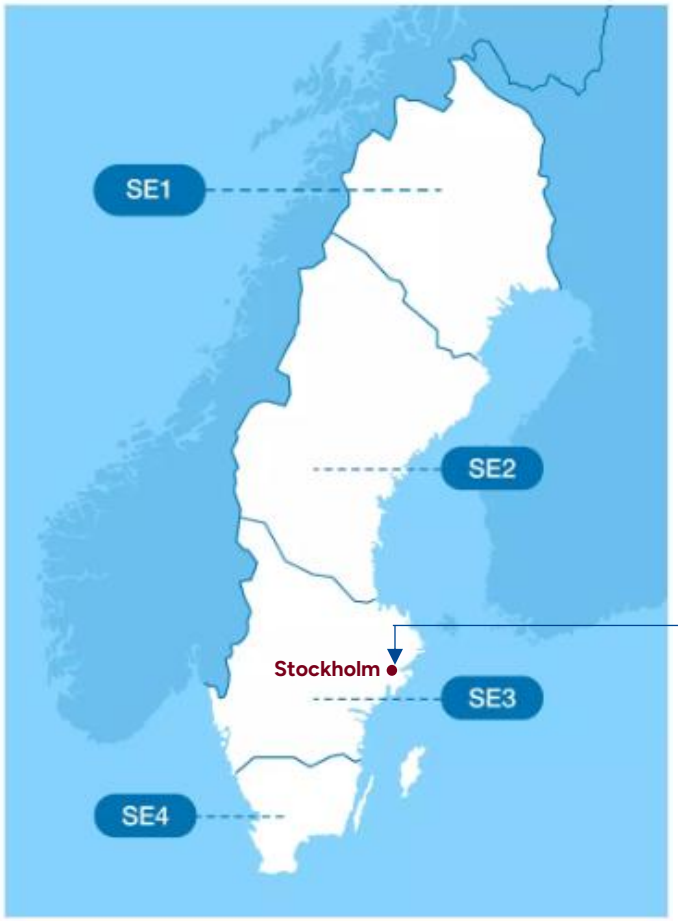
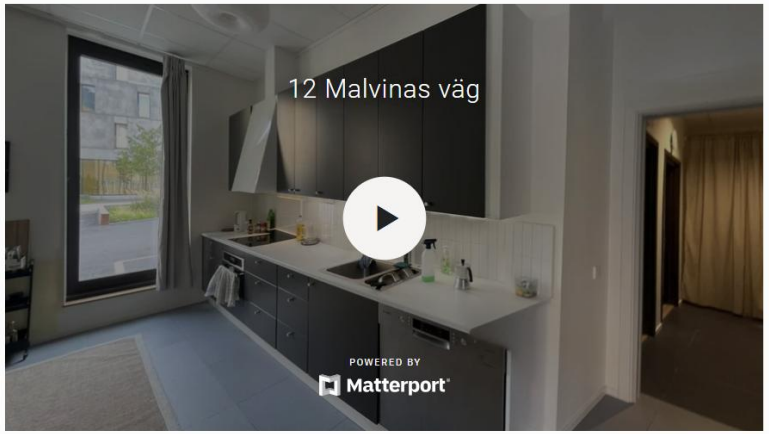
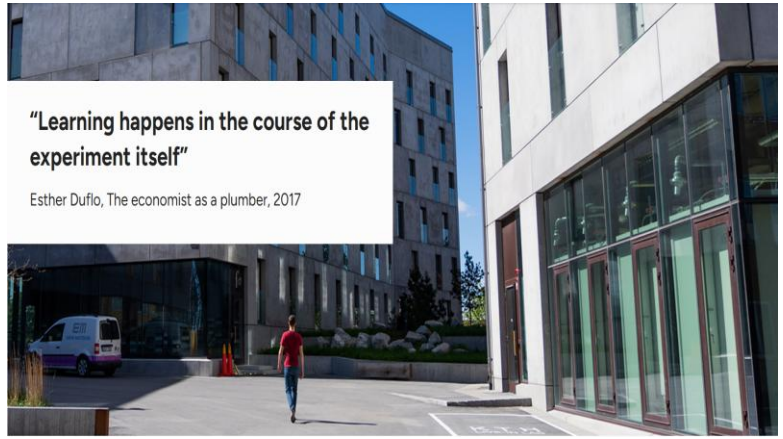
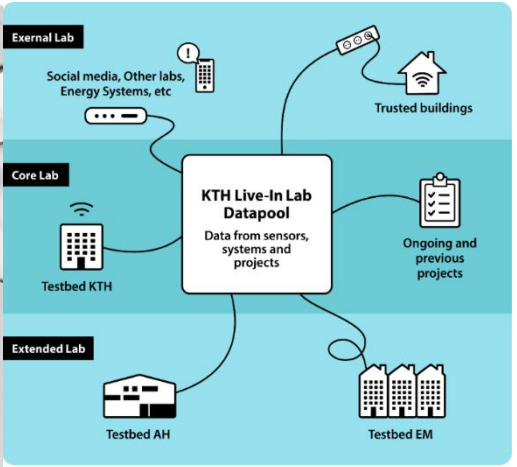
PCM Heating Solution (Stockholm)







