Comparison and Improvement of Numerical Simulation Tools for Large Thermal Energy Storages

Thomas Schmidt, 23.04.2026

Research, Consulting and
Transfer for Sustainable
Thermal Energy Systems
in the Steinbeis Network

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Introduction

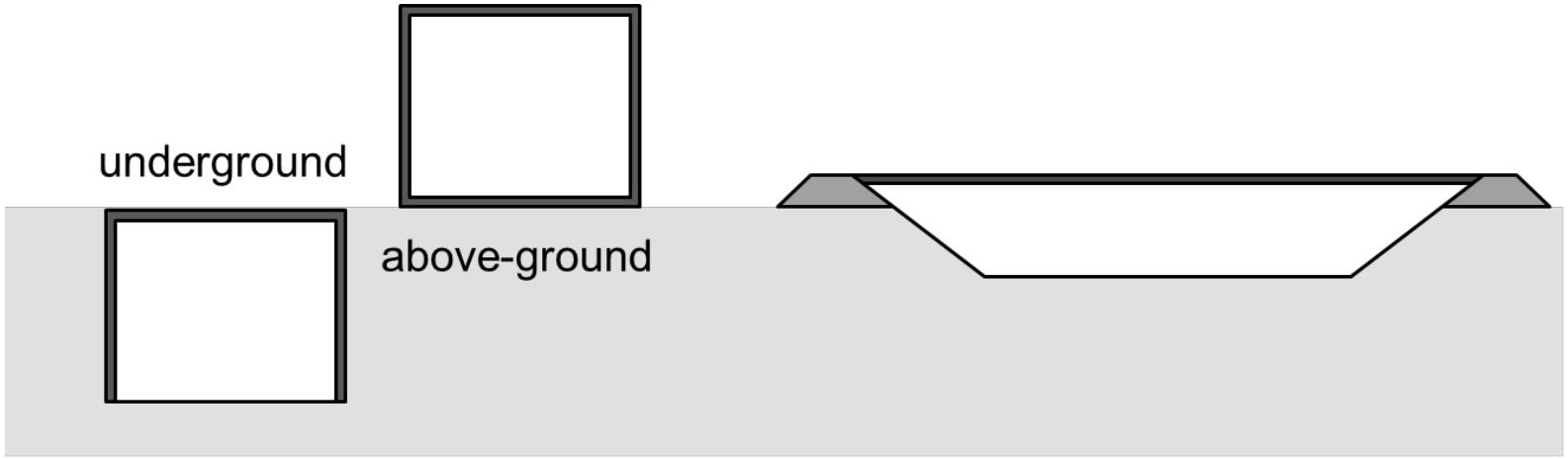
Ongoing work and results from:

- ES Task 39 – Large Thermal Energy Storages for District Heating
  - Subtask C: Round Robin Simulation (2021 – 2023)
- ES Task 45 – Accelerating the Uptake of Large Thermal Energy Storages
  - Subtask 1: Numerical Simulation (2024 – 2027)

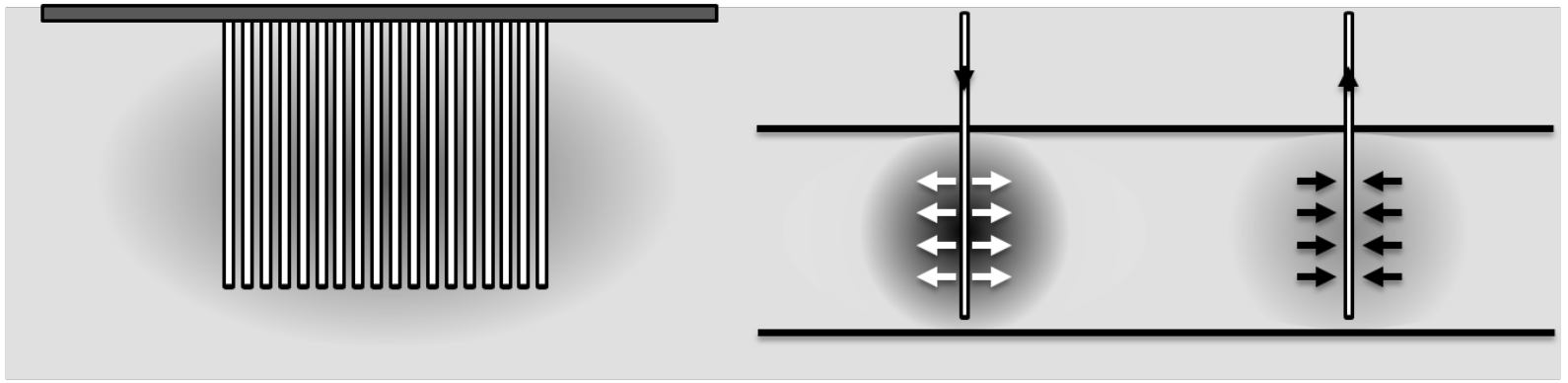
Objectives:

