River water heat pumps for district heat supply in large cities in Austria

Study of potential and techno-economic optimization

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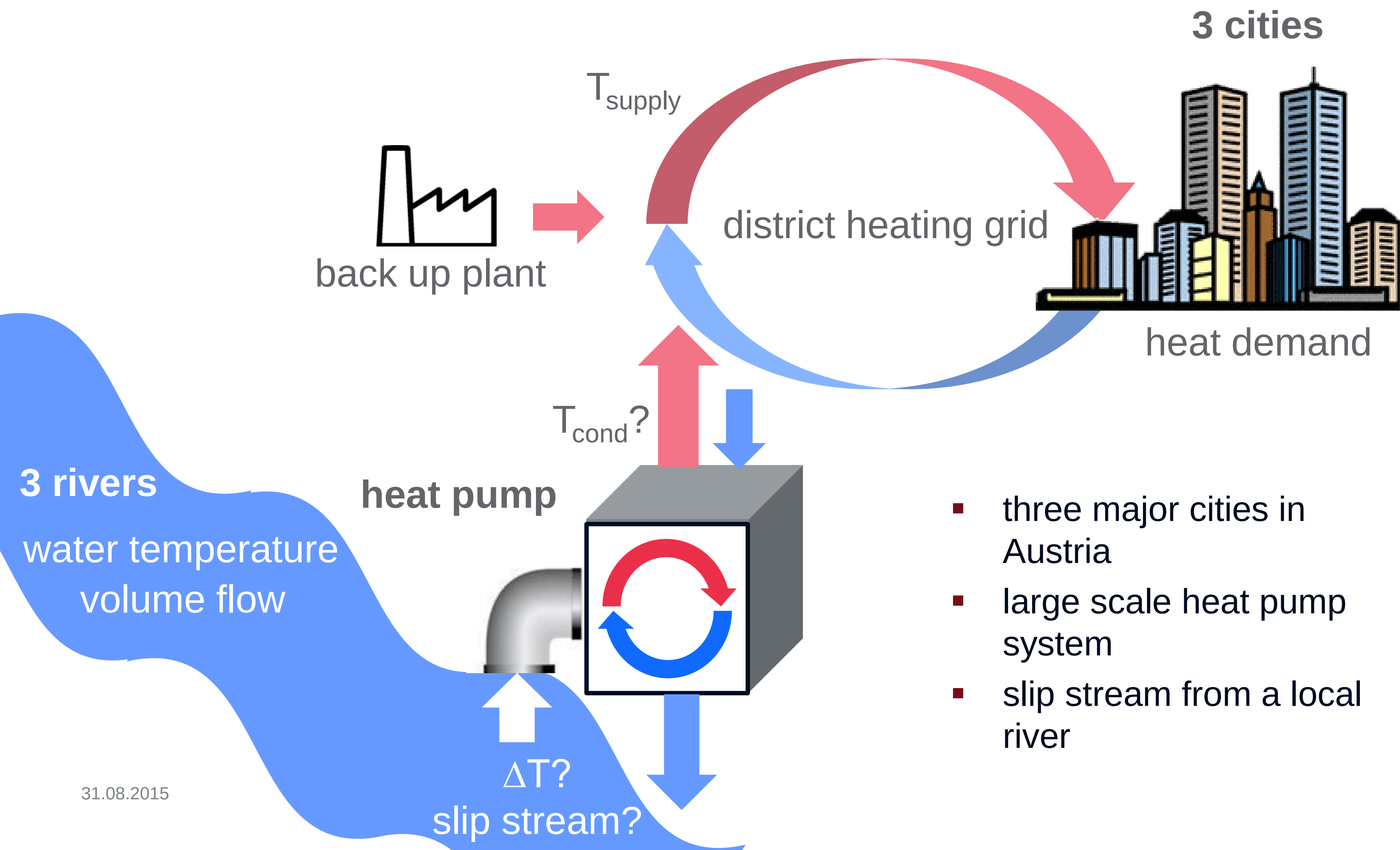
River water heat pumps in Austria

