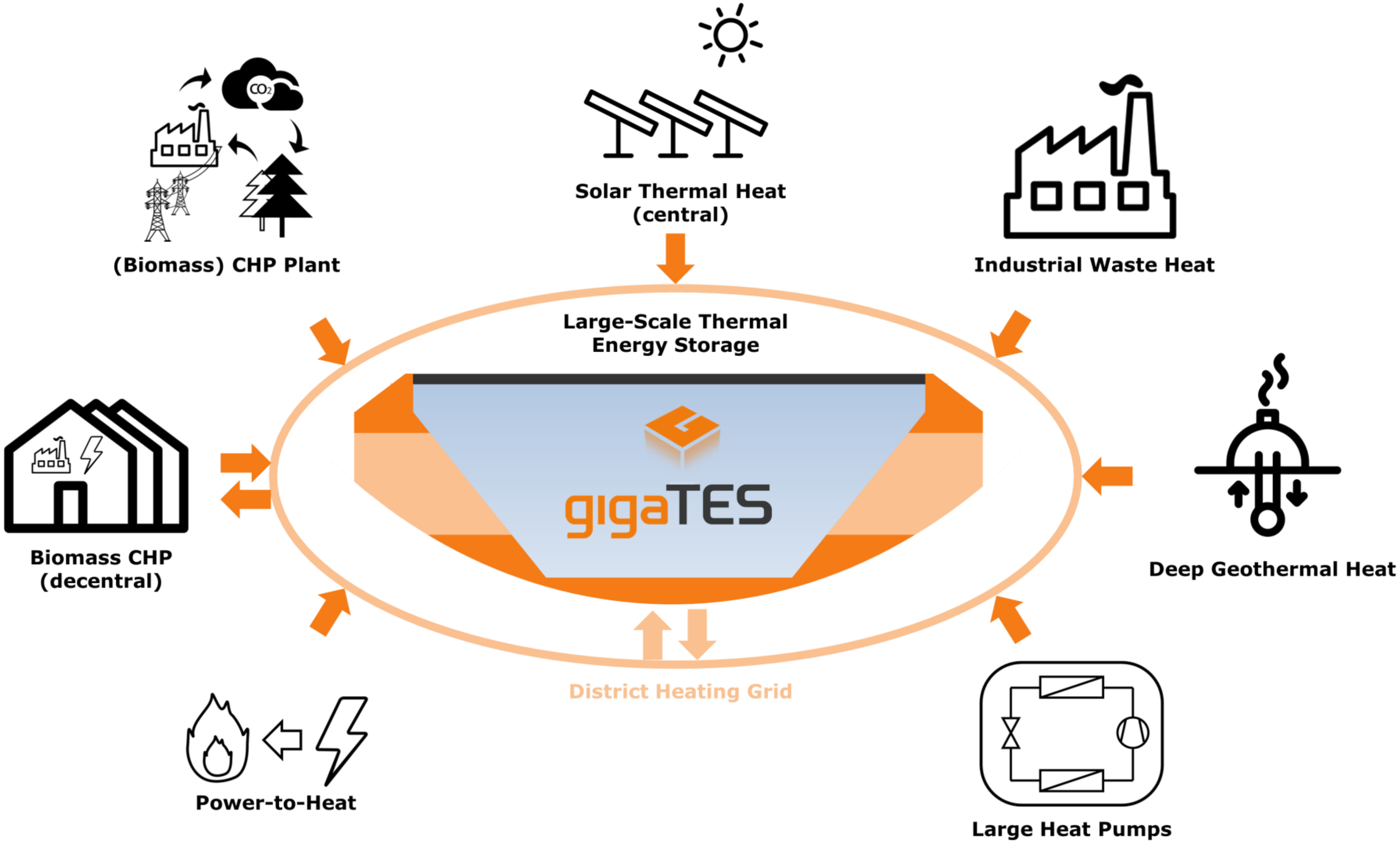
Task 39: Large Thermal Energy Storage for District Heating

Webinar series on Large Thermal Energy Storages
IF Technology, RVO and TKI Urban Energy
Online, 23 November 2023.

