Willkommen
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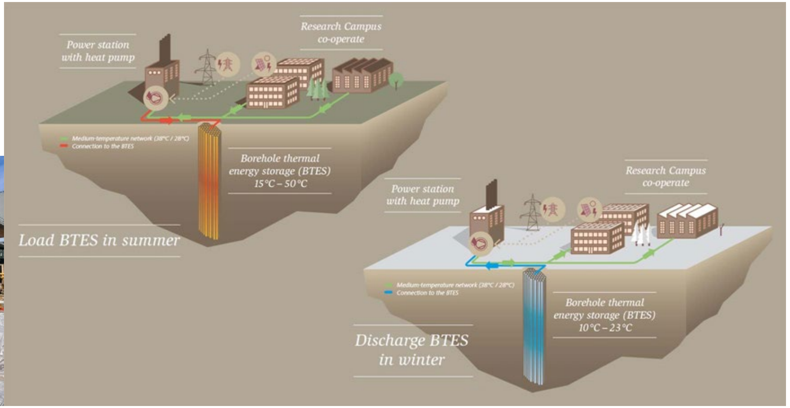
LeSoPot

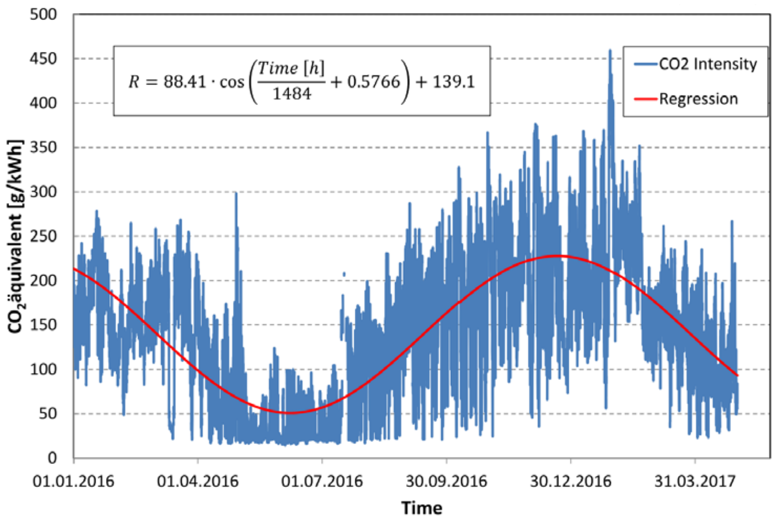
Leveraging solar potential and waste heat utilization in buildings with a high temperature borehole thermal energy storage (BTES)

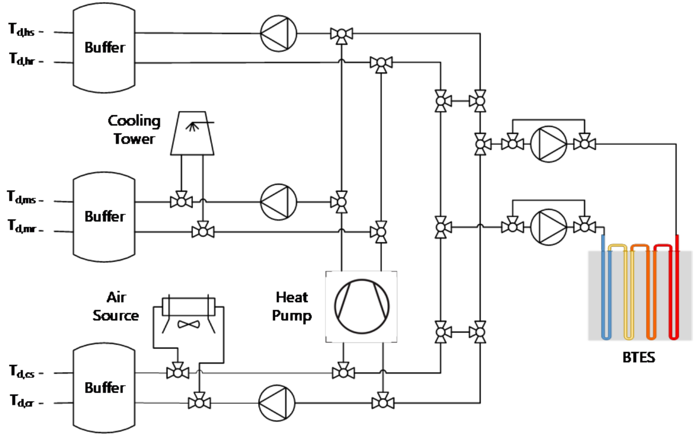
Massimo Fiorentini



LeSoPot Intro

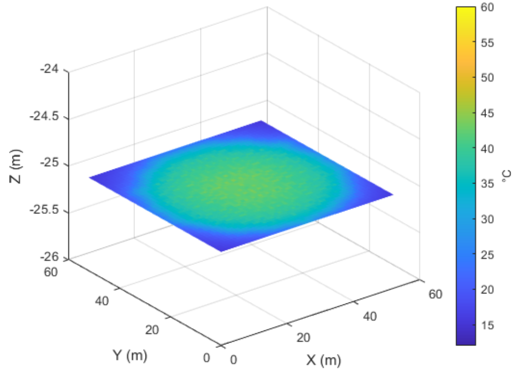
- Goal: finding optimal energy system configurations with a BTES to leverage the solar potential to minimize CO2 emissions.
- Hypothesis: a higher temperature BTES (compared to current low temp std) can enable lower yearly CO2 emissions
- Two research problems, i) operational, ii) design/sizing.

