ThumbsUp

HYSTORE
Hybrid Services from Advanced Thermal Energy Storage Systems

Knowledge Exchange Forum on

TES Modeling & Integration

Tuesday December 02, 2025

Online

THUMBS UP
project GA101096921
funded by the European Union

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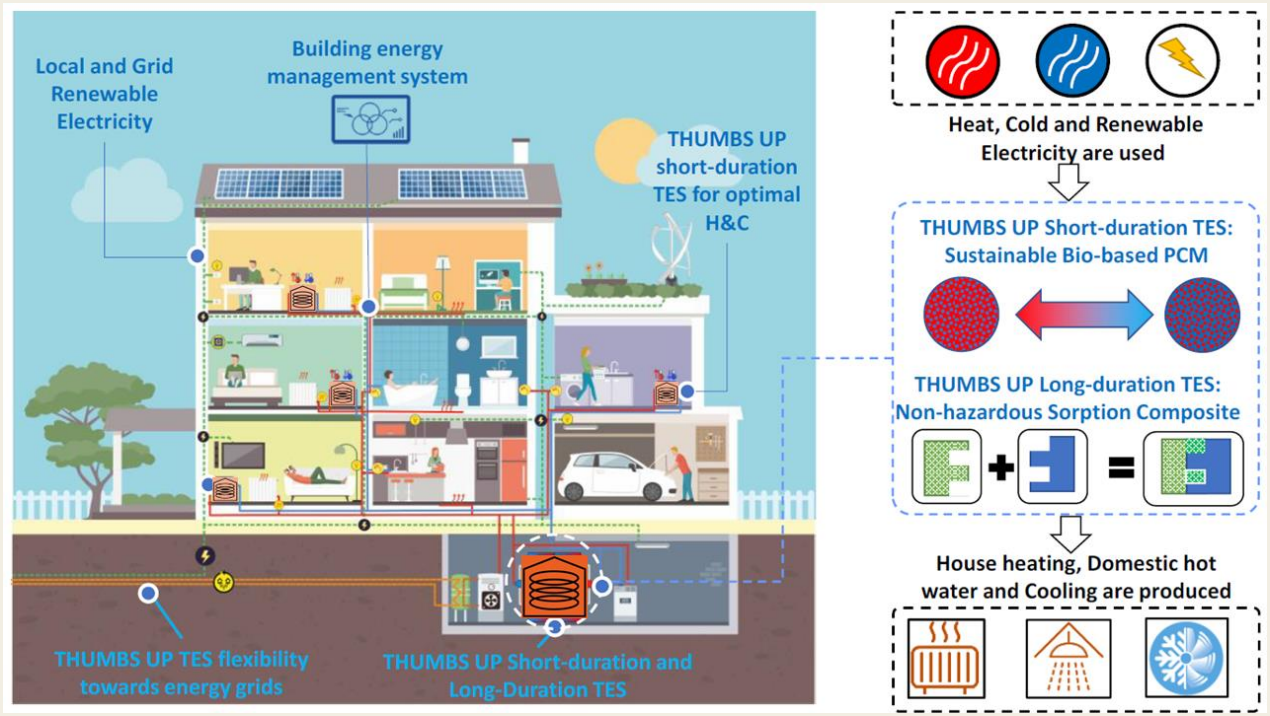
Unlocking the potential of your home!



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The sun does not always shine when we want it to…

Photo by Giorgio Trovato on Unsplash

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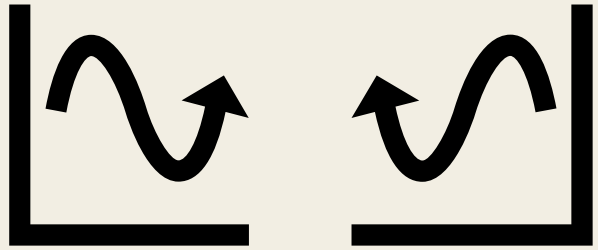
What can we do?



Production Demand

Let it be

Share

Store

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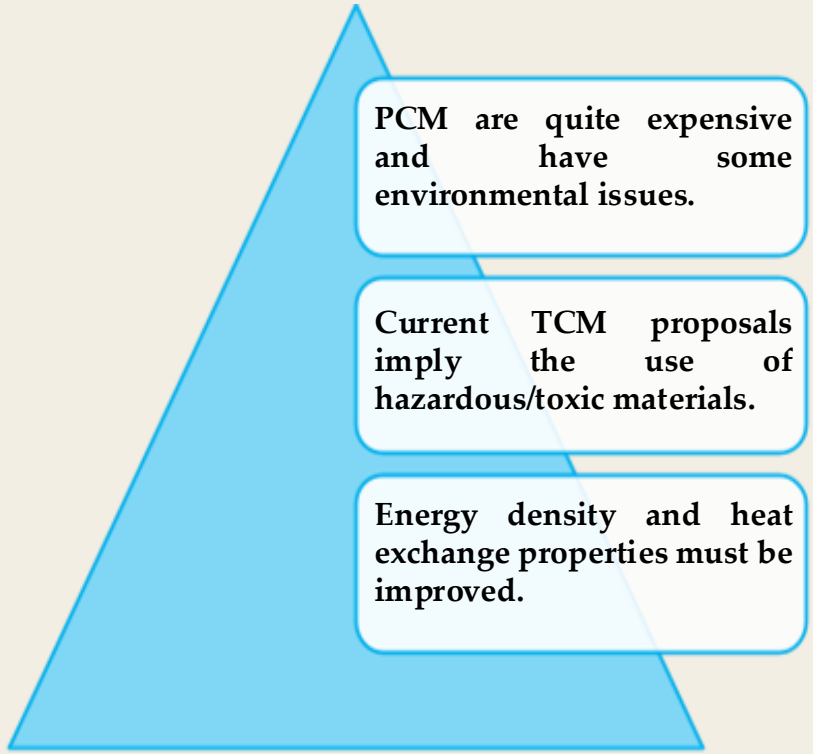
What is the challenge?



The available heating and cooling storage solutions are:

- **Expensive**
- **Inefficient**
- Use **hazardous materials**
- Have a large **environmental footprint**
- **Standalone** – not easily integrated to the existing infrastructure

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Thermal energy storage solUtions to optimally Manage BuildingS and Unlock their grid balancing and flexibility Potential

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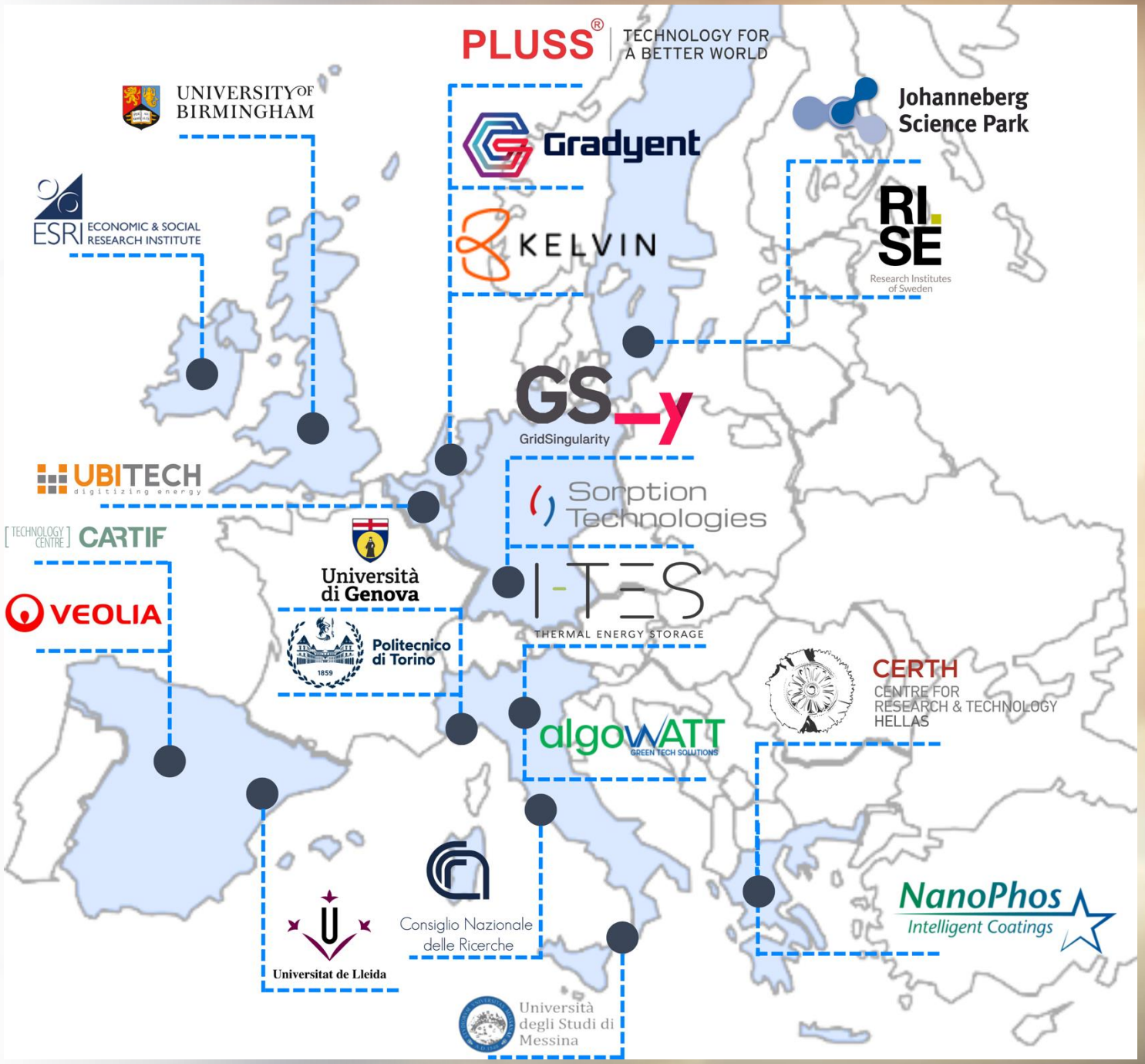
Working with the best

