Influence of the pinch-point-temperature difference on the *Preheat-parallel* CHP configuration

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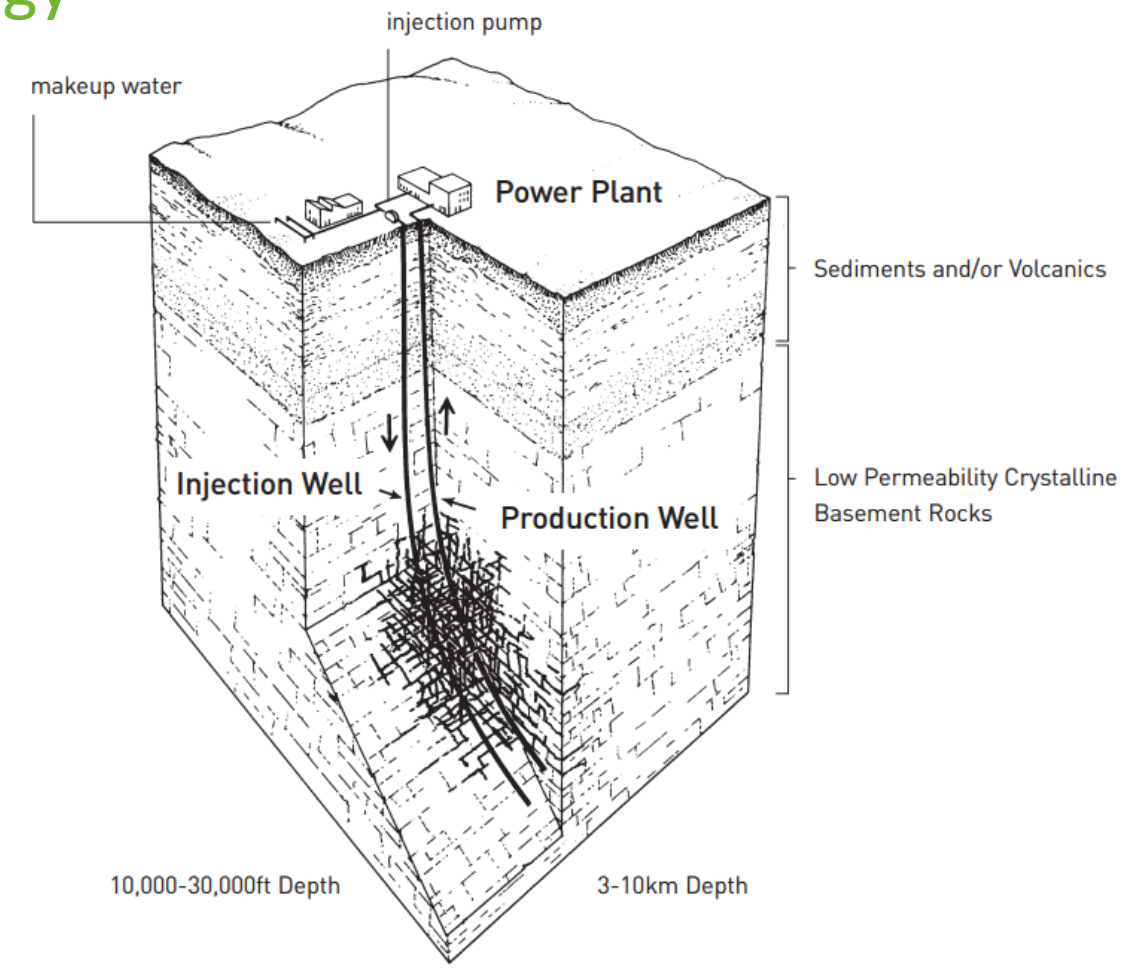
Problem statement – geothermal power plant

- Electricity from deep-geothermal energy
  - Renewable & sustainable
  - Constant power output, independent of the weather conditions
    - ➔ baseload
      - ⇔ PV/wind



MIT, The future of geothermal energy, 2006.

Problem statement – feasibility?

- Geothermal conditions NW Europe (Belgium)
  - Thermal gradient: 30°C/km
  - Low brine temperature: T=130°C
  - High drilling costs

    >50% of total costs

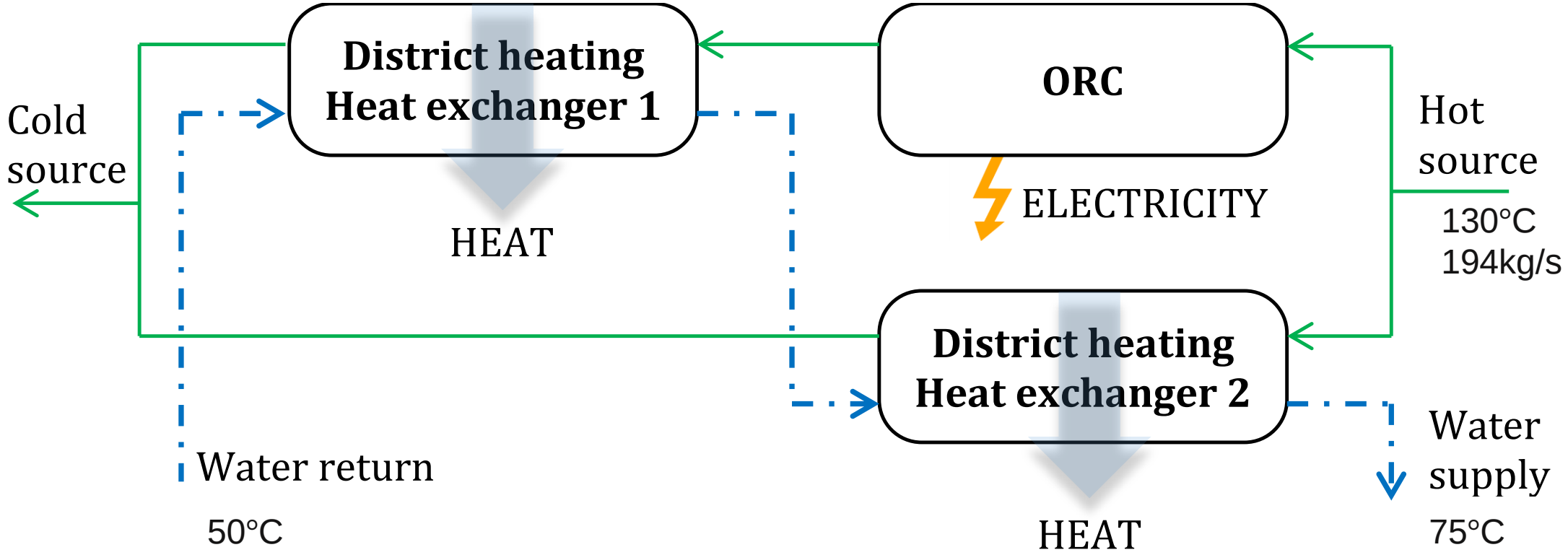
  - Pure electrical power plant not economically feasible