Wim van Helden
AEE INTEC, Gleisdorf, Austria

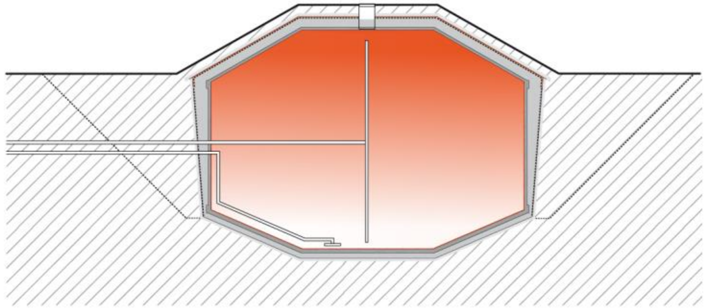
LTES as pivotal element in the future district heating systems



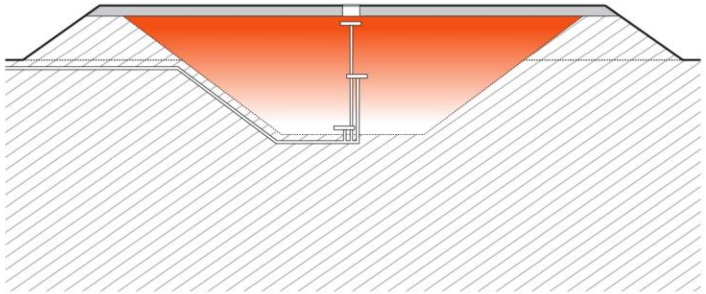
LTES technologies addressed in Task39

- Water or soil
- LTES in DH or in industries
- Seasonal, daily, and multifunctional storage
- Dissemination targeted to decision makers in policy, municipalities, utilities and DH companies

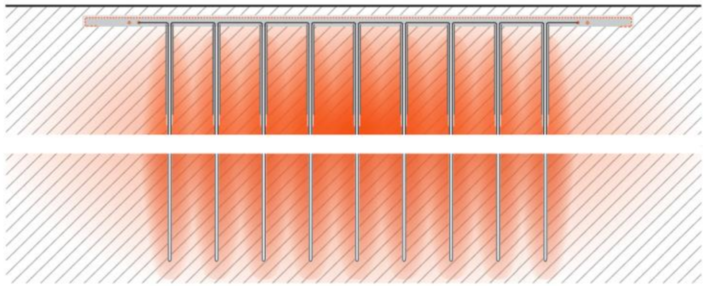
Tank thermal energy storage (TTES)



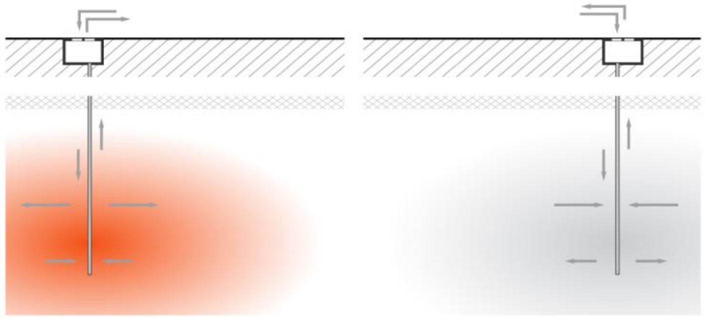
Pit thermal energy storage (PTES)



Borehole thermal energy storage (BTES)



Aquifer thermal energy storage (ATES)



