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Combining a thermally supported ground source heat pump with an ORC

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THERMODYNAMIK

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Motivation

Conventional solar systems - collector standstill whenever the maximum temperature of the storage is reached

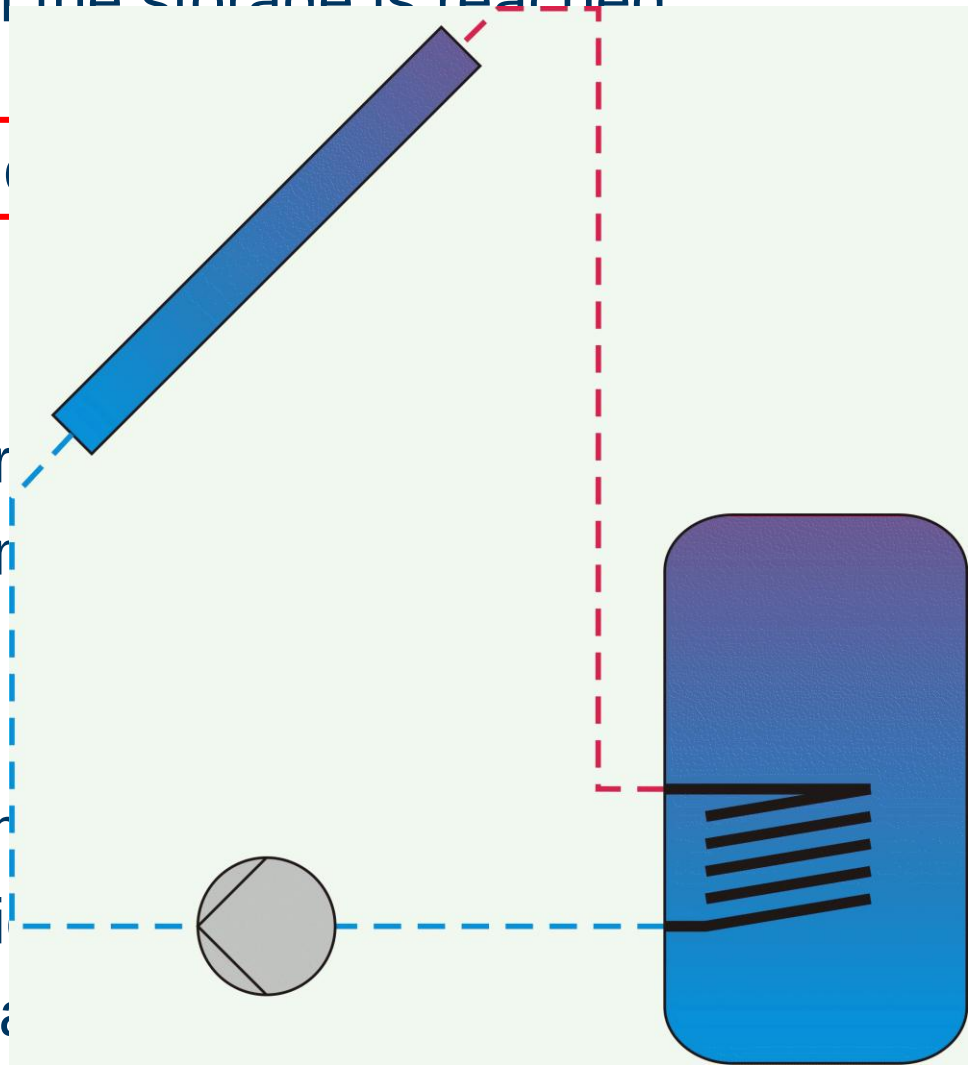
The resulting excess heat

Approach:

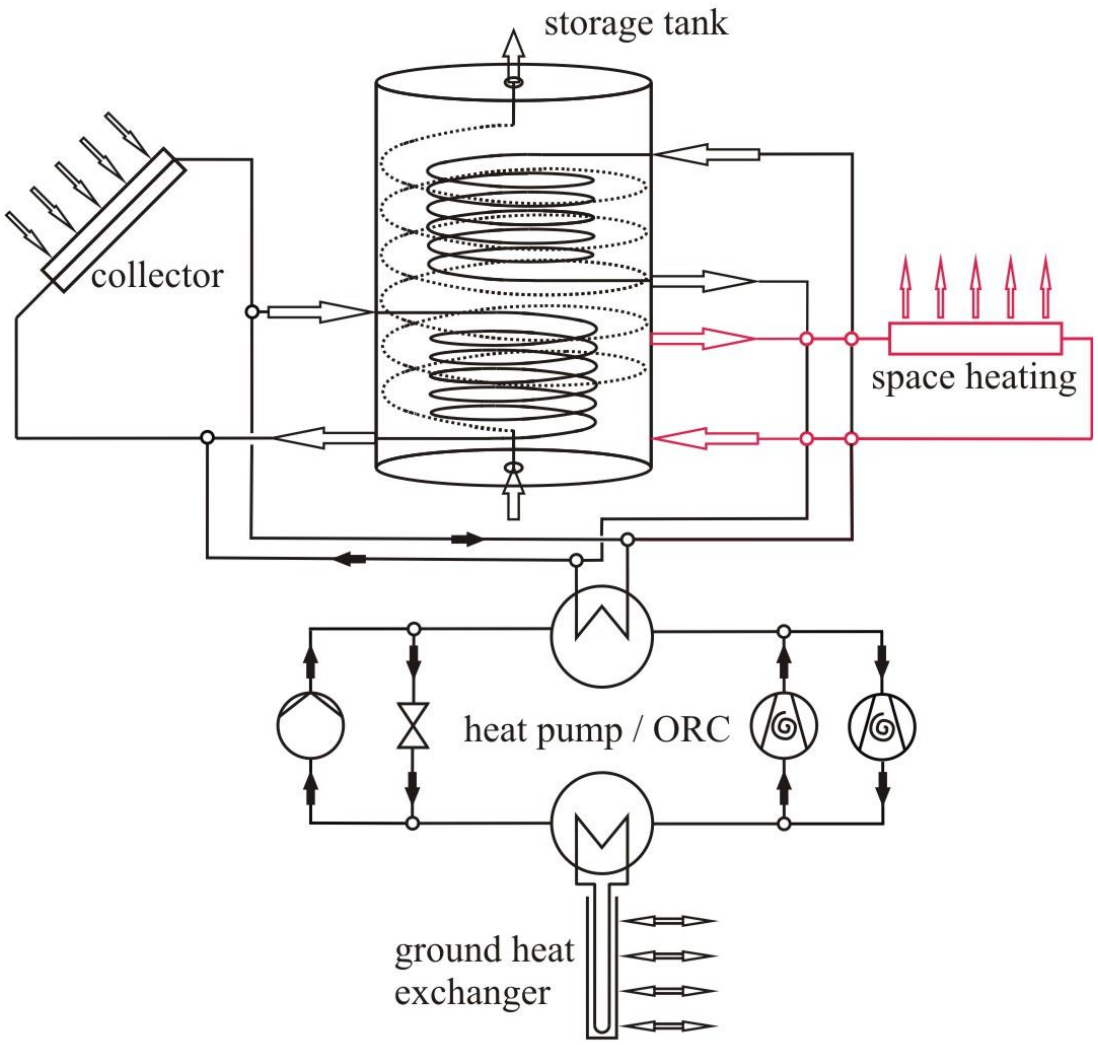
- Combination of market pr
- Minimal additional investm

Goal:

- Selection of appropriate r
- Simulation and optimisati
- Energetic and economic a



