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Comprehensive Comparison of Different Models for Large Scale Thermal Energy Storage

IRES 2021

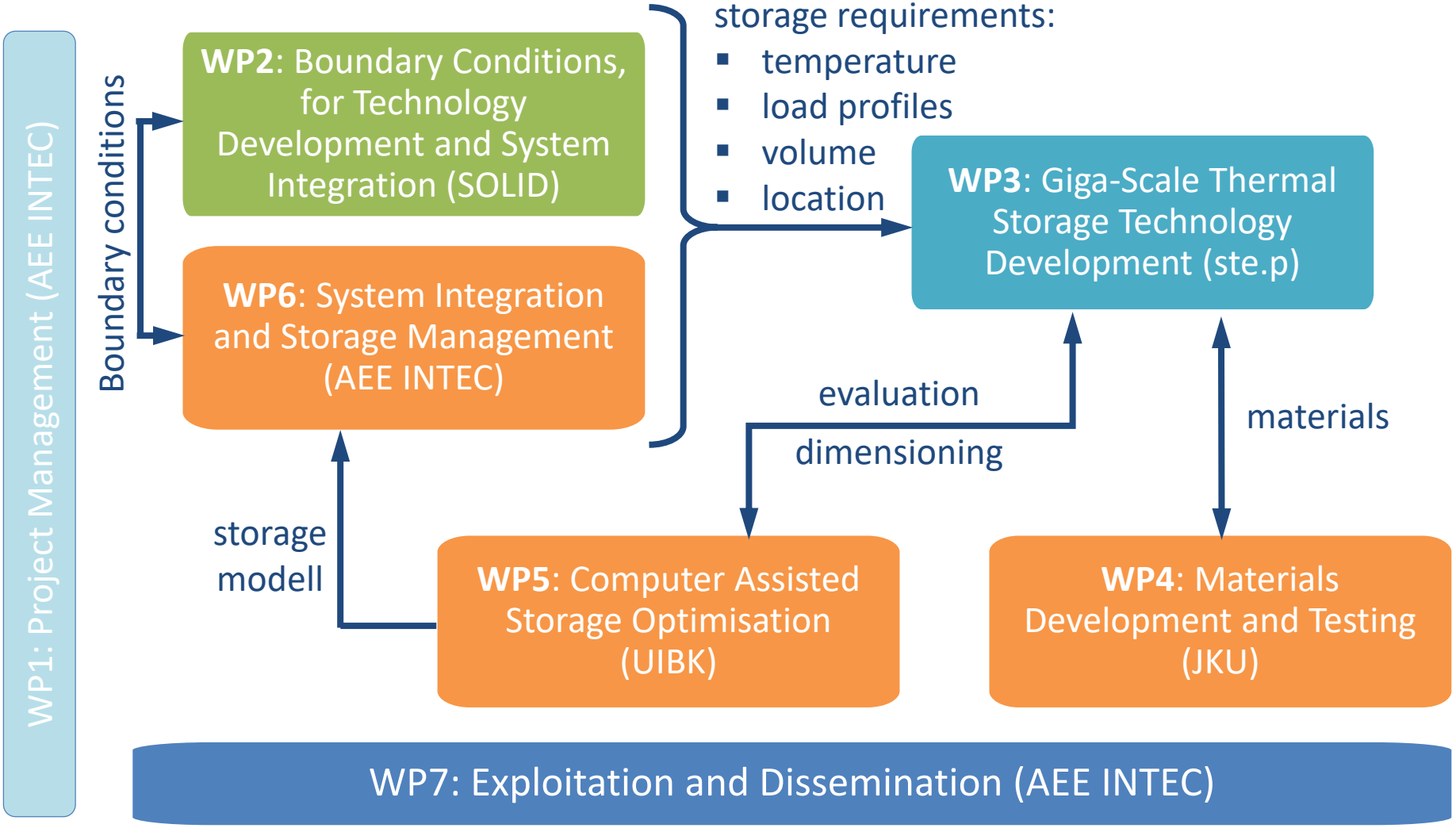
Fabian Ochs, Abdulrahman Dahash, Alice Tosatto, Michael Reisenbichler, Keith O'Donovan, Geoffroy Gauthier, Christian Kok Skov, Thomas Schmidt

Austrian FFG Flagship Project (Energieforschung)

giga_TES
Giga-Scale Thermal Energy Storage for Renewable Districts

Total cost: 4.4 M€
Funding requested: 3.3 M€
Duration: 36 Months

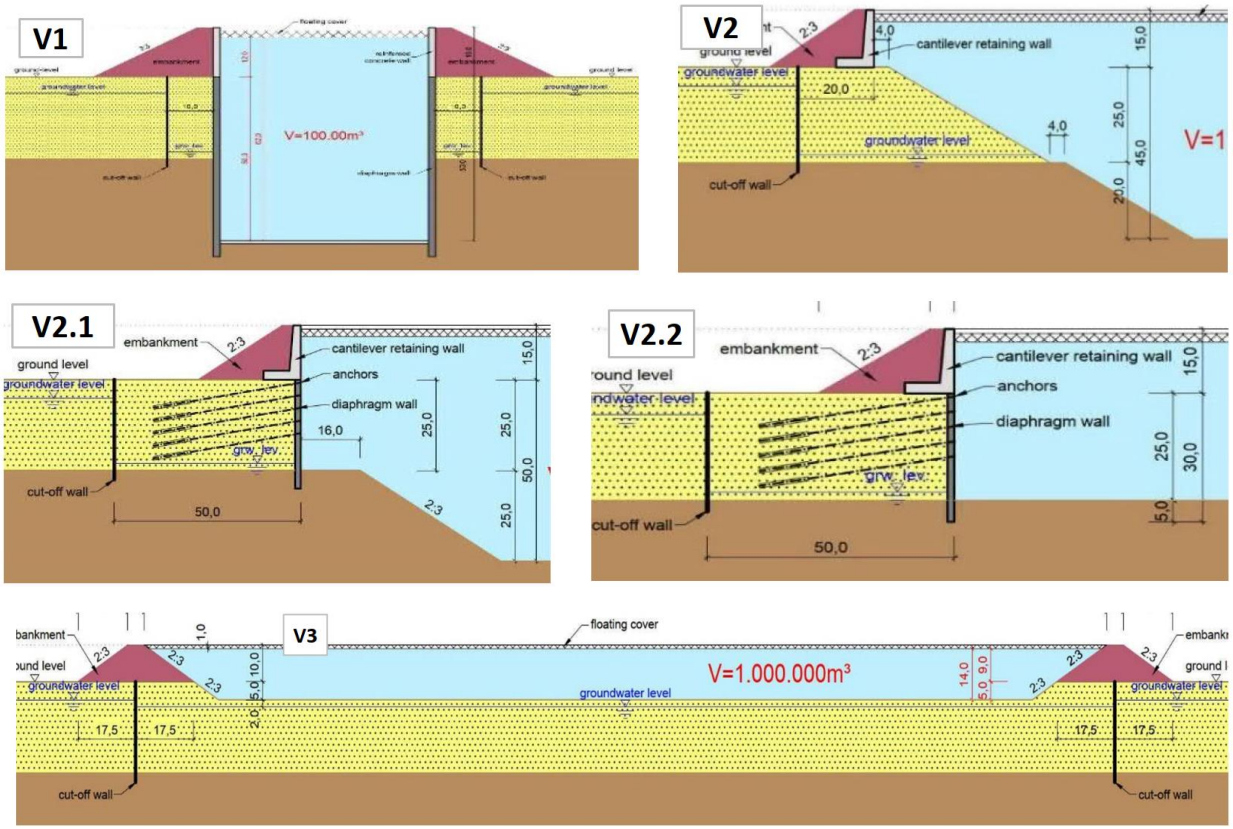
Work Package structure



Large-scale TES construction types

- Tank (cylinder)
- Steep pit
- Hybrid
- Shallow pit

(cone, pyramid)