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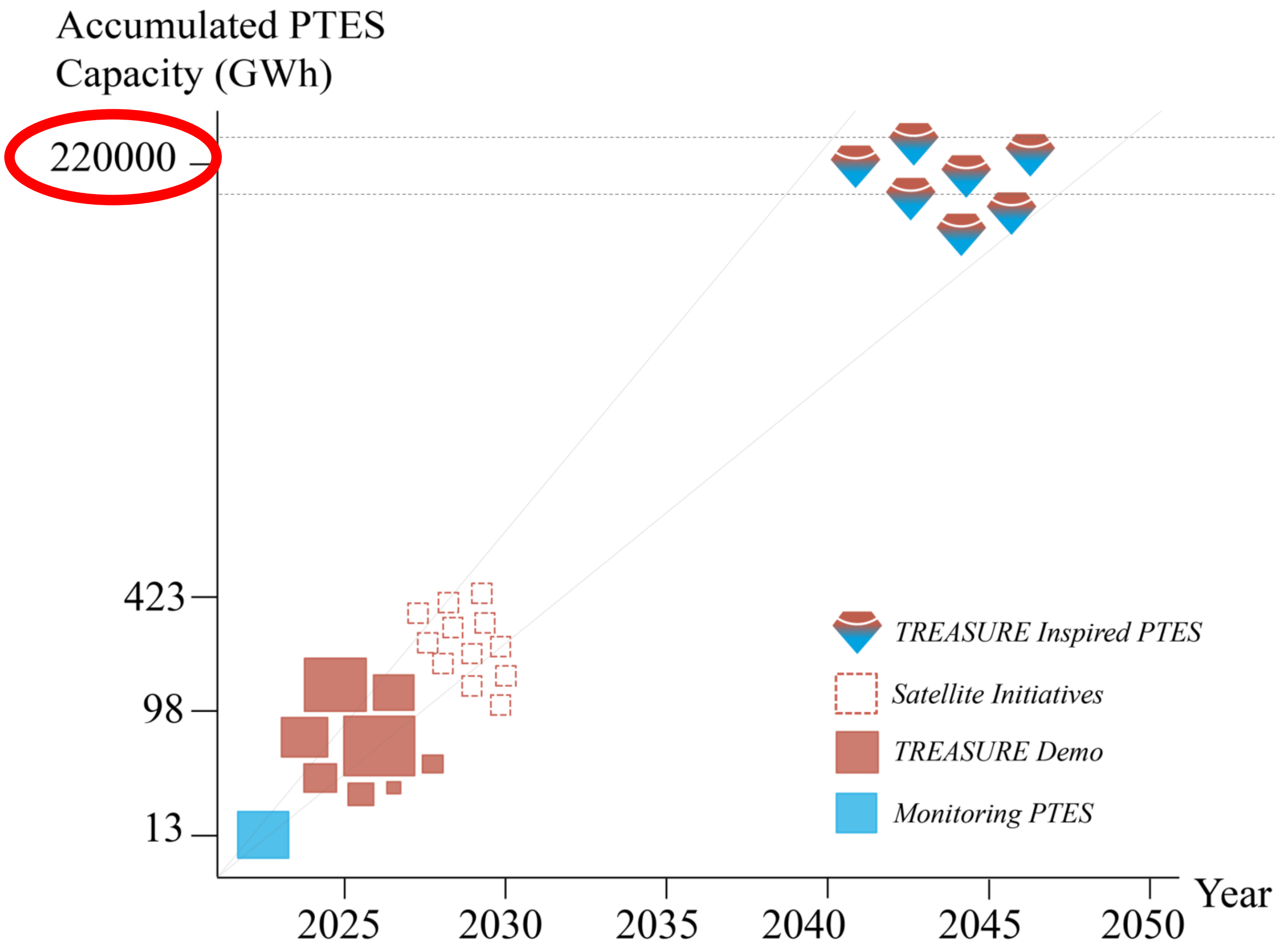
Potential of Pit Thermal Energy Storage for DH in Europe

Based on:

- EU total DH final energy consumption 446 TWh (2018)
- 40% of LTES for DH is PTES
- 30% of annual heat sales to be stored
- Presently needed PTES capacity for DH of 54000 GWh
- 4-fold growth of DH until 2050



Our definition of Large

The systems studied in Task 39 are large **sensible** thermal energy storages, defined as facilities designed to store **at least 1 GWh/year**, at **atmospheric pressure**.