Consortium of 21 organisations

- ✓ R&D Centers
- ✓ SMEs
- ✓ Large companies

9 European countries

- ✓ Sweden
- ✓ United Kingdom
- ✓ Ireland
- ✓ Netherlands
- ✓ Spain
- ✓ Belgium
- ✓ Germany
- ✓ Italy
- ✓ Greece



Balancing the grid
one building at a time

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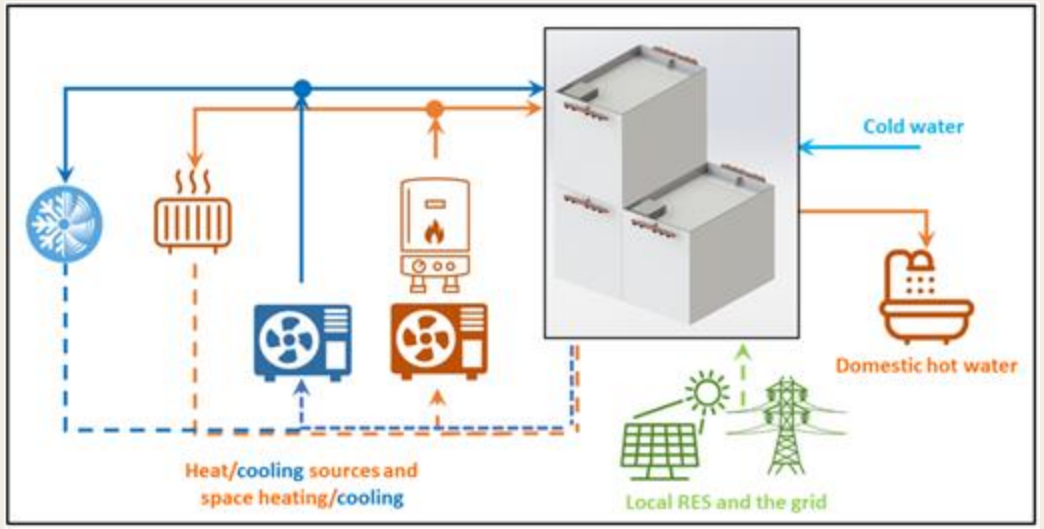
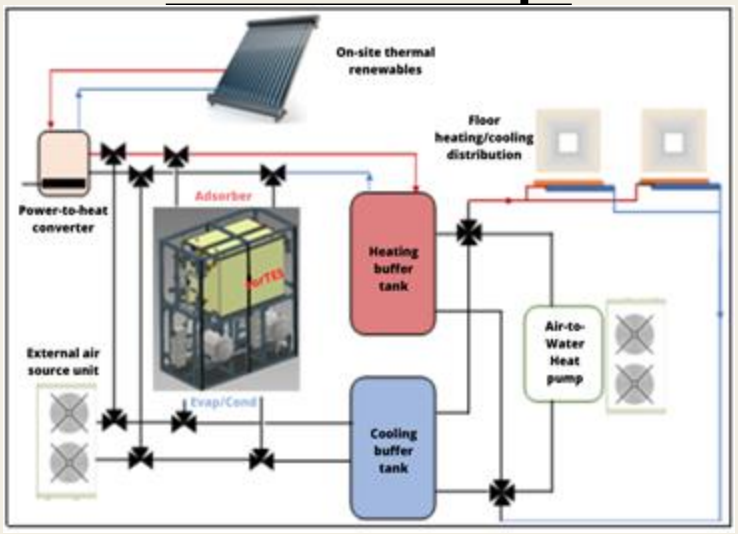
Developing groundbreaking technologies

FractLES concept



- Development and **optimisation of bio-based PCMs** (cost, energy density, stability, scalability).
- Use of **wastes from food industry** and **environmental friendly** fabrication process.
- Validated cycling stability **up to 12,000 cycles**.
- **Short duration latent TES** for intraday use with a high energy density storage.

SorTES concept



- **Optimisation of a composite sorbent** (cost, energy density, stability, scalability).
- Use of **environmentally friendly** and **low corrosive materials**
- Validated cycling stability **up to 10,000 cycles**.
- **Long duration TES** guaranteeing high energy density storage for **more than 4 weeks**.

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From lab to life with validation and pilot sites

Validation Site
CARTIF III, Spain

Student Housing
Gothenburg, Sweden

Single Family Building
Valladolid, Spain

Elderly Home
Valladolid, Spain

Different climate areas, building typologies and user behaviours

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Get engaged!!

Knowledge Exchange Forums

Bringing together engaged actors to share, inspire and discuss how to achieve the energy transition though the deployment of thermal energy storage.

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On the spotlight

Prof. Mohammad Saffari
Principal Investigator
Speaker

Juan Carlos del Castillo García
Technical Coordinator
Speaker

Andreas Fränne
Senior Consultant
Keynote Listener

Ola Gustafsson
Project Manager
Co-Moderator

Emilia Pisani
Project Manager
Co-Moderator

HY STORE
Hybrid Services from Advanced Thermal Energy Storage Systems

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HY STORE
Hybrid Services from Advanced
Thermal Energy Storage Systems

Modelling and Simulation Approaches for Integrated Energy Systems with Thermal Energy Storage

Prof. Mohammad Saffari , 2/12/2025
HYSTORE DCU Principal Investigator & WP Leader

Grant agreement ID: 101096789

DCU
Ollscoil Chathair
Bhaile Átha Cliath
Dublin City University

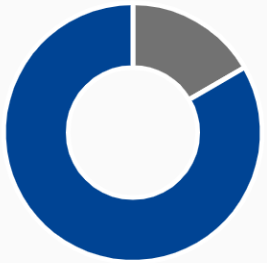
Nº	Name	Acronym	Country	Type
1-Coord.	ARC	ARC	ES	SME
2	Consiglio Nazionale delle Ricerche	CNR	IT	RTO
3	KTH Royal Institute of Technology	KTH	SE	UNI
4	Rubitherm GmbH	RUBI	DE	SME
5	Austrian Institute of Technology	AIT	AT	RTO
6	OCHSNER	OCHS	AT	SME
7	PINK GmbH	PINK	AT	SME
8	Sorption Technologies	SOR	DE	SME
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