Source: ste.p

Modelling TES

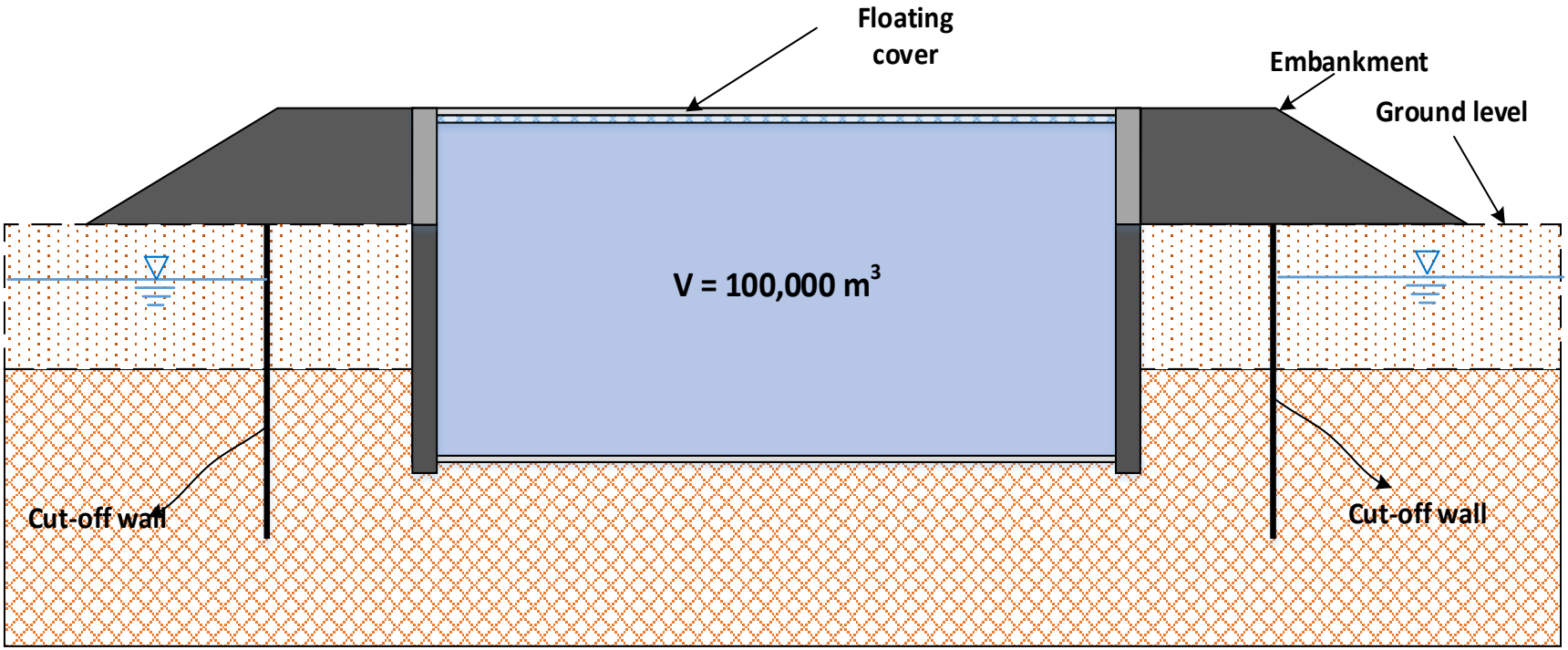
Motivation

- Improve Modelling of TES
    - Models for complex geometries
    - Models accounting for ground water flow
    - Component and system level models
    - Improve simulation performance
- Intermodel comparison (cross-validation)
- Model calibration and validation

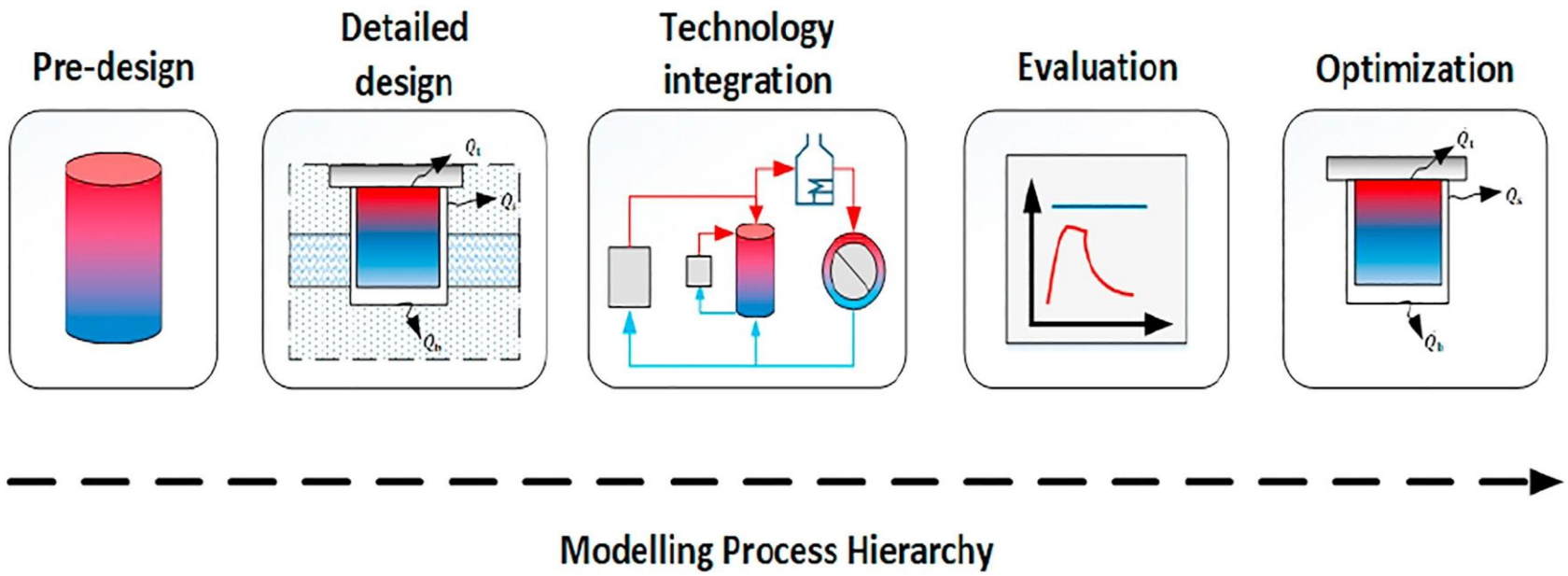
F. Ochs, A. Dahash, A. Tosatto and M. Bianchi Janetti, "Techno-economic planning and construction of cost-effective large-scale hot water thermal energy storage for Renewable District heating systems," Renewable Energy, vol. 150, pp. 1165-1177, 2019.

Performance Assessment of TES

Hybrid TES geometry
- dam
- cuboid
- pyramid stump



modeling process of large-scale TES in DH systems



Limited information	measured data
low degree of detail	detaild design
fast simplified model	calibrated detailed model

A. Dahash, F. Ochs, M. Bianchi Janetti and W. Streicher, "Advances in seasonal thermal energy storage for solar district heating applications: A critical review on large-scale hot-water tank and pit thermal energy storage systems," Applied Energy, vol. 239, pp. 296-315, 2019