➔**Improve plant economics via CHP**

➔Potential of ***Preheat-parallel*** **CHP** layout

Preheat-parallel CHP configuration

- Combination of series and parallel CHP layouts
- *Preheating-effect*



Goals

- Preheat-parallel CHP plant performance
- Effect of pinch-point-temperature difference
- Preheat-parallel versus series and parallel CHPs

- Maximization of net electrical power output

$$\dot{W}_{net} = \dot{W}_t \eta_g - {}^{\dot{W}_p}/_{\eta_m} - \dot{W}_{wells}, \qquad \dot{W}_{wells} = 600kW$$

- Comparison based on exergetic plant efficiency

$$\eta_{ex} = \frac{\dot{W}_{net} + \dot{E}x_{DH}}{\dot{E}x_{b,prod}}$$

- Model implementation: Python + CasADi/IpOpt + REFPROP

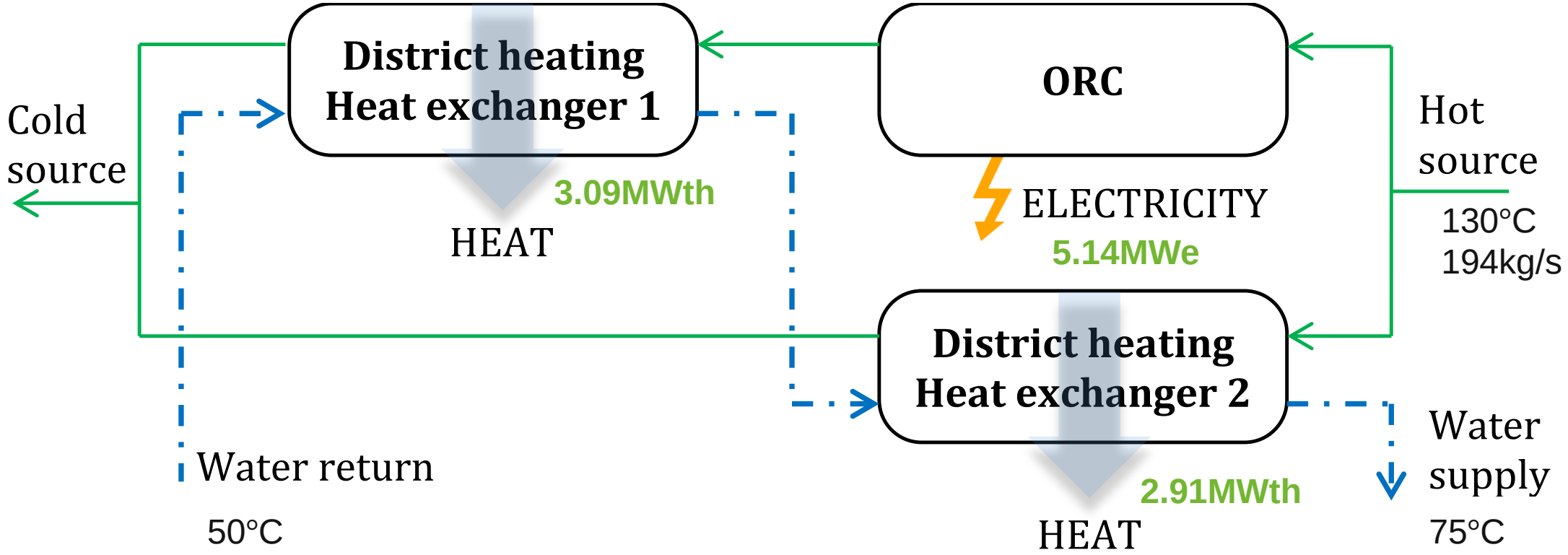
Preheat-parallel: Performance

- 75/50 DH system, $\dot{Q}_{DH} = 6MWth$

$$\dot{W}_{net} = \dot{W}_t \eta_g - \dot{W}_p / \eta_m - \dot{W}_{wells} = 5.14MWe$$