Funded under

Climate, Energy and Mobility

Total cost

€ 8 769 951,13



EU contribution

€ 7 313 464,26

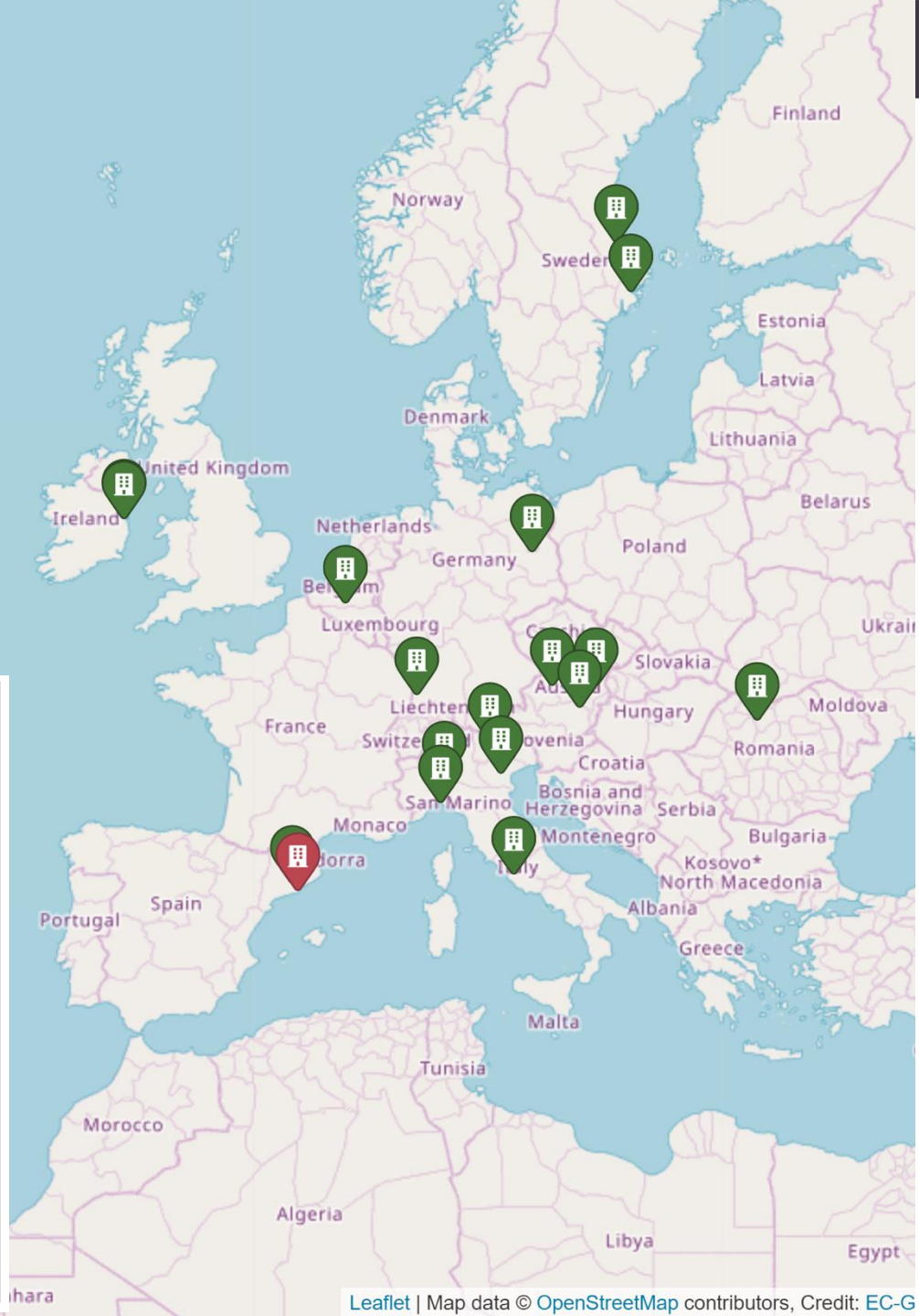
Coordinated by

ARMENGOL & ROS CONSULTORS I ASSOCIATS SLP

Spain 2

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.



Project Description

Duration:
January 2023 - December 2026 (48 months)

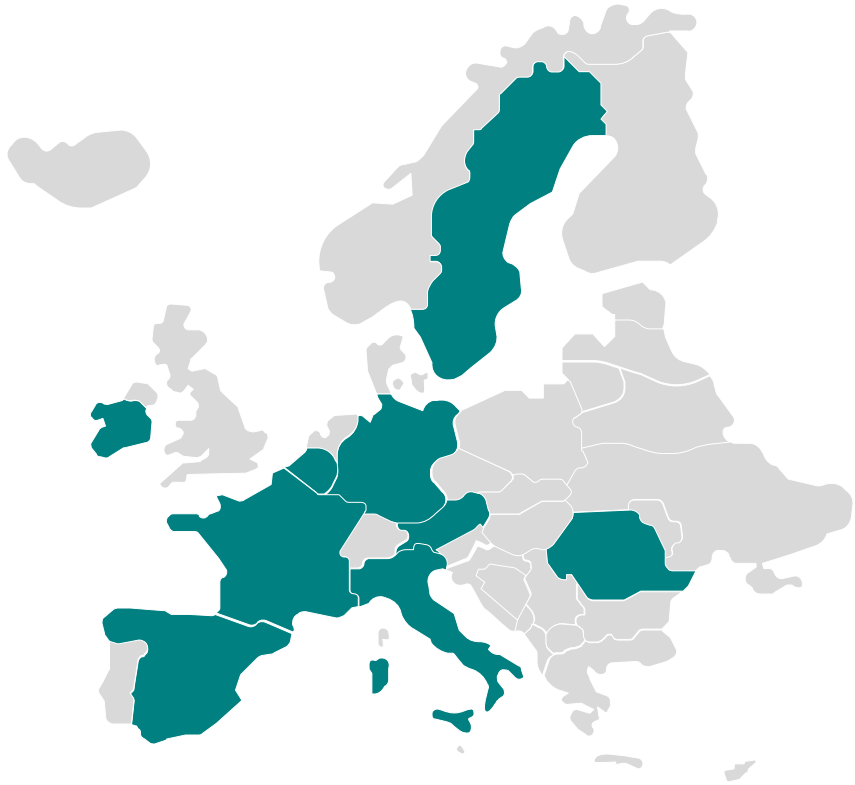
Call:
HORIZON-CL5-2022-D3-01

Partners:
18 partners from 8 countries

TRL:
4-7

Coordinator: ARCbcn.
David Verez (d.verez@arcbcn.cat)

Website:
https://www.hystore-project.eu/



Consortium

HYSTORE
Hybrid Services from Advanced Thermal Energy Storage Systems

ARC BCN ENGINYERS CONSULTORS

KTH VETENSKAP OCH KONST

RUBITHERM Phase Change Material

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

OCHSNER HEAT PUMPS

PINK

Sorption Technologies

inovaLab

STAM MASTERING EXCELLENCE

MASTON

DCU
Ollscoil Chathair Bhaile Átha Cliath
Dublin City University

eurac research

R2M RESEARCH TO MARKET SOLUTION

University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

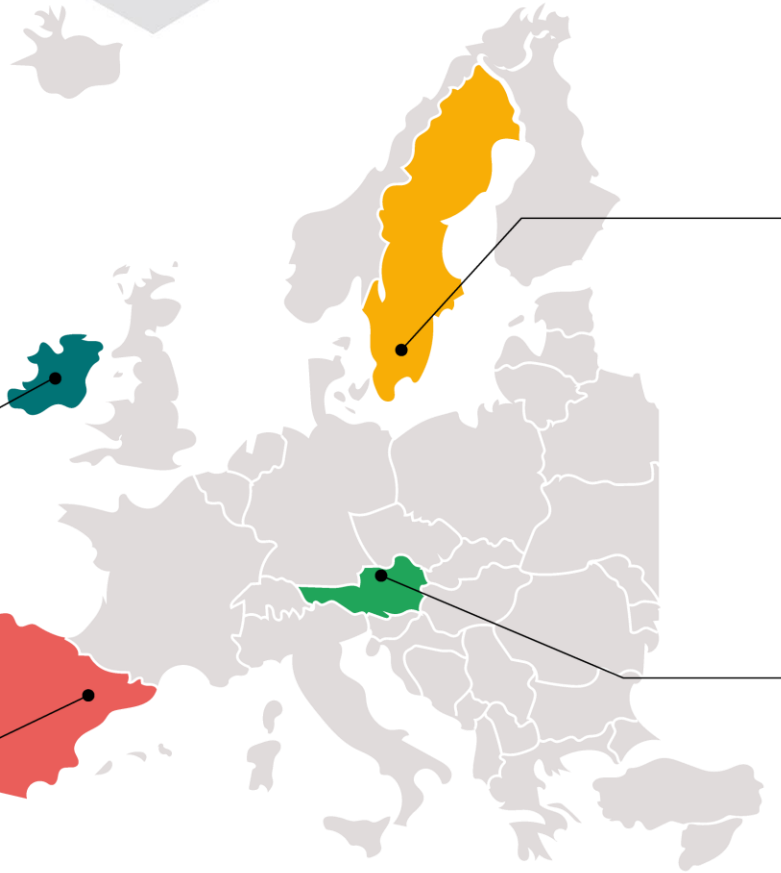
Montserrat

RAAL complete cooling solutions

EIM
European Innovation Marketplace

The HYSTORE demonstration sites

- 4 use cases.
- For each use case a representative business model will be selected.



Use Case 4: DUBLIN

What: TCM H&C + smart platform
Use case: heterogeneous complex (university campus) with high RES share
Building services: heating
Grid services: higher RES usage, peak shaving, balance management

Replication scope: overall campus (30,000 people) and other Northern countries multi-functional buildings

Use Case 3: MONTSERRAT

What: TCM H&C + + low T H&C PCM + smart platform
Use case: heterogeneous complex with high RES share
Building services: heating and cooling
Grid services: peak load shifting, frequency and voltage regulation

Replication scope: overall complex (10 buildings) and mid-scale DHC (2.5 MWth)

Use Case 2: STOCKHOLM

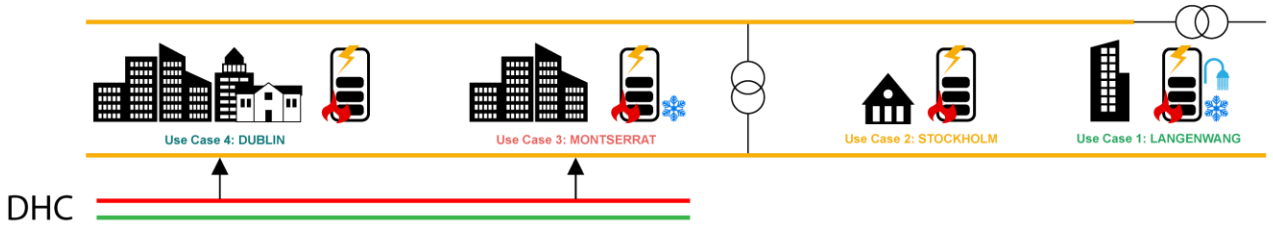
What: PCM HEATING + smart platform
Use case: residential building
Building services: heating
Grid services: peak shaving and shifting, demand-side management

Replication scope: overall campus and other close residential districts

Use Case 1: LANGENWANG

What: PCM-ALL-IN-ONE
Use case: multi-purpose building
Building services: heating,cooling, DHW
Grid services: peak shaving and shifting, demand-side management