From component Level to system level

Pre-Design (feasibility), System Integration

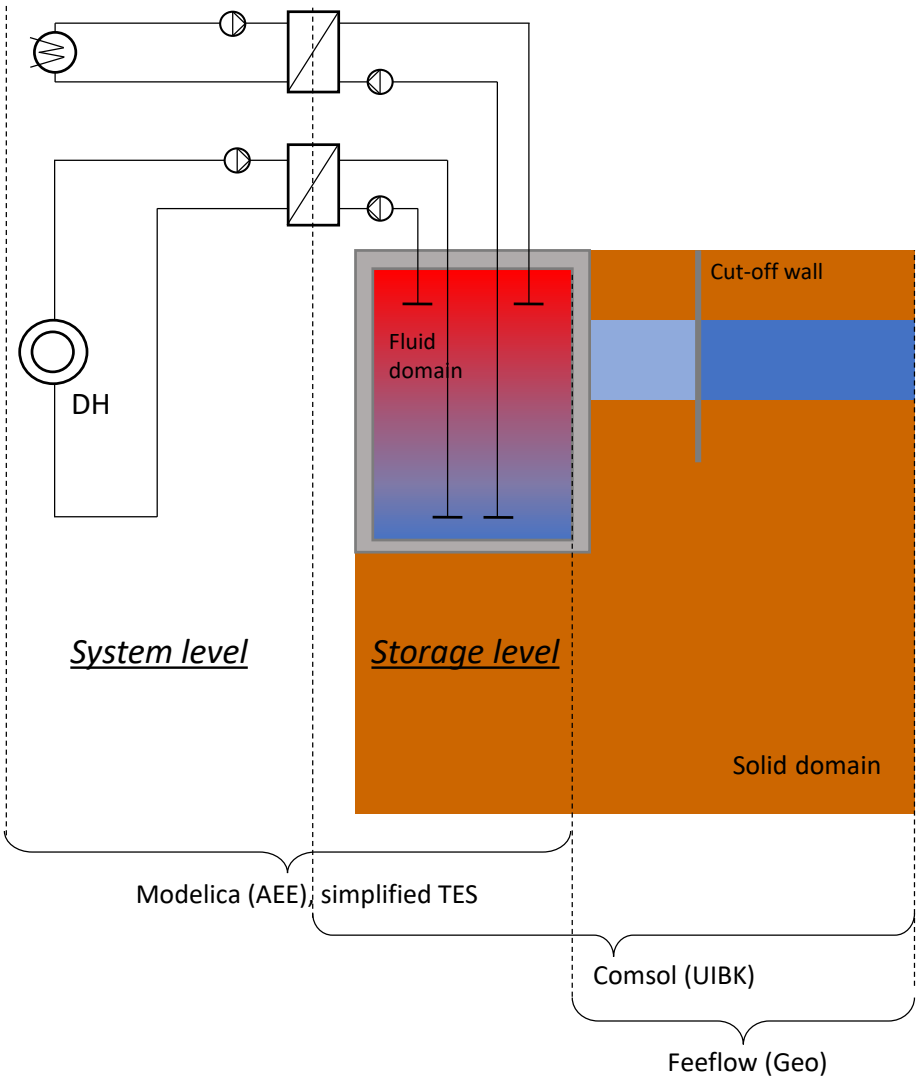
Storage Optimisation

- Component level
- TES Level
- …

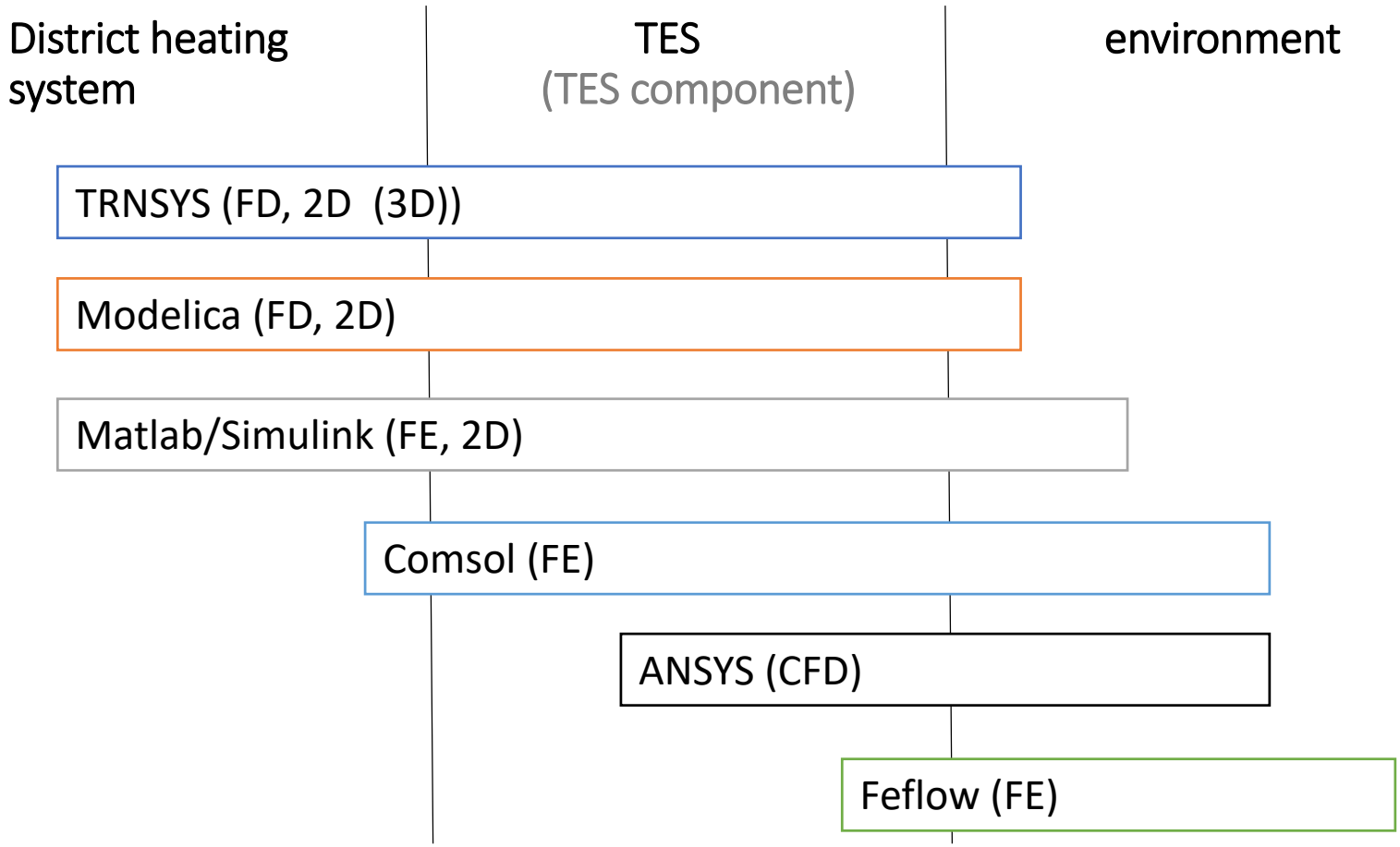
System Optimisation

- TES integration
- Control
- …

Environmental Impact Assessment



DH and TES Tools and Scope

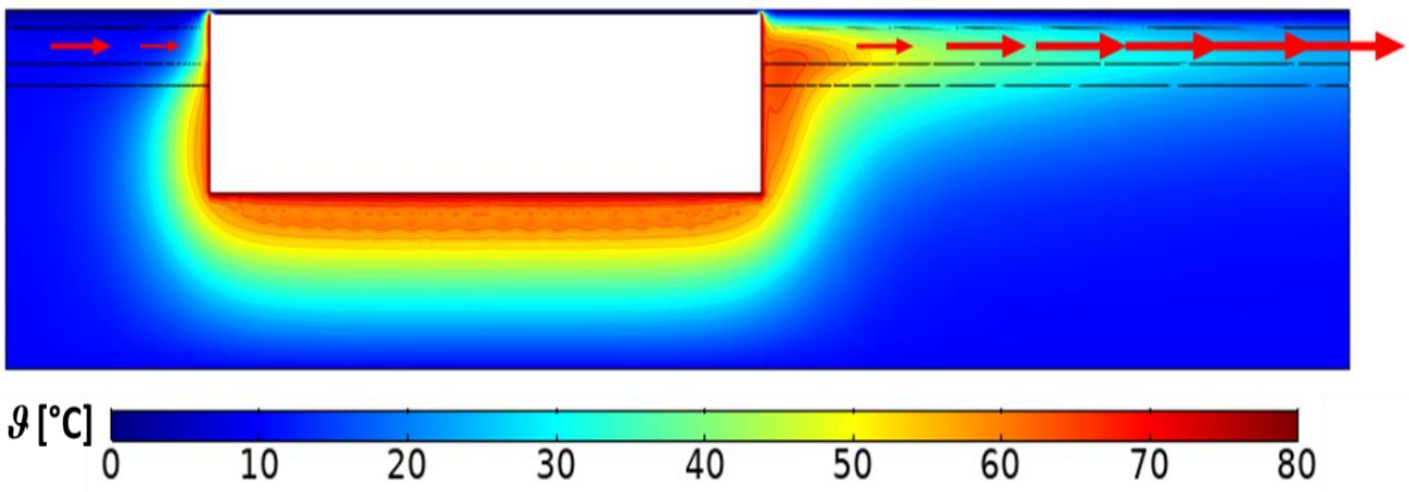


TES and environment

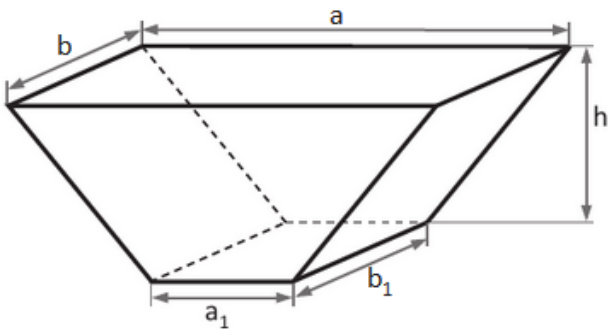
Interaction between TES and environment

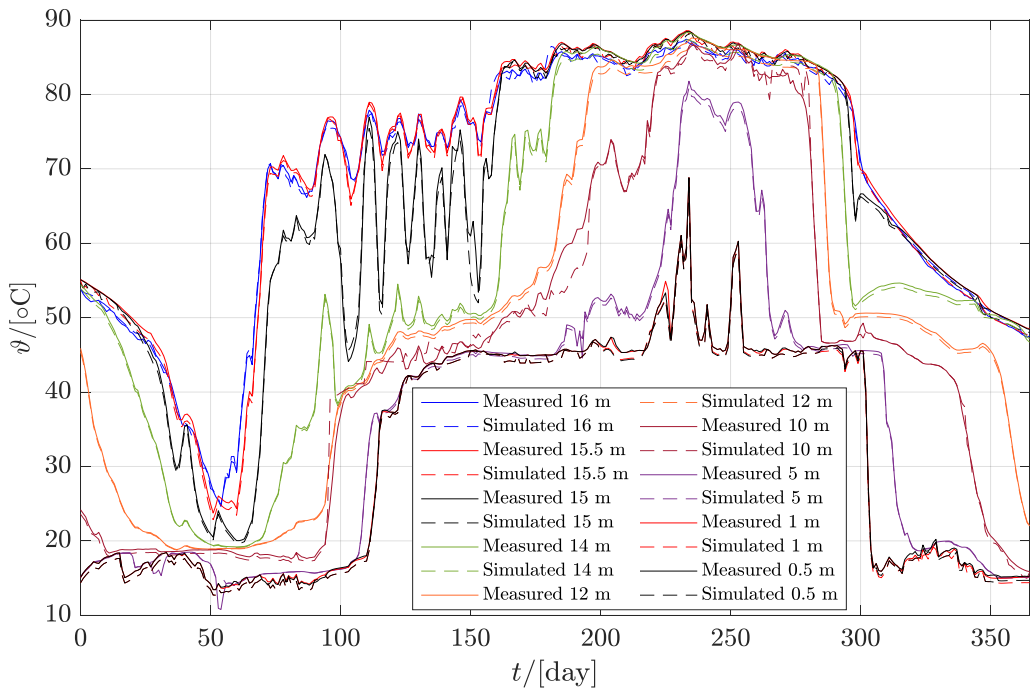
- Influence of ground water (flow) on thermal losses
- Influence of TES on ground water temperature (limit max. GW temperature)

Example. Ground water flow in surroundings of TES (COMSOL)



TES model validation (Comsol, Droninglund Pit TES)





- **Validation case:**
  - Dronninglund pit TES in Denmark
  - V_{Pit} = ~ 60,000 m^3
  - a = b = 90 m
  - $a_1 = b_1$ = 26 m
  - h = 16 m
  - α = 26.5 °

- **Measured data:**
