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Triple well ATES system

Analysis of feasibility of a self-supporting ATES

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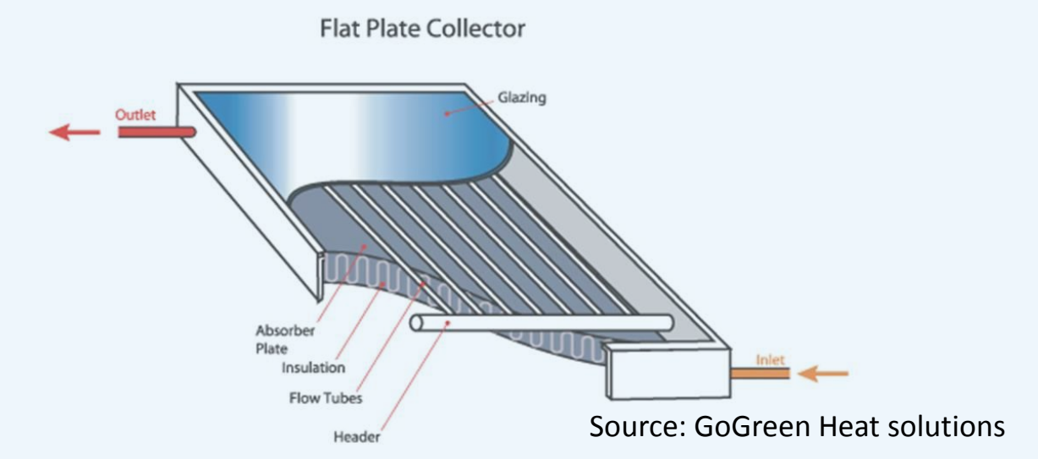
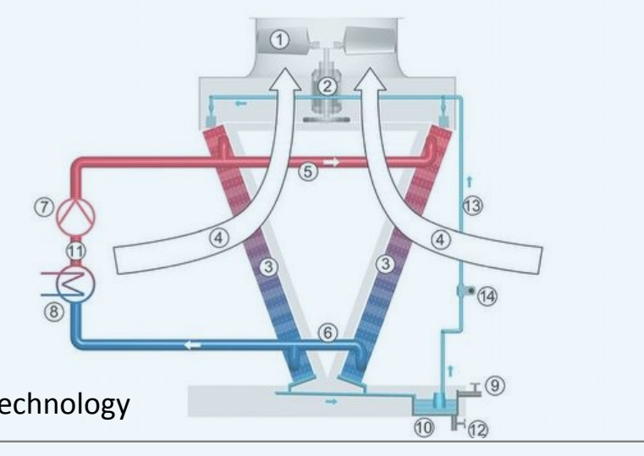
Concept of an ATES Triplet



Source: GoGreen Heat solutions

Solar Heat Collector
Transforms incoming solar radiation into heat.