Combined solar system



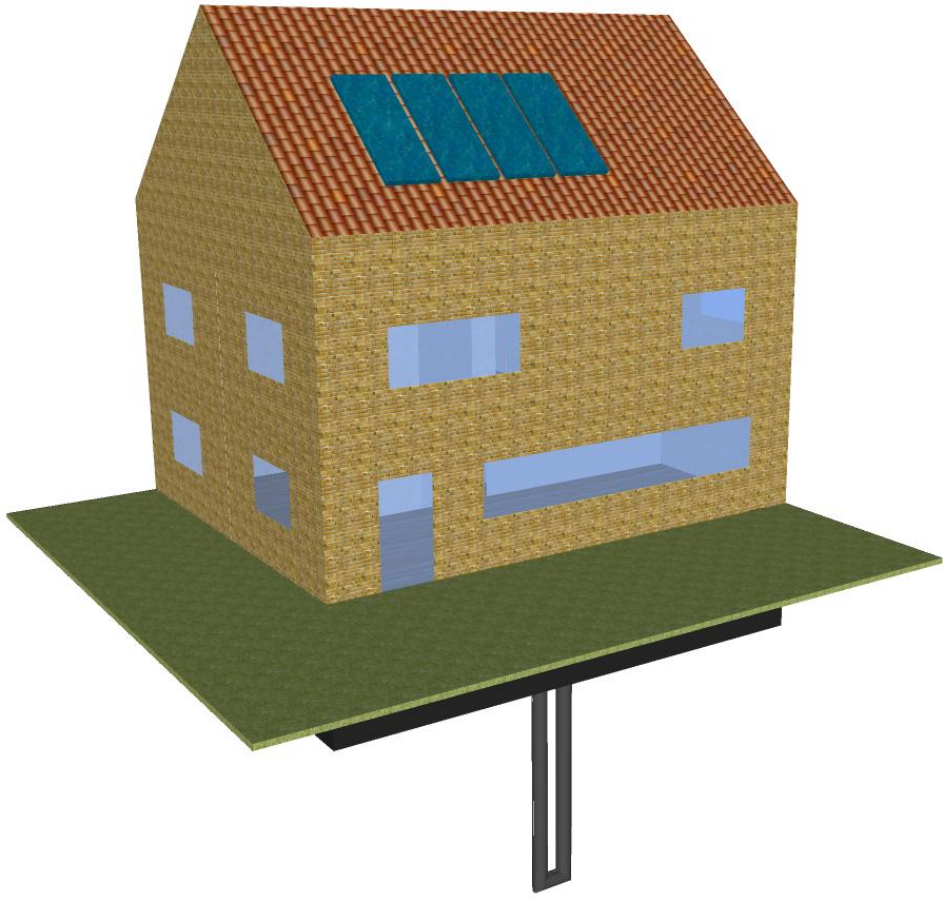
- Solar thermal system
- Space heating
- Domestic hot water
- Desalination device
- advanced controls

Overview of the System

Single family house
German low-energy standard
Floor space: 150 m²

Heating power: 5 kW
Borehole depth: 80 m

Evac. tube collector area: 10 m²
Storage tank volume: 900 l



Software SH-PORT

Simulation results

Ankara	ORC	conv.
ORC gain / kWh	96	-
Energy demand / kWh	1444	1524
savings (20 years) / €	389	-

