BS 2019 2-4 SEPT ROME

16th IBPSA INTERNATIONAL CONFERENCE AND EXHIBITION

universität innsbruck

INTERNATIONAL BUILDING PERFORMANCE SIMULATION ASSOCIATION

Numerical Analysis and Evaluation of Large-Scale Hot Water Tanks and Pits in District Heating Systems

Speaker:

Abdulrahman Dahash,
University of Innsbruck

Authors:

Abdulrahman Dahash, Michele Bianchi Janetti and Fabian Ochs
Unit of Energy Efficient Buildings, University of Innsbruck

gigaTES

Austrian FFG Flagship Project

- **giga_TES: Giga-Scale Thermal Energy Storage for Renewable Districts**

gigaTES

bmvit
Bundesministerium
für Verkehr,
Innovation und Technologie

FFG
FORSCHUNG WIRKT.

Contents

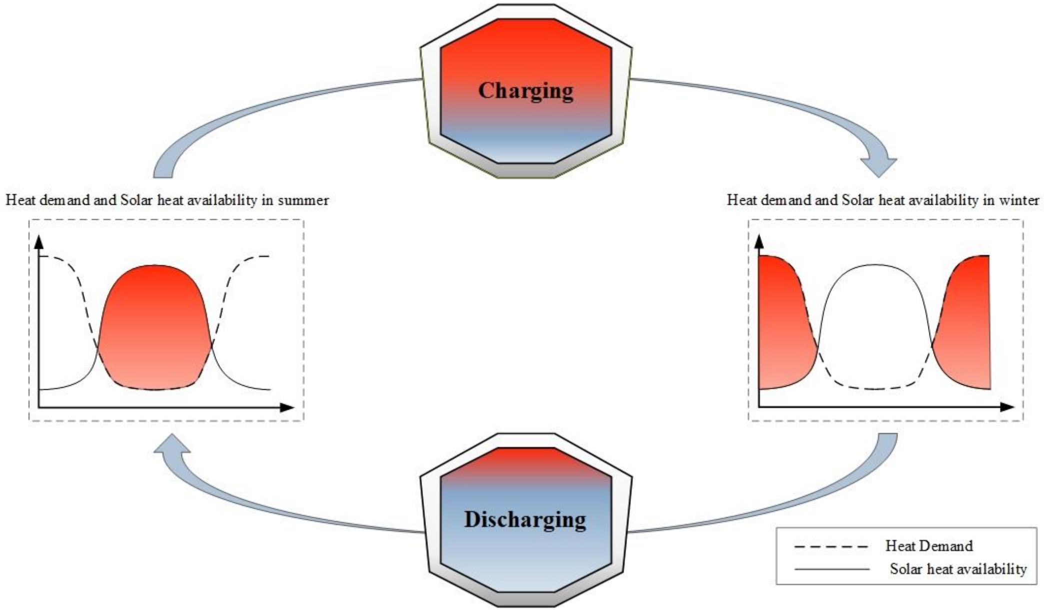
Contents

Introduction: TES in DH Systems

- Seasonal TES ➔ Bridging up the gap between energy demand and supply on seasonal pattern.

- Different types:
  - Tank TES (TTES)
  - Pit TES (PTES)
  - Aquifer TES (ATES)
  - Borehole TES (BTES)

- TTES and PTES are the core



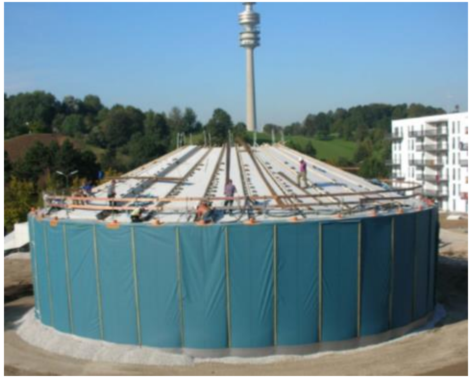
Dahash, A. et al. (2019). **Advances in Seasonal Thermal Energy Storage for Solar District Heating Applications: A Critical Review on Large-Scale Hot- Water Tank and Pit Thermal Energy Storage Systems**. *Applied Energy, 239*, 296-315. doi:10.1016/j.apenergy.2019.01.189

Introduction: Tanks in DH Systems

- DH TES Theiß:
  50 000 m³ Water
  (former oil tank)