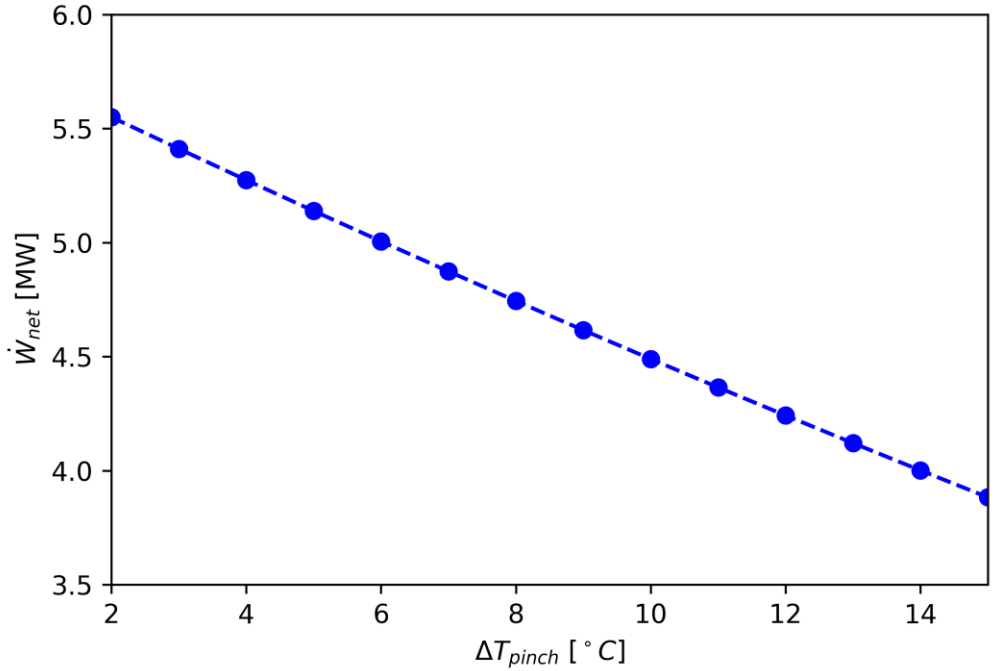
$$\eta_{ex} = \frac{\dot{W}_{net} + \dot{E}x_{DH}}{\dot{E}x_{b,prod}} = 38.31\%$$