KTH Live-in-Lab Testbed KTH



https://www.liveinlab.kth.se/start-1.1064463

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"PCM Heating" Solution @KTH in a Nutshell

The ***design, construction & operational and control optimization of a "Combined System of LHTES and Heat Pump* (PCM Heating Solution)",**
aiming for:

EGI

- Optimal **material** selection (for minimal supercooling & hysteresis analyzed in a **bench-scale LHTES** unit, considering different PCMs including bio-based)
- Optimal **LHTES+ HEX component** analysis, design & construction, followed by the integration with a suitable **HP**, for **pilot-scale**
- Optimized control and operational strategies of **the combined LHTES+HP system** (i.e., the **PCM Heating Solution)** to cater to a **real heating application** in KTH Live-in-Lab (demo site)

EGI+ ABE

- Optimized **building (energy) system management** and control with the **PCM Heating solution**
- Optimal **techno-economic performance analysis** for heating application (with *peak shaving*, *load shifting* & *flexible sector coupling*) at **Nordic climate conditions**

2023 → 2025 → 2026

LHTES: Latent Heat Thermal Energy Storage (i.e., a TES using phase change materials (PCMs))
HP: heat pump, HEX: Heat Exchanger

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"PCM Heating" Solution @KTH…

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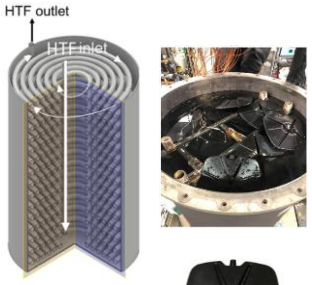
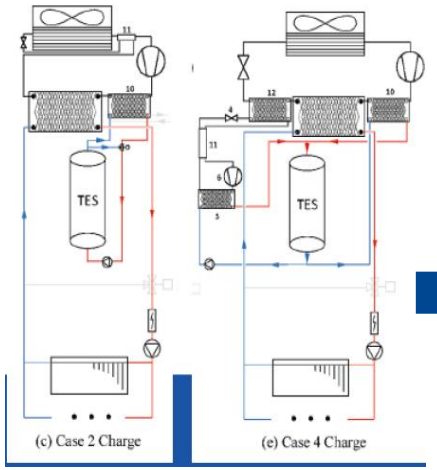


LHTES HEX

Improved design of LHTES+ HEX (submerged: HEX in PCM or encapsulated PCM in HTF

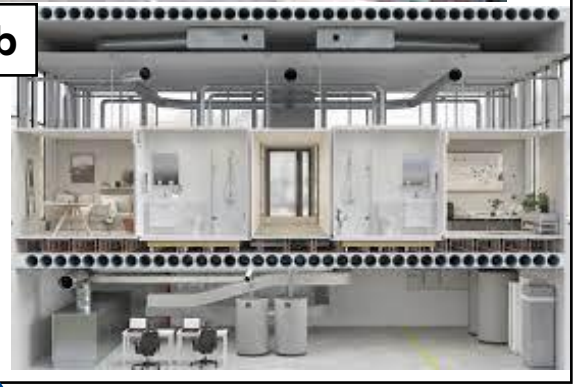
Pilot-scale LHTES to be further designed & optimized **for combined operation with a HP**