- Verification of numerical simulation models for Large Thermal Energy Storages (LTES) by means of comparative simulations
- Provision of pre-design tools for LTES system integration

Large Thermal Energy Storage (LTES) - Scope



Tank TES (TTES) | Pit TES (PTES)



Borehole TES (BTES) | Aquifer TES (ATES)

LTES definition
in ES Tasks 39/45:

- **sensible** TES
- designed to store at least **1 GWh** heat per year
- at temperatures higher than **50°C**

TES: Thermal Energy Storage

Means for numerical model verification or validation

1. **using analytical solutions**
   - only possible for simple cases and single heat transfer aspects
2. **using experimental data**
   - high requirements on data quality regarding accuracy and completeness
3. **using other (validated) numerical models**
   - several LTES simulation models have been validated in the past
   - method is possible for all storage concepts
   - method can be used for various TES sizes, configurations and applications

Overview of LTES simulation models used by Task 39/45 partners

Purpose / Storage type	System simulation			TES design optimization
	TRNSYS	Modelica	MATLAB Simulink	
ATES	Type 345 TRNAST Type 1380			FEFLOW MODFLOW HST2D/3D
BTES	Type 346 SBM Type 370 Type 557 DST Type 1373	MoSDH library – BTES		COMSOL Multiphysics Ansys Fluent FEFLOW
PTES	Type 343 (cone) Types 1535/1301 (cone) Type 1322 (pyramid) UGSTS	Dymola DisPlaTES, LargeTESmtk – PTES MoSDH library – PTES	Large-Scale TES	COMSOL Multiphysics Ansys Fluent OpenFOAM
TTES	Type 340 (AG) Type 342 (buried and AG) Types 534/708 (buried) Type 1534 (AG) Types 1534/1302 (buried)	Dymola Dis PlaTES LargeTESmtk – TTES MoSDH library – TTES	Large-Scale TES	

Detailed definition of test cases for comparative simulations

- LTES configuration, e.g.
  - geometry (PTES/TTES)
  - well configuration (ATES)
  - borehole heat exchanger configuration (BTES)
  - hydraulic devices / connections for charging and discharging
  - insulation
- Thermophysical properties
  - water
  - insulation material
  - ground properties
- Numerical parameters
  - discretisation
  - far field boundaries
  - simulation period and time step
- Boundary conditions
  - initial conditions
  - operational profiles
- Model outputs
  - flows and temp.'s of hydraulic circuits
  - heat flows
  - temperature sensor positions:
    - inside the storage volume
    - in the surrounding ground

Overview of test cases for comparative simulations Task 39 – stage 1

Test case	ATES-1	BTES-1	PTES-1-C	PTES-1-P	TTES-1-AG	TTES-1-UG
Description	ATES two wells	BTES cylindrical	PTES truncated and inverted cone	PTES truncated and inverted pyramid	TTES above-ground	TTES underground
TES volume	375 000 m³ (soil)	80 000 m³ (soil)	100 000 m³ (water)	100 000 m³ (water)	50 000 m³ (water)	100 000 m³ (water)
Storage medium	soil-water	soil	water	water	water	water
Insulation	-	top	top	top	top, side, bottom	top
CH/DC devices	two wells	128 BHE	top & bottom diffusors	top & bottom diffusors	top & bottom diffusors	top & bottom diffusors