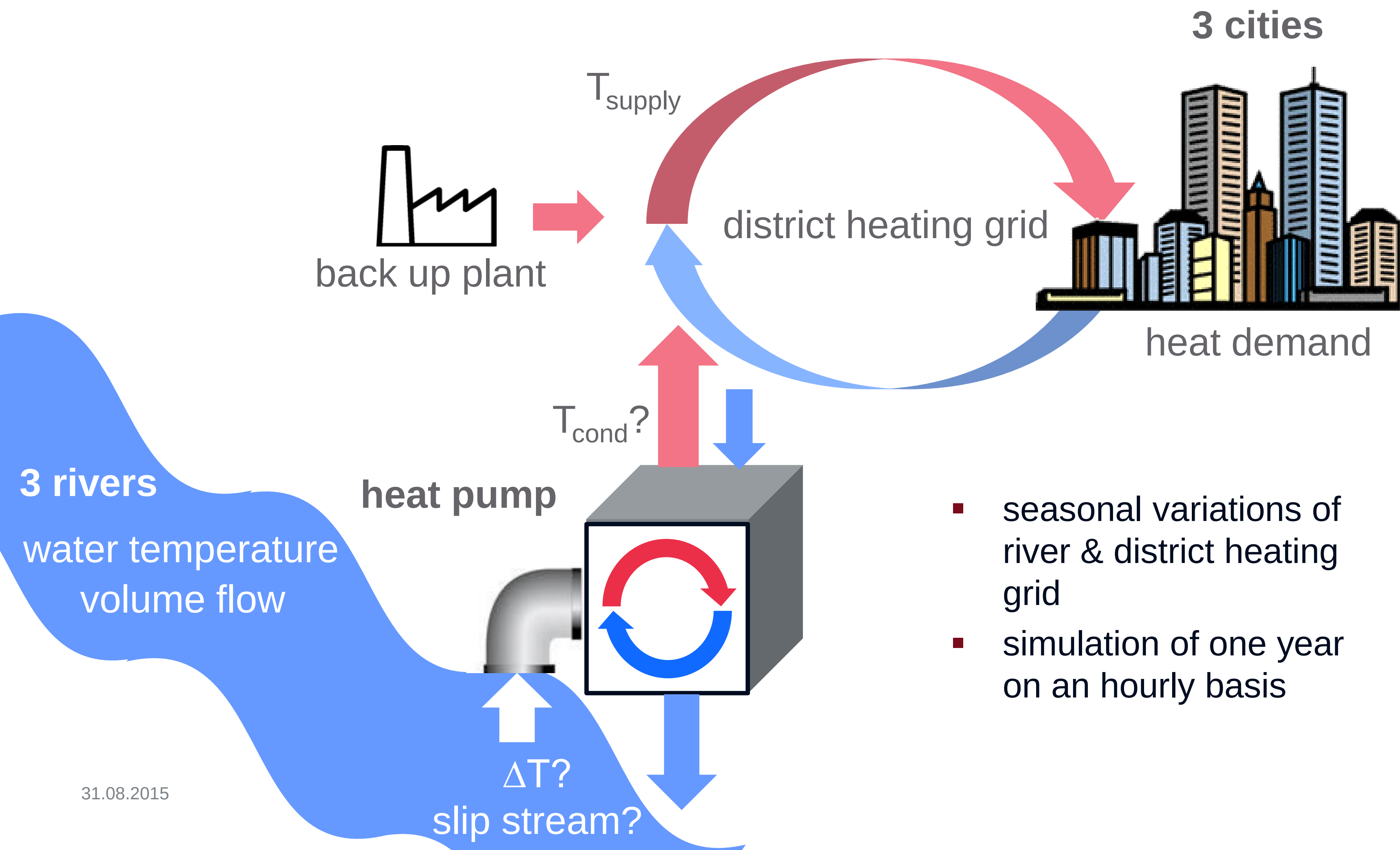
- surface water = sources of ambient heat
- sea water heat pumps in Drammen (Norway)