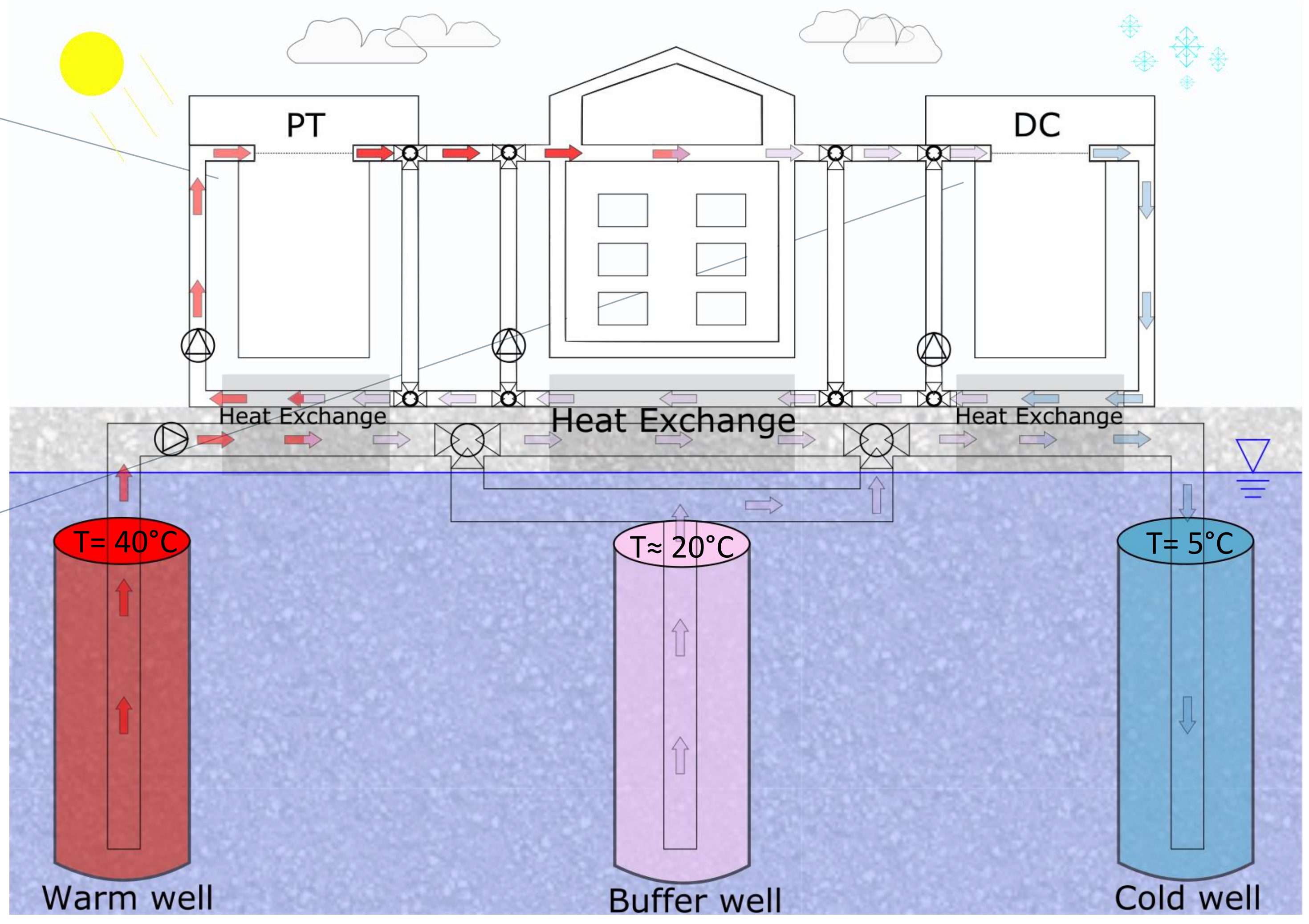
Charge of warm well depending on climatologic conditions:
- Incoming Radiation → Charge Warm from Cold or Buffer
- No incoming Radiation → Use Buffer Well