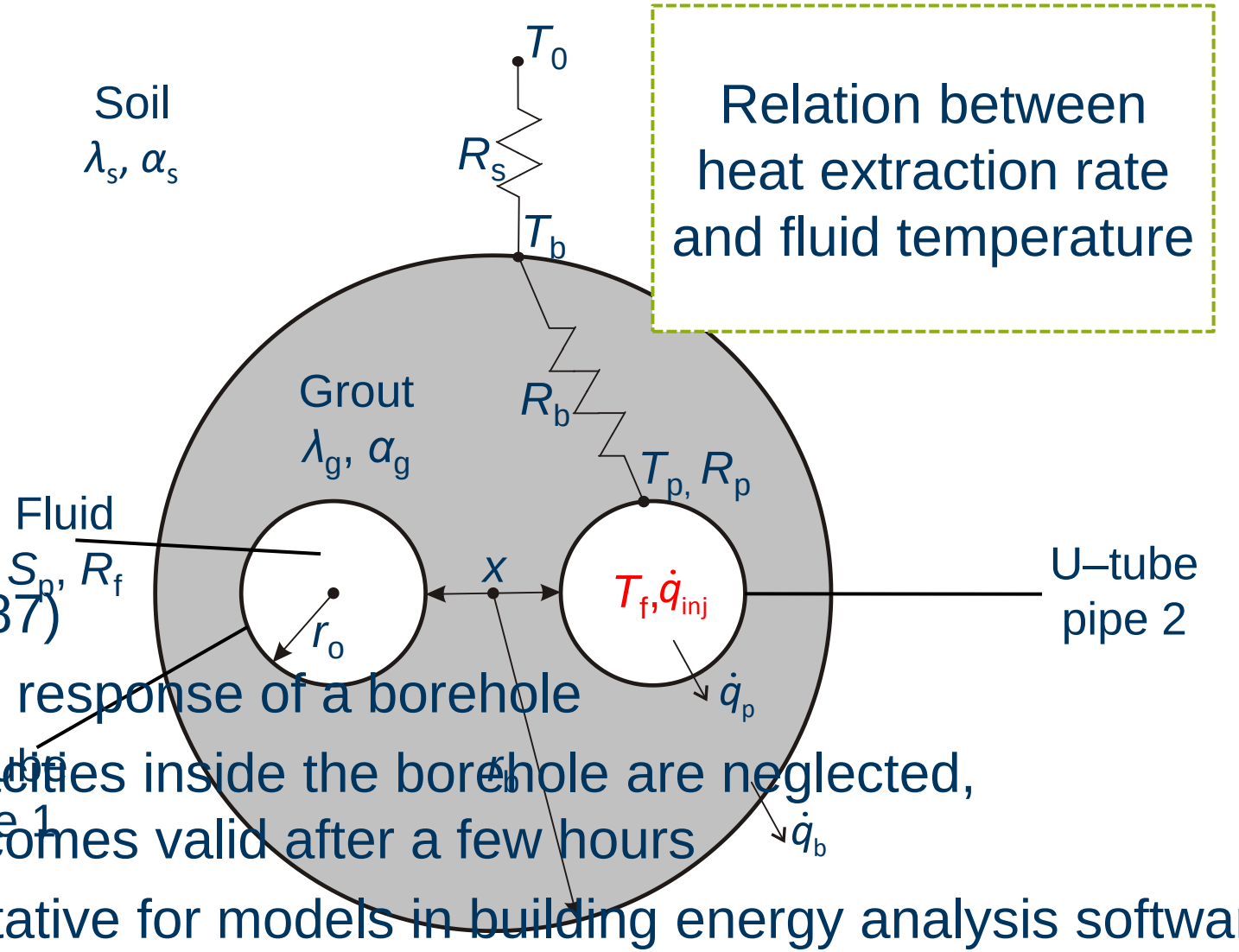
Denver	ORC	conv.
ORC gain / kWh	112	-
Energy demand / kWh	1735	1849
savings (20 years) / €	333	-

The combined ORC-system is energetically superior but under current conditions economically unfeasible!