⇔ Pure power plant: $\dot{W}_{net} = 5.58MWe$ & $\eta_{ex} = 35.73\%$

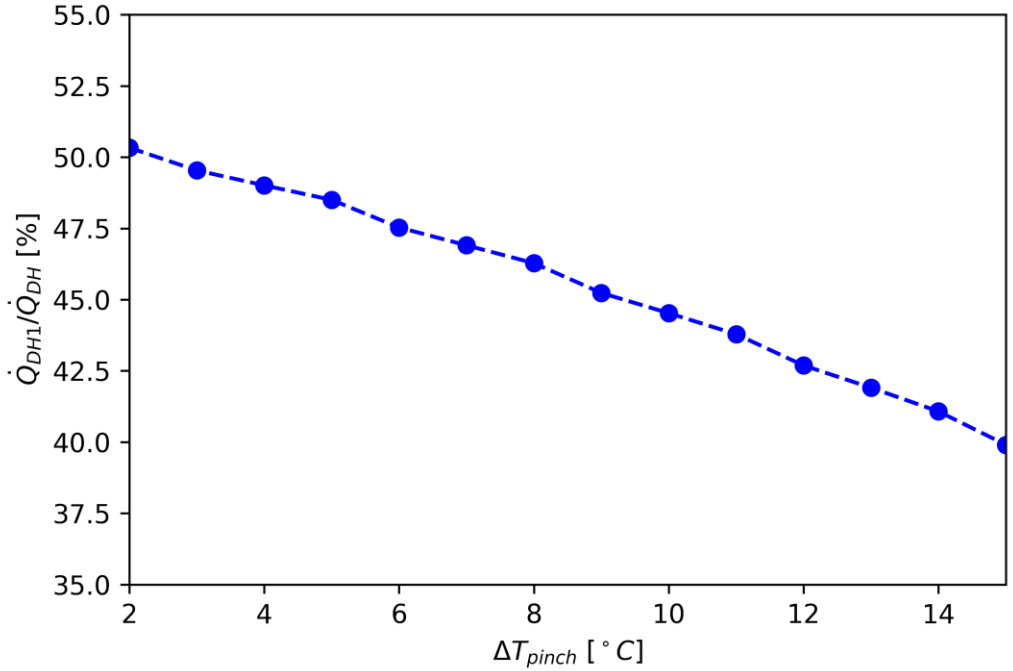


Preheat-parallel: Influence of ΔT_{pinch} on performance

- 75/50 DH system, $\dot{Q}_{DH} = 6MWth$



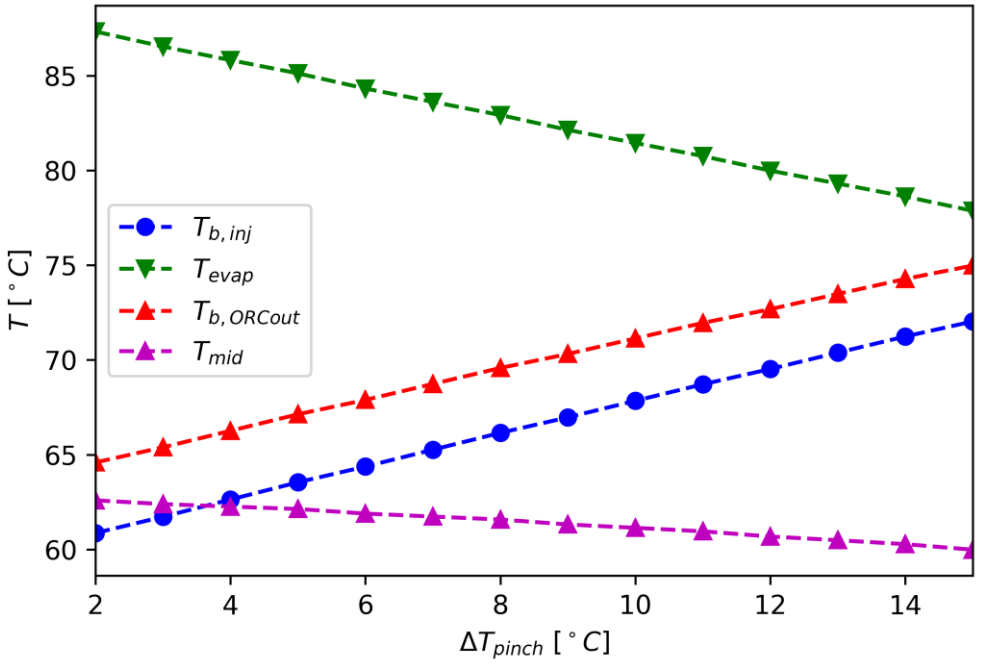
$\dot{W}_{net}$ ↓ with ΔT_{pinch}

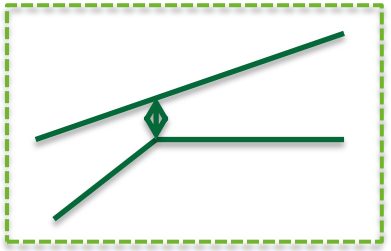


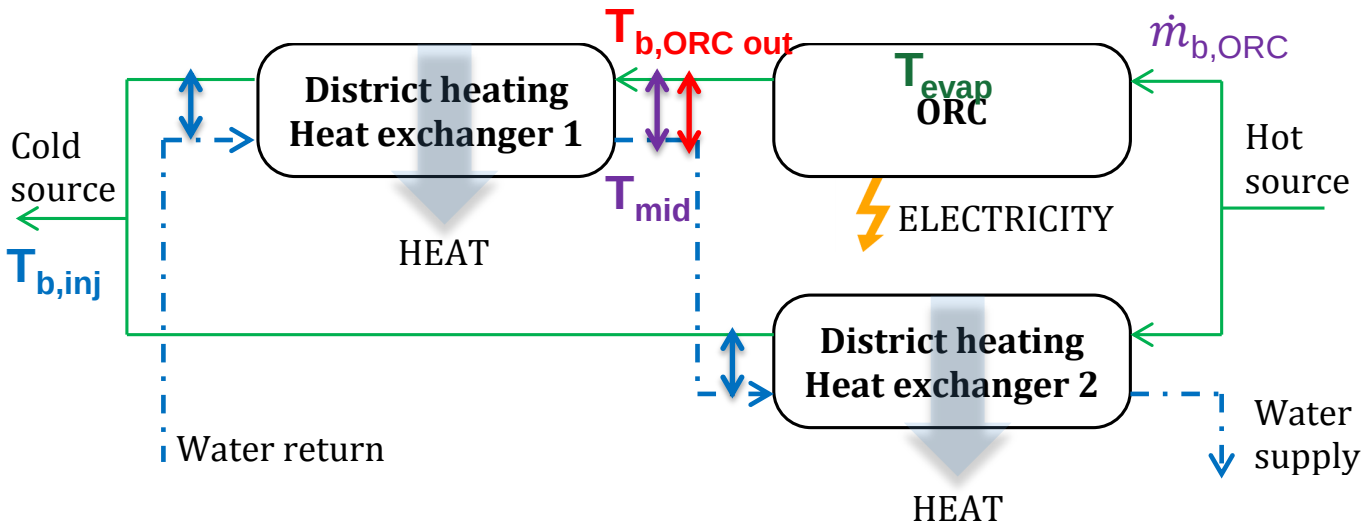
preheating-effect ↓ with ΔT_{pinch}

Preheat-parallel: Influence of ΔT_{pinch} on operating conditions