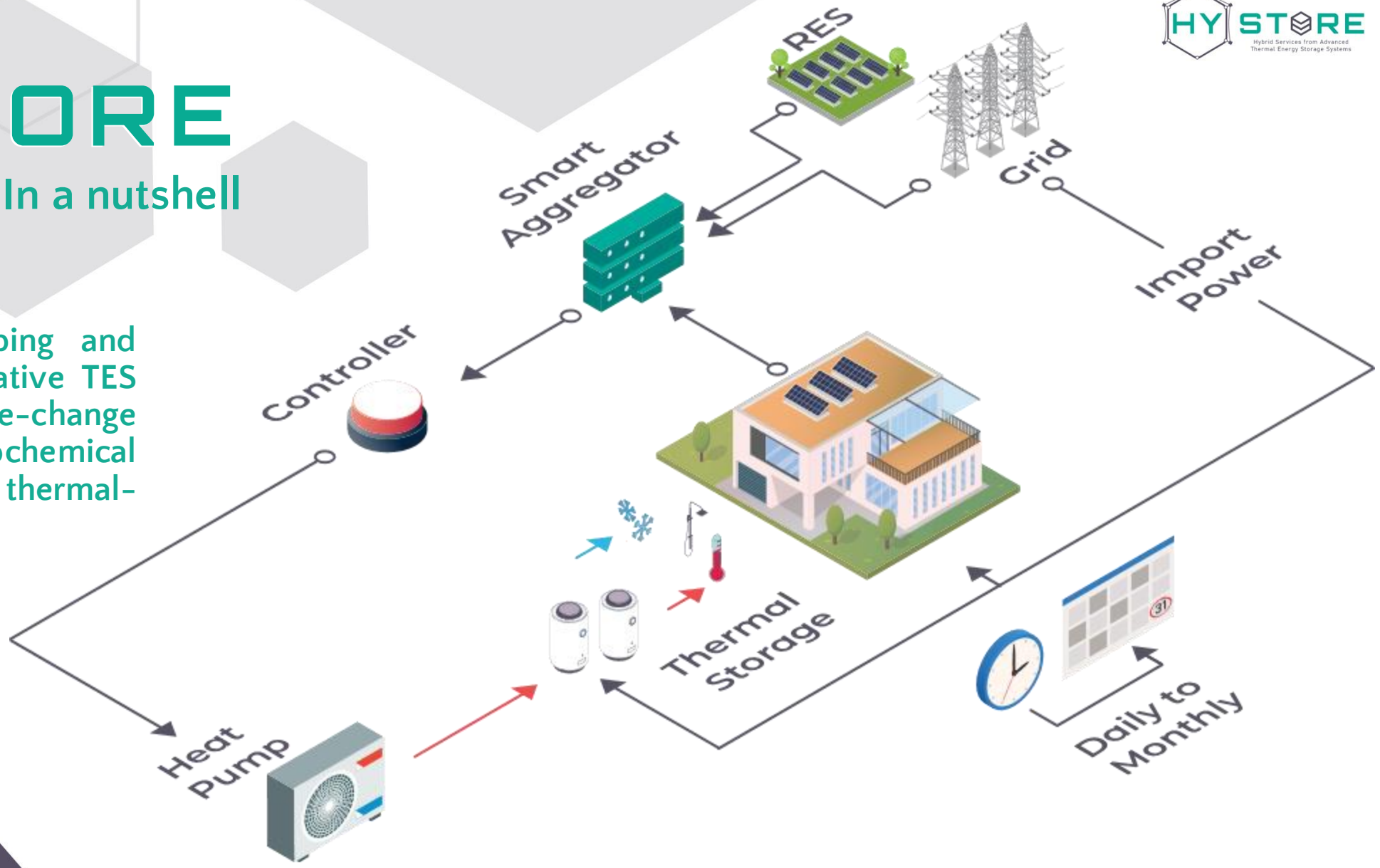
Replication scope: other close mixed residential/industrial districts



HYSTORE

In a nutshell

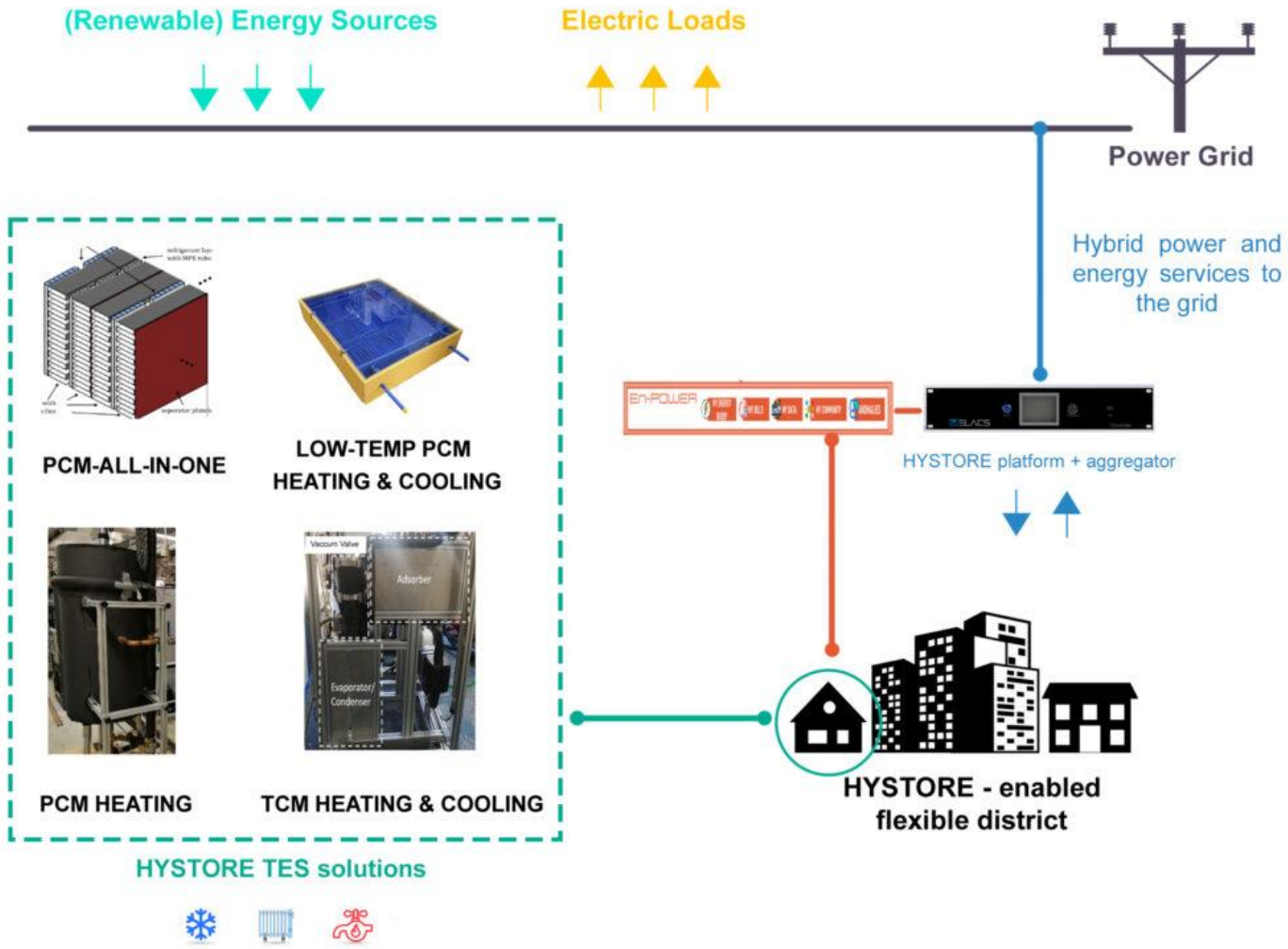
HYSTORE is developing and validating four innovative TES concepts using phase-change materials and thermochemical storage within hybrid thermal-electric networks.



HYSTORE

In a nutshell

- What modelling approaches have been used in the HYSTORE project?
- How are HYSTORE solutions modelled, simulated, and optimised?



HYSTORE Modelling Approaches

White-box

1

Modelica Language

EnergyPlus

TRNSYS 18

Dymola Ansys

Built from first-principles physics, fully representing the system using its physical laws and properties.

Black-box

2

Modelica Language

Dymola

Use data-driven methods, historical records, simulations, statistical analysis, and AI to describe the system without modelling its internal physics.

Grey-box

3

Dymola

Modelica Language

EnergyPlus

Blend physics-based equations with data-driven parameter estimation, providing a balance between interpretability and adaptability.