Bochum	ORC	conv.
ORC gain / kWh	37	-
Energy demand / kWh	2144	2164
savings (20 years) / €	142	-

- Electr. pricing Ankara: 14,7 ct/kWh
- Electr. pricing Denver: 8,9 ct/kWh
- Electr. pricing Bochum: 21,4 ct/kWh
- Inflation electricity: 5 %

Modelling the ground heat exchanger



Relation between heat extraction rate and fluid temperature

Eskilson (1987)

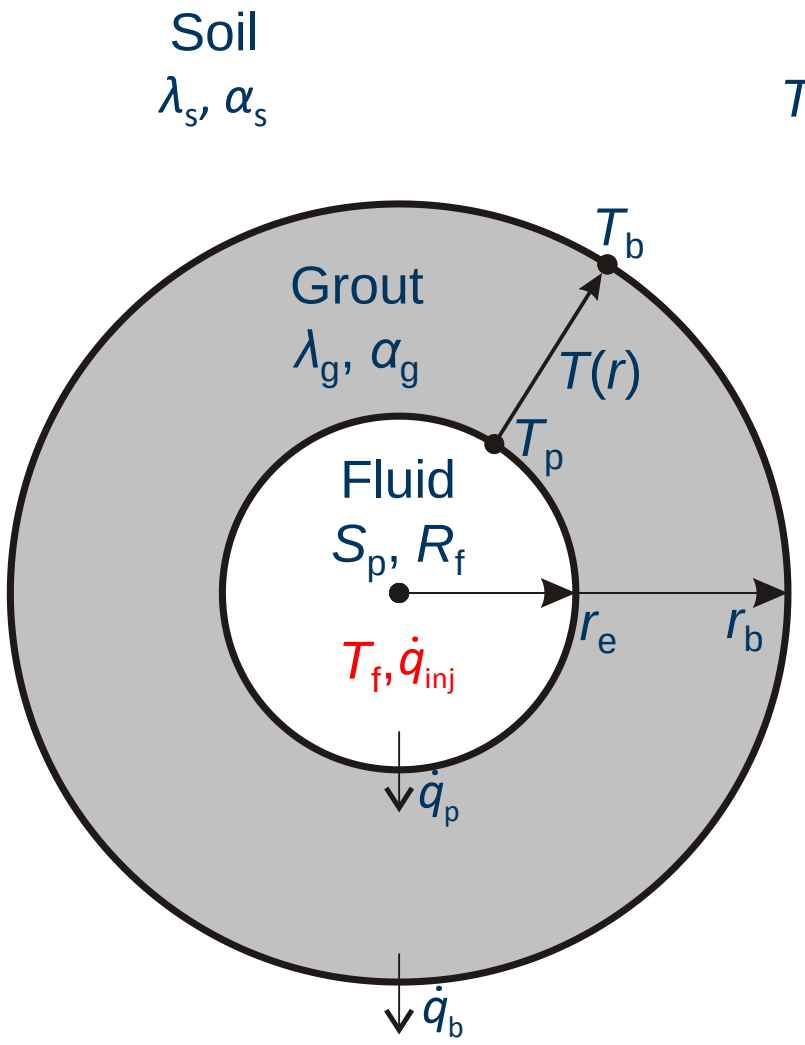
- Long-term response of a borehole
- Heat capacities inside the borehole are neglected, model becomes valid after a few hours
- Representative for models in building energy analysis software

Analytical short timestep model

$$T_f(t) = T_{f,0} + \dot{q}_{inj} \underbrace{\frac{2}{\pi}\int_0^{\infty} \frac{1 - e^{-\beta^2 \cdot \frac{t}{t_0}}}{\beta}\cdot L \, d\beta}_{G\left[\tilde{t}(t)\right]}$$