LEFT: The pilot-scale LHTES system at KTH that will be further developed and designed, and *RIGHT*: conceptual designs of this developed LHTES for combined operation with HPs (Air-source and Ground-source) → **PCM Heating Solution**

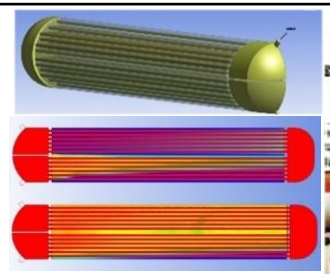
KTH Live-in-Lab

The demo site: where **PCM Heating Solution** will be run for optimized operation &contr



Bench-scale LHTES material testing)

LHTES with a shell-and-tube HEX for supercooling & hysteresis analysis



BMS, Internet of Things (IoT) & Techno-economic optimization

Work packages

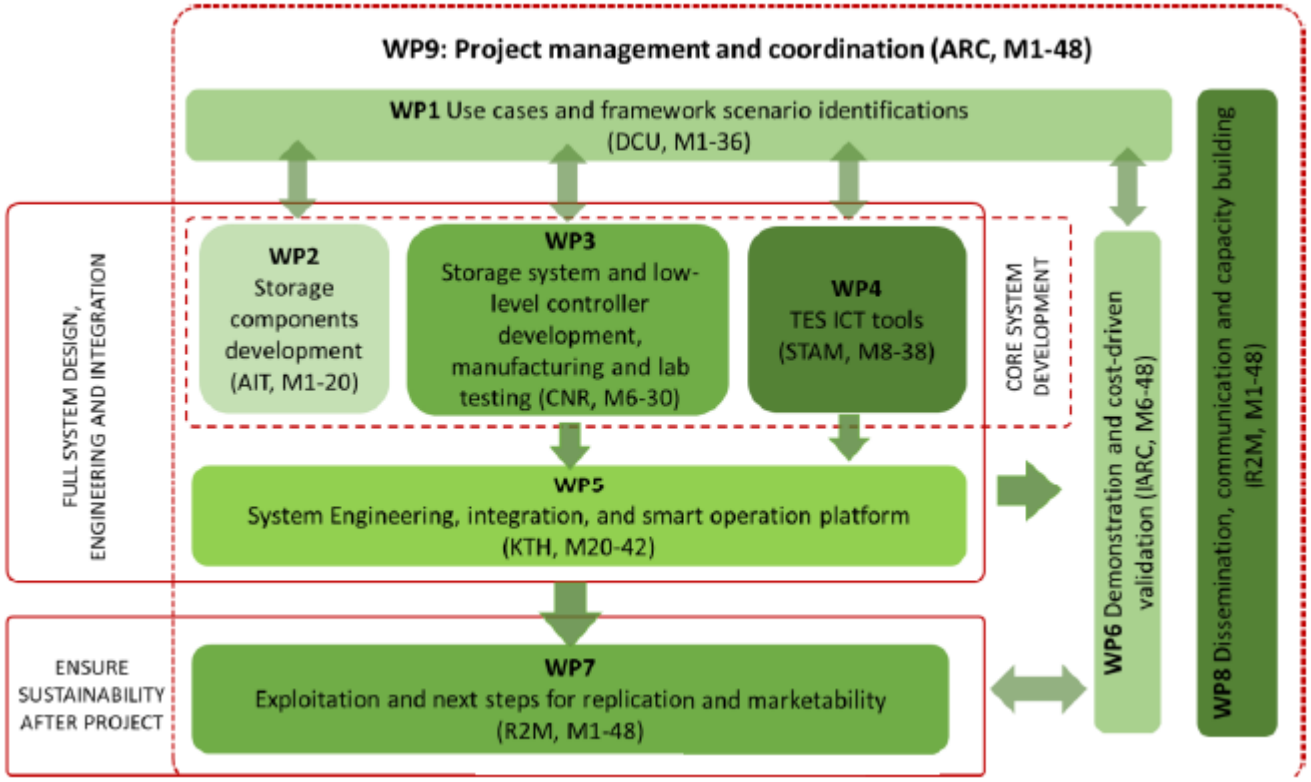
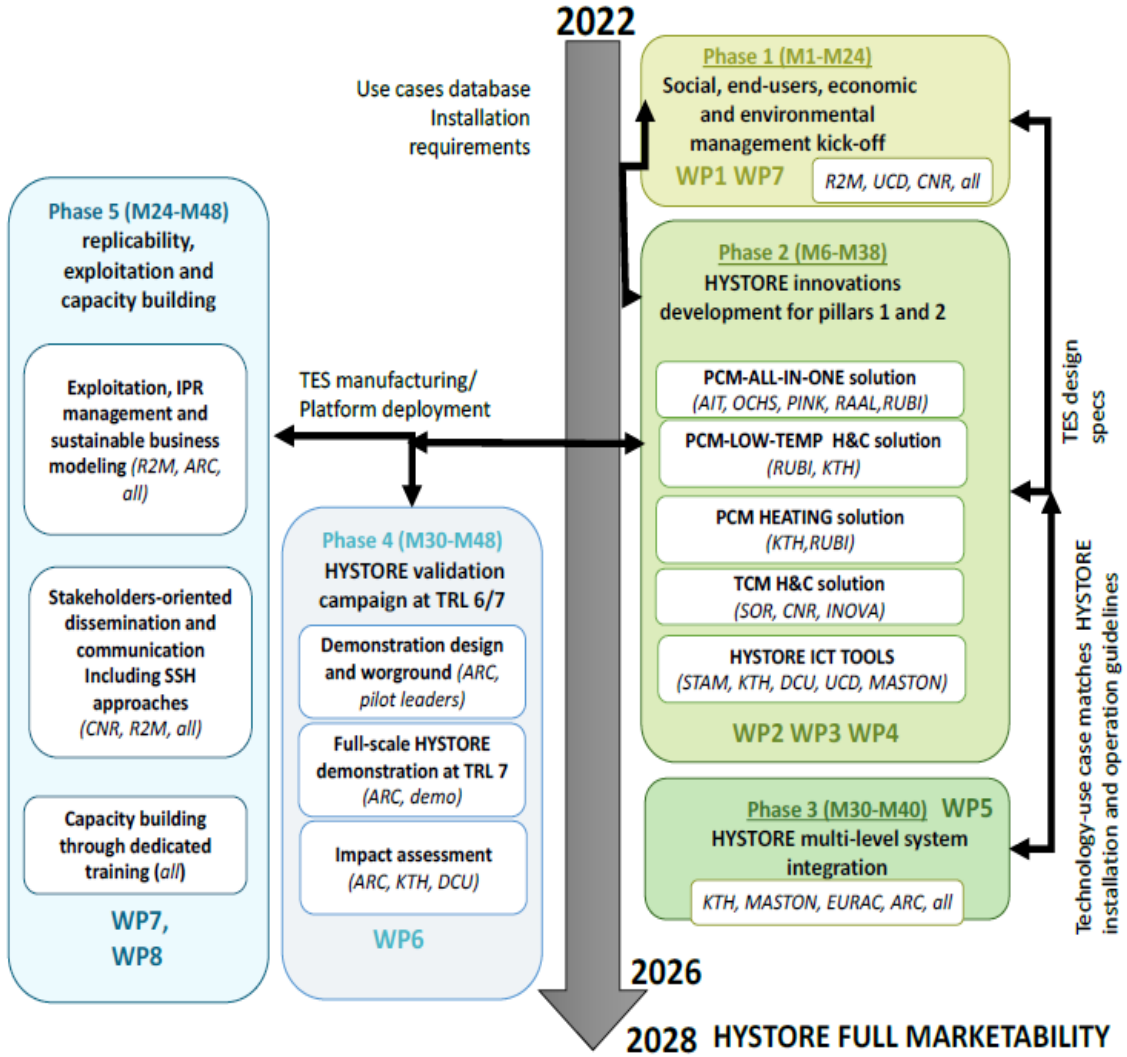