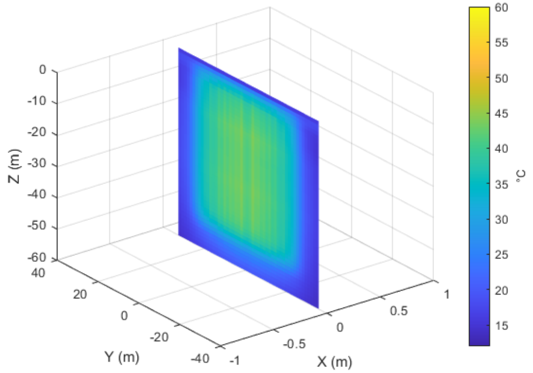




LeSoPot Intro

- TRNSYS Superposition borehole model: 8 years -> ~8 hours of sim
- Need for a modelling and optimization approach for both operation and sizing problems
- Optimize considering boundary conditions such as dynamic CO2 emissions





LeSoPot - Operational

Control optimization (MPC)

- Predict future behaviour using a model, given measurements of states and disturbances and hypothetical future input trajectory.
- Inputs are used to optimize a predicted cost.
- First control input of the optimal sequence is implemented and the process is repeated (feedback).

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Higher initial temperature of swing:

- (+) higher discharging temperature (and HP efficiency)
- (-) higher charging temperature (lower chiller efficiency), higher thermal losses

Larger temperature swing amplitude:

- (+) storage capacity, higher discharging temperature
- (-) higher th. losses, higher charging supply temperature

higher flowrate:

- (+) higher heat transfer rate
- (-) higher el. consumption

In-series vs in-parallel:

- (+) lower th. losses, less tot flow
- (-) lower heat transfer/capacity, higher pumping losses
- higher core temperature