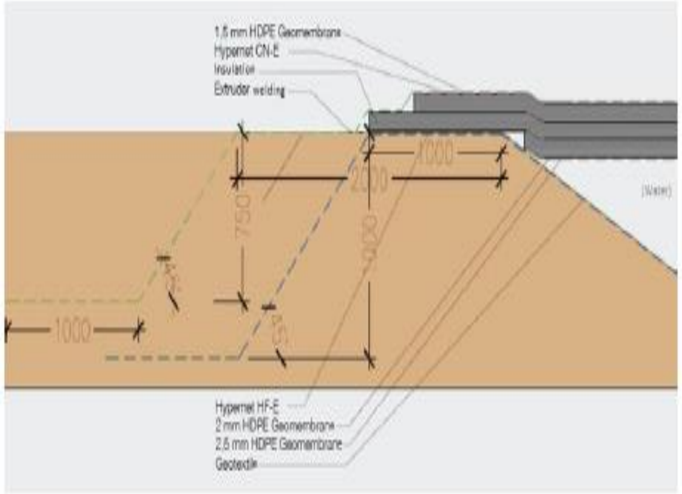
Source: Bilfinger VAM Anlagentechnik GmbH, 2013

- Construction:
  - Concrete, or stainless-steel
  - Segmented, or solid
  - Freestanding, or underground



Introduction: Pits in DH Systems

- 2012: Dronninglund (60,000 m^3)
- 2013: Marstal (75,000 m^3)
- 2015: Gram   (122,000 m^3)
- 2015: Vojens (~200,000 m^3)



Large-Scale TES in Austria

Challenges

- Space availability
- Boundary conditions (hydro-geological, political)
- Cost-effective technologies

Solution

- Provide in-depth know-how
- Set planning guidelines

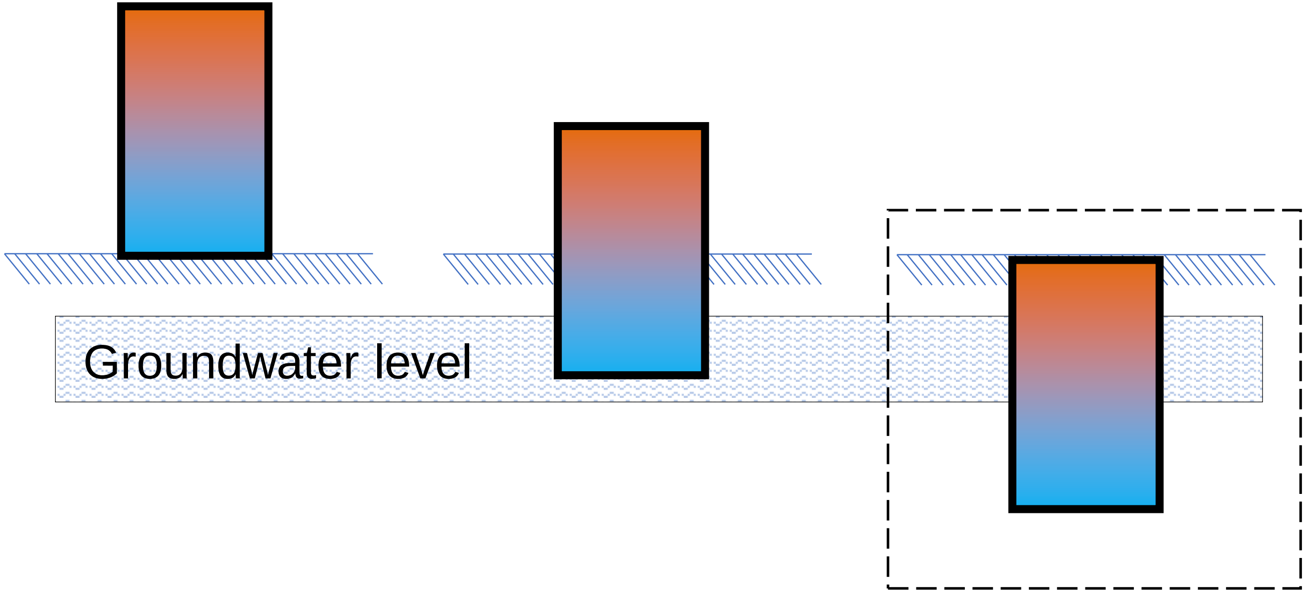
Approach

- Evaluation of STES under a wide list of BCs.