  - Year: 2015
  - Hourly resolution flowrates and temperatures

A. Dahash, F. Ochs, A. Tosatto and W. Streicher, "Toward efficient numerical modeling and analysis of large-scale thermal energy storage for renewable district heating," Applied Energy, vol. 279, 2020.

TES Models overview

a. COMSOL Multiphysics (UIBK);
b. TRNSYS (SOLITES, PlanEnergi,):
   - Type 1300/Type 1301 (SOLITES);
   - Type 1322 (PlanEnergi)
   - Type 342 (PlanEnergi);
c. Modelica/Dymola (AEE INTEC).
d. Modelica/Dymola (UIBK).
e. Matlab/Simulink (UIBK)

- tank (cylindrical and cuboid) and pit (cone, pyramid stump)
- V_{TES} = 100,000 m^3 and h_{TES} = 25 m;

TES Models-Tools Comparison

Case Study

TES with V_{TES} = 100,000 m^3 and h_{TES} = 25 m;

Two primary cases cases:

a. <u>Case 1:</u> no insulation on the sidewall and bottom;

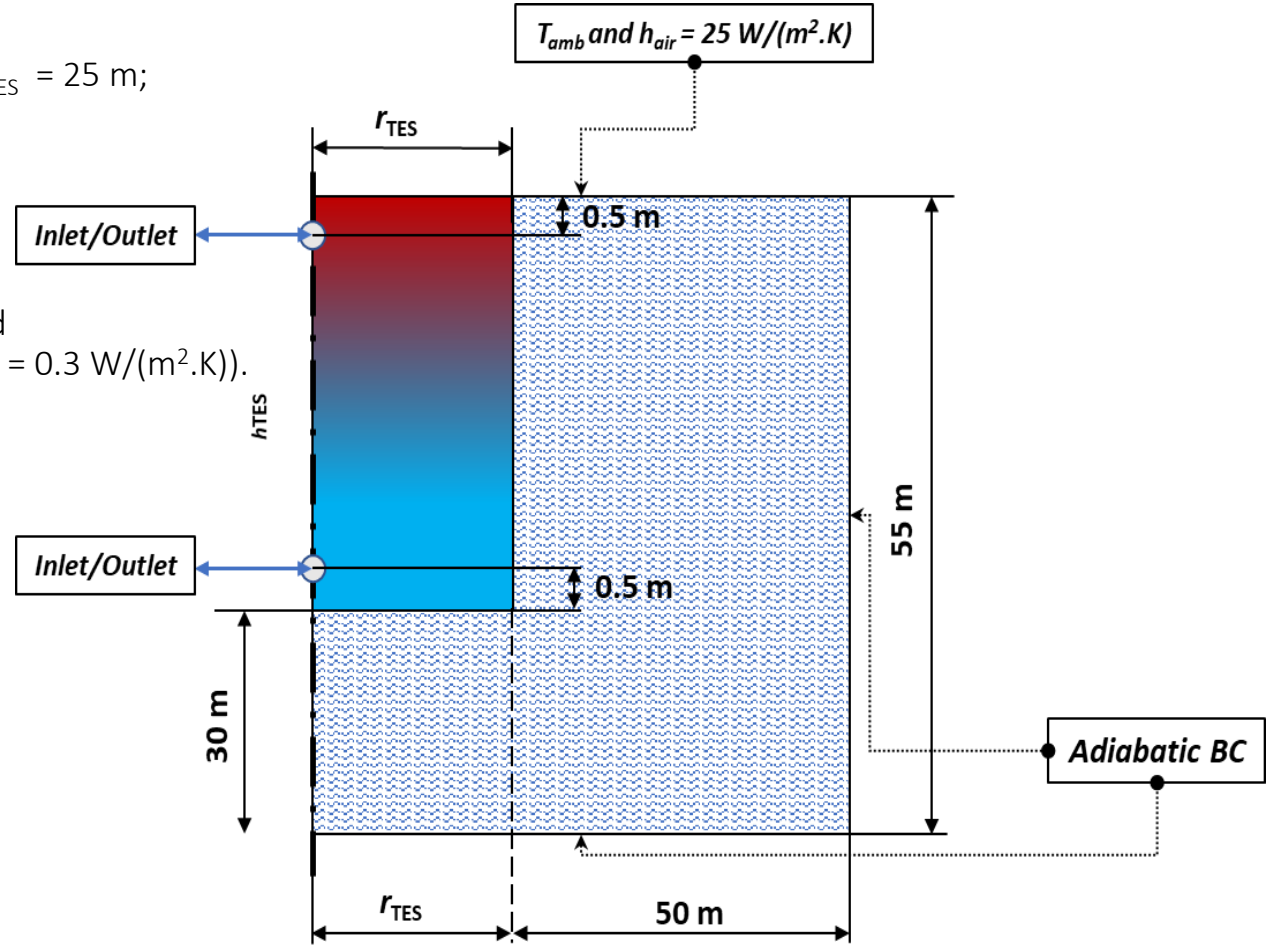
b. <u>Case 2:</u> insulated sidewall and bottom (U_{side} = U_{bottom} = 0.3 W/(m^2.K)).