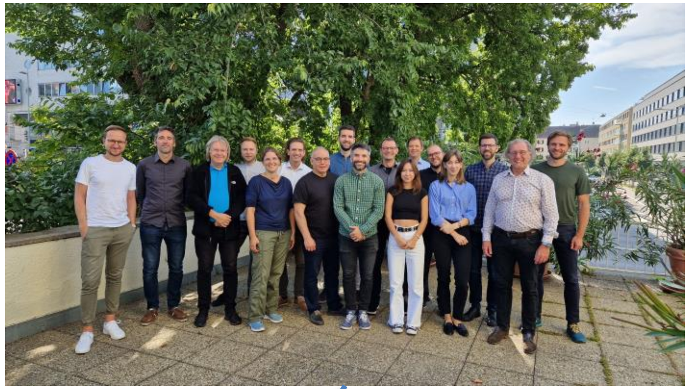
The stored heat should be suitable for **discharge into district heating networks**, i.e. at temperatures **higher than 50°C** and **lower than 100°C**.

Working in IEA Tasks

Work Plan

Visit to Dronninglund PTES

Visit to Meldorf PTES



Kick-off Online Oct. 2020

Online May 2021

Online Nov. 2021

Graz April 2022

Aalborg Sept. 2022

Hamburg May 2023

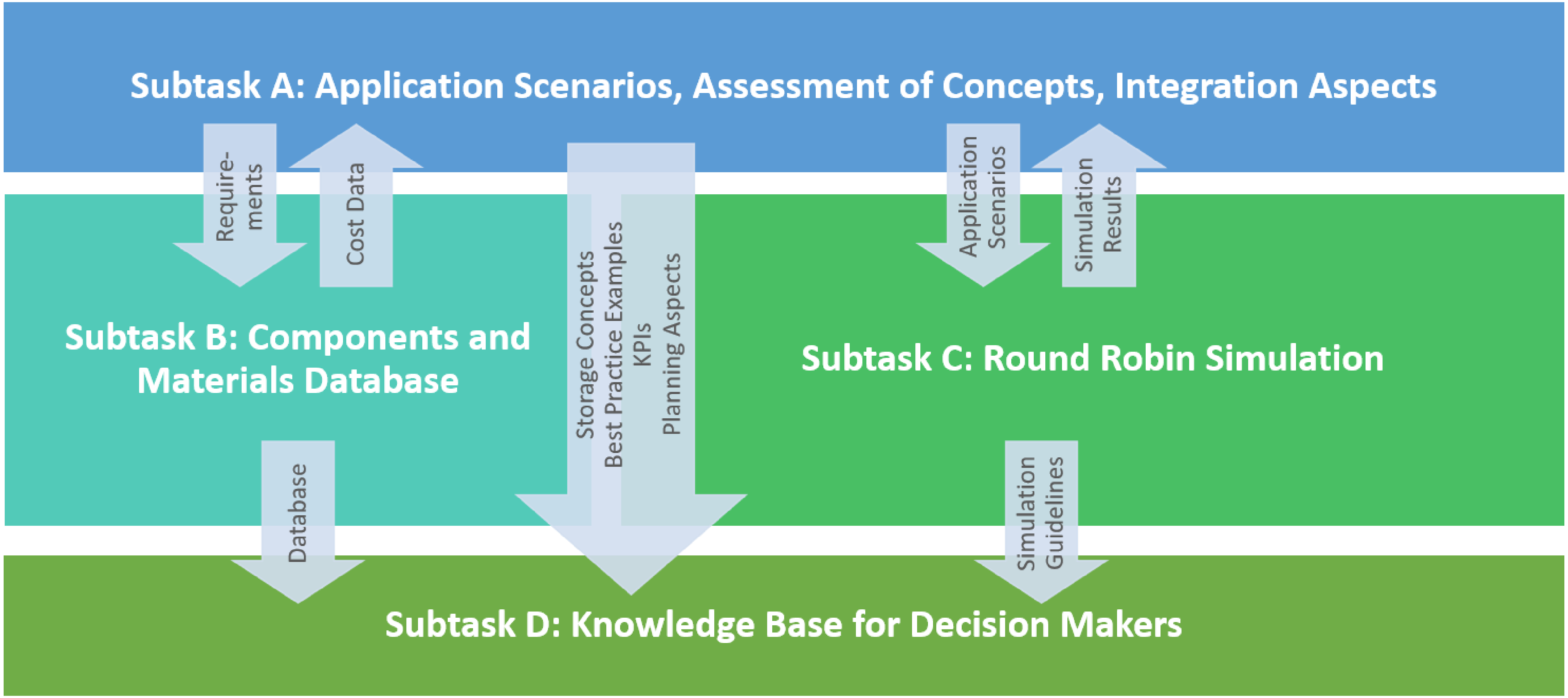
Final meeting Graz, Sept. 2023

Dec. 2023 Task end

Semi-annual experts meetings

Experts collaborate on common work plan; all have to bring their own funding

Subtasks and their interdependencies



Subtask A: KPI List

- KPIs are split in three categories :
  - **Technical**
    - e.g., MIX number, charged/discharged heat, energy efficiency…
  - **Economic**
    - Proposal for a common economic KPI, Levelized Cost Of Energy Storage (defined for third-party investor):

$$LCoES = \frac{I_0 - S_0 + \sum_{t=1}^{T}\left(\frac{C_t * (1 - LTR) * (1 - CTR) - DEP_t * CTR - S_t}{(1+r)^t}\right) - \frac{RV}{(1+r)^T}}{\sum_{t=1}^{T}\frac{E_t * (1 - LTR) * (1 - CTR)}{(1+r)^t}}$$

    - e.g., CAPEX, OPEX, DHN weighted marginal heat cost with or without LTES…
  - **Environmental**
    - Do not always include a clear definition or protocol for measurement, but they are introduced in order to be highlighted in the guidelines
    - e.g., changes in microbial populations related to temperature changes, changes in physical properties of the aquifer due to temperature changes, groundwater flow related to changes in the hydrologic equilibrium…

S_t Subsidy at year

S_0 Subsidy before construction (year 0)

C_t Operational costs at year t (OPEX)

I_0 Investment before construction (year 0) = CAPEX

T HPA contract duration (years)

LTR Local tax rate (%)

CTR Company tax rate (%)

DEP_t Investment depreciation at year t