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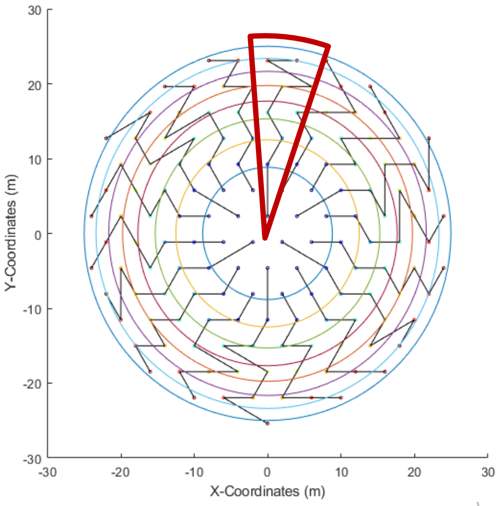
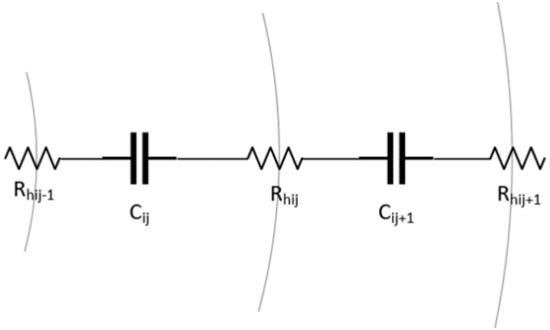
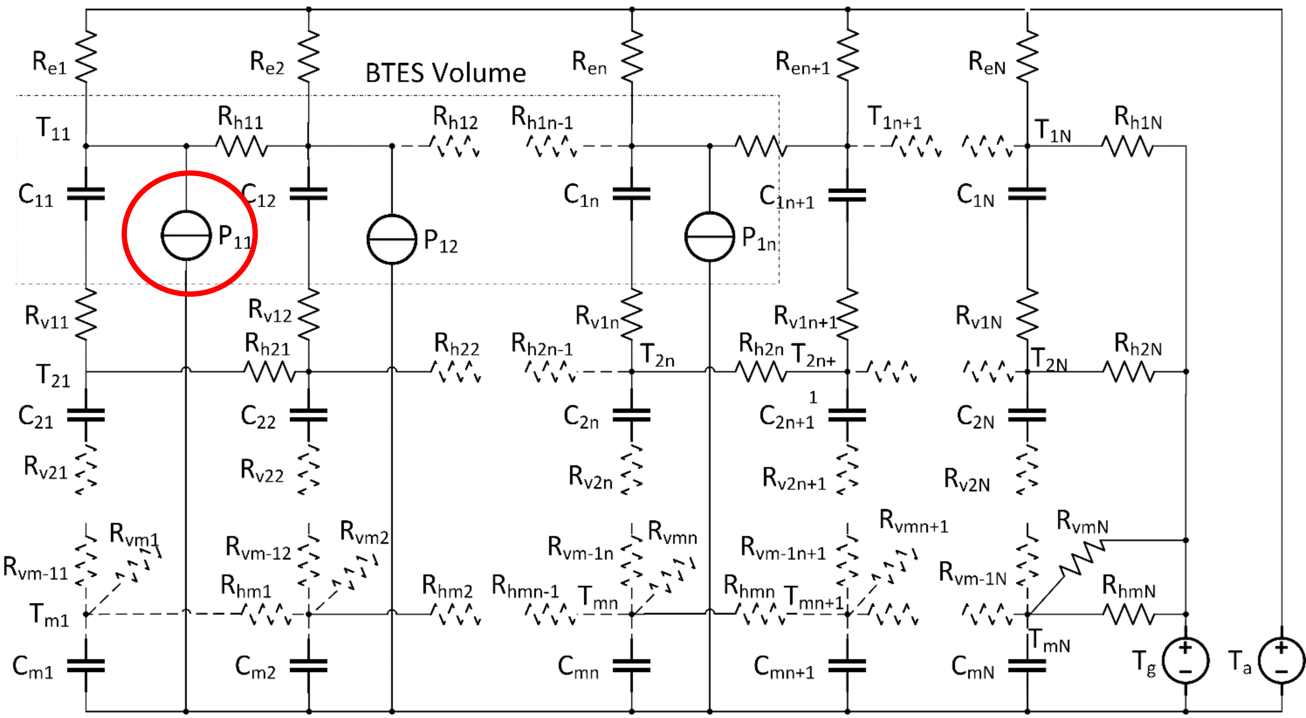


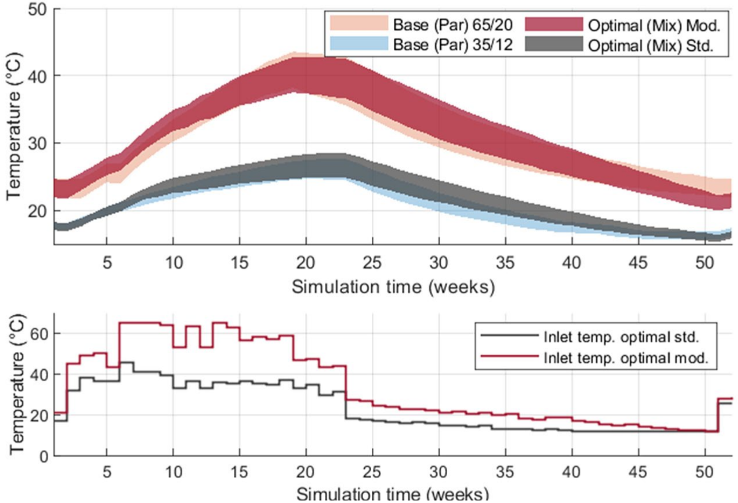




Ref: [1] Fiorentini, M., & Baldini, L. (2021).