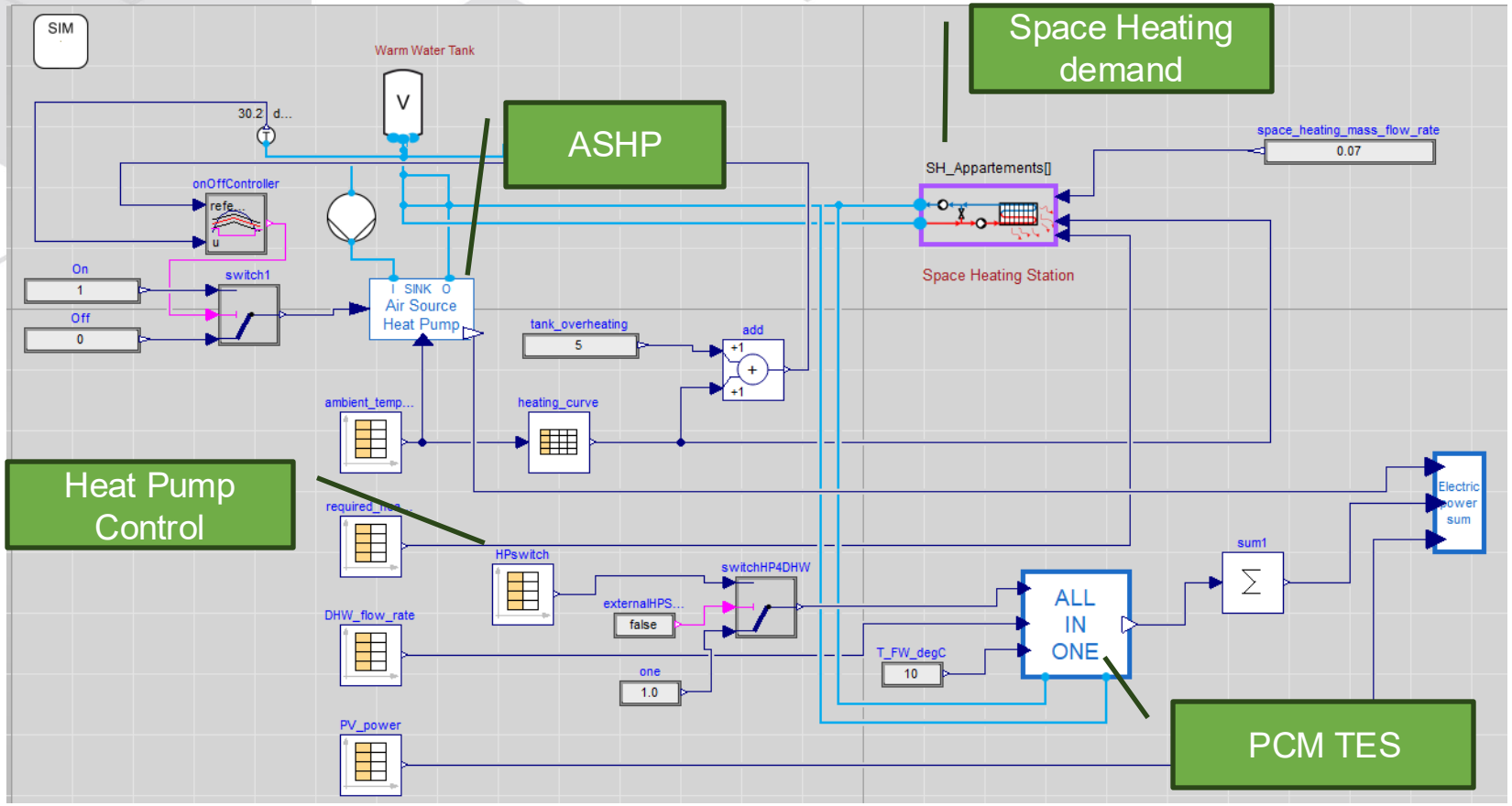
Saffari 2025

HYSTORE Simulation Approaches

Modelling, Simulation & Optimisation Categories

- Physics-based modelling (Modelica, Dymola, Ansys)
- Data-driven & ML & Optimisation (Python, SciPy)
- Optimisation (PyMOO, PySwarms)
- Co-simulation & FMUs (FMI/FMU)
- Edge/Federated learning (Flower)
- Knowledge-modelling and semantic-modelling approach

HYSTORE White-box simulation model in Dymola

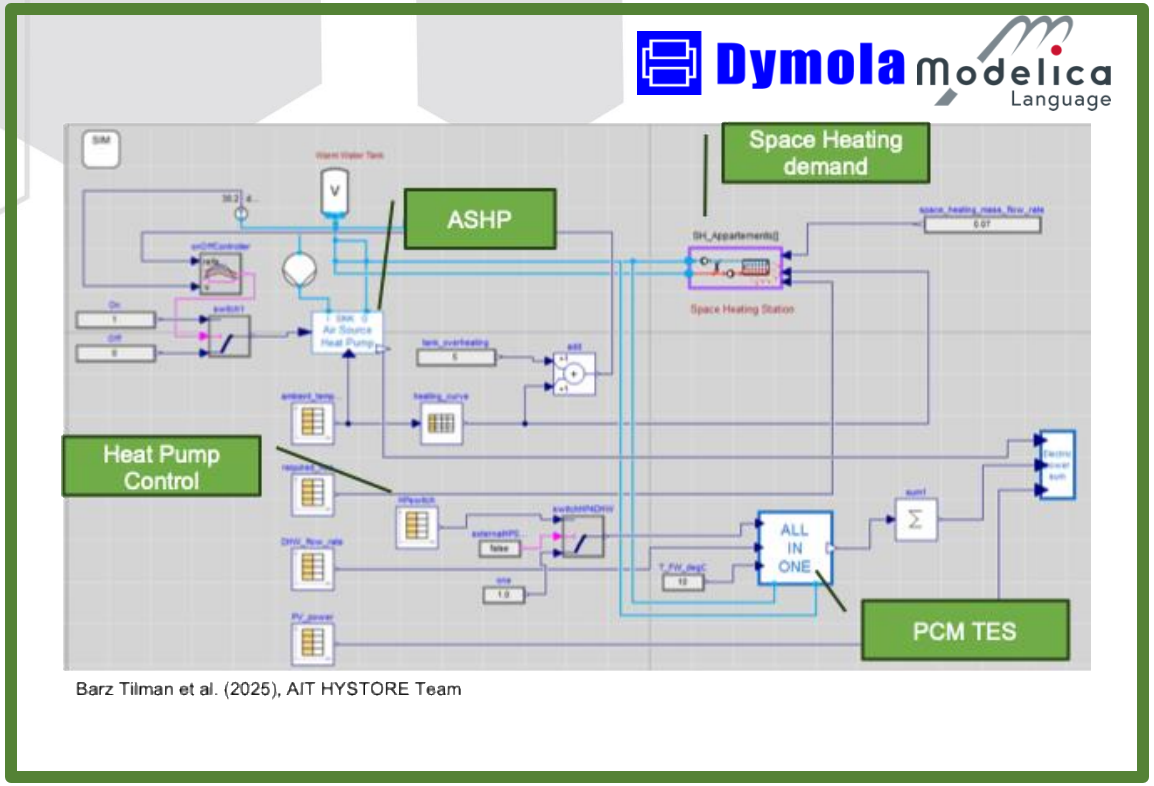


Barz Tilman et al. (2025), AIT HYSTORE Team

FMU (Functional Mock-up Unit)

Export as .FMU

Input(s)



Barz Tilman et al. (2025), AIT HYSTORE Team

Output(s)

An **FMU (Functional Mock-up Unit)** is a file container for a simulation model that uses the open standard called the **Functional Mock-up Interface (FMI).** It allows for the exchange and integration of dynamic models between different simulation tools, so a model created in one tool can be used in another without needing the original modelling tool to be present.

HYSTORE co-simulation and model-exchange framework

Modelica Language

Modelling & Simulation

Modelica
OpenModelica
Dymola, &
(ANY software with FMU function)

Dymola

Export as (Functional Mock-up) FMU

Functional Mockup Interface (FMI)

Functional Mock-Up Interface

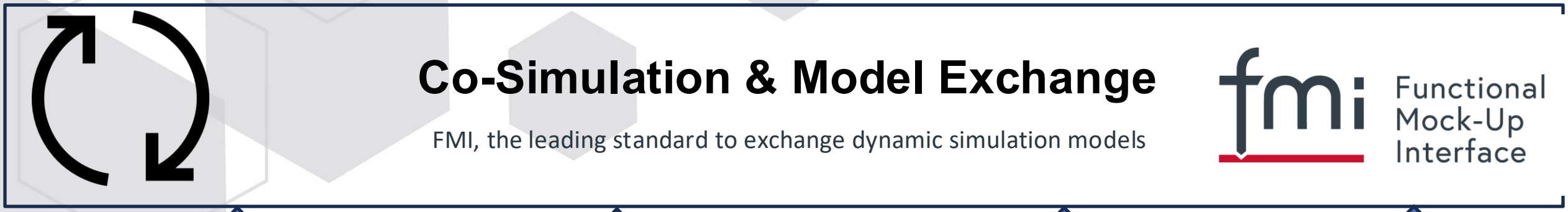
python™

Optimisation

Python
e. g. SciPy,
Pymoo

pymoo
Multi-objective Optimization in Python

HYSTORE fmi to develop advanced grey-box models!