Contents

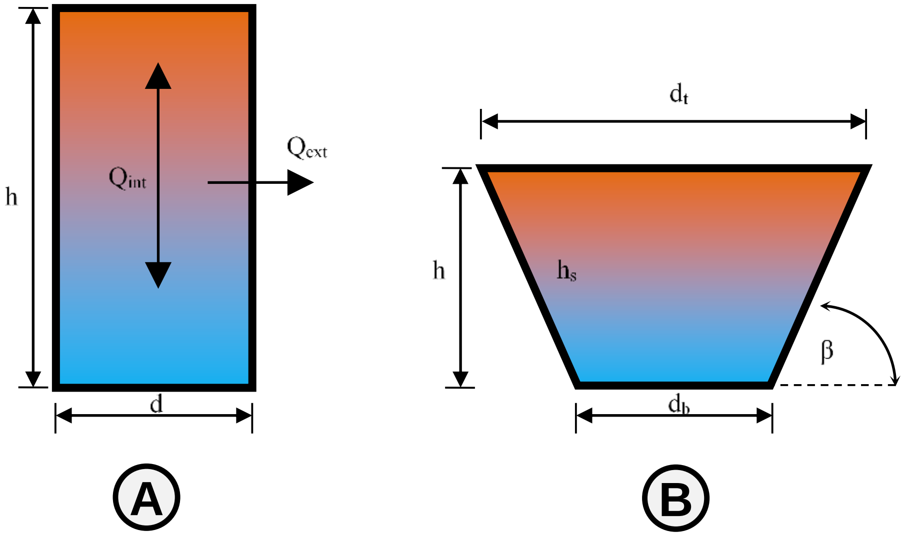
Construction of Large-Scale Hot-Water TES

- Freestanding, partially buried, buried – ground water, special heavy works



Construction of Large-Scale Hot-Water TES

- Cylinder (Tank), or
- Truncated cone or pyramid stump (Pit)



Contents

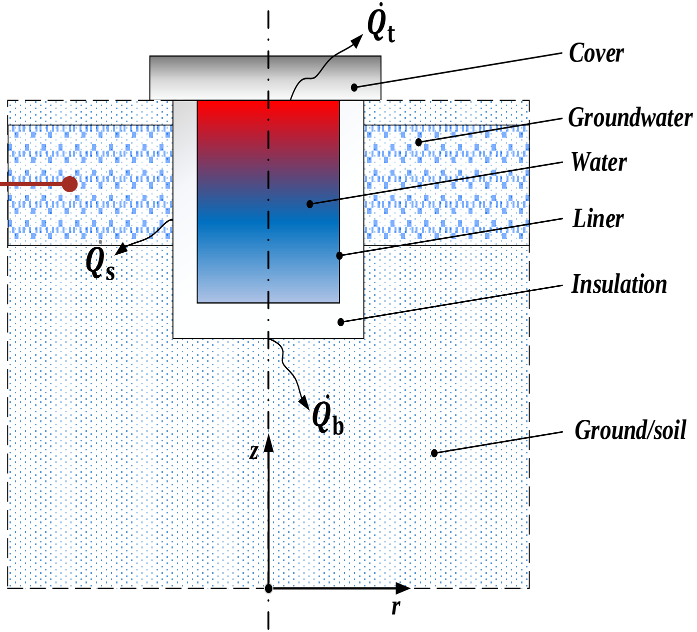
Abdulrahman Dahash, University of Innsbruck

Modeling of Large-Scale Hot-Water TES

- **<u>Modeling of STES:</u>**
  - COMSOL Multiphysics
  - 2-D axisymmetric ➔ no groundwater
  - 3-D ➔ with groundwater
    - Darcy's law:

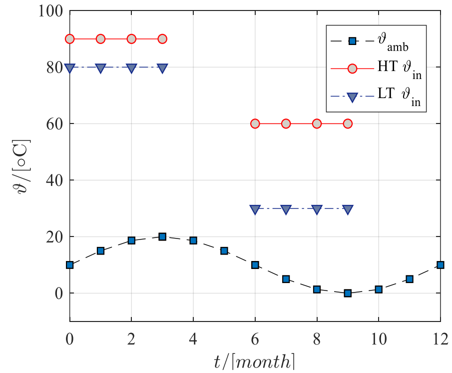
$$\frac{\partial}{\partial t}(\rho \epsilon_{\mathrm{p}}) + \nabla \cdot (\rho u) = G_{\mathrm{m}}$$