75/50 DH system, $\dot{Q}_{DH} = 6MWth$







For ΔT_{pinch} ↑

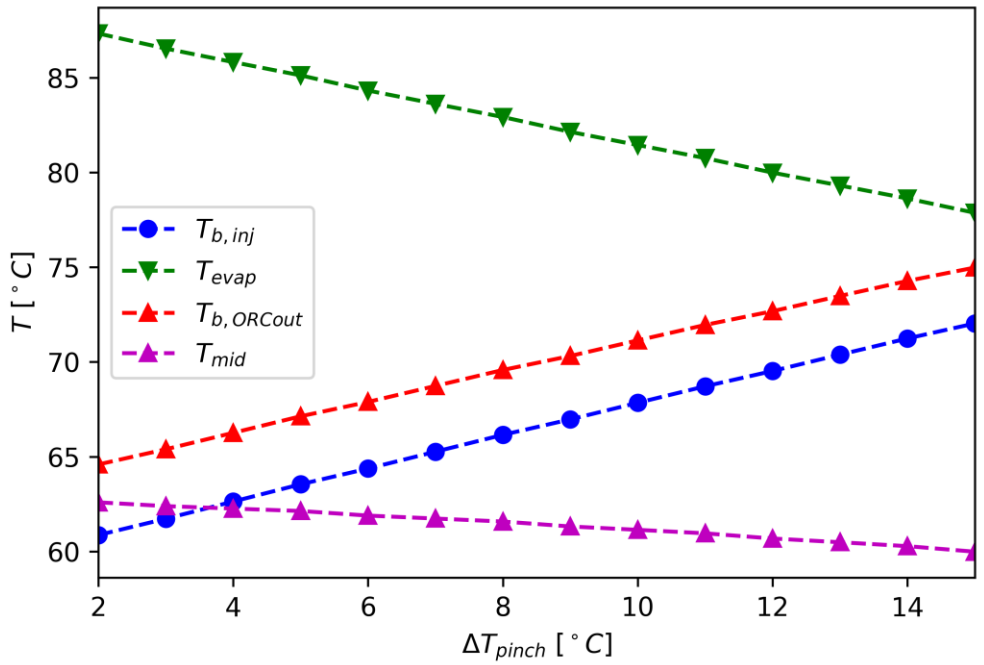
- $T_{b,ORCout}$ ↑
- T_{mid} ↓

➔ keep $\dot{m}_{b,ORC}$ high

- T_{evap} ↓
- $T_{b,inj}$ ↑

Preheat-parallel: Influence of ΔT_{pinch} on operating conditions

75/50 DH system, $\dot{Q}_{DH} = 6MWth$



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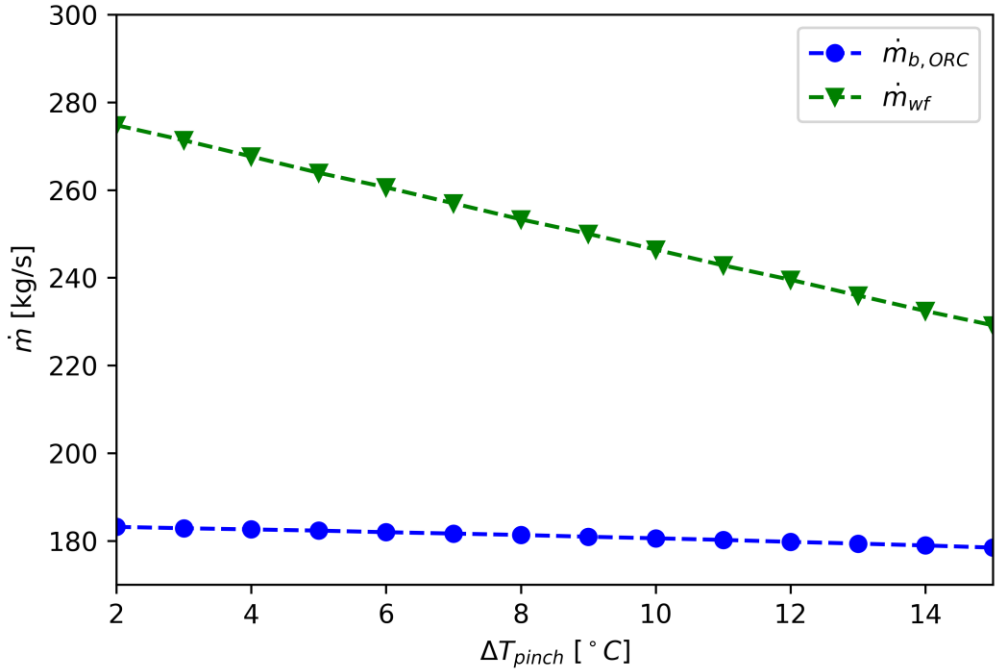
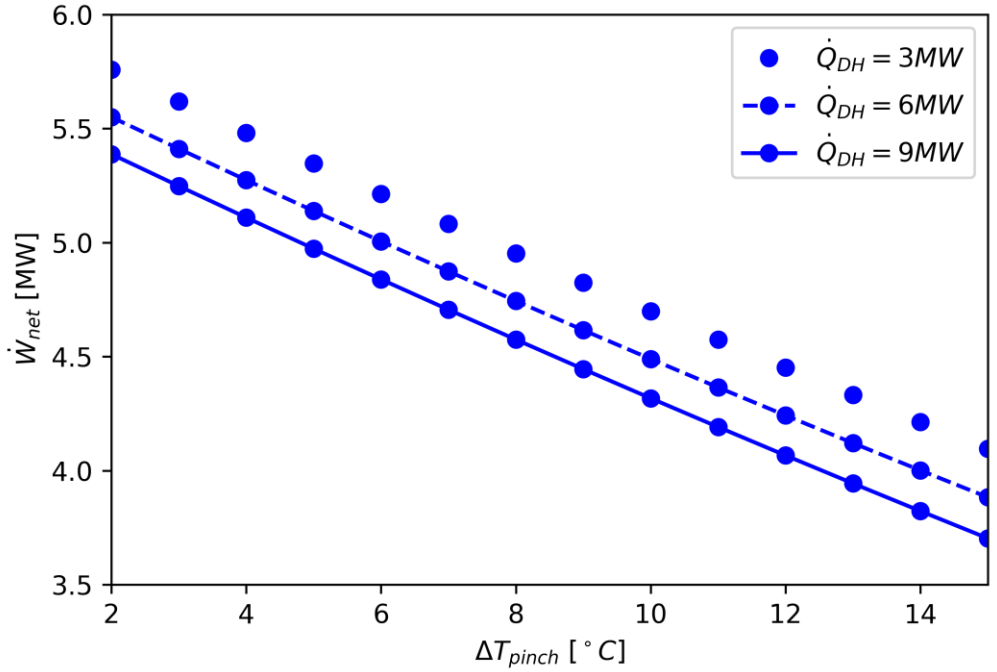