Source: Jaeggi Hybridtechnology

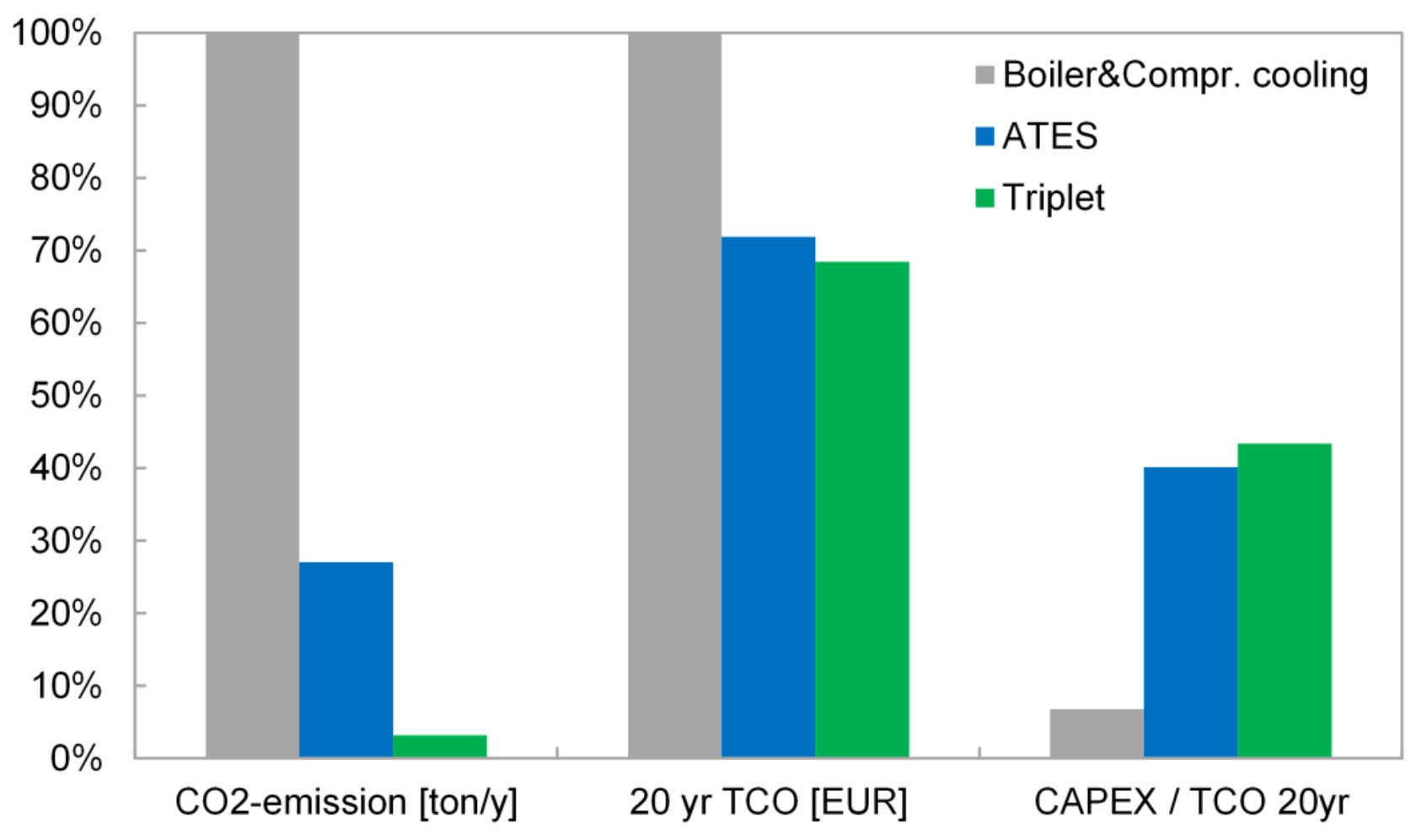
Dry Cooler
Uses ambient air temperature to cool down water.

Charge of cold well from dry cooler:
- if $T_{air} < 4°C$ → Charge Cold from Warm or Buffer
- if $T_{air} > 4°C$ → Use Buffer Well



Benefits ATES Triplet

Benefits compared to conventional ATES and space conditioning:
- Direct heating and cooling from wells
- No need for a heat pump
- Additional savings on operational costs



Based on: Dutch energy production, prices and emission rates.
CO2 emission from production not taken into account.