Simulation: boundary conditions



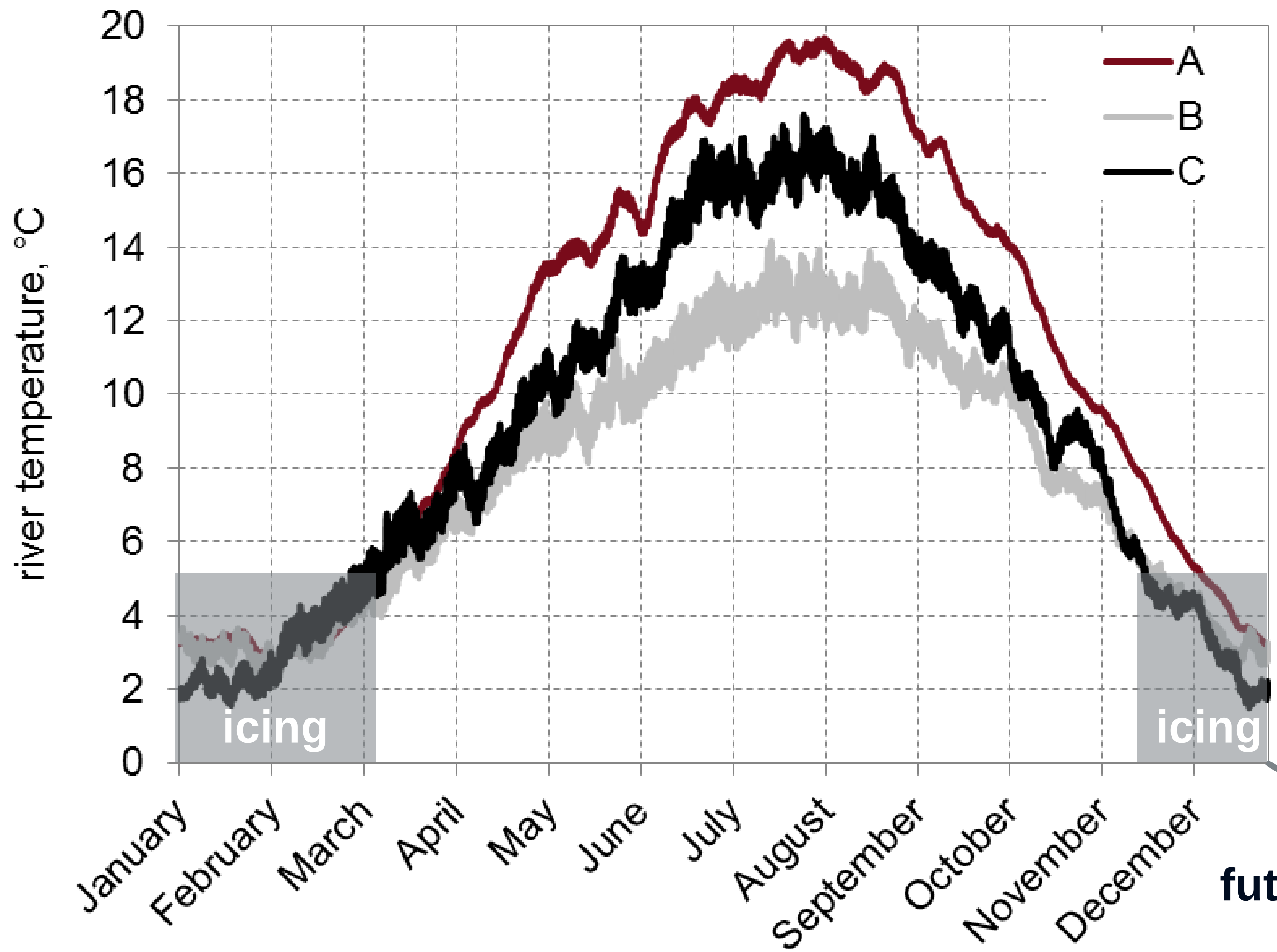
- three major cities in Austria
- large scale heat pump system
- slip stream from a local river

Simulation: boundary conditions



- seasonal variations of river & district heating grid
- simulation of one year on an hourly basis