RV Residual value of the installation at the end of the project

HPAE_t Heat sold through the HPA at year t

r Discount rate considered

HPA Heat purchase agreement

IRR Internal rate of return

Main hypotheses :

- Defined for third party investor, to be adapted for other actors (especially tax rates)
- No loan contracted to finance the project (100% equity)

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A lot of Technical and Economic Indicators.

Limited maturity / understanding for Environmental Indicators

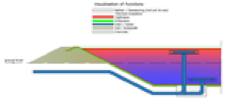
Subtask B: Materials Database and Material Tests

Structure of materials database for LTES

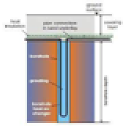
Thermal storage type
Selection by user

Technology selection

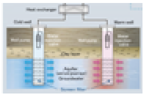
PIT storage



Borehole storage



Aquifer storage



Component selection

Soil
Clay/Silt dry
Clay/Silt moist
Sand, dry
Sand, moist
Sand, saturated
Gravel, dry
Gravel, saturated
Sedimentary rock sandstone
Sedimentary rock limestone
(2) VDI 4640, ÖWAV 207

Protection
Geotextile
Drainage mats
Sandmats

Tightness
High Temp. PolyEthylene (PE HTR) t=2,5 mm
High Temp PolyPropylene (PP HTR) t=2,5 mm
Stainless Steel
Concrete

Water
A table/recommendation

Thermal Insulation
Foam (XPS, EPS, ...)
Mineral Wool
Vacuum panels
Foam glass gravel

Soil
Clay/Silt dry

Density [kg/m³] x 10³	Thermal conductivity λ (W/(mK))	Heat capacity [MJ/m³K]
2.0 - 2.2	0.4 - 1.0 (0.5)	1.5 - 1.6

The selected data are saved to a document

Selection criteria
- Technology (PIT, Borehole, etc.)
- Component (soil, protection, etc.)
- Properties
  - Min/Max

Results listed according to selection parameters

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Subtask C: Round Robin Simulation

Round robin simulations for stage 1 (simplified load profile)