Cover

a. U_{top} = 0.05 W/(m^2.K);

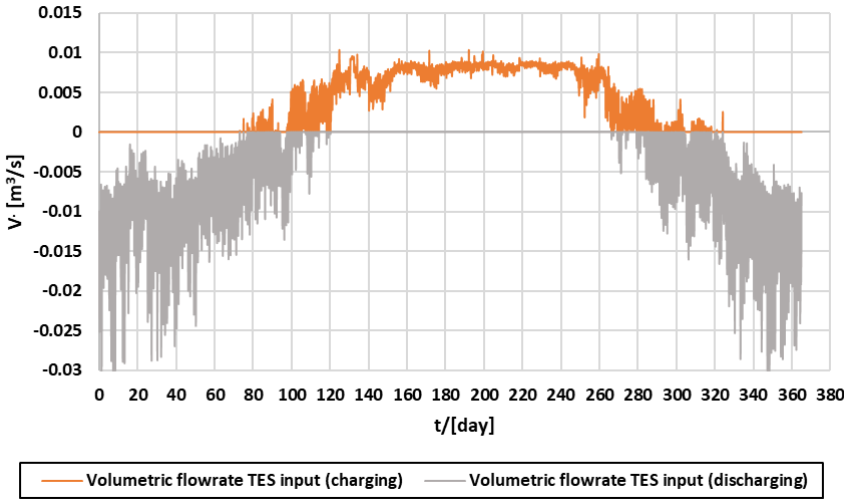
b. U_{top} = 0.1 W/(m^2.K);

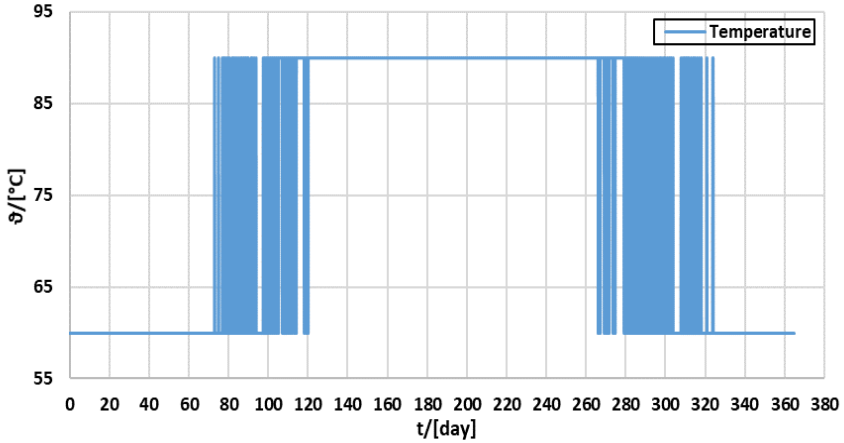
c. U_{top} = 0.15 W/(m^2.K).



TES Model Comparison - Steps

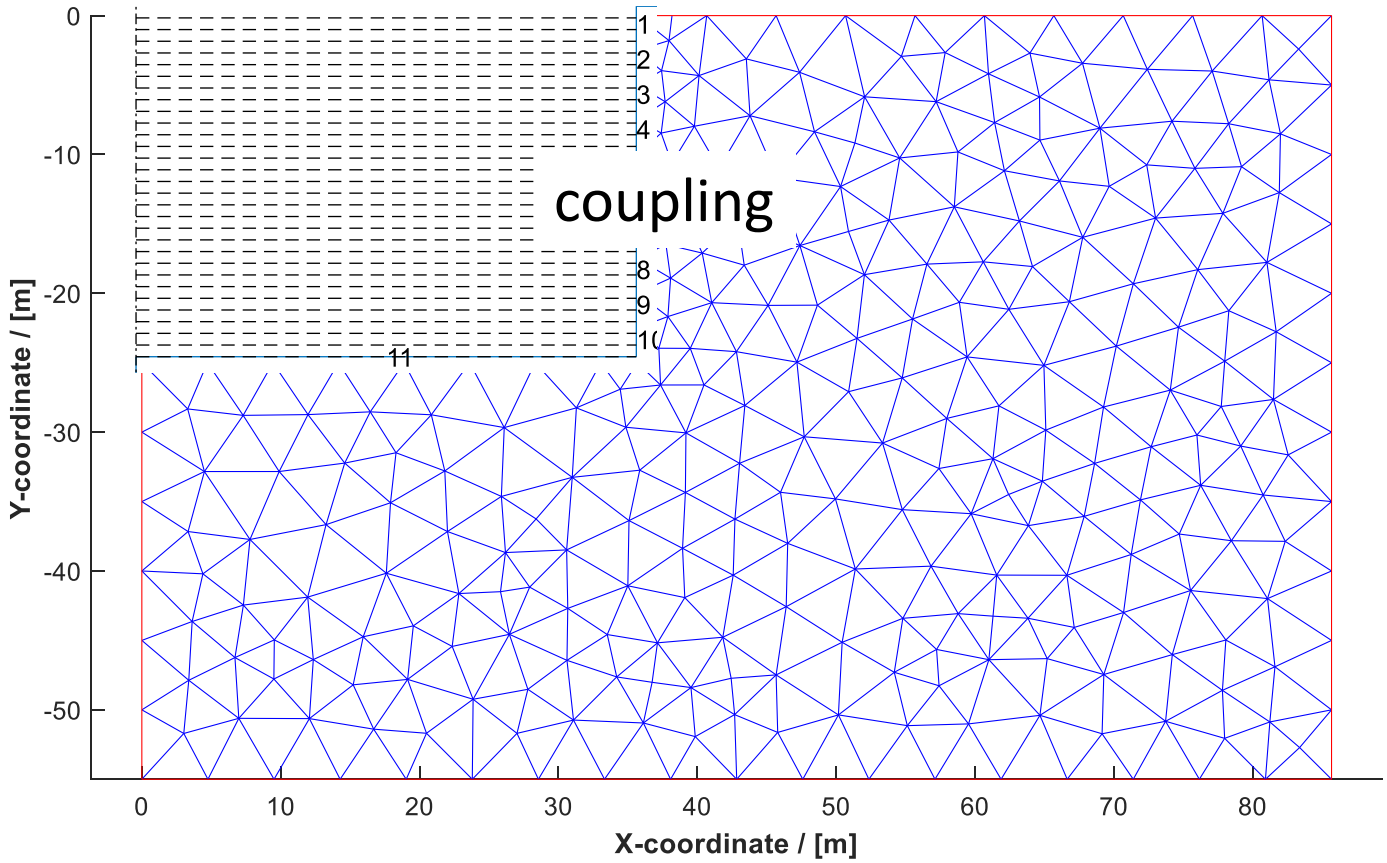
1) **Cooling Curve**
2) **Load Profile (Discharge and Charge massflow and temperature)**
3) Load Curve (Load Profile (Power, T) and Source Profile (Power, T)