Dymola

Modelica Language

FMU

python™

FMU

MATLAB®

FMU

EnergyPlus

FMU

THANKS FOR YOUR ATTENTION

E-mail: mohammad.saffari@dcu.ie

HYSTORE – Grant Agreement n. 101096789

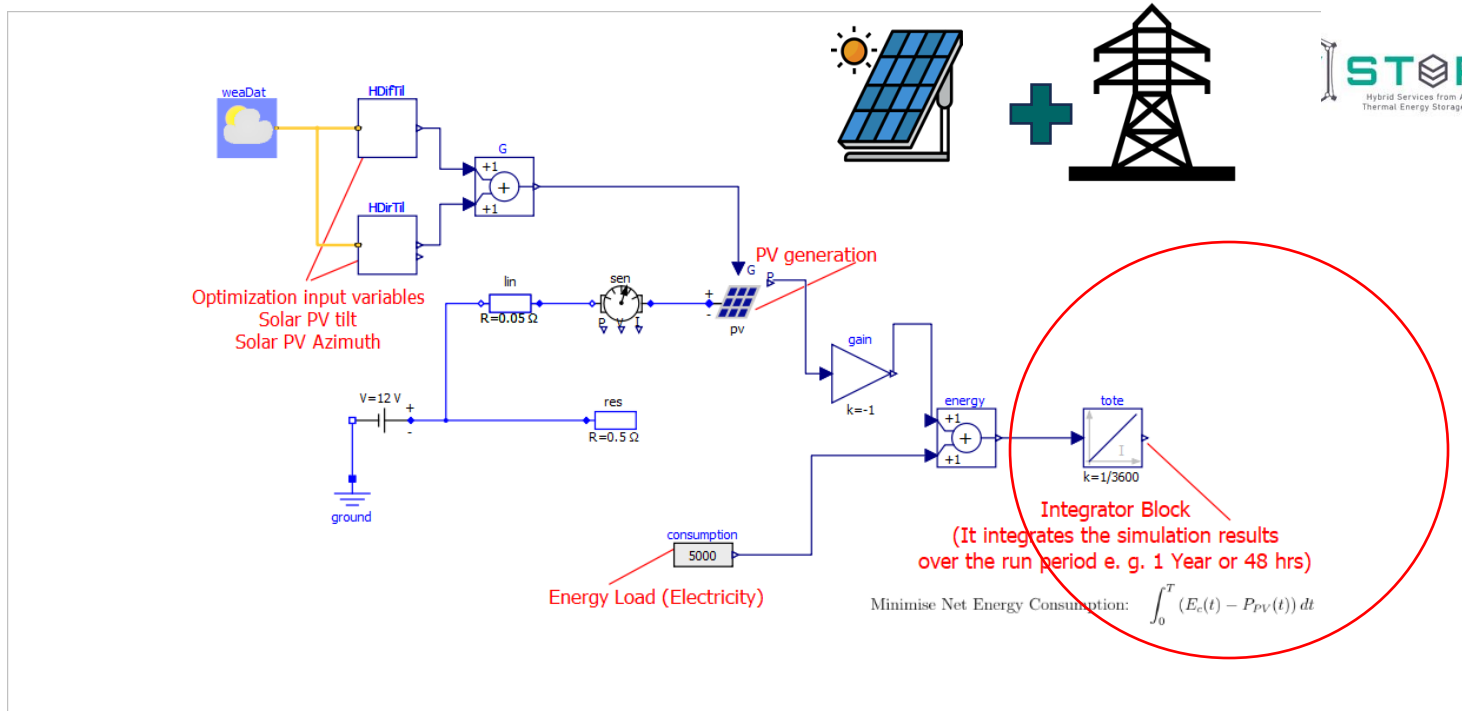
Funded by the European Union

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them"

Modelica Model Example

Modelling & Simulation

Modelica (OpenModelica Dymola)




```
model PVSimple "Example for the PVSimple model with constant load"
  extends Modelica.Icons.Example;
  //parameter Real tilt1 = 0.34906585039887 "Tilt angle (rad)";
  //parameter Real azi1 = -0.78539816339745 "Azimuth angle (rad)";
  parameter Real tilt1 = 0.34906585039887 "Tilt angle (rad)" annotation( ...);
  parameter Real azi1 = -0.78539816339745 "Azimuth angle (rad)" annotation( ...);

  Buildings.Electrical.DC.Sources.PVSimple pv(A = 10, V_nominal = 12) "PV module" annotation( ...);
  Modelica.Electrical.Analog.Basic.Ground ground annotation( ...);
  Buildings.Electrical.DC.Loads.Resistor res(R = 0.5, V_nominal = 12) "Resistance" annotation( ...);
  Buildings.Electrical.DC.Sources.ConstantVoltage sou(V = 12) "Voltage source" annotation( ...);
  Buildings.BoundaryConditions.SolarIrradiation.DiffusePerez HDifTil(til= tilt1, azi= azi1) "Diffuse irradiation on
tilted surface" annotation( ...);
  Buildings.BoundaryConditions.SolarIrradiation.DirectTiltedSurface HDirTil(til = tilt1, azi = azi1) "Direct
irradiation on tilted surface" annotation( ...);
  Buildings.BoundaryConditions.WeatherData.ReaderTMY3 weaDat(computeWetBulbTemperature = true, filNam =
Modelica.Utilities.Files.loadResource("modelica://Buildings/Resources/weatherdata/USA_CA_San.Francisco.Intl.AP.
724940_TMY3.mos")) annotation( ...);
  Modelica.Blocks.Math.Add G "Total irradiation on tilted surface" annotation( ...);
  Buildings.Electrical.DC.Lines.TwoPortResistance lin(R = 0.05) "Transmission line" annotation( ...);
  Buildings.Electrical.DC.Sensors.GeneralizedSensor sen "Sensor" annotation( ...);
  Modelica.Blocks.Sources.RealExpression consumption(y = 5000)  annotation( ...);
  Modelica.Blocks.Math.Add energy annotation( ...);
  Modelica.Blocks.Math.Gain gain(k = -1)  annotation( ...);
  Modelica.Blocks.Continuous.Integrator tote(k = 1/3600, initType = Modelica.Blocks.Types.Init.InitialState)
annotation( ...);
equation
```

Modelica Model Example cont'd

Modelica Language

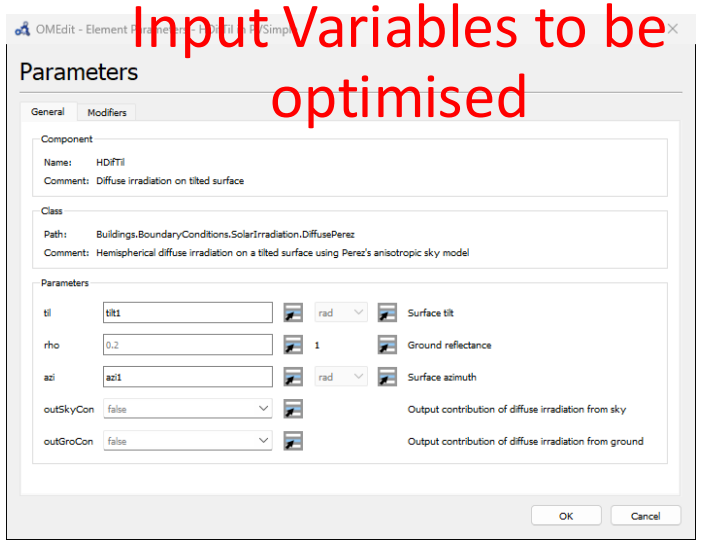
Modelling & Simulation

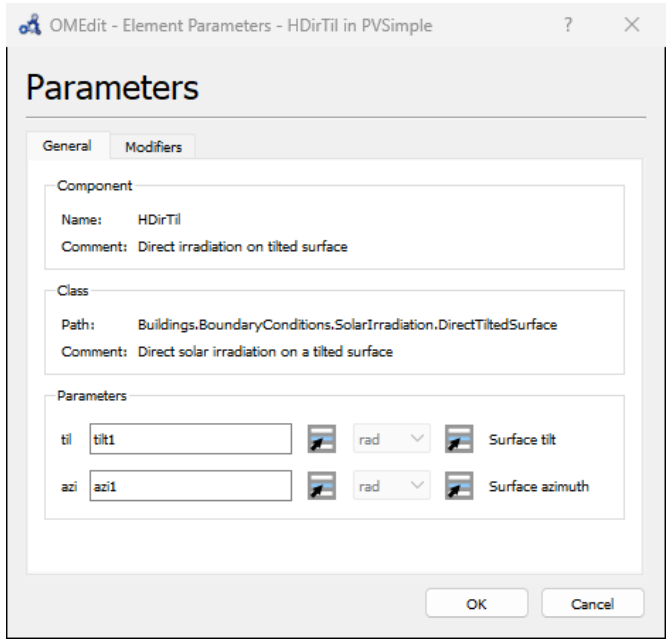
Modelica

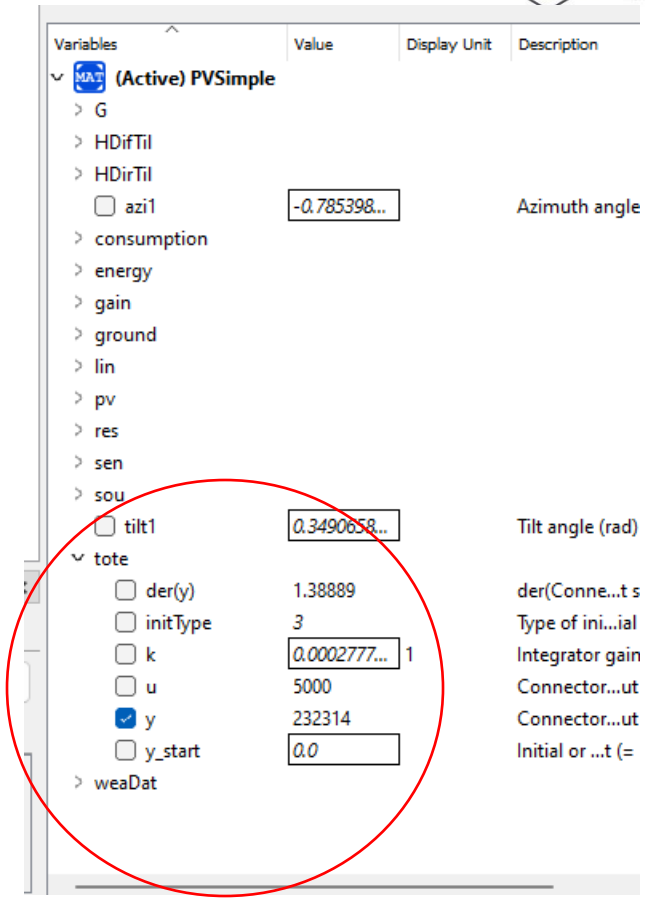
OpenModelica

Dymola

Input Variables to be optimised







Output (Objective Function to be minimised and optimised)