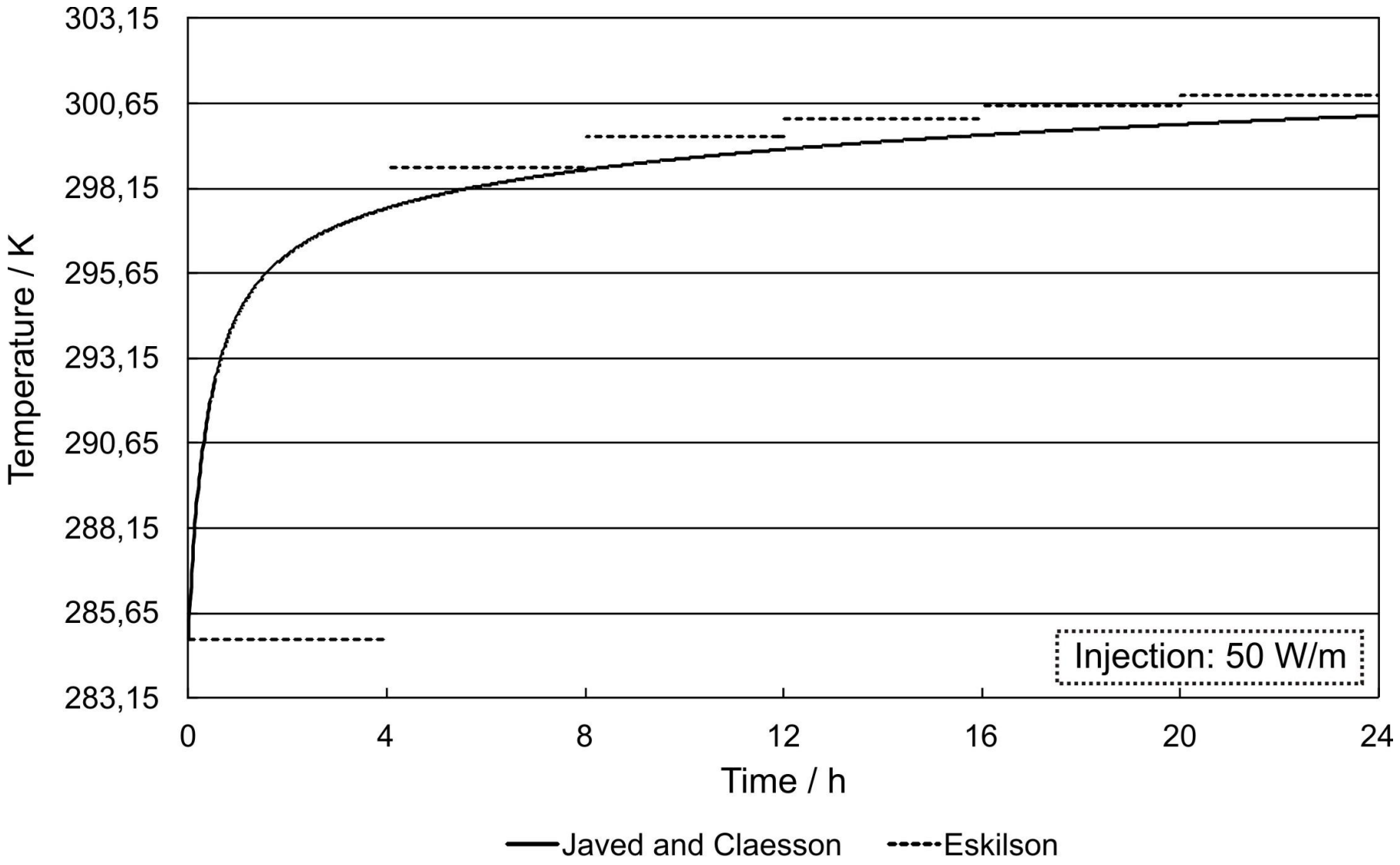
$$\tilde{t}(t)$$

$$L = \Im\left[\frac{-1}{C_p \cdot \frac{-\beta^2}{t_0} + \frac{1}{R_p + \frac{1}{\bar{K}_p + \frac{1}{\bar{R}_t + \frac{1}{\bar{K}_b + \bar{K}_s}}}}}\right]$$



Javed and Claesson (2011): Simplifies geometry but considers all parts of the borehole and thermal resistances.