LeSoPot - Operational

- Two CO2 intensity profiles tested, 1 standard and 1 with summer reduced by 2/3 → Objective minimize operational CO2
- Lower relative intensity in summer compared to the one in winter leads to a higher optimal operating temperature of the storage
- Charging with rejected heat from cooling only, emissions reduced by 13%-20% (only BTES contrib.)



Ref: [1] Fiorentini, M., & Baldini, L. (2021).

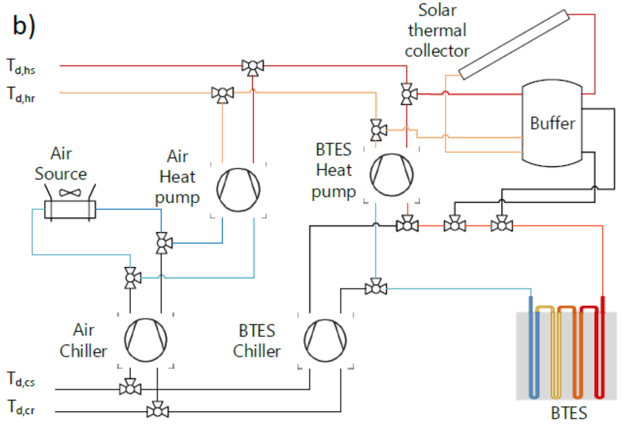
LeSoPot - Design

- Typical energy-hub-like approaches use defined capacity, do not model temperature evolution – see [4]

- Optimal sizing of solar thermal collectors area, and volume of the BTES, heat pump and chillers thermal capacity.

- Optimal operating conditions (e.g. temperature evolution of BTES)

- **Objective:** minimizing capital + operational + CO_2 emissions costs (10 prices, 50€/t - 500€/t)



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- Approached with a simpler model, single capacitance and losses calculated as in [5].
- Sizes of BTES discretized, COP of HP and chiller linearized.
- Maximum heat transfer function of supply temperature and # GHXs

$$
\begin{cases}
T_s(k+1) = T_s(k) + \frac{\Delta t}{M_{gr} V_j}\big(P_{th,ch\_BT}(k) - P_{th,hp\_BT}(k) + \\
\qquad P_{th,sol\_tr}(k) - U_i A_{BT,j}(T_s(k) - T_a(k)) - k_{gr} h \frac{D_j}{2}(T_s(k) - T_g)\big) \\
P_{th,ch\_BT}(k) <= UA_j \Delta T_{ch} \\
P_{th,hp\_BT}(k) <= UA_j \Delta T_{dis} \\
P_{sol,tr}(k) <= UA_j (T_{sol} - T_s(k)) \\
J_{BT} = D_j n_{GHX,j} \lambda_{GHX} \omega_{BT}
\end{cases}
$$

Ref: [2] Fiorentini, M., Heer, P., & Baldini, L. (2022).
Ref: [3] Fiorentini, M., Vivian, J., Heer, P., & Baldini, L. (2022).
Ref: [5] Hellström, G. (1991).

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Result set #1: with solar

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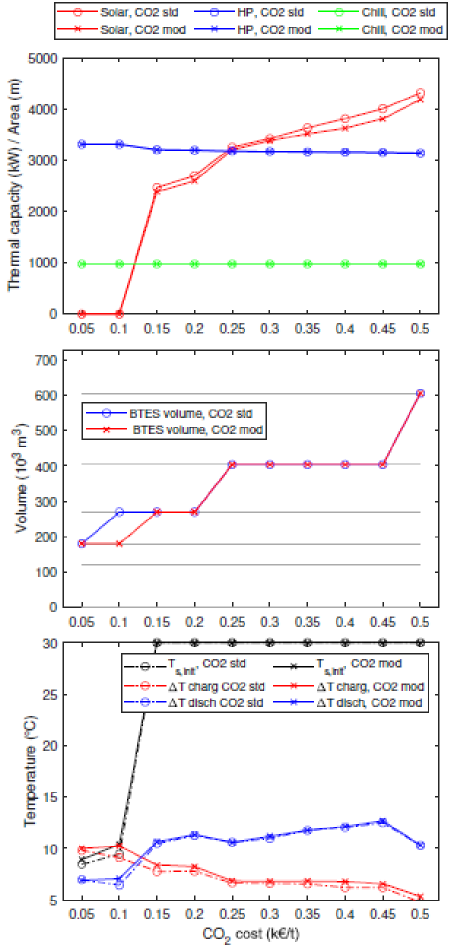