River water as heat source: temperature



volume flow

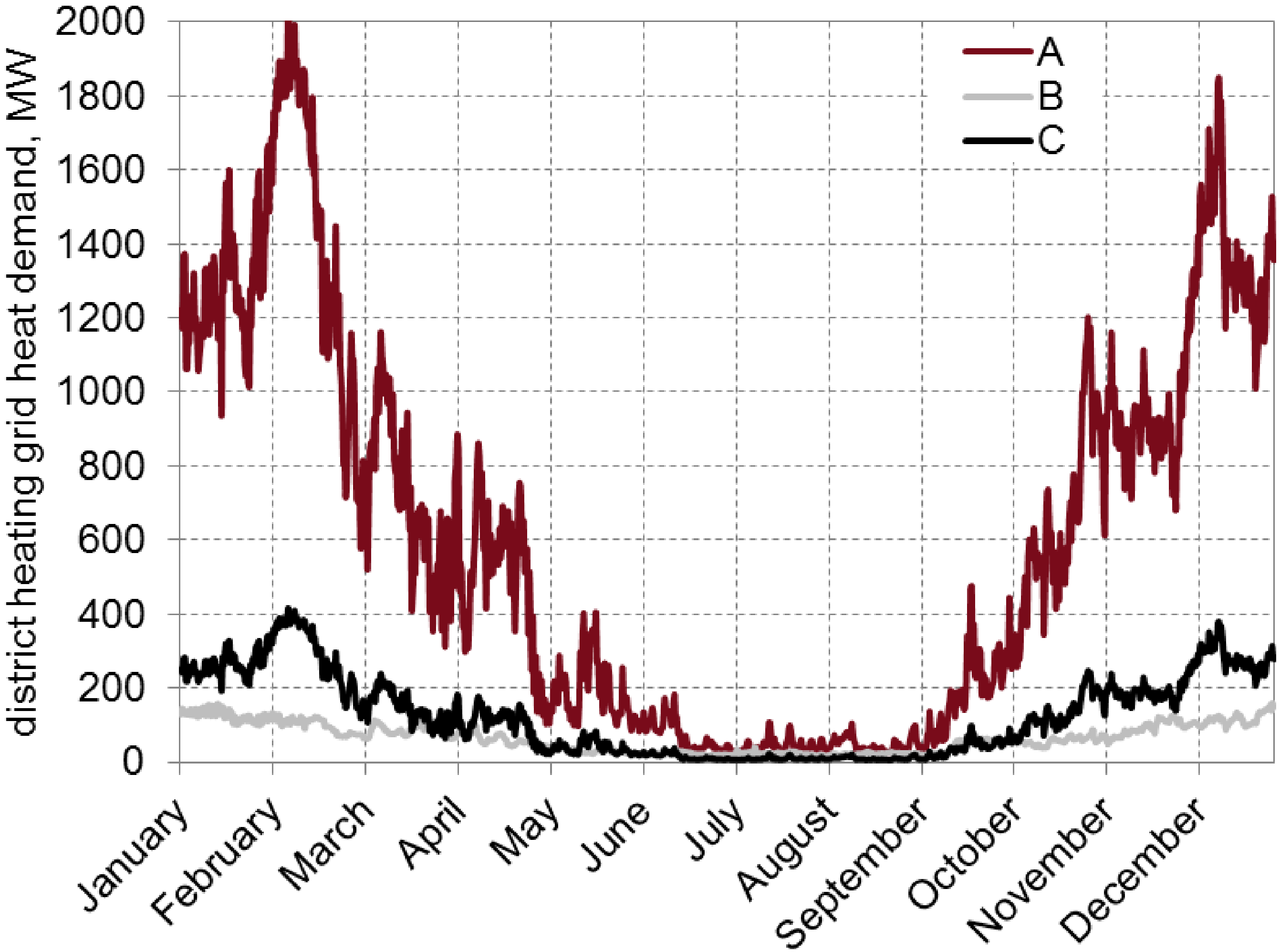
A ≈ 1800 m³/s

B ≈ 180 m³/s

C ≈ 105 m³/s

future scenarios

Heat demand in district heating grids



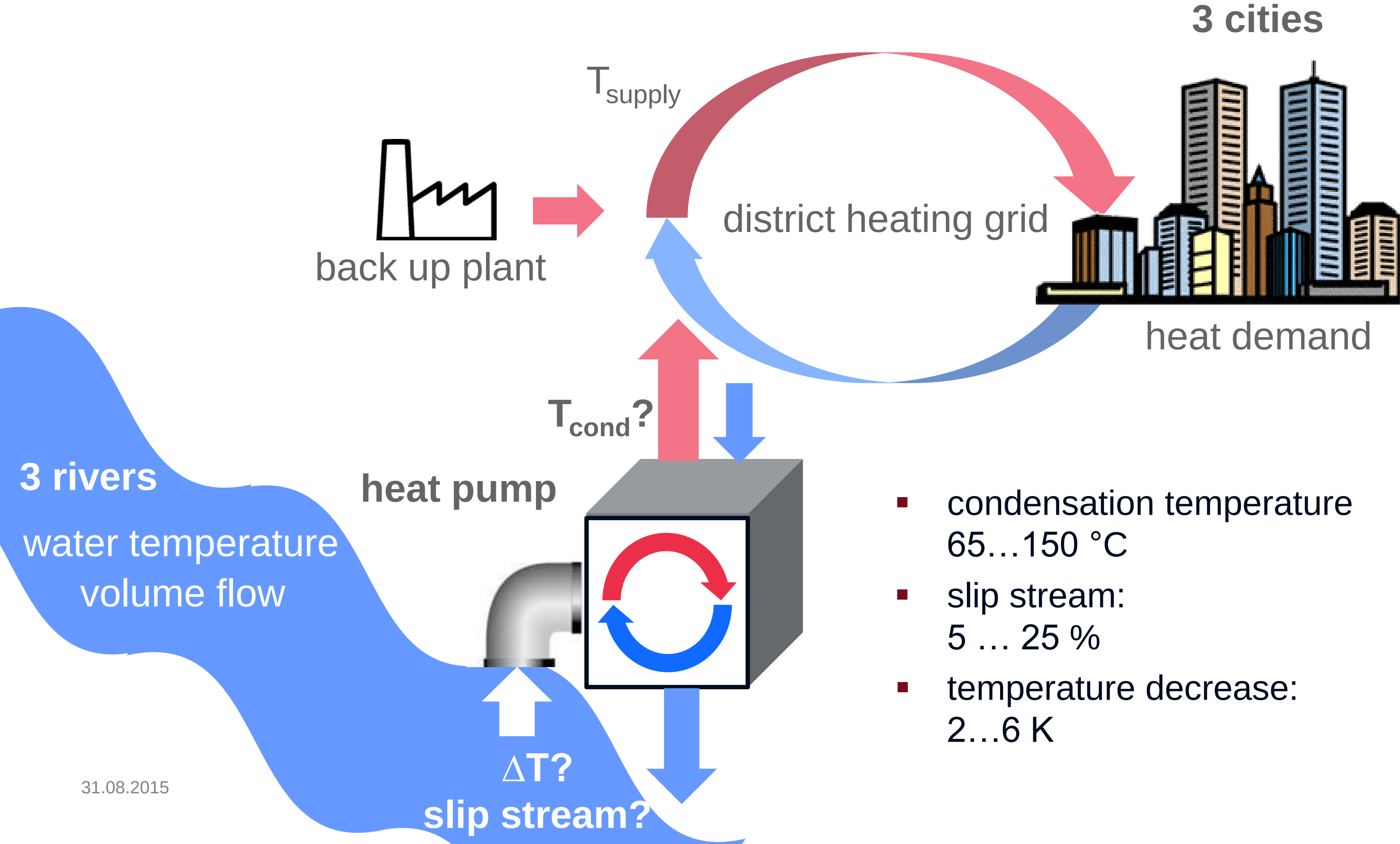