Simulation results – Comparison of GHX-models



Conclusion

- ORC-system saves energy but its economic feasibility is questionable
- Comparison of two ground heat exchanger models
  - Eskilson (1987): long-term analytical model
    - neglects heat capacities of fluid and grout
    - representative for building energy software
  - Lamarche (2011): short-time step model
    - simplifies geometry
- Long-term response model overestimates ORC-gain
- Simulation of small-scale ORCs with condensation in a ground heat exchanger requires a short-time step model

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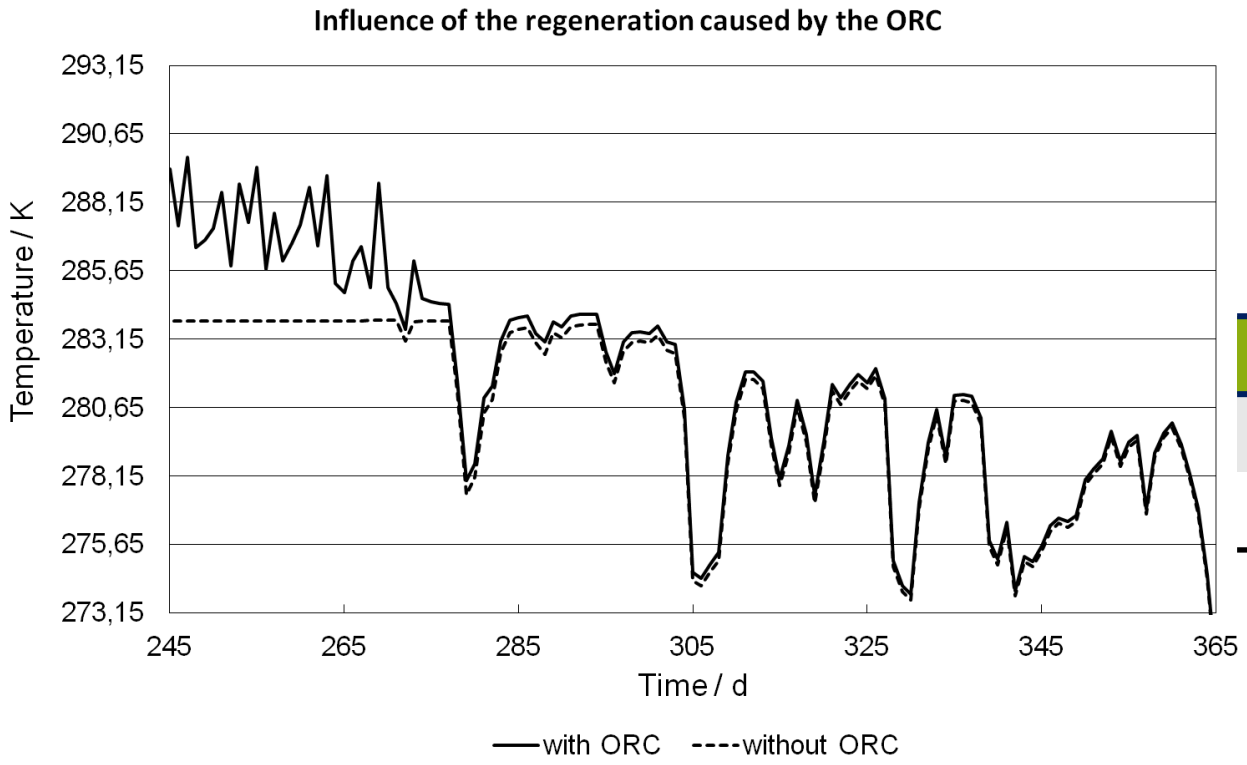
Influence of the regeneration caused by the ORC

		with ORC			without ORC		
Annual electricity demand and gains		October	November	December	October	November	December
electricity consumption of the heat pump for space heating	[kWh]	68,0	271,2	342,4	68,5	272,7	343,8
electricity consumption of the heat pump for domestic hot water	[kWh]	1,1	19,8	20,9	0,8	19,9	21,0



Denver	ORC
Extracted heat / kWh	5060
Injected heat/ kWh	2008