Analytic Triplet Model & Heat Demand

Approach

An analytic model is developed in order to describe the interaction between the wells based on the following equations:

Heating/cooling demand
=
Exchanged Heat (MWh)

Temperatures coming in and out heat exchange $(°C)$

Pumping rate $(m^3 \cdot h^{-1})$

$$Q_{HE} = C_w \cdot u \cdot \left(T_{HE}^{out} - T_{HE}^{in}\right) \cdot \Delta t \qquad (1)$$

Length of the time period (h)

Heat capacity $(MWh \cdot m^{-3} \cdot K^{-1})$

Emperical loss term $(°C)$

Temperature at time i $(°C)$

Average temperature added $(m^3 \cdot °C)$

$$T_{well}^{i} = \frac{T_{well}^{i-1} \cdot V_{well}^{i-1} + T_{in}^{i-1} \cdot dV_{in}^{i-1} - \alpha\left(T_{well}^{i-1} - T_{ambient}\right)}{V_{well}^{i-1} + dV_{in}^{i-1}} \qquad (2)$$

Initial + added volume (m^3)

Average temperature that was in $(m^3 \cdot °C)$

Setup analytical relations

Export pumping rates to Modflow

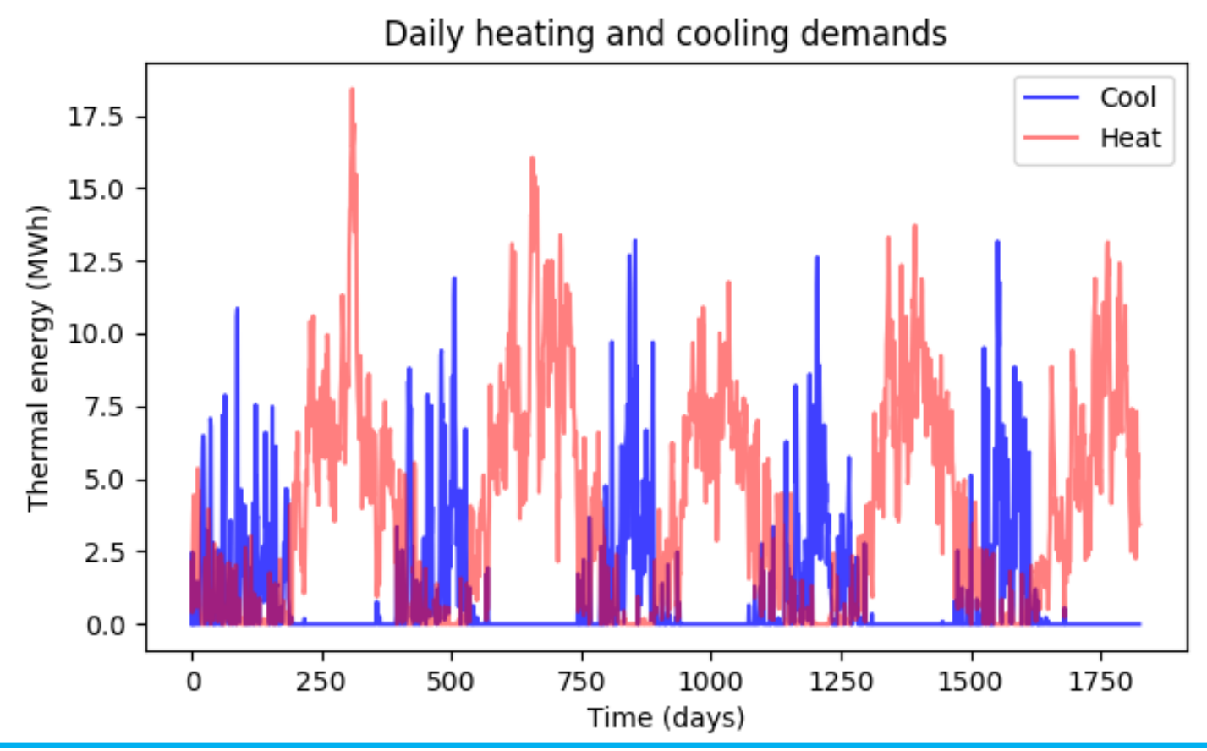
Compute subsurface temperature profiles

Analyse subsurface processes

Asses feasibility

Energy Demand & Analytic Model Output

Demand determined based on:
- Building type and surface area
- Local weather variability (de Bilt, the Netherlands)
- Distribution with Heat Degree Days method.