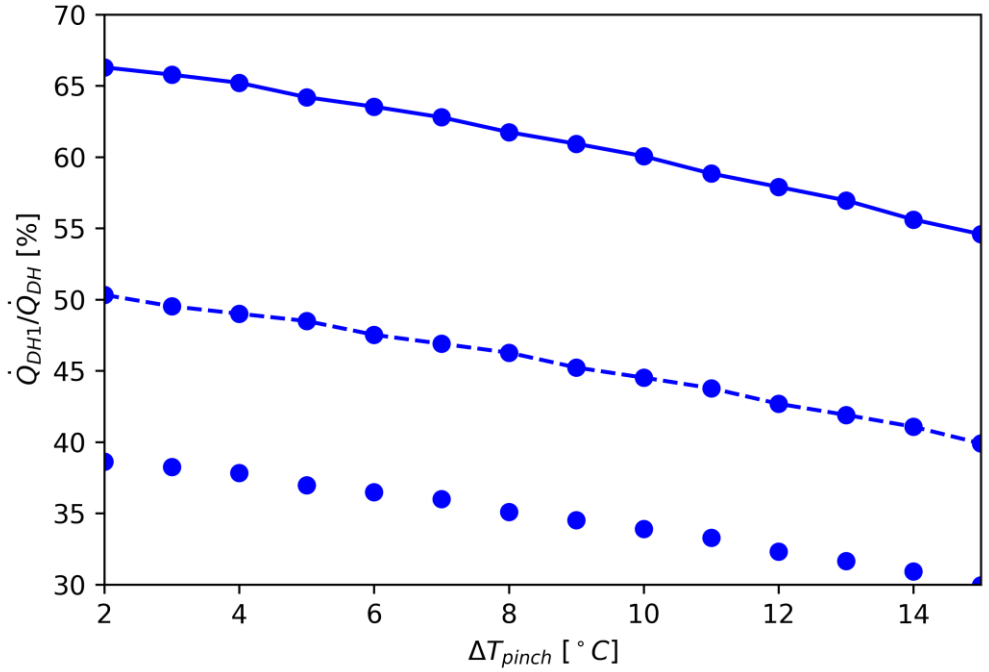
For ΔT_{pinch} ↑

- $\dot{m}_{b,ORC}$ ↓ to satisfy heat demand
- $\dot{m}_{wf}$ ↓ due to lower heat addition to ORC