T_{max}

A = 129 °C

B = 123 °C

C = 116 °C

Simulation: 650 scenarios

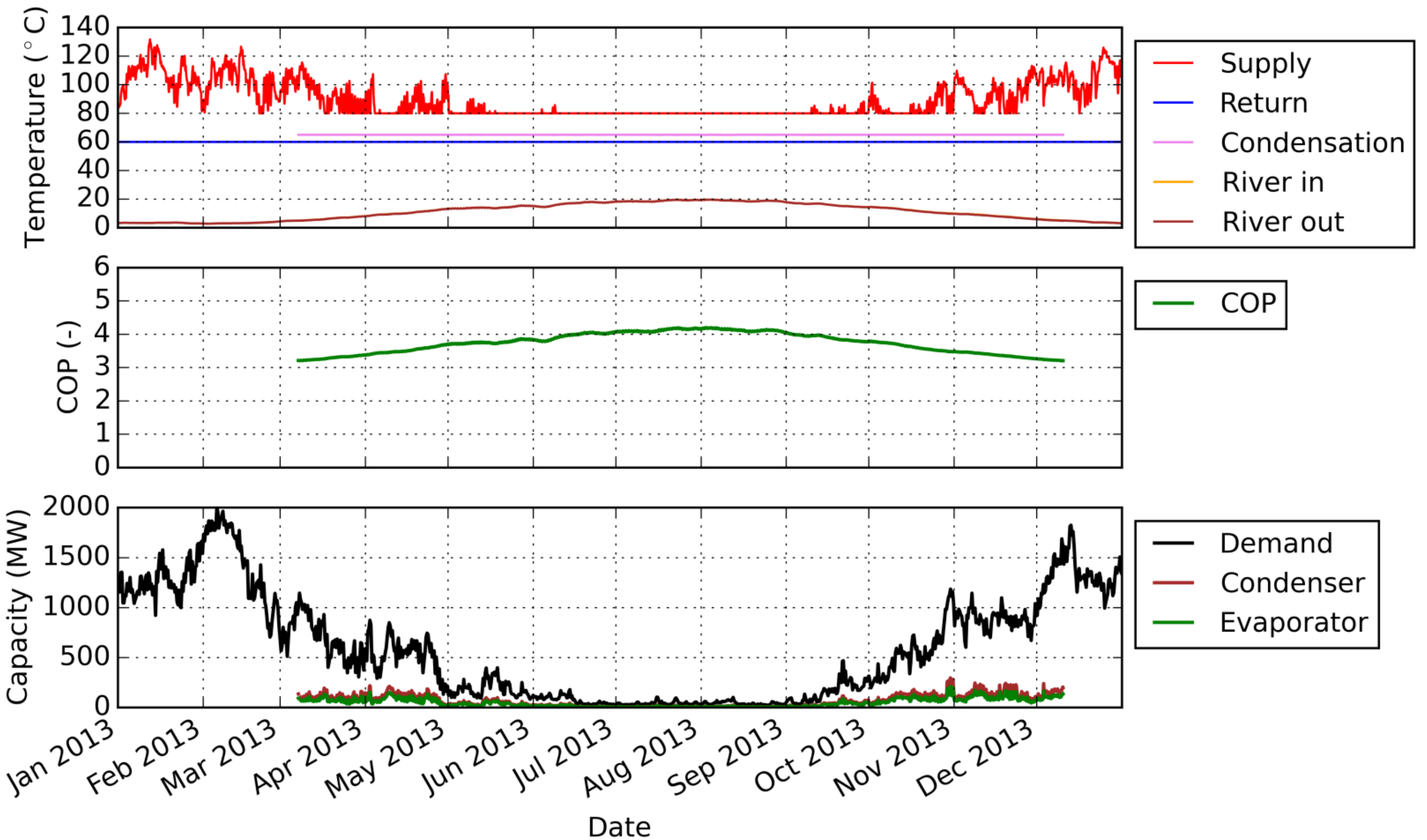


- condensation temperature 65…150 °C
- slip stream: 5 … 25 %
- temperature decrease: 2…6 K