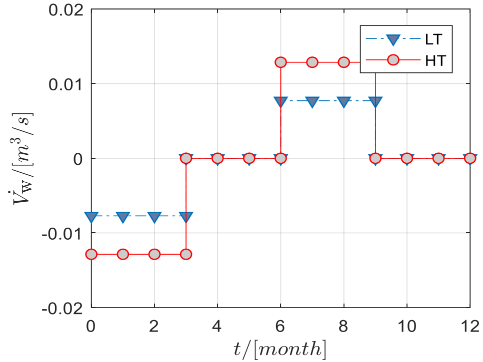
$$u = -\frac{k}{\mu} \nabla p$$



Modeling of Large-Scale Hot-Water TES

- **STES operation:**
  - High temperature (HT) 90/60°C
  - Low temperature (LT) 80/30°C
  - Phases: charging, standby, discharging and idle, each with 3 months.





- **STES construction:**
  - Tank (with diaphragm wall), pit (sloped wall of 60°)
  - With or without insulation

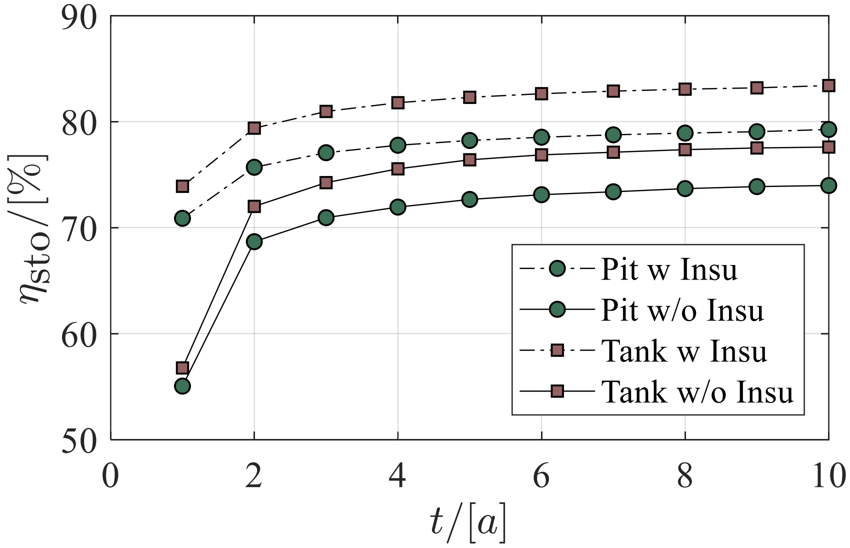
Contents

Influence of TES Geometry and Insulation Level

- V_{TES}= 100,000 m^3, 10 years of operation
- Tank **<u>outperforms</u>** pit under same BCs
- Start-up phase up to **<u>3 years</u>**
- Insulation cost?

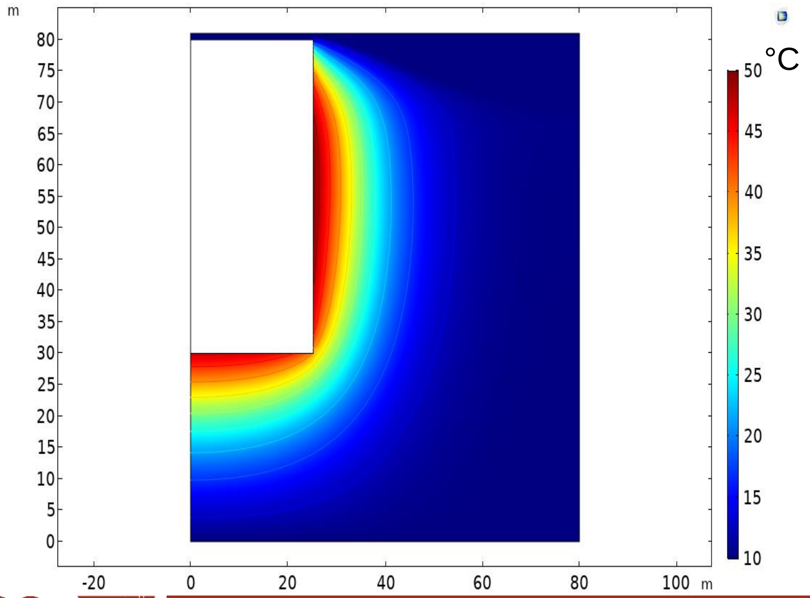
$$\eta_{\mathrm{sto}} = 1 - \frac{\sum_{i=1}^{t} Q_{\mathrm{loss}}}{Q_{\mathrm{sto}}}$$