CH: charging, DH: discharging, BHE: borehole heat exchanger

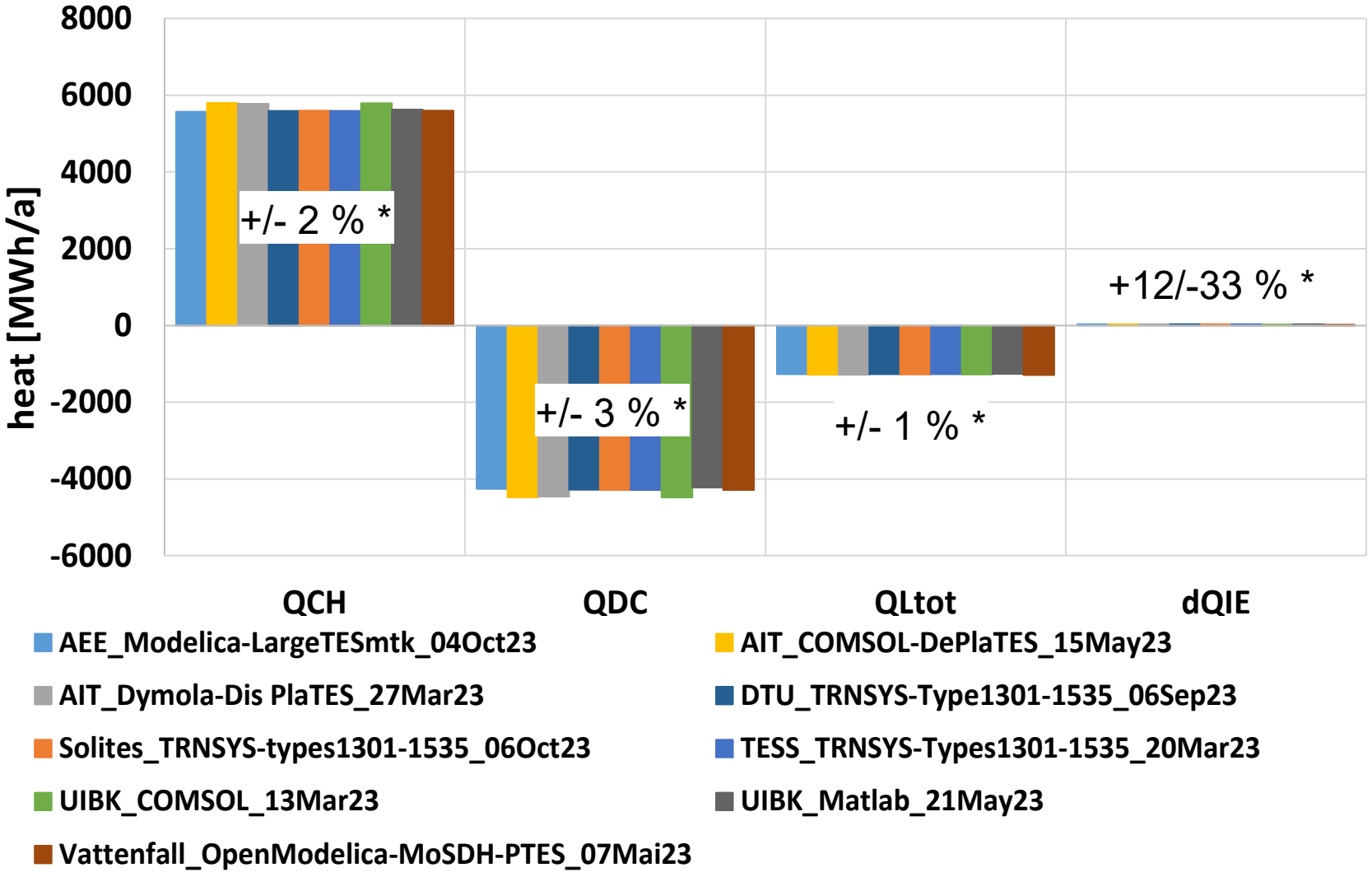
Participation in the Task 39 comparative simulations

Test case	No. of participations	No. of participating institutions	No. of different LTES models
ATES-1	4	3	4
BTES-1	8	5	5
PTES-1-C	14	10	7
PTES-1-P	2	2	2
TTES-1-AG	4	3	4
TTES-1-UG	10	8	7