Simulation results

- 650 different versions to design the heat pump systems (condensation temperature, slip stream and temperature difference)
- how to find the best scenario for each city?
- seasonal performance factor (SPF) of the heat pump

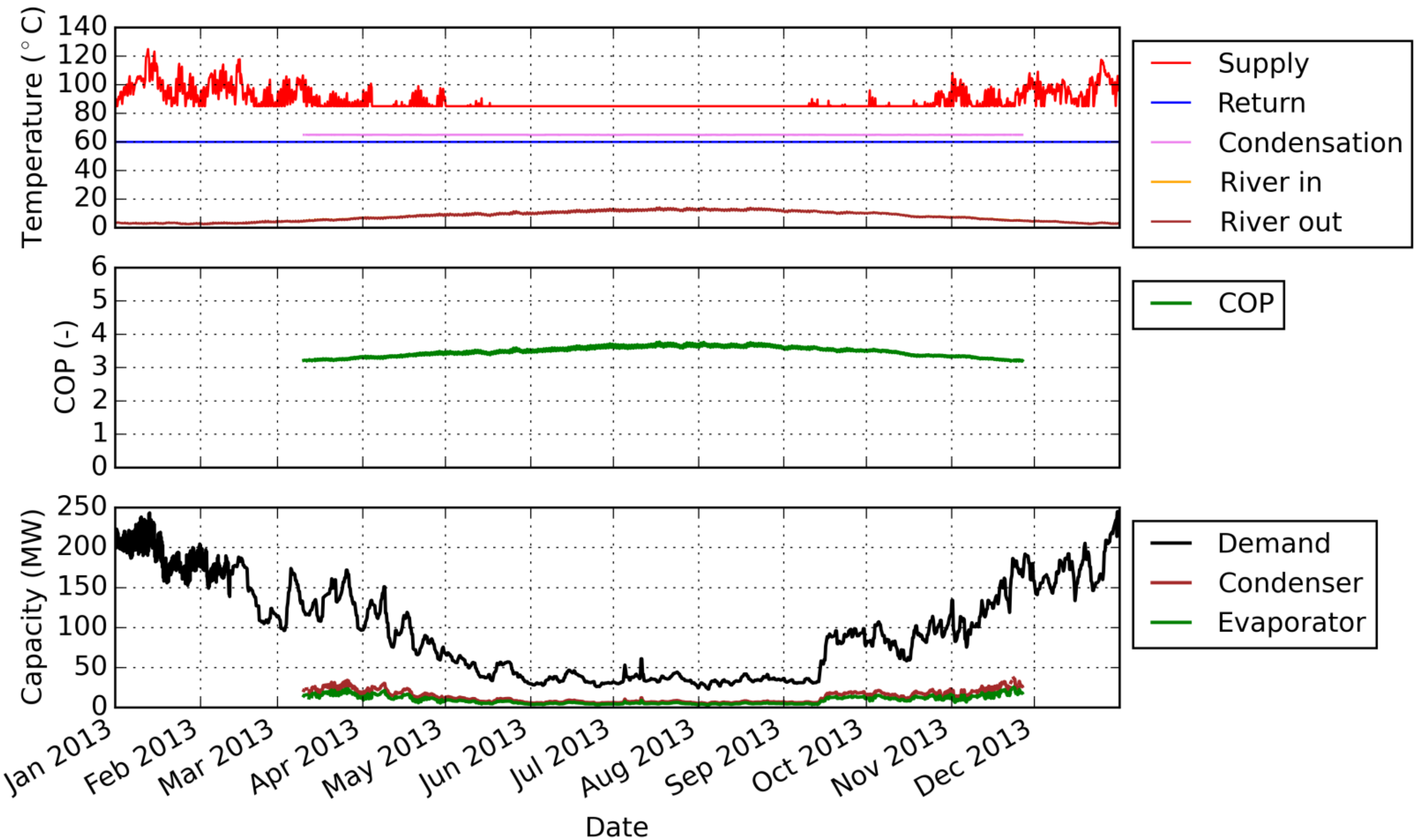
River A: highest seasonal performance factor