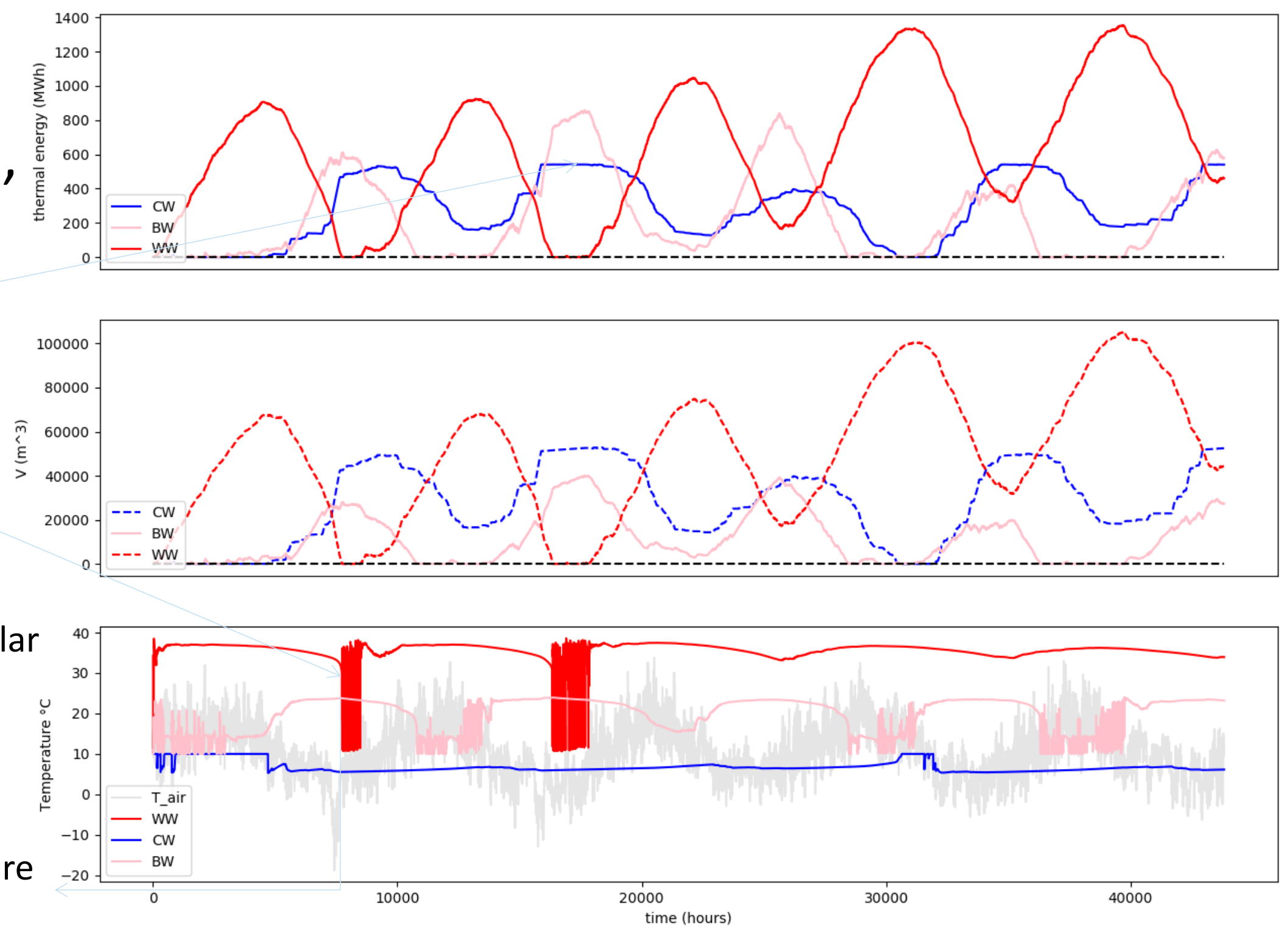


Analytic Model Outputs:
- Hourly variation in Thermal Energies, Volumes and Well Temperatures
- Maximum thermal energies
- Cut-off temperatures
- Pumping rates