Overview of test cases for comparative simulations Task 45 – stage 2

Test case	Description	Changes to stage 1 test case
TTES-2-UG	TTES-2 base cases	• 3rd diffuser layer for charging and discharging • dynamic operation profile based on real operational data
TTES-2-AG		
PTES-2-C	PTES-2 base cases	
PTES-2-P		
PTES-2-P-GW	PTES with groundwater	• ground layer with groundwater flow
PTES-2-P-DL	PTES validation test case	• validation against experimental data
TTES-2-UG-I1	PTES/TTES with extended insulation	• additional insulation on side walls and bottom
PTES-2-C-I1		
PTES-2-P-I1		
ATES-2	ATES-2 base case	• dynamic operation profile based on real operational data
BTES-2	BTES-2 base case	

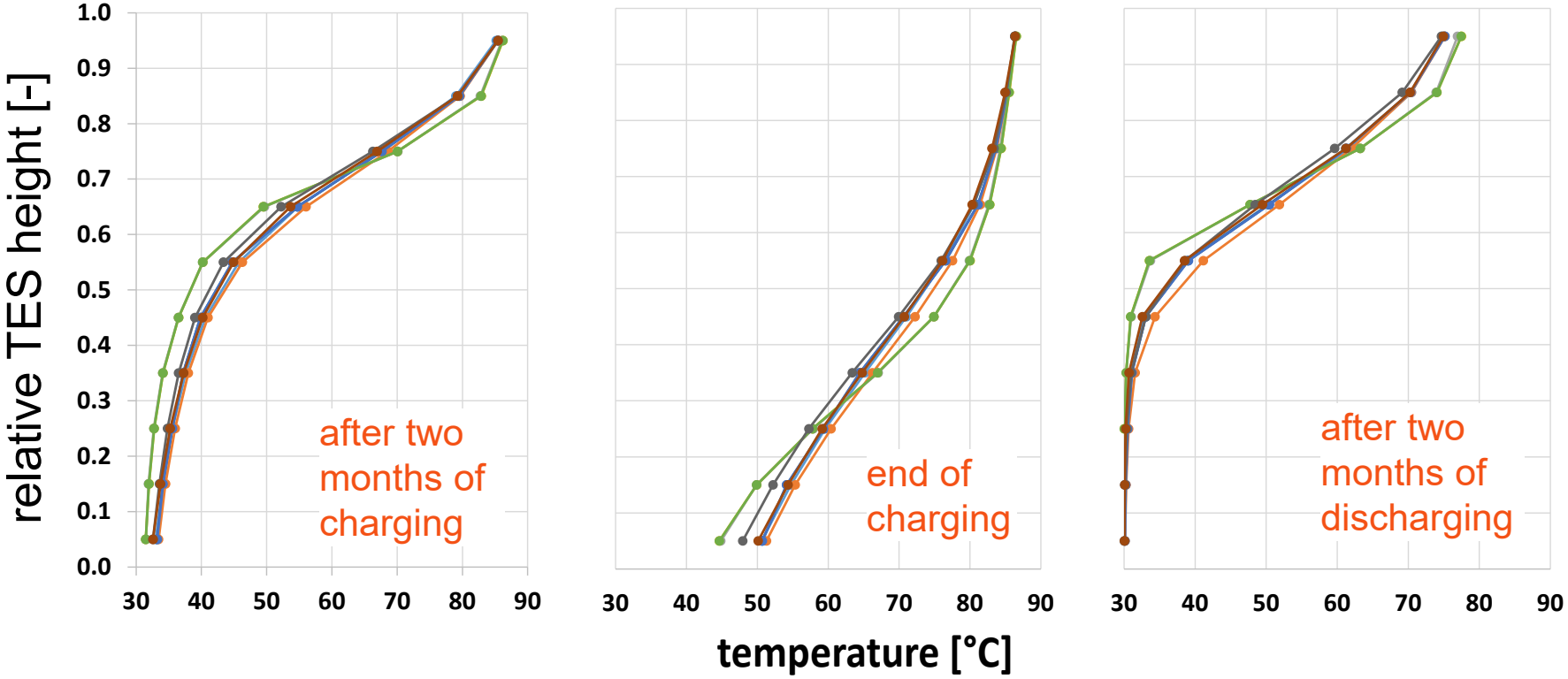
Results for PTES-1-C – yearly energy values