Tcond = 65 °C
ΔT = 2-6 K
slip stream = 25 %

SPF = 3.44
457 GWh/a
9 % of district heating demand

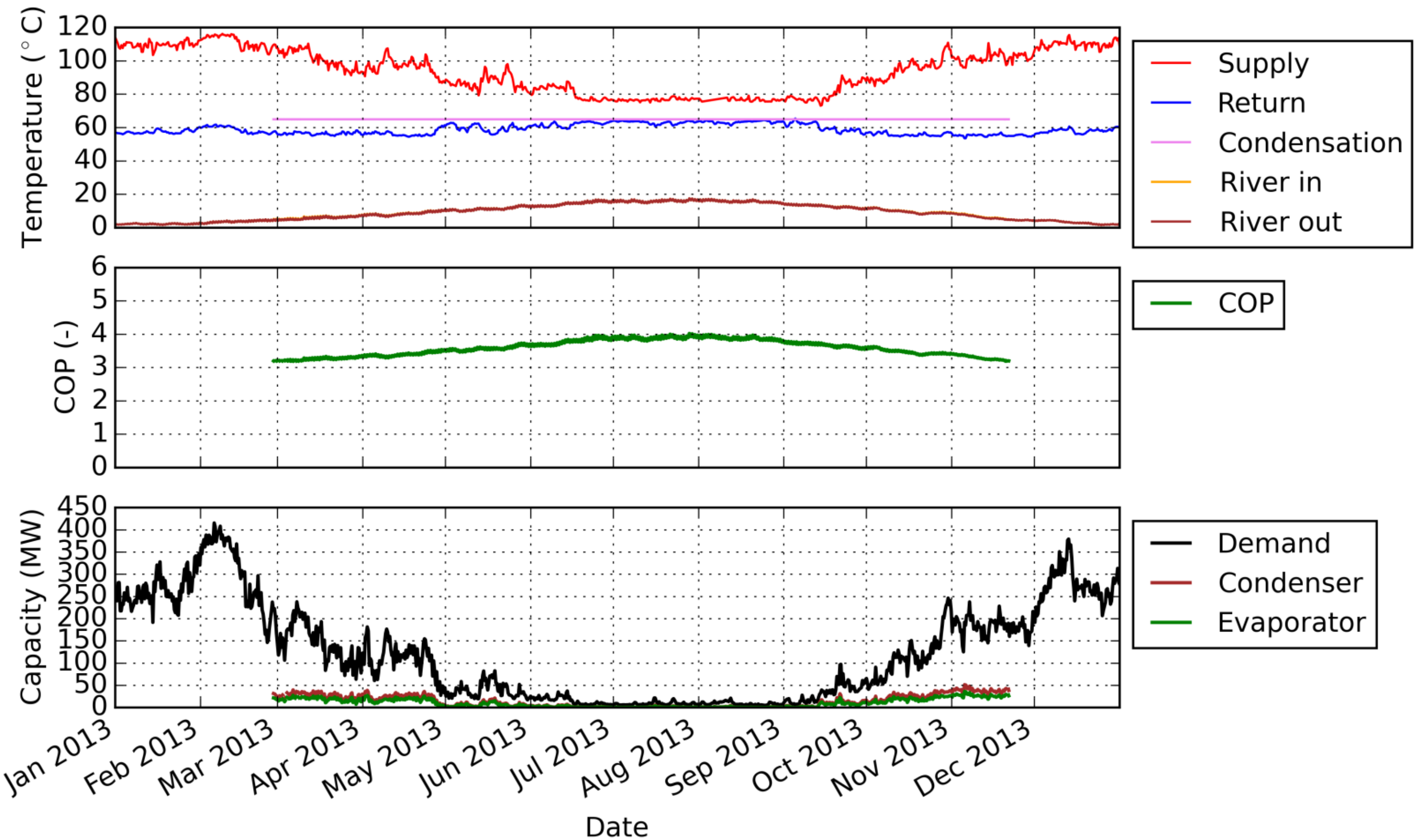
River B: highest seasonal performance factor