Results:
- Determine minimal solar heat collector area
- Minimum dry cooler capacity

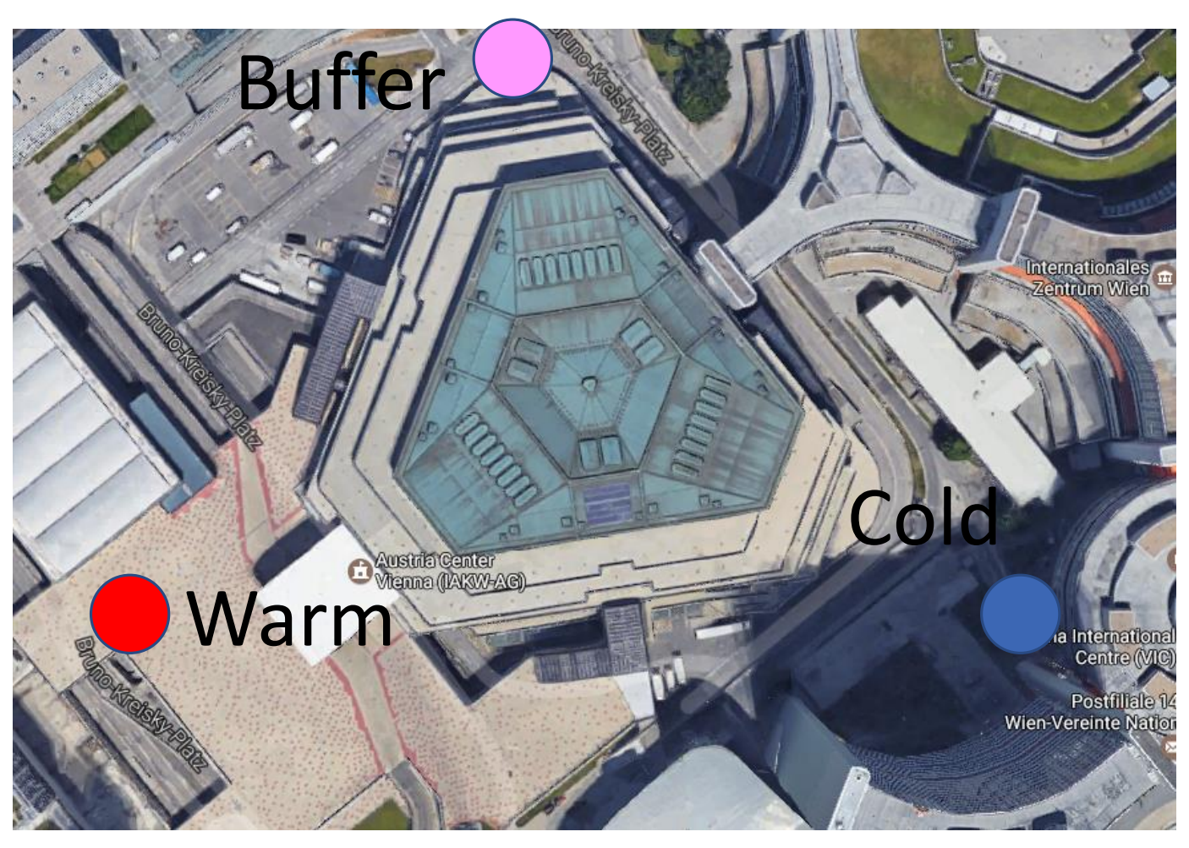
Increase area of solar heat collectors

Cut-off temperature reached



Case Study EGU Building & Conclusion

EGU Building

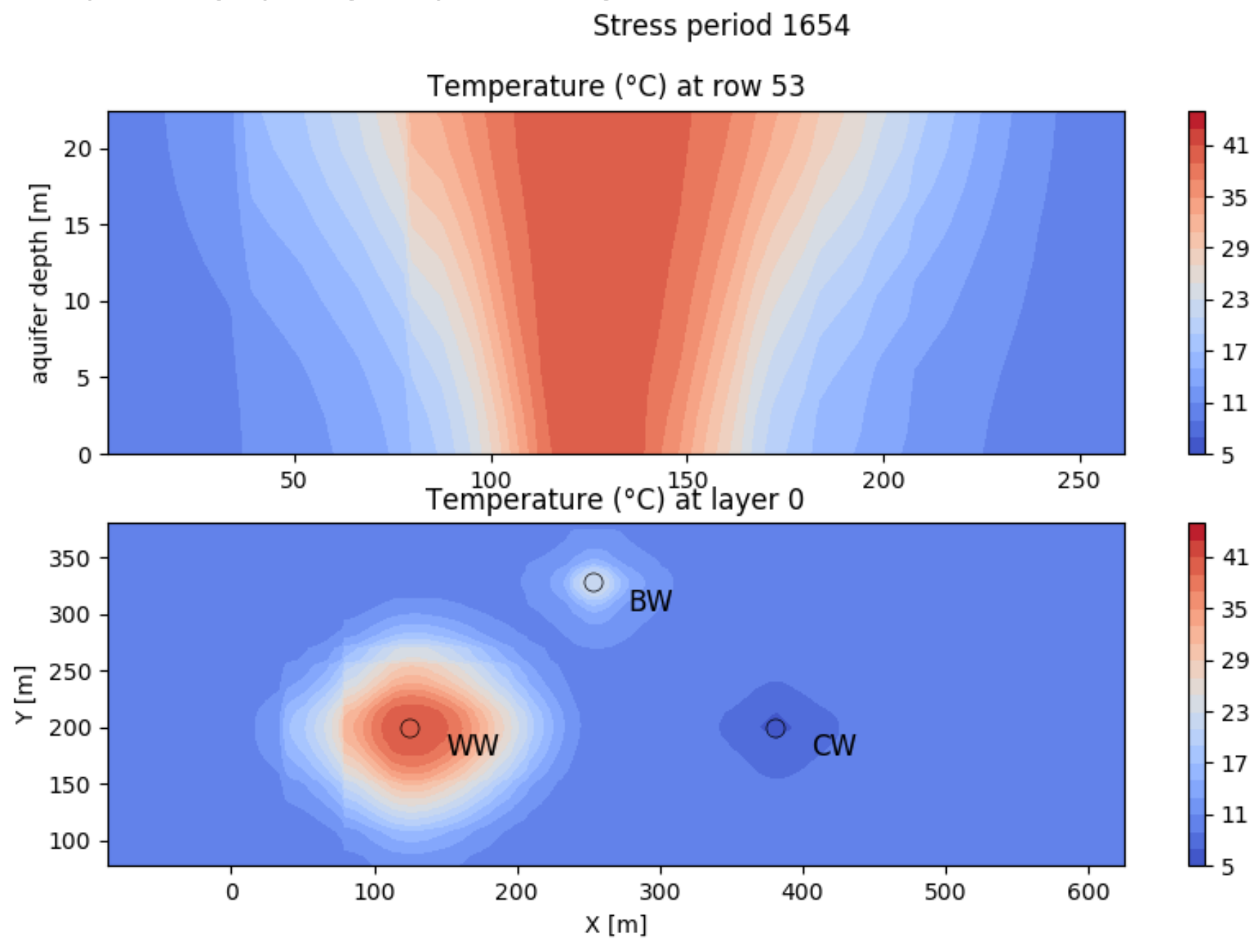


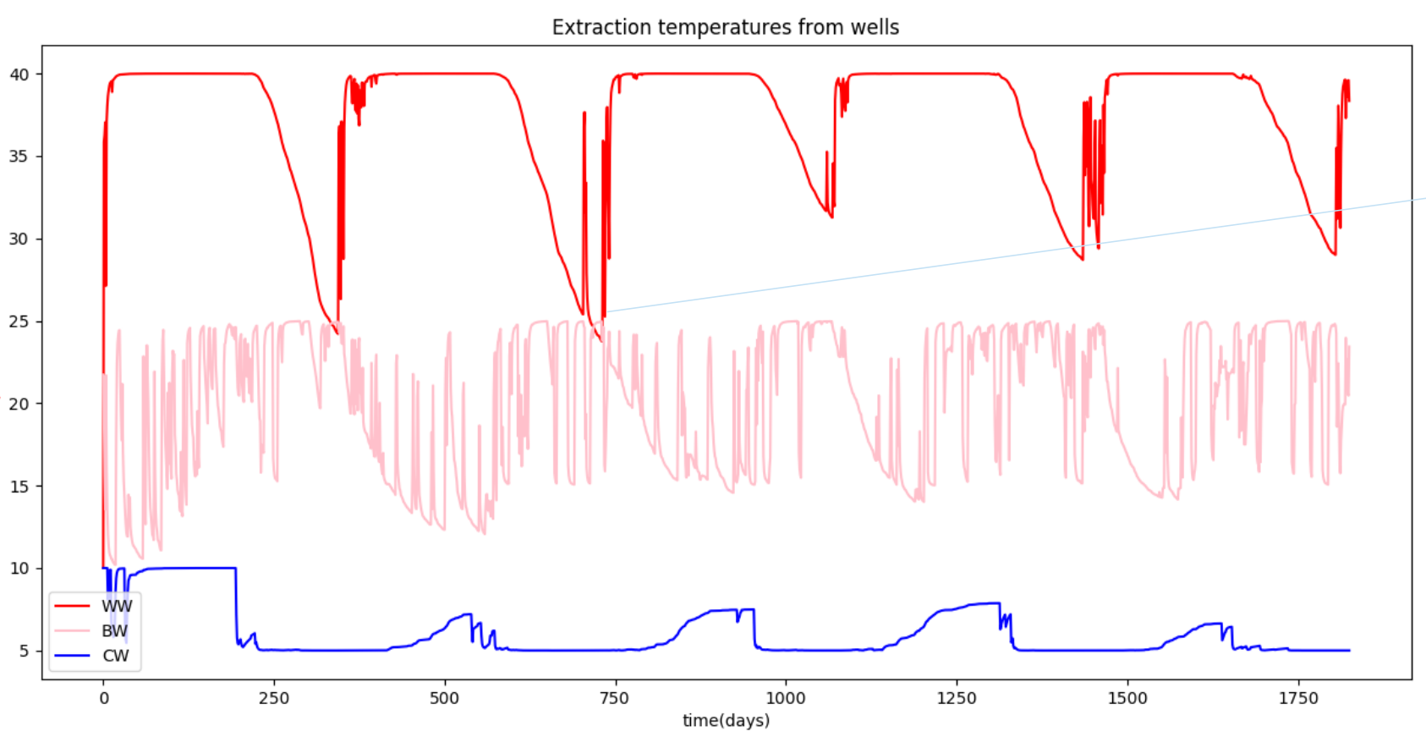
Source: Google Maps

Test case:
- Office building, 5 floors
- Roof area ≈ 7.813m^2
- Gross conditioned surface area ≈ 40.000m^2
- Area of solar heat collectors = $^4/_5$ · Roof area
- Analytic results represented in previous section
- Assumed: coarse-sanded, homogenous aquifer of 25m

Modflow Simulation

Maximum volume warm well





Two peak losses in extraction temperature of warm well

Modflow outputs coincide with Analytic model outputs

Modflow Outputs:
- Temperature profiles and cross-sections at any time t
- Time series of extraction temperatures
- Buoyancy due to higher injection temperatures
- Thermal radii of wells

Animation:

Results:
- Verify thermal energy and temperature losses
- Storages don't interact

Conclusions

- ✓ Self-supporting ATES is feasible under assumed conditions
- ✓ Better suitable for larger storage volumes
- ✓ Better applicable on buildings with large roof area compared to gross surface area

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