Example TES Matlab/Simulink

FD fluid domain and FE solid domain



Example TES Matlab/Simulink

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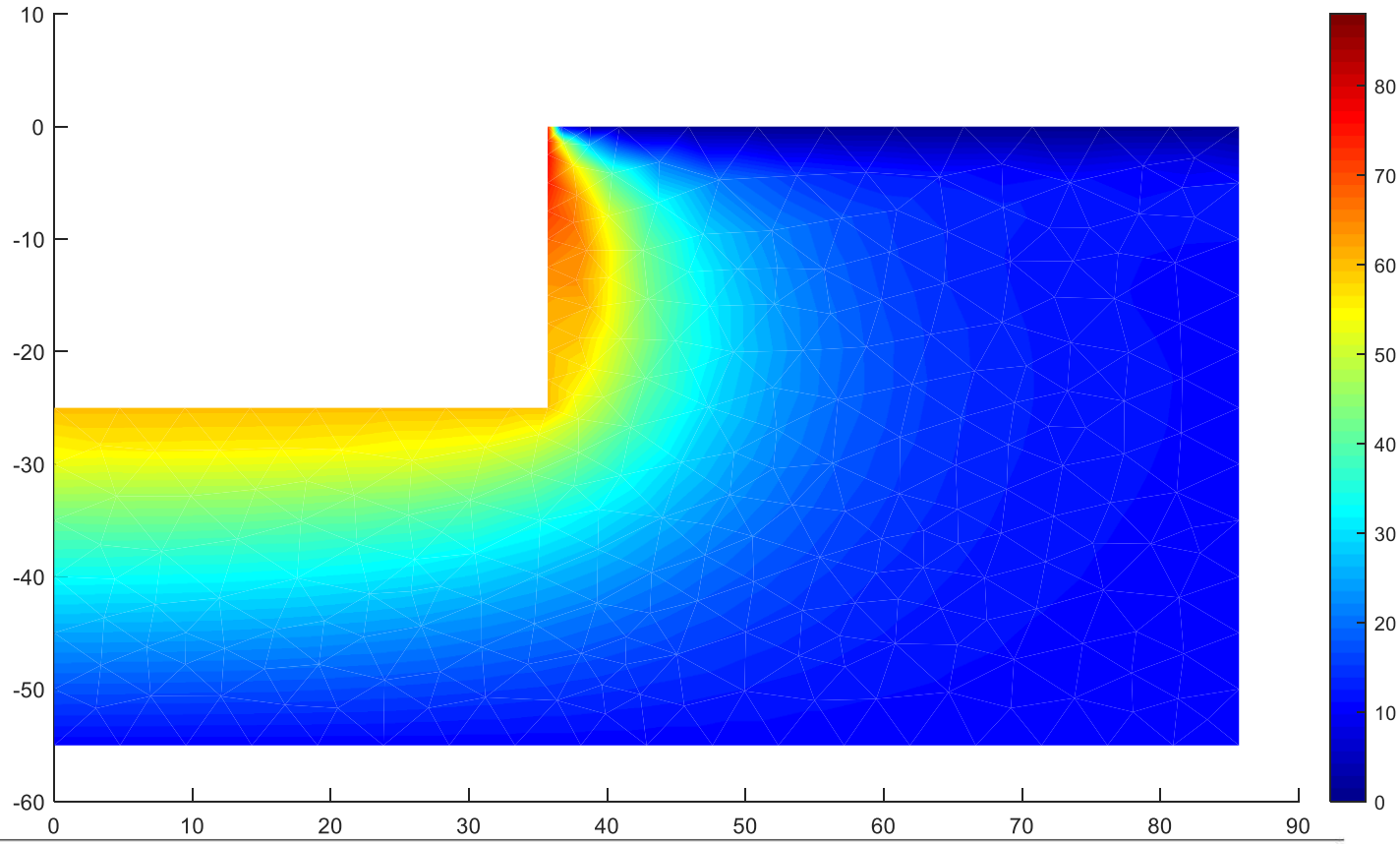
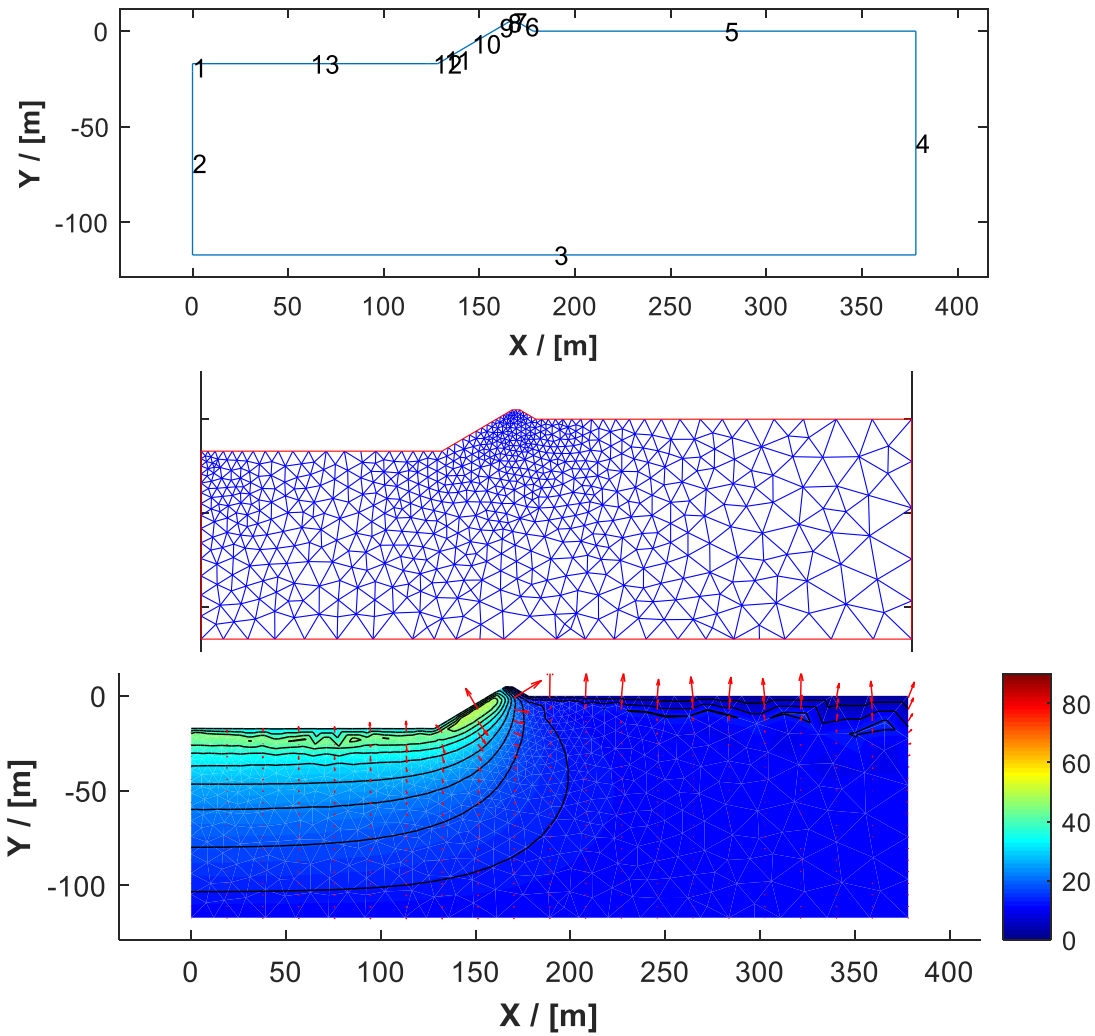
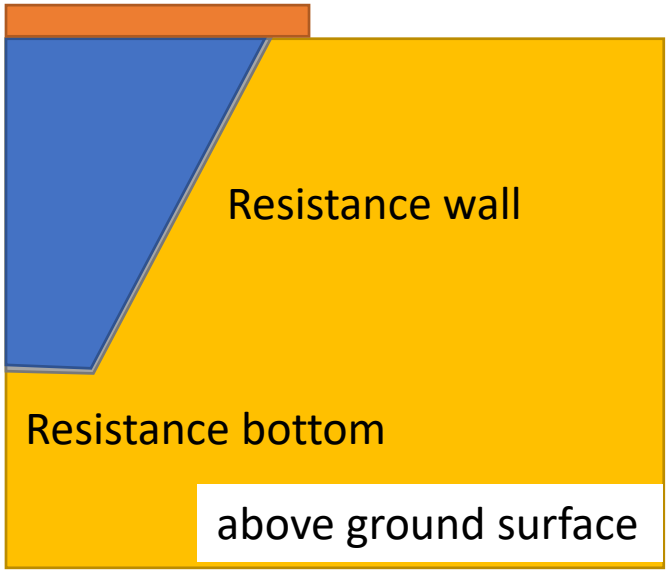