Preheat-parallel: Influence of the heat demand

75/50 DH system

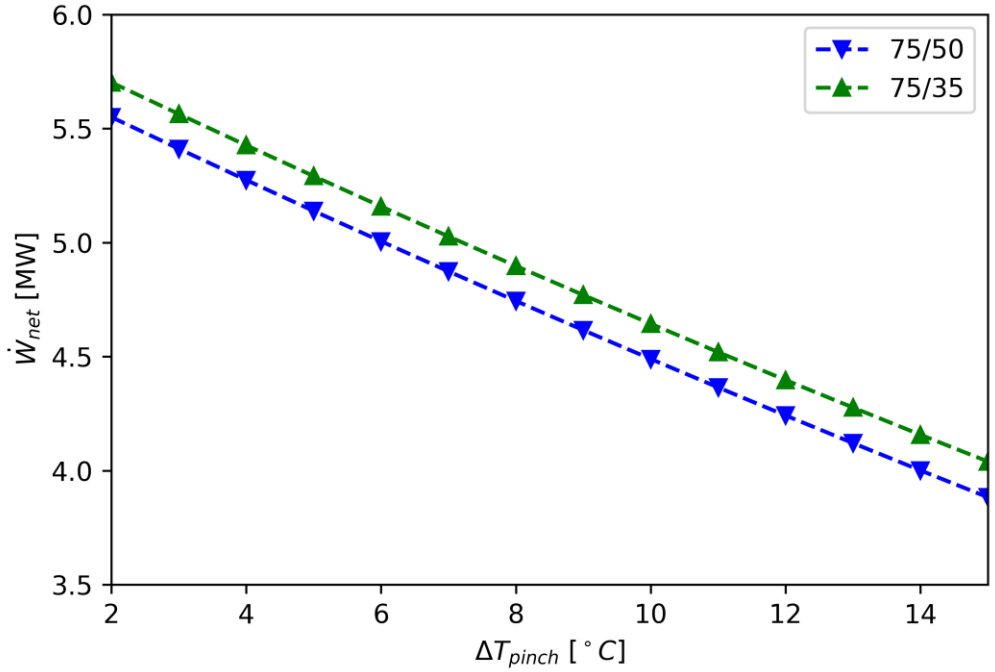


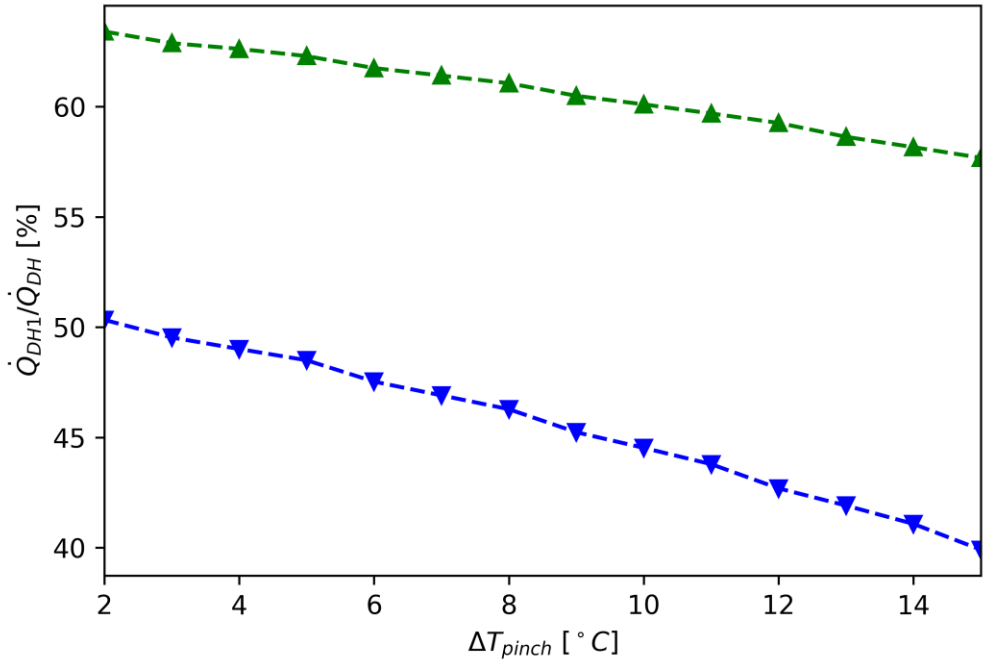


For $\dot{Q}_{DH}$ ↑ , the preheating-effect ↑ but $\dot{W}_{net}$ ↓

Preheat-parallel: Influence of the return temperature

- 75/50 and 75/35 DH system, $\dot{Q}_{DH} = 6\text{MWth}$



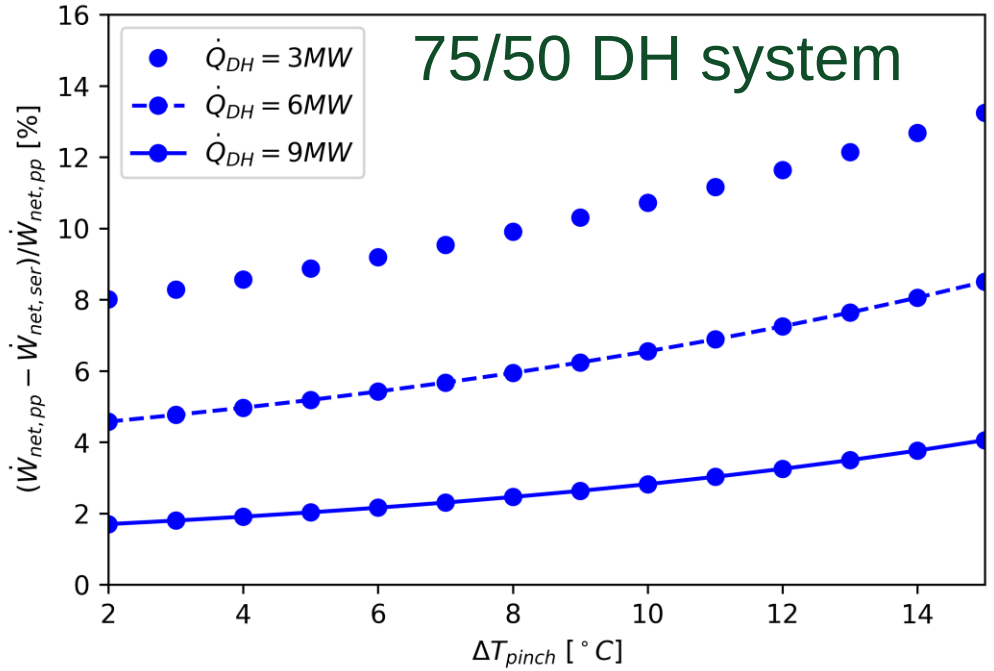


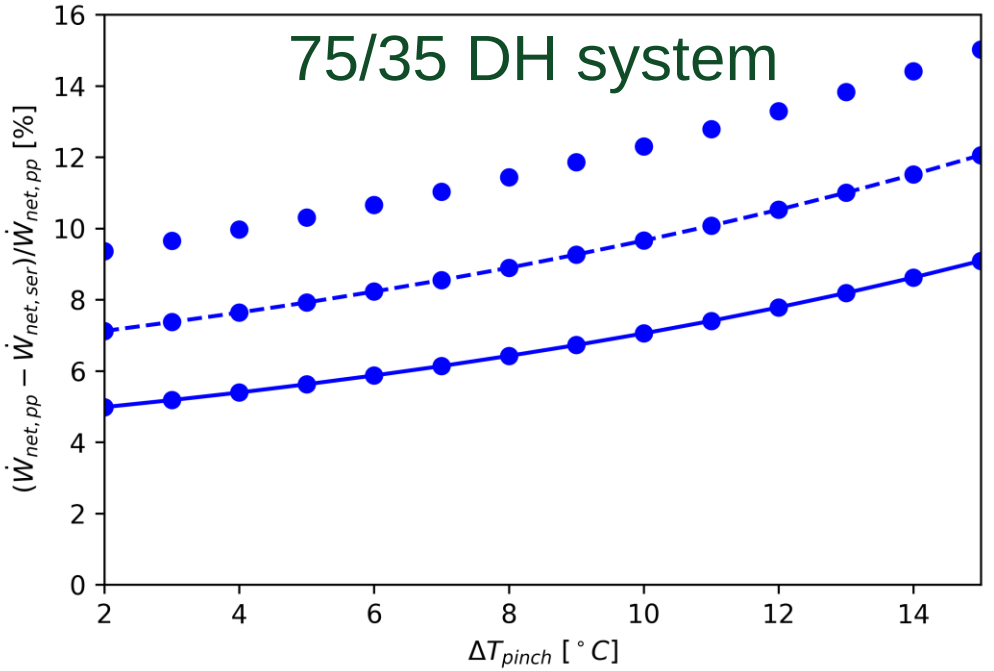
For $T_{return} \downarrow$, $\dot{W}_{net} \uparrow$ and preheating-effect $\uparrow$

Preheat-parallel versus series

Preheat-parallel CHP

- Higher $\dot{W}_{net}$ and η_{ex} than series CHP
- Less sensitive to $\dot{W}_{net}$ ↓ with ΔT_{pinch}
- Highest gains for low $\dot{Q}_{DH}$ and low T_{return}