Test case	Description	No. of actual participants / models in round robin simulations
TTES-1-UG	underground TTES with 100,000 m^3 water volume	7
TTES-1-AG	above ground TTES with 50,000 m^3 water volume	4
PTES-1-C	conical PTES with 100,000 m^3 water volume	9
PTES-1-P	pyramidal PTES with 100,000 m^3 water volume	2
ATES-1	ATES with 365,000 m^3 soil volume	4
BTES-1	BTES with 80,000 m^3 soil volume	4

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Subtask D: Knowledge Base For Decision Makers

- Leaflets, information material (ready end of this year)
- Task39 Webinar (this one)
- Policy workshop 5 December (online)
  - Are Large Thermal Energy Storages a key element of the future energy system?
  - Panel of National energy agencies (AT, DK, DE, SE), EC, T39 experts
  - Introductions and discussion

Tank Thermal Energy Storages
Use case Berlin (DE)

Leaflet Example

About the TTES

Technology: TTES (Storage medium: water)
Type of usage: daily storage of heat
Year commissioned: 2023

Technical details

Water volume: 56’000 m^3
Dimensions: Ø 43 m x h 45 m
Storage capacity: 2’750 MWh
Charge-discharge capacity: up to 200 MW_{th}
~70-120 cycles of charge/discharge per year
Max operational temperature: 98°C (atmospheric)
Static pressure holding function possible

Auxiliary equipment

Power-to-heat: 120 MW_{th}
Waste-water heat pump: 75 MW_{th} (planned for 2026)
Waste incineration: 99 MW_{th}

Increasing flexibility for the DHN of Berlin

This TTES is used in the conversion of the site from a coal fired CHP plant towards a multimodal energy hub in Reuter West. It is the largest TTES in the world in 2023 and is owned by Vattenfall in Germany

The main purpose of this LTES is to increase the fossil free heat share, while ensuring flexibility and security of supply of the Berlin DHN

Photo: Vattenfall

About the distribution DHN

Owner: Vattenfall Wärme Berlin AG (Germany)
Name: Berlin district heating
Type of ownership: private
Network length: > **2’000** km
Consumers connected: **1.4 Mio** household equivalents
Total heat production: **10.2** TWh/year
Total heat sold: **9.6** TWh/year

Leaflet Example

Aquifer Thermal Energy Storages Technology Summary

A HT-ATES is a TES where the heat is stored directly in an aquifer: the storage medium is groundwater and soil/ground. The basic system consist of a medium temperature well for "cold" water abstraction and a hot well for the injection of the charging heat

An ATES is built in 4 main steps (see illustration beside & below)

1. Drill the well pair(s)

2. Install the well tubes

3. Install Submersible Electric Pumps (ESPs)

4. Install well heads with injection units

HT-ATES in Middenmeer, main implementation steps. Pictures: IF Technology

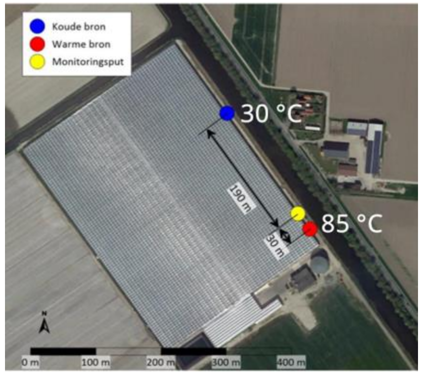
The most technical/crucial elements of an ATES are:
- The hydro-geological investigations
- The drilling & well development
- The water treatment*
- Use of ESPs

The ATES surface can be used for other purposes after implementation, only 2 well heads remain

When heat is required, water is abstracted from the hot well and re-injected in the medium temperature well. Heat exchangers are used to exchange the heat from the groundwater to the district heating network and vice versa

- Cold well
- Monitoring well
- Hot well

Top view presenting the location of the wells of the HT-ATES of ECW



Technical Characteristics, HT-ATES	
Size range, 1 pair of wells [m^3 yearly pumped water vol.]	250'000 - 800'000
Max thermal power [MW_{th}]	5 - 15
Response time [minutes] from 0 to full power	60 - 120
Technical lifetime [years]	> 30
Usage	Seasonal storage
Maturity	
Number of implemented** full-scale projects by 2022	4
TRL	8