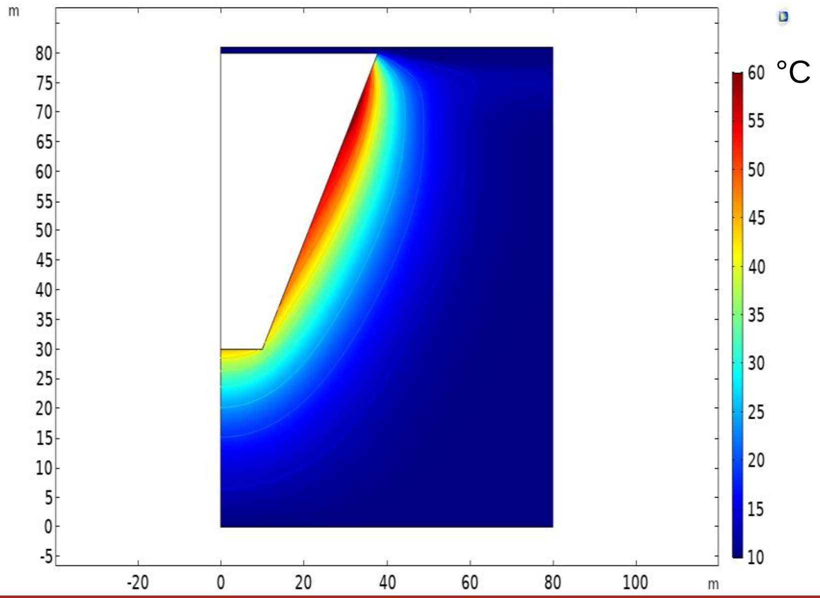
- With insulation (cover, side and bottom)
- Without insulation (only cover)



Influence of TES Geometry and Insulation Level

- V_{TES}= 100,000 m³, insulated TES
- Could be worst w/o insulation



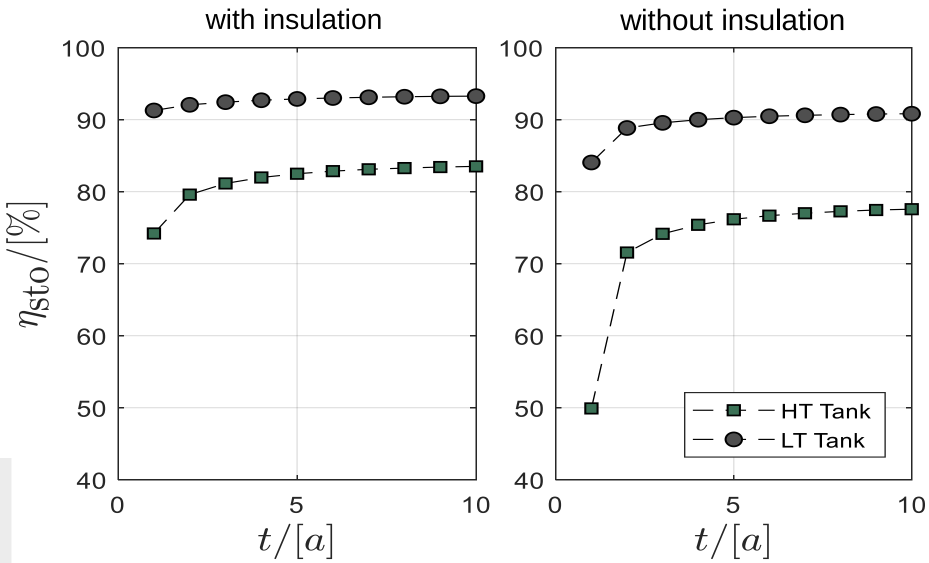


Influence of DH System

- Tank with 100,000 m^3, 10 years of operation
- Lowering DH temperature ➔ better TES performance under same BCs