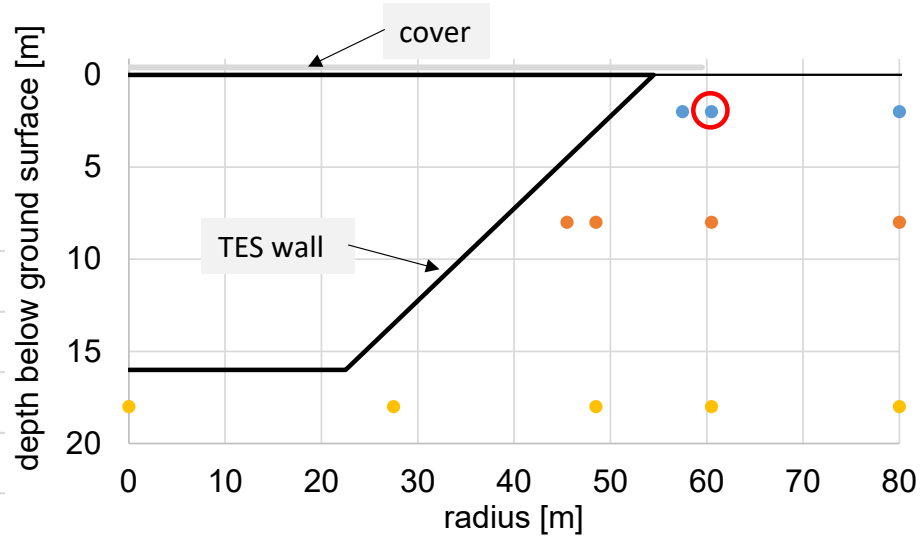
Results for charged (QCH) and discharged (QDC) heat, overall thermal losses (QLtot) and change in internal energy content (dQIE) in the 5th year of operation for nine participations in the PTES-1-C test case