Figure 25: HYSTORE Pert Chart



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Project Deliverables @KTH

STO: Specific technical objectives

EGI & ABE collaborating with LiL, Rubitherm, AIT and CNR

STO1: to design, manufacture and characterize modular and plug-and-play thermal energy storage solutions for daily to monthly storage with different functions (heating, cooling, DHW). **Targeted WPs: WP2, WP3**

STO1.2 to develop a modular short-term storage for cost-effective and long-term reliable operation in heating-driven climates under combined operation with heat pumps in residential buildings

- 48.5 kWh/m^3 nominal storage capacity, up to +140% compared to sensible water storages currently employed in buildings
- 3 kWth charging/discharging power, use of PCM and storage configurations that allow high ΔT also at low State of Charge (SoC)
- Use of PCMs that show limited supercooling and hysteresis and guarantee functional robustness

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Project Deliverables @KTH…

STO: Specific technical objectives

ABE collaborating with EGI, LIL, Rubitherm, AIT and CNR

STO2: to develop and deploy optimised control strategies from TES controller level, aggregation and community-levels for efficient TES operation and energy services provision. **Targeted WPs: WP3, WP4**
STO 2.1: to provide interoperable algorithms for soft sensor-based online monitoring and SoC estimation and fault detection of all HYSTORE solutions.
• Robust data-driven regression models which can be exported to target control hardware and software on cloud platforms • Development and training using existing Dymola open-source libraries (e.g. SorpLib) and creation of a new PCMlib open-source library. Interoperable models thanks to FMU and API functionalities • First-time deployment of soft sensor-based algorithms for real-time feedback estimation and fault-dectection functionalities for storages
STO 2.2: to develop modular hardware aggregators with IoT and edge computation functionalities for different TES configurations
• Modular, low-cost hardware (edge) solutions with built-in advanced edge and AI capabilities and IoT interoperability • Whole-building energy system integration, monitoring, and control using hardware solutions • Hardware solutions support direct grid integration and intelligent demand response functionality • Built-in advanced security features to protect critical system operation • Federated learning framework for training and deploying AI and machine learning models locally (building-level) at the edge (hardware) solutions without sharing local data (preserve data privacy)
STO 2.3: Technical-economic analysis of TES-integrated energy systems using metaheuristic optimization
• Metaheuristic optimization methods that will give the best system combination for given installed capacities and system costs, and annual operational costs for at least 10 replication scenarios

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Project Deliverables @KTH…

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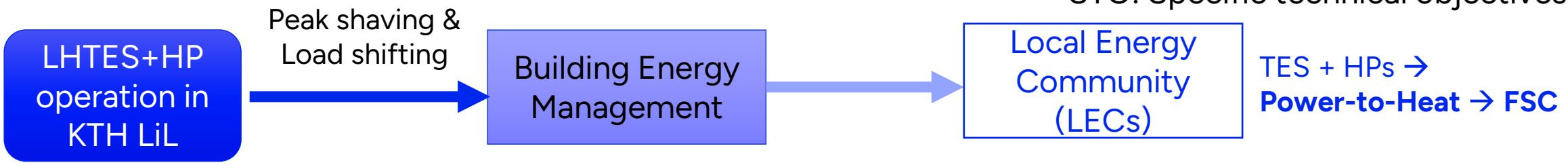
STO: Specific technical objectives



PCM Heating solution @KTH → at least 10% OPEX savings

ABE collaborating with EGI, LiL and all technical partners

STO4: to validate all technical solutions and ICT tools in 4 representative demonstrators able to simulate different building sizes and usages, in 4 different climates. **Target WPs: WP6**
STO4.1 successful testing and validation of the combined performance of HYSTORE technologies and the innovative ICT tools
• Achieve at least 20% OPEX saving thanks to operation of the storage as an asset to the grid • 20 % peak load reduction thanks to storage optimised operation in combination with heat pumps and the grid • At least 15% energy cost savings on the bills
STO4.2: Critical analysis of the selected technologies and tools with respect to ODS, user acceptance and sustainability principles both based economic (LCOS, LCOE) and environmental (LCA) approaches.
• minimum materials criticality and alternative evaluation and decision-making through a multi-criteria optimised life cycle perspective • Site-specific assessment of the services provided by HYSTORE solutions to user and grids through compilation of HYSTORE guidelines under different use cases

Discussion...

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