$$\eta_{sto} = 1 - \frac{\sum_{i=1}^{t} Q_{loss}}{Q_{sto}}$$

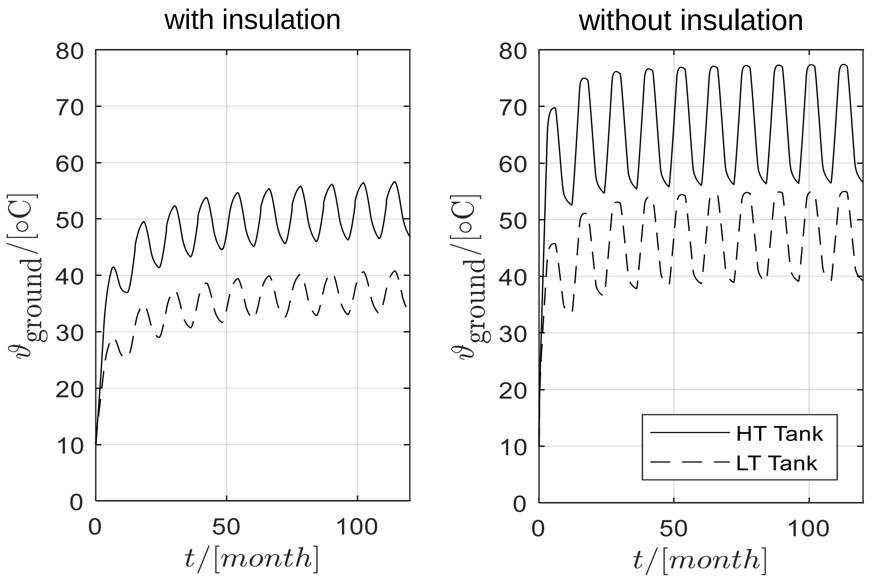
- With insulation (cover, side and bottom)
- Without insulation (only cover)



Ochs, F., Dahash, A., Bianchi Janetti, M.(2019). **The Challenge of Planning and Constructing Large-Scale Hot Water TES for District Heating System: A Techno-Economic Analysis**. *IRES 2019: 13th International Renewable Energy Storage Conference* . Düsseldorf (Germany), 12-14 March 2019.

Influence of DH System

- Tank with 100,000 m^3, 10 years of operation
- Optimistic case: LT-DH with insulation ➔ ground temperature reaches 40°C
- Insulation is needed only to protect the ground

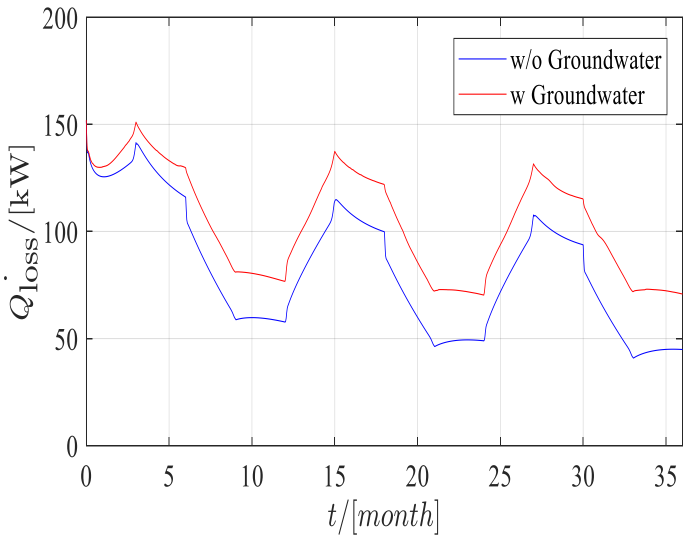


- With insulation (cover, side and bottom)
- Without insulation (only cover)