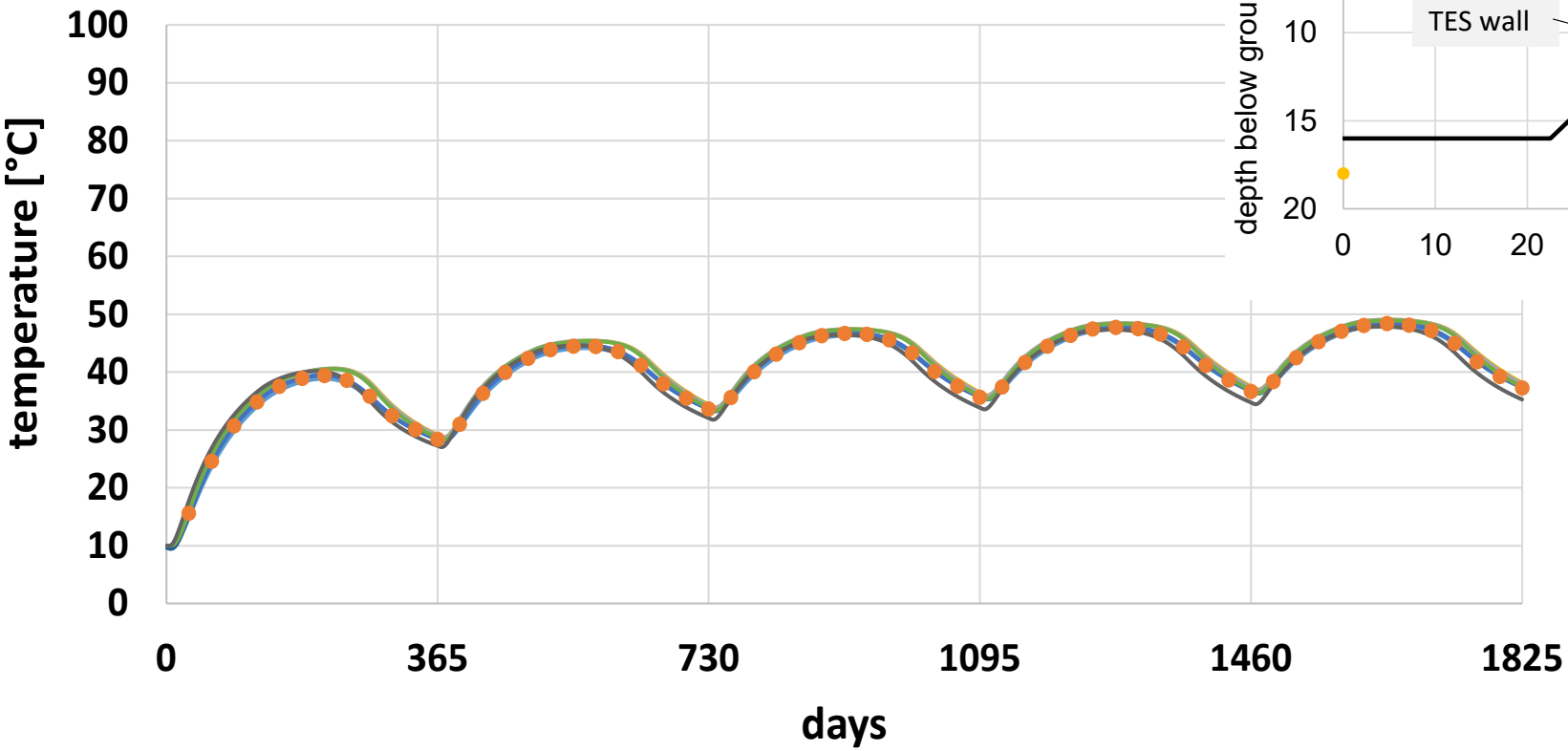
*: referred to mean value of all models

Results for PTES-1-C – temperature stratification in the water volume (5th year)



Results for PTES-1-C
daily ground temperatures





AEE_Modelica-LargeTESmtk_04Oct23
AIT_COMSOL-DePlaTES_15May23
AIT_Dymola-Dis PlaTES_27Mar23
DTU_TRNSYS-Type1301-1535_06Sep23
Solites_TRNSYS-types1301-1535_06Oct23
TESS_TRNSYS-Types1301-1535_20Mar23
UIBK_COMSOL_13Mar23
UIBK_Matlab_21May23

temperature position: 2 m below surface, 7 m distance from side wall

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Public deliverables from IEA ES Task 39 STC

Deliverable	Type of deliverable
Overview and descriptions of LTES simulation models	
C1: Collection of model fact sheets	Report
Description of test cases	
C2a: Description of Test Cases for Comparative Simulations	Report
C2b: Load profiles for test cases	MS Excel-File
C2c: Result template for test cases	MS Excel-File
Results of comparative simulations	
C3a: Results of comparative simulations	Report / reference book
C3b: Result files from participating models / partners	MS Excel-Files

Deliverables available at https://iea-es.org/task-39

Summary

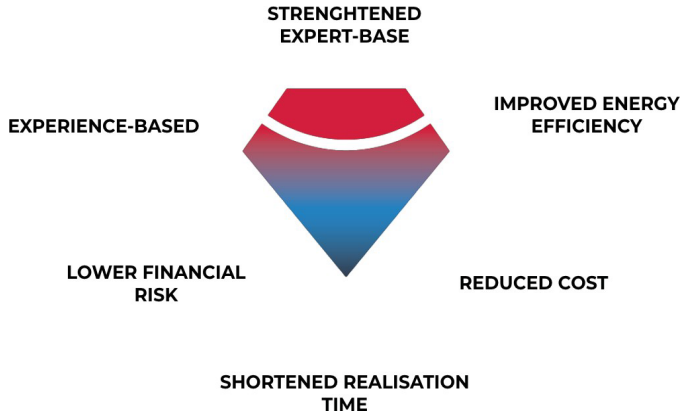
- ES Task 39 Subtask C (2021 – 2023)
  - 6 test cases for LTES were described in detail, including TES configuration, boundary conditions and operation profiles, for the purpose of model comparison and validation
  - results and test cases are available on https://iea-es.org/task-39
- ES Task 45 Subtask 1 (2024 – 2027)
  - continuation of Task 39 STC work
  - definition of 11 additional test cases
  - provision of pre-design tools for LTES system integration

TREASURE

DEMONSTRATING LARGE PIT THERMAL ENERGY STORAGES

Demonstrators

Monitoring PTES



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2024 - 2027

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Thank you for your attention!

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