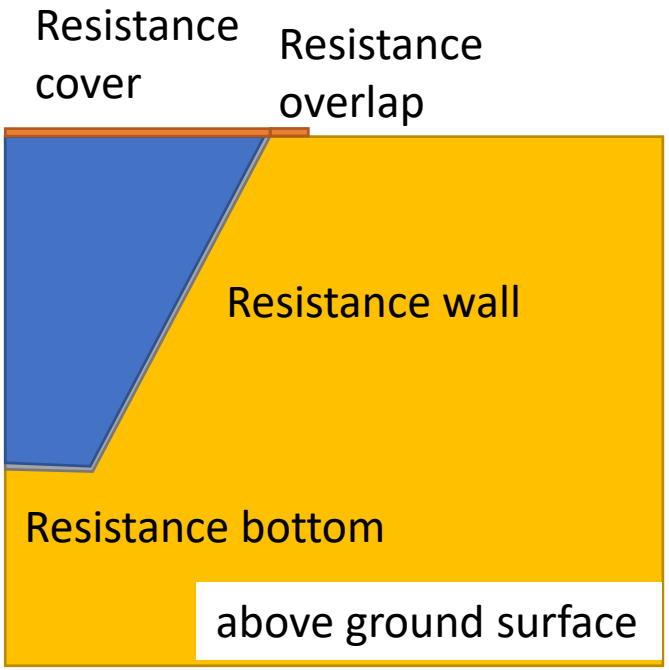
FE based TES (Comsol, Matlab/Simulink)

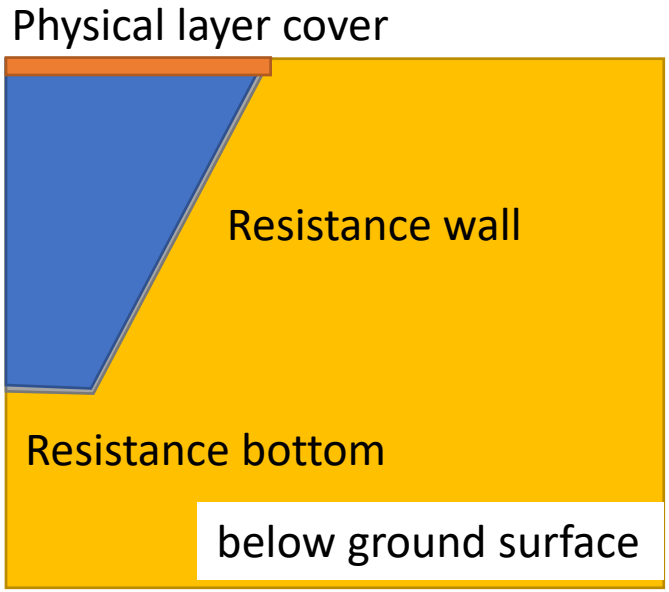
- Cylinder
- Pit
- Dam
- Hybrid
- Partially buried
- etc.

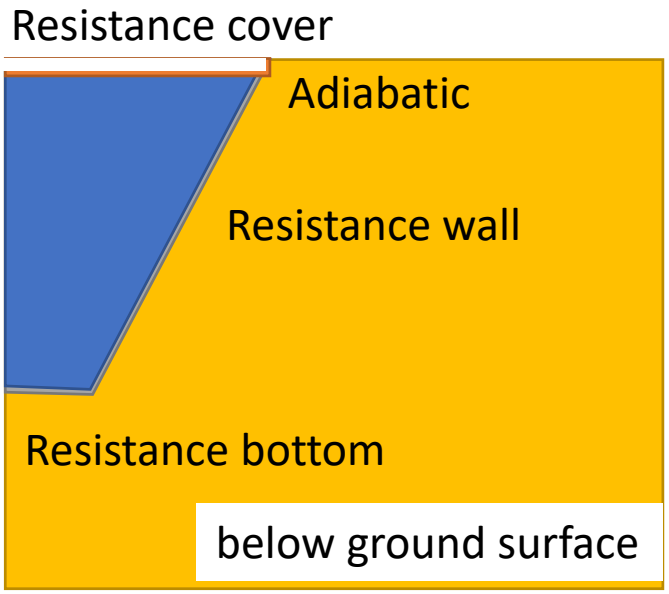


Cover and Thermal Bridge





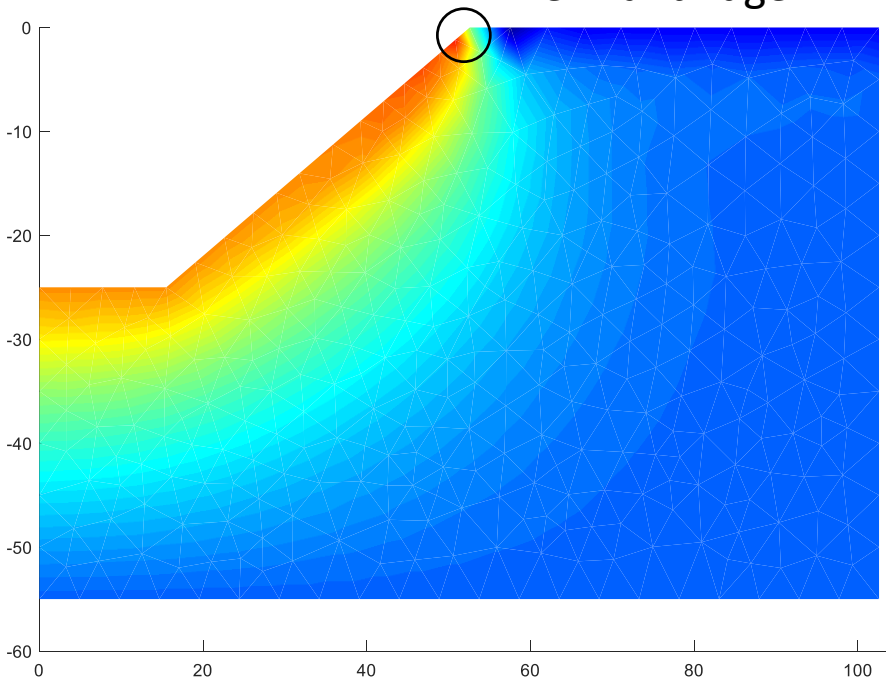




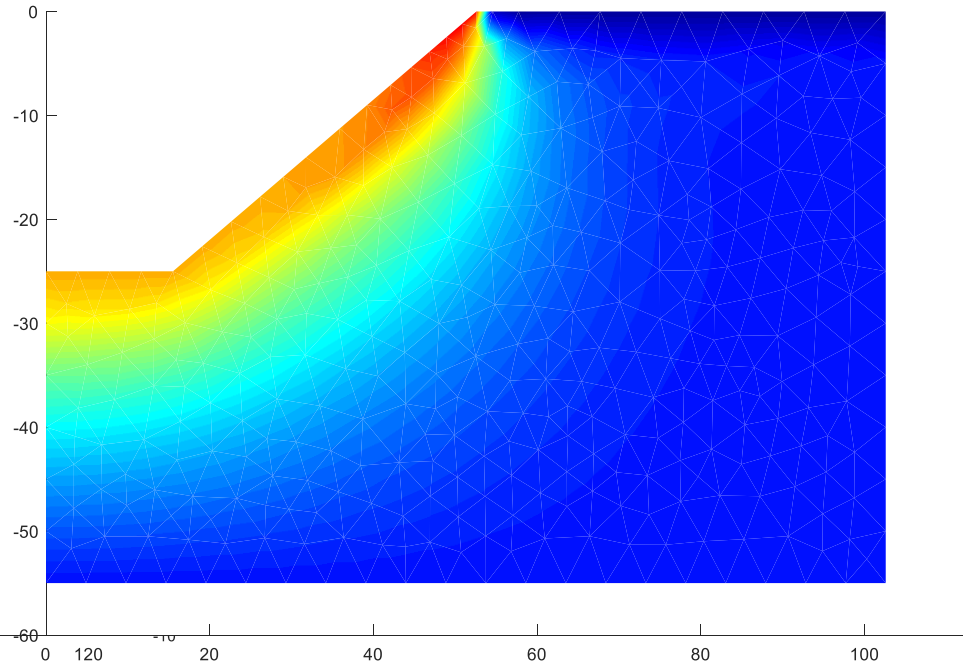
Cover insulation and thermal bridge

no overlap no insulation, cover 0.1 W/(m² K)