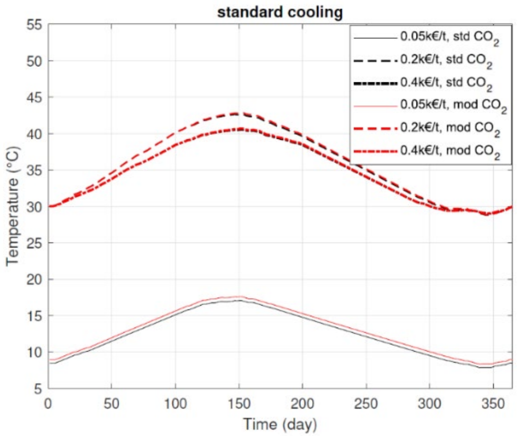

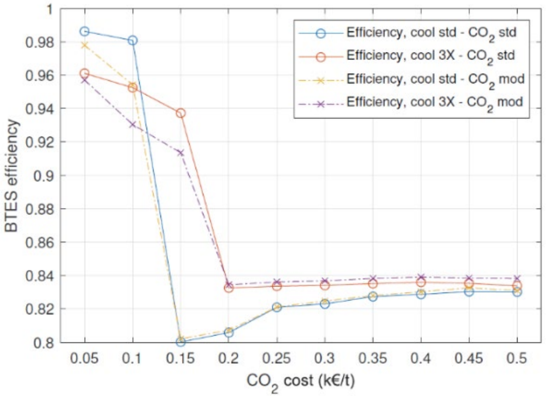

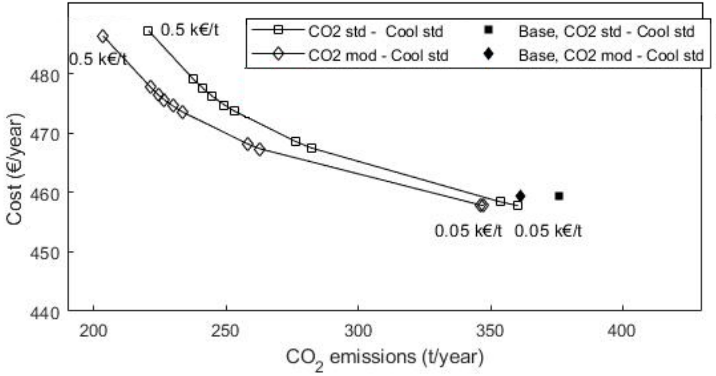

Ref: [2] Fiorentini, M., Heer, P., & Baldini, L. (2022).

Thank you for your attention

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References

[1] Fiorentini, M., & Baldini, L. (2021). Control-oriented modelling and operational optimization of a borehole thermal energy storage. *Applied Thermal Engineering*, *199*, 117518. https://doi.org/10.1016/J.APPLTHERMALENG.2021.117518

[2] Fiorentini, M., Heer, P., & Baldini, L. (2022). Design optimization of a district heating and cooling system with a borehole seasonal thermal energy storage. *Submitted*.

[3] Fiorentini, M., Vivian, J., Heer, P., & Baldini, L. (2022). Design and optimal integration of seasonal borehole thermal energy storage in district heating and cooling. *CLIMA 2022 Conference*. https://doi.org/https://doi.org/10.34641/clima.2022.64

[4] Wirtz, M., Kivilip, L., Remmen, P., & Müller, D. (2020). 5th Generation District Heating: A novel design approach based on mathematical optimization. *Applied Energy*, *260*, 114158. https://doi.org/10.1016/j.apenergy.2019.114158

[5] Hellström, G. (1991). Ground heat storage: Thermal analyses of duct storage systems. *Lund University*, 310. http://search.proquest.com/docview/303983441?accountid=14357

[6] Empa Campus BTES construction: https://www.empa.ch/web/s604/eq73-waermedepot