*Together with the selection of materials & components, resistant to high temperature, corrosion & expansion
**1 of the HT-ATES projects is now decommissioned, and another is used as a geothermal heat source

Leaflet Example

Aquifer Thermal Energy Storages
Use Case HT-ATES Middenmeer (NL)

About the ATES

Technology: ATES (Storage medium: groundwater)
Type of usage: seasonal storage of heat
Year commissioned: 2021
Main heat source: geothermal heat of 90 °C from 2’400 m
Owner: Ennatuurlijk Aardwarmte

Technical details of the LTES

Water volume: 440’000 m^3
Storage capacity: 28 GWh
Charge-discharge capacity: 10-8 MW_{th}
1 cycle of charge/discharge per year
Max operational temperature: 85°C (infiltration temperature); 85-50 °C abstraction temperature

Auxiliary equipment

The HT-ATES is connected to 2 heat exchangers
Groundwater is treated with CO_2 dosing to prevent calcite precipitation
The well heads are controlled with N_2 to prevent oxygen from entering the system
Heat is used by the greenhouse directly (without extra heat pump)

ATES can be used as a geothermal heat source or as a thermal storage

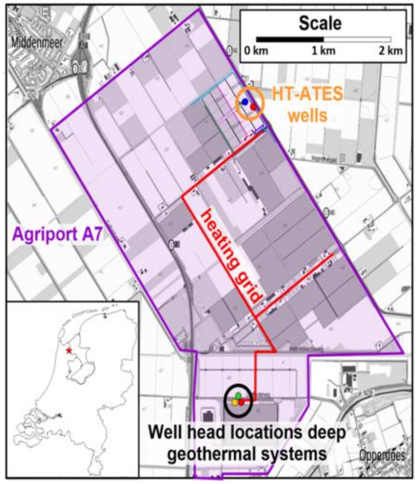
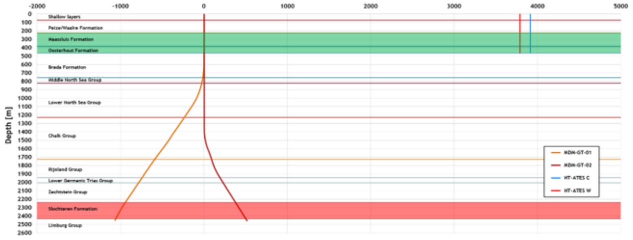


Figure beside: top view presenting the location of the wells of the HT-ATES (blue and red dots at the top of the sketch) as well as the deep geothermal wells (yellow, green and red dots at the bottom of the sketch) of ECW, as well as the location of the greenhouse in the Netherlands (bottom left corner of the sketch), in the city Middenmeer

Figure below: cross-section presenting the wells of the HT-ATES (blue and red lines at the top-right of the sketch) as well as the deep geothermal wells (orange and dark-red lines at the left of the sketch) of ECW, together with key facts about respective reservoirs



HT-ATES Aquifer (~400 m depth)
- ~ 25 m thick Aquifer
- Unconsolidated sand
- Between thick clay layers

Geothermal Reservoir (> 2km)
- Sandstone
- Slochteren Formation

About the user

Name: Helderman
Type of ownership: Greenhouse
Network length: directly connected
Consumers connected: paprika greenhouse

Future: Task39 has a follow-up: Task45

Task45 will build further on the work and achievements of Task39, with a slight shift to opening up markets for LTES:

„ Accelerating the Uptake of Large Thermal Energy Storages“

4 year duration, starting 1 January 2024

Already 22 organisations from 7 countries signed up for participation (of which 8 industries)