Thermal bridge



2 m overlap no insulation, cover 0.1 W/(m² K)

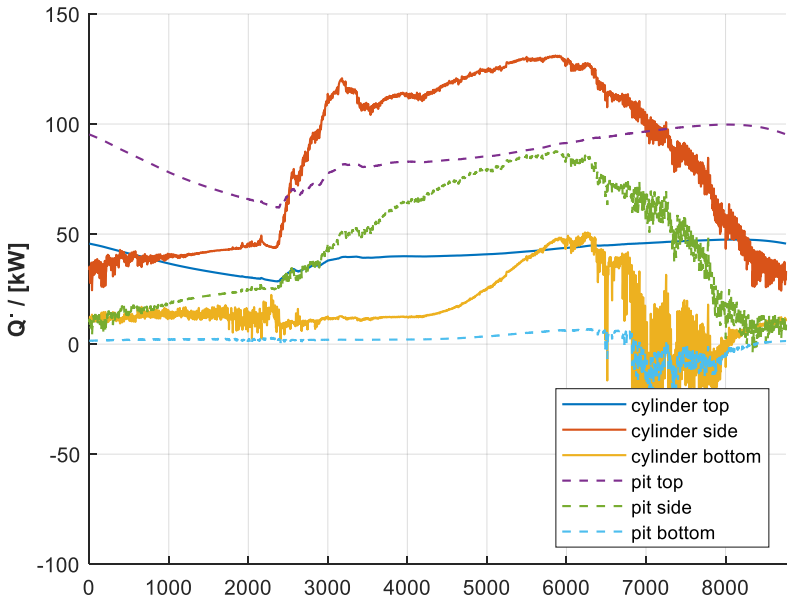


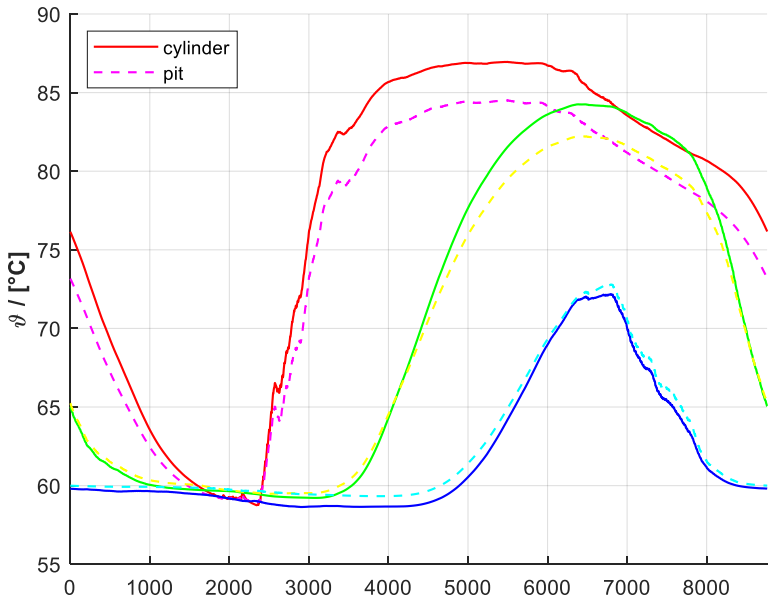
Exampl Tank (cylinder) vs. Pit (cone)

Matlab/Simulink

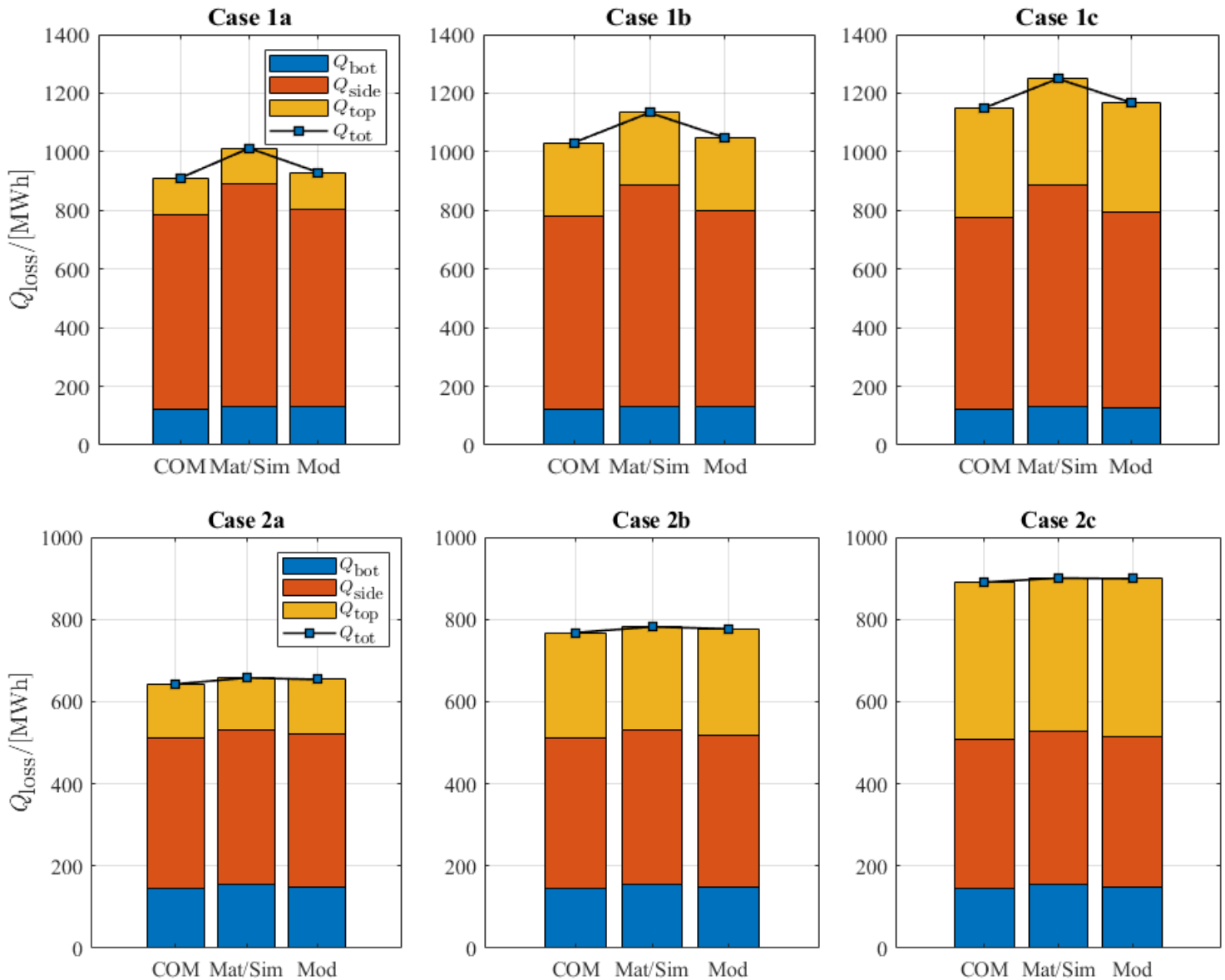
100 000 m³, 25 m, 34°

100 000 m³, 25 m, 90° (50 m, 90°)





Results


Case 1a
Case 1b
Case 1c
Case 2a
Case 2b
Case 2c
$Q_{\mathrm{loss}}/[\mathrm{MWh}]$
Q_{bot}
Q_{side}
Q_{top}
Q_{tot}
COM
Mat/Sim
Mod

Conclusions

Different TES models in different platforms available

TES model comparison reveals some defficiencies (improvements ongoing)

After paramterisation, generally good agreement

Significant differences in model flexibility and simulation speed

Further work within IEA ECES Annex 39.

Acknowledgements

This project is financed by the Austrian “Klima- und Energiefonds” and performed in the frame of the program “Energieforschung”. It is part of the Austrian flagship research project “Giga-Scale Thermal Energy Storage for Renewable Districts” (giga_TES, Project Nr.: 860949). Therefore, the authors wish to acknowledge the financial support for this work.

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