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Model to BEMS integration

Juan Carlos del Castillo García, CAR

Tuesday, 2nd December 2025

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project GA101096921
funded by the European Union

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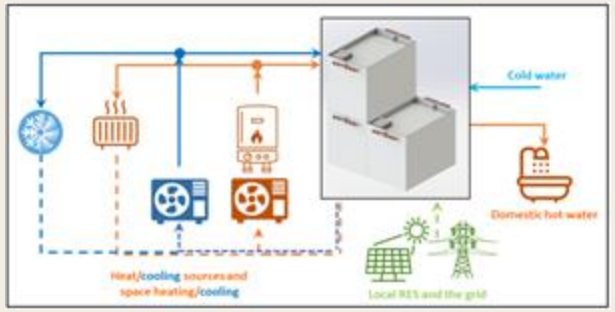
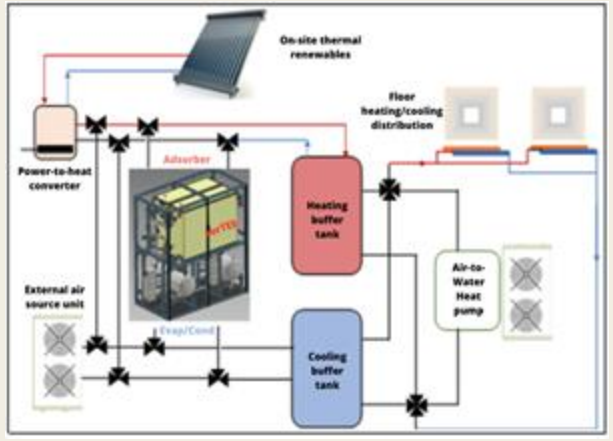
PHASE I

FractLES/SorTES development for intraday/up to 4 weeks use





PHASE II

Validation/Demonstration campaigns to reach a TRL6/TRL7

Applications to H&C and DHW at different levels and with the most suitable module combination

PHASE III

Replication campaign to study further impact of the solutions in 5 replication sites

Dedicated studies of the **impact at DHN and electric grid level**

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Model integration and simulation of the building towards overall controller development

Model integration and simulation of the building towards overall controller development

How to manage energy usage?

Primary Charging

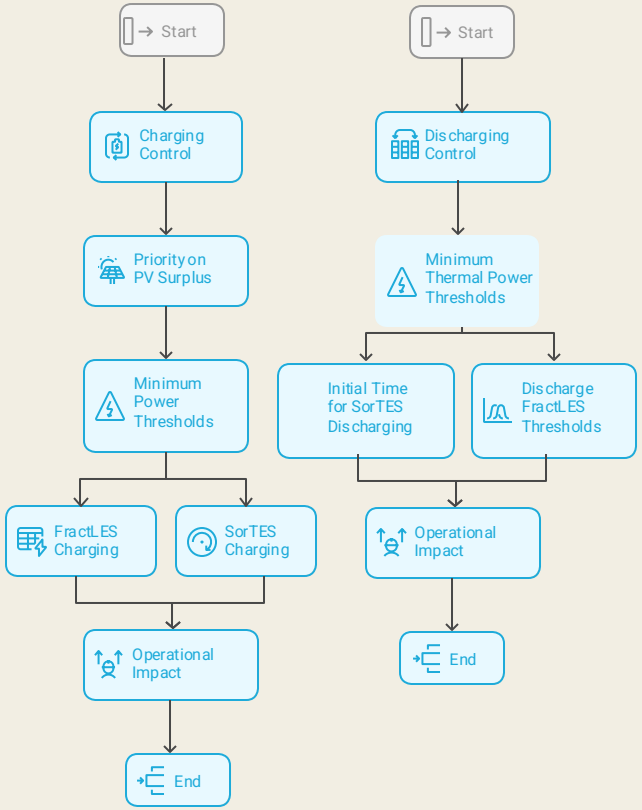
Utilize excess solar PV energy for charging

Alternative Charging

Charge during off-peak hours when PV is insufficient

Discharging

Use stored energy when thermal demand is high



ThumbsUp

Model integration and simulation of the building towards overall controller development

CARTIF III: Heating & Cooling Control rules

Mode	FractLES	SorTES
Heating – Charging	• Min PV Surplus Power: 1.18 kW (Centralized) 3.36 kW (Distributed) • Charging window: 01:00–05:00	• Charging window: 00:00–02:00
Heating – Discharging	• Thresholds: 46 kWt (Centralized HP) 21 kWt (Distributed AHU)	• Initial discharging time: 09:00
Cooling – Charging	• Charge with PV surplus	• Charge only with PV surplus (daytime, PV > demand)
Cooling – Discharging	• 16:00–18:00 → relieve HP in afternoon peak	• 14:00–16:00 → cover early cooling peak
Impact	• Very low flow vs HP flow • HP inlet temp rise ≤ 1 °C (Heating)	• Similar to FractLES: very low flow impact

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Model integration and simulation of the building towards overall controller development

CARTIF III: Heating Simulations

Use case (heating)
Case 1 – FractLES only with PV
Case 2 – FractLES + SorTES (2 h night + PV)
Case 3 – FractLES + SorTES (4 h night + PV)

Month	Scenario	PV Surplus Reduction (kWh)	Grid Consumption Reduction (kWh)	Building Consumption Reduction (kWh)
JAN	Case 1 (SorTES)	−129.8 (50,9%)	−40.5 (0,38%)	−170.3 (1,3%)
	Case 2 (FractLES centralized)	−129.7 (50,8%)	−150.6 (1,41%)	−168.9 (1,29%)
	Case 3 (FractLES distributed)	−81.1 (31,8%)	−434.6 (4,07%)	−396.0 (3,03%)
FEB	Case 1 (SorTES)	−82.4 (33,3%)	−22.0 (0,19%)	−104.4(0,74%)
	Case 2 (FractLES centralized)	−82.9 (33,5%)	−129.3 (1,14%)	−105.0 (0,75%)
	Case 3 (FractLES distributed)	−41.8 (16,9%)	−435.7 (3,83%)	−370.3 (2,64%)
MAR	Case 1 (SorTES)	−114.9 (17,5%)	−27.4 (0,26%)	−142.3 (0,98%)
	Case 2 (FractLES centralized)	−117.9 (17,9%)	−136.0 (1,31%)	−144.3 (0,99%)
	Case 3 (FractLES distributed)	−52.9 (8%)	−410.6 (3,95%)	−354.9 (2,45%)

Cycles (Jan–Mar):
Centralized FractLES: Case1/2 → 3/3/4; Case3 → 9–10/month.
Distributed FractLES: Case1/2 → 7/3/4; Case3 → 16–20/month.
SorTES: always 4/month.

(Positive "Reduction" = improvement; negative = increase vs. baseline)

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CARTIF III: Cooling Simulations

Use case (cooling)
Case 1A – SorTES night charging, discharge 14–16
Case 1B – SorTES only with PV, discharge 14–16
Case 2A (9 kWh) – FractLES PV, discharge 16–18
Case 2A (14 kWh) – FractLES PV, discharge 16–18
Case 2B (9 kWh) – FractLES PV, discharge 14–18
Case 2B (14 kWh) – FractLES PV, discharge 14–18

Scenario	PV Surplus	Grid Consumption	Building Consumption
CASE 1B – JUL (SorTES)	1100.68 (−6.7%)	10093.95 +0.8%	16031.56 (+1.0%)
CASE 2A_9kWh – AUG (FractLES)	41.6 (−0.6%)	5.1 −0.05% grid reduction	36.6 (+0.23%)
CASE 2A_14kWh – AUG (FractLES)	56.2 (−0.8%)	5.6 −0.06% grid reduction	50.6 (+0.32%)