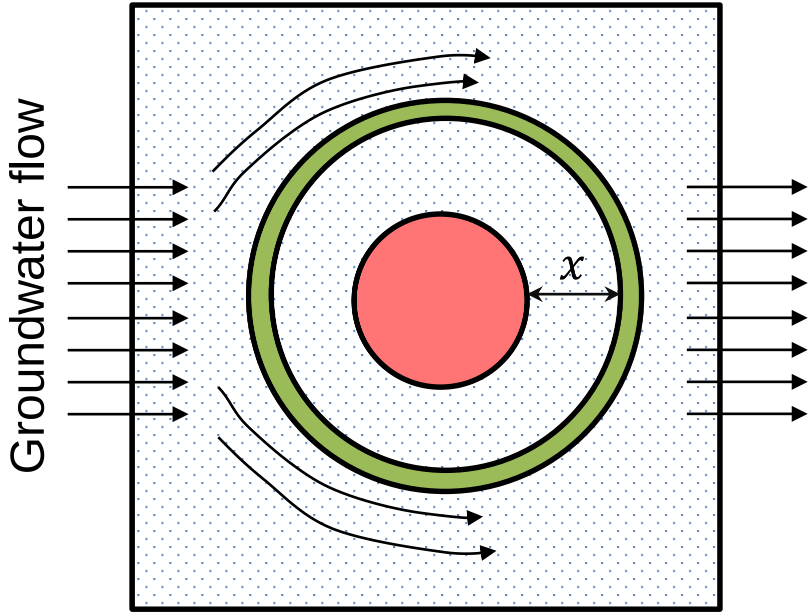
Ochs, F., Dahash, A., Bianchi Janetti, M.(2019). **The Challenge of Planning and Constructing Large-Scale Hot Water TES for District Heating System: A Techno-Economic Analysis**. *IRES 2019: 13th International Renewable Energy Storage Conference* . Düsseldorf (Germany), 12-14 March 2019.

Influence of Groundwater

- BCs: Tank, 100,000 m³ , high temperature DH (90/60°C)
- 3 years of operation
- Groundwater: u = 0.0002 m/s

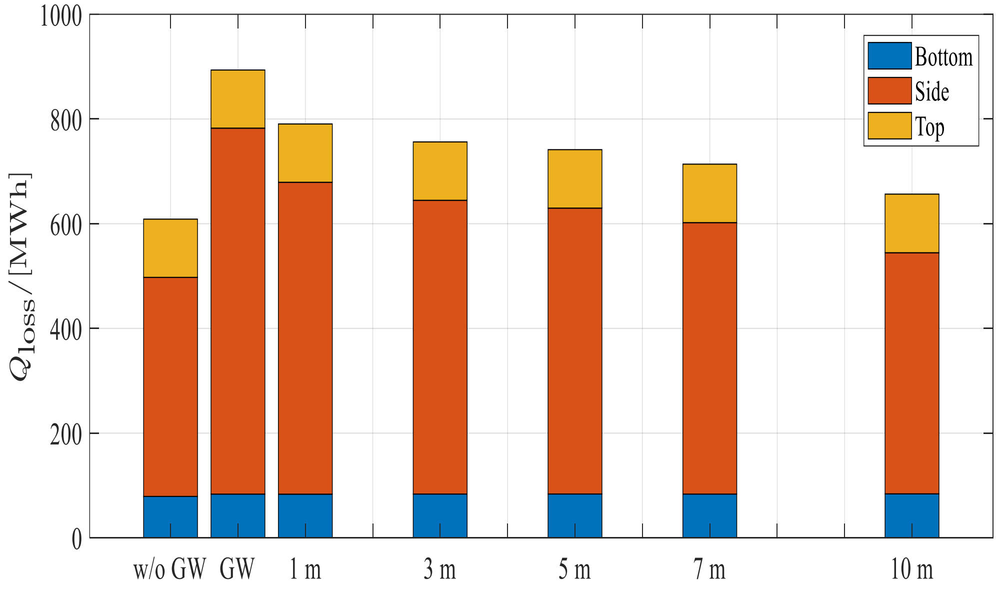


- Cut-off walls?



Influence of Groundwater

- BCs: Tank, 100,000 m^3 , high temperature DH (90/60°C)
- 3 years of operation
- Groundwater: u = 0.0002 m/s



Contents

Conclusions

- Tanks and pits are crucial for renewables-DH systems.
- Darcy’s law for modeling of groundwater.
- Tanks outperform pits under same BCs.
- Ground temperature violates the standards ➔ insulation is required only to protect the ground.

16th IBPSA International Conference and Exhibition — BS 2019, 2-4 Sept, Rome

universität innsbruck

International Building Performance Simulation Association

Numerical Analysis and Evaluation of Large-Scale Hot Water Tanks and Pits in District Heating Systems

Questions and Comments

Speaker:

Abdulrahman Dahash,

Unit of Energy Efficient Buildings, University of Innsbruck

Contacts:

Abdulrahman.Dahash@uibk.ac.at