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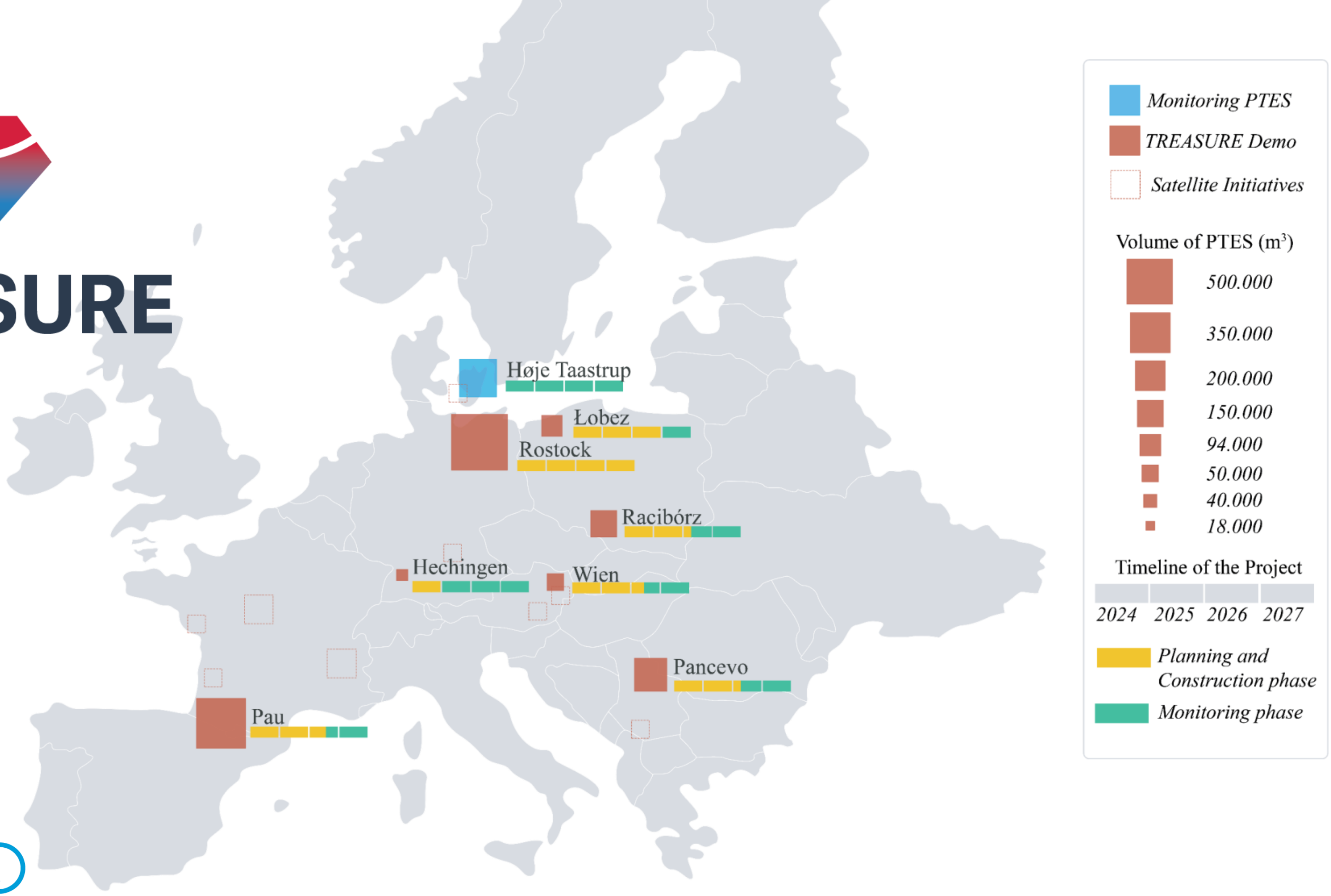
A bit more about Pit Thermal Energy Storages, PTES

Source: Arcon-Sumark

Pit thermal energy storage in Vojens, Denmark.
Volume 200.000 m³

Treasure: demonstrating and accelerating the uptake of PTES



7 demonstrators

15 satellite initiatives

Tools, Components

Methods

Processes

25 Partners, 8 countries

Starting 2024, 4 years

References

Leaflets, KPI list, LTES systems overview, further documentation on Task 39 website:

https://iea-es.org/task-39/

Giga_TES final report:

https://gigates.at/index.php/en/publications/reports

Policy Workshop 5 December 2023:

https://lnkd.in/dwRMn3ZB

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