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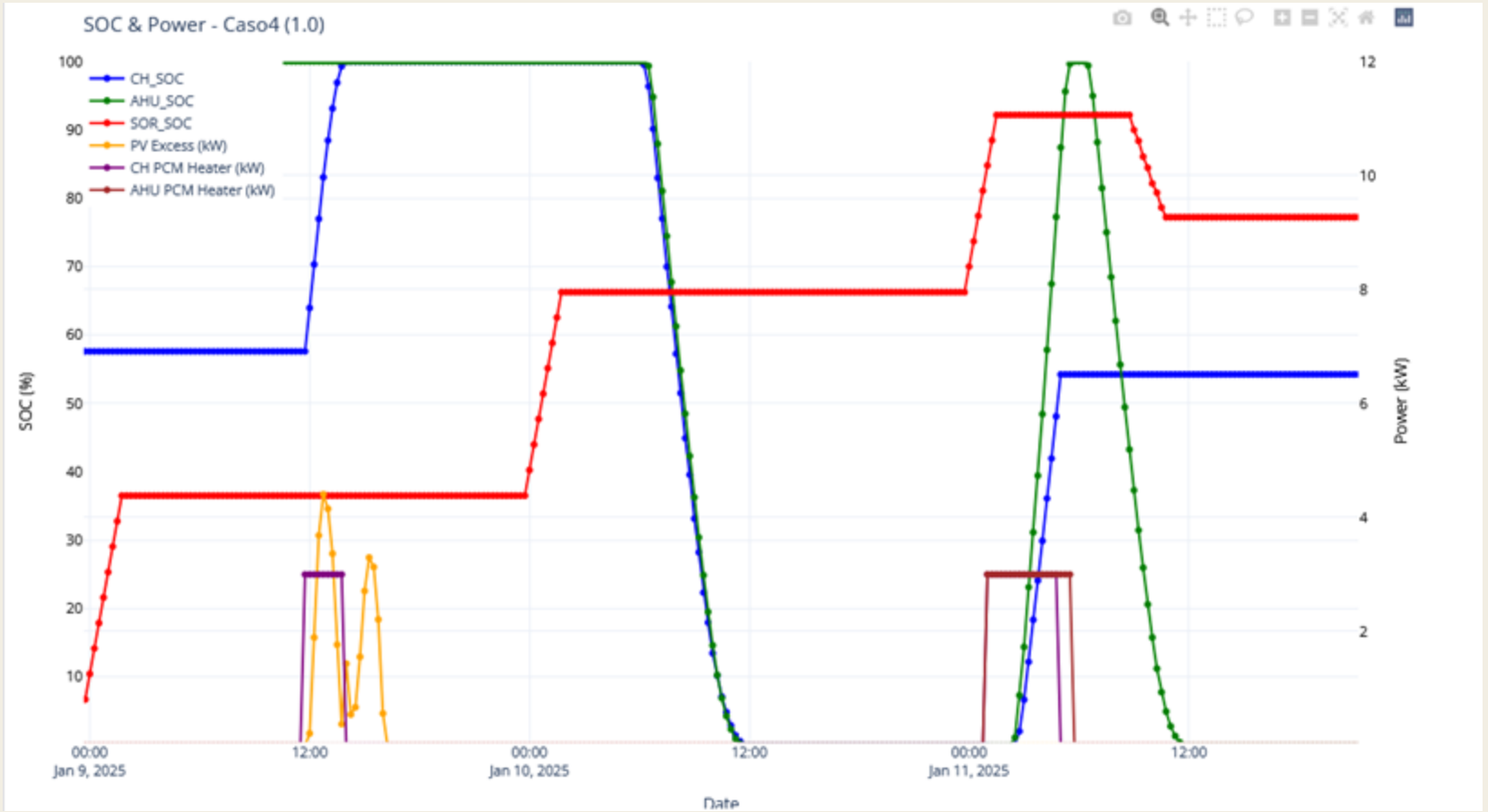
CARTIF III: Charging & Discharging cycles



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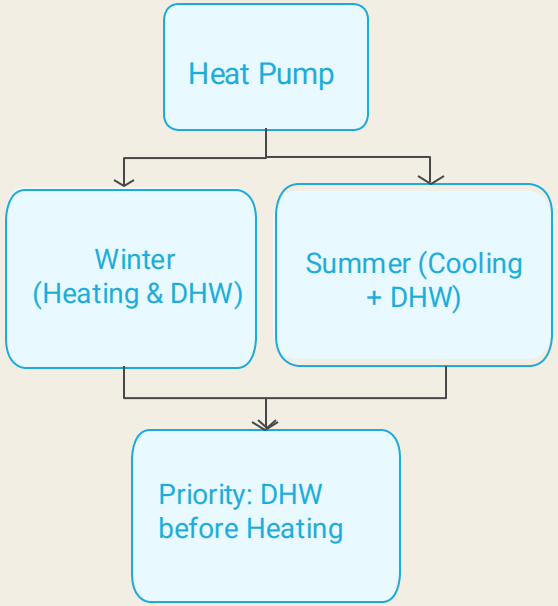
Veolia SFH: Heating & DHW Control rules & simulations

Component	Charging rules	Discharging rules
FractLES (DHW, 9 kWh)	Allowed 11:00–20:00 if PV surplus > 0 (PV − load > 0) Minimum 15 min once started	Only when DHW demand is present
SorTES (Heating/Cooling support)	Case 2: night charging (00:00–06:00) Case 3: PV-only charging	From 06:00 for 2–4 h



Use case	PV surplus ↓	Building consumption ↓
Case 1 – DHW FractLES only (PV charging)	209.0 (annual)	−81.2 (annual)
Case 2 – FractLES (PV)+ SorTES (night charging)	209.0	−1,241.6
Case 3 – FractLES + SorTES (PV-only charging)	903.1	−624.7

Cycles:
DHW FractLES: ~2 charge–discharge per month
SorTES: 3–4 cycles/month.

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Model integration and simulation of the building towards overall controller development

Veolia MFH: Heating & DHW Control rules

Configuration	Charging rules	Discharging rules
Centralized FractLES	• Forced charging if flow > 5,400 l/h • PV-surplus mode (May–Jun) when HP ON • Night backup 00:00–06:00	• Support HP if HVAC demand ≥ 213.6 kW
Distributed FractLES	• Allowed only when no water flow in radiant floor	• ON when radiant floor demand ≥ 50 kW
FractLES for DHW	• Night schedule 00:00–06:00 (if not forced)	• Min. 30 min/cycle to avoid short cycling • Summer (Jul–Sep): discharge with any DHW demand

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Veolia MFH: Heating & DHW simulations

Centralized

HP Elec. Use [kWh]	HP Saving %	Boiler Saving %
~19,800 (vs ~19,900)	−14 %	+2.1 %

Distributed

HP Elec. Use [kWh]	HP Saving %	Boiler Saving %
~12,300 (vs ~13,160)	+6 %	0 %

DHW

HP Saving %	Boiler Saving %
+0.3–0.5 %	negligible

Centralized:
Net effect: less boiler use, small extra HP electricity → aligns with goal of lowering fossil dependency.

Distributed:
HP electricity: instead of rising like in centralized, distributed PCM shows slight reductions (≈ −40 to −60 kWh/month).
Effect:

- Works mainly as peak shaving for the radiant floor demand.
- Benefits are modest in terms of energy balance, but strong in operational flexibility (many short cycles).

DHW:

- Boiler demand is unchanged (DHW PCM only supports the HP).
- Biggest benefit: improved HP efficiency & PV self-consumption in summer.
- In winter, benefit is negligible — main impact is clearly in summer months.

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Model integration and simulation of the building towards overall controller development

HSB Living Lab: Control Rules

Aspect	DHW FractLES (centralized)	Distributed FractLES (RF2, RF4)
Priorities	- Reduce DHN energy - Flatten electric load	- Reduce DHN energy - Flatten electric load
Charging	• 04:00–06:00 (cascaded start) • Activate if Tin ≥ T_PCM+2 °C and ≥ 2 h cycle	• RF2: 06:00–08:00 • RF4: 08:00–10:00 • Activate if Tin ≥ T_PCM+2 °C and ≥ 2 h cycle
Discharging	• 17:00–20:00 if DHW demand ON • Min. 2 h per discharge	• RF2: 15:00–18:00 if floor demand ON • RF4: 10:00–13:00 if floor demand ON • Min. 2 h per discharge

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HSB Living Lab: Simulations

Distributed FractLES

KPI (monthly average)	Value (kWh)	Conclusions
HP electricity reduction	+78	310 kWh saved across 4 months → ~78 kWh/month
FractLES heater use	+122	488 kWh across 4 months → ~122 kWh/month
DHN energy reduction	+179	714 kWh across 4 months → ~179 kWh/month
Net electric balance	-44	(Heater – HP savings) ≈ +44 kWh/month

DHW FractLES

KPI (monthly average)	Value (kWh)	Conclusions
HP electricity reduction	+10	−78 kWh across 8 months → ~10 kWh/month
FractLES heater use	0	No auxiliary heater used
DHN energy reduction	+138	1,107 kWh across 8 months → ~138 kWh/month

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Q&A

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Thank you!

Juan Carlos del Castillo García, CAR

juagar@cartif.es

Learn more at
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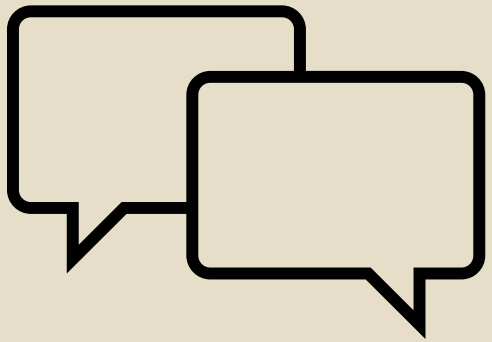
Let’s talk about it!



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What did you think?

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Thank you!

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Thermal energy storage solutions to optimally manage buildings and unlock their grid balancing and flexibility potential.