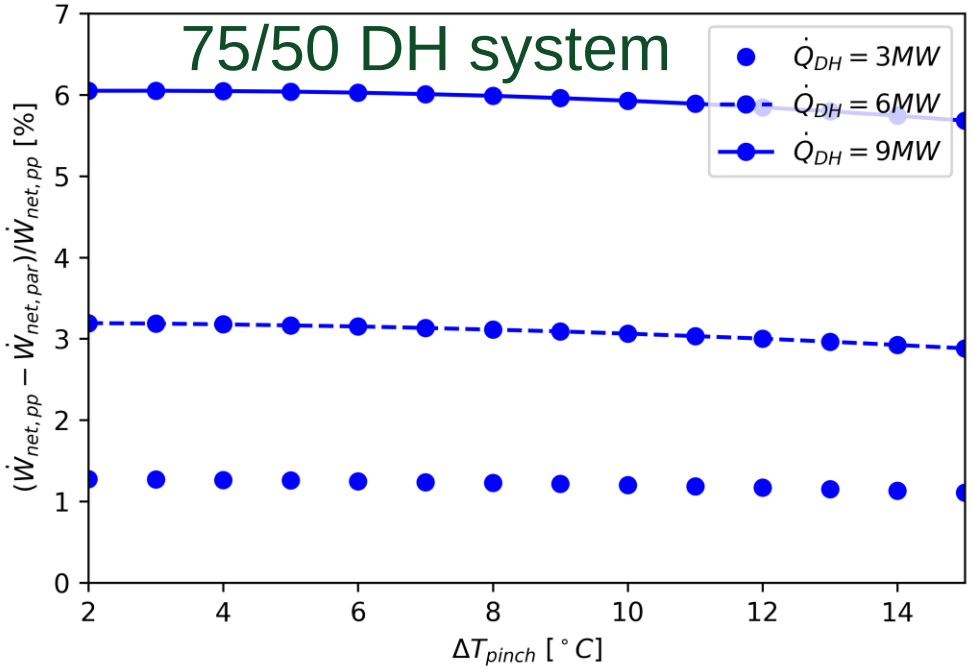


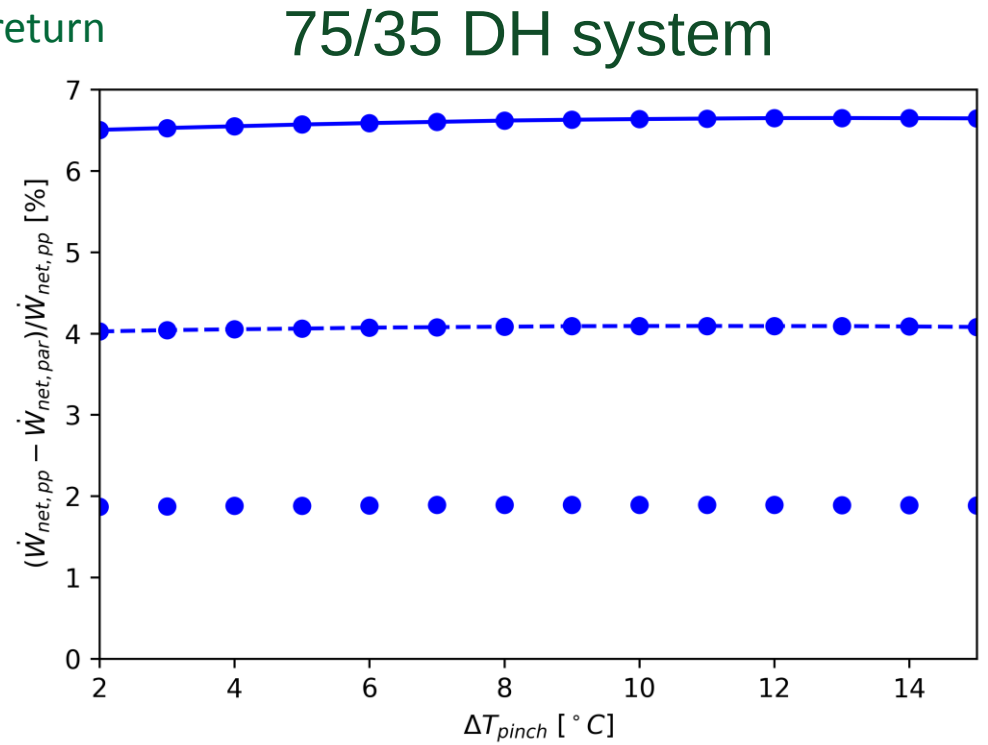


Preheat-parallel versus parallel

Preheat-parallel CHP

- Higher $\dot{W}_{net}$ and η_{ex} than parallel CHP
- More/equally sensitive to $\dot{W}_{net}$ ↓ with ΔT_{pinch}
- Highest gains for high $\dot{Q}_{DH}$ and low T_{return}





Preheat-parallel versus series and parallel CHPs

- The preheat-parallel CHP has
  - Higher $\dot{W}_{net}$ and η_{ex} for investigated conditions

    Brine: 130°C & 194kg/s & DH system: 75/50 and 75/35
  - Higher gains for low T_{return}
  - Highest sensitivity towards variations in ΔT_{pinch}

    Series > **Preheat-parallel** > Parallel

- Versus series
  - Highest gain for **low** $\dot{Q}_{DH}$

- Versus parallel
  - Highest gain for **high** $\dot{Q}_{DH}$

Conclusions – ***Preheat-parallel*** CHP

- Performance
  - 75/50 DH system & $\dot{Q}_{DH}$ = 6MWth ➔ $\dot{W}_{net}$ = 5.14MWe & η_{ex} = 38.31%
  - ⇔ pure power plant η_{ex} = 35.73% ➔ **better utilization of low-T geoth. source!**
- Effect of ΔT_{pinch} on
  - Performance: $\dot{W}_{net}$ ↓ and η_{ex} ↓ with ΔT_{pinch}
  - Optimal operating conditions
- Preheat-parallel favorable when
  - Large $T_{supply} - T_{return}$, Low T_{return}
  - Higher $\dot{Q}_{DH}$

  } *preheating-effect*
- Preheat-parallel better than series and parallel CHP (for considered conditions)

Thanks for your attention!

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