Tcond = 65 °C
ΔT = 2-6 K
slip stream = 25 %

SPF = 3.35
81 GWh/a
9 % of district heating demand

River C: highest seasonal performance factor

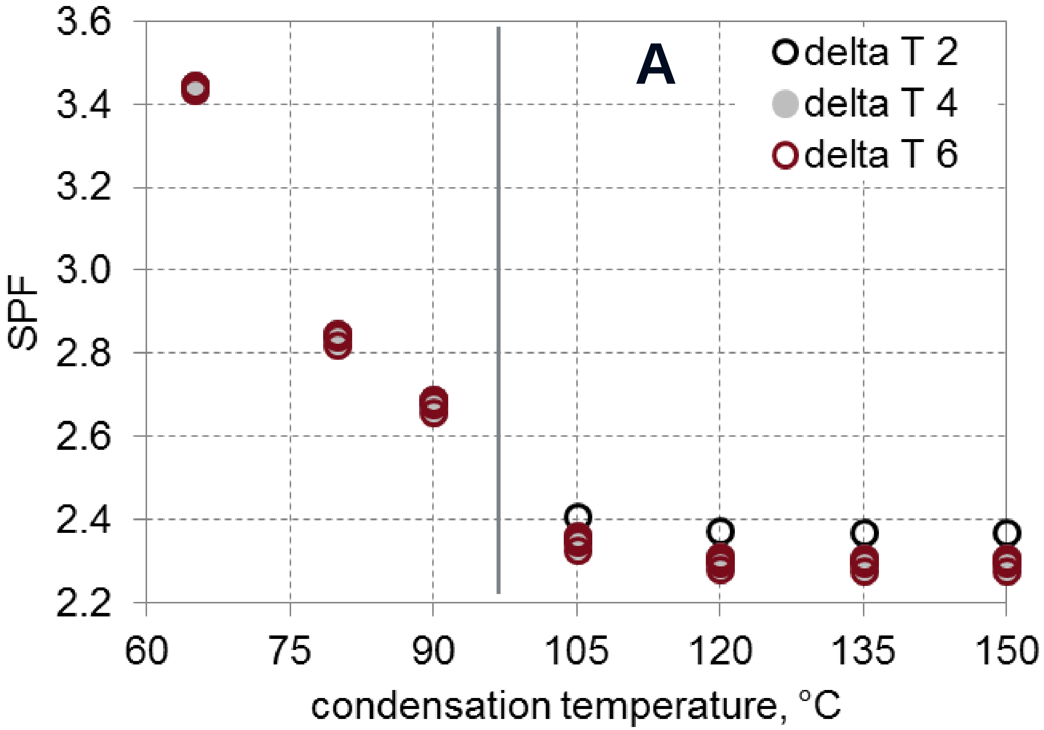


Tcond = 65 °C
ΔT = 2-6 K
slip stream = 25 %

SPF = 3.34
88 GWh/a
8 % of district heating demand

Highest seasonal performance factor

- most efficient operation of the heat pump
- base load only
- condensation temperature of 65 °C sufficient
- state-of-the art scenario
- no operation in winter because of icing at the evaporator



Range of SPF

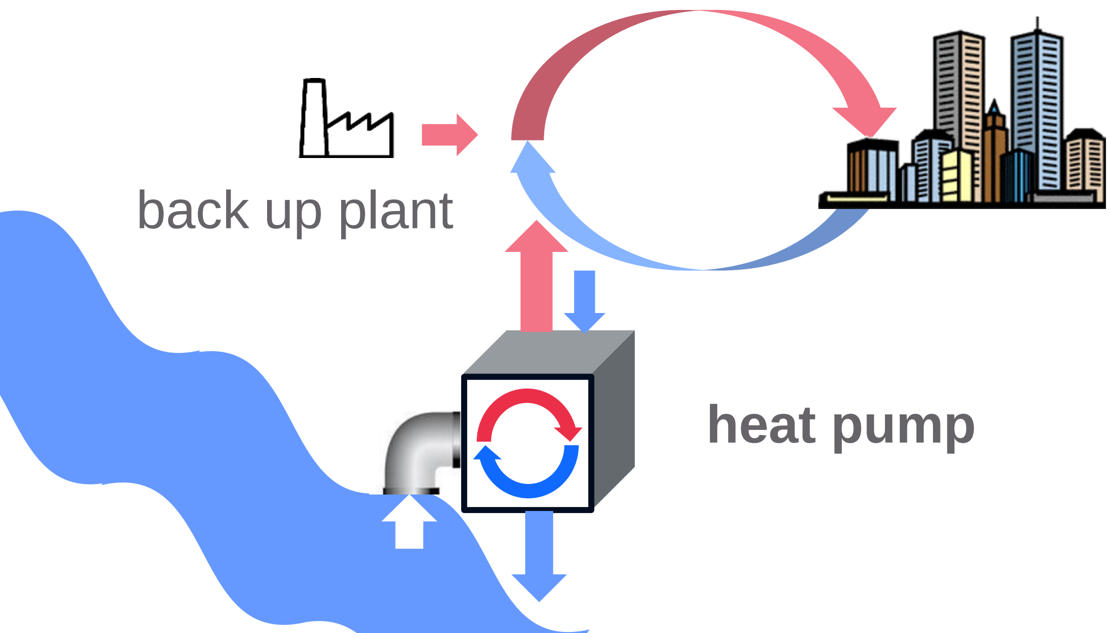
A: 2.3 – 3.4

B: 2.4 – 3.4

C: 2.2 – 3.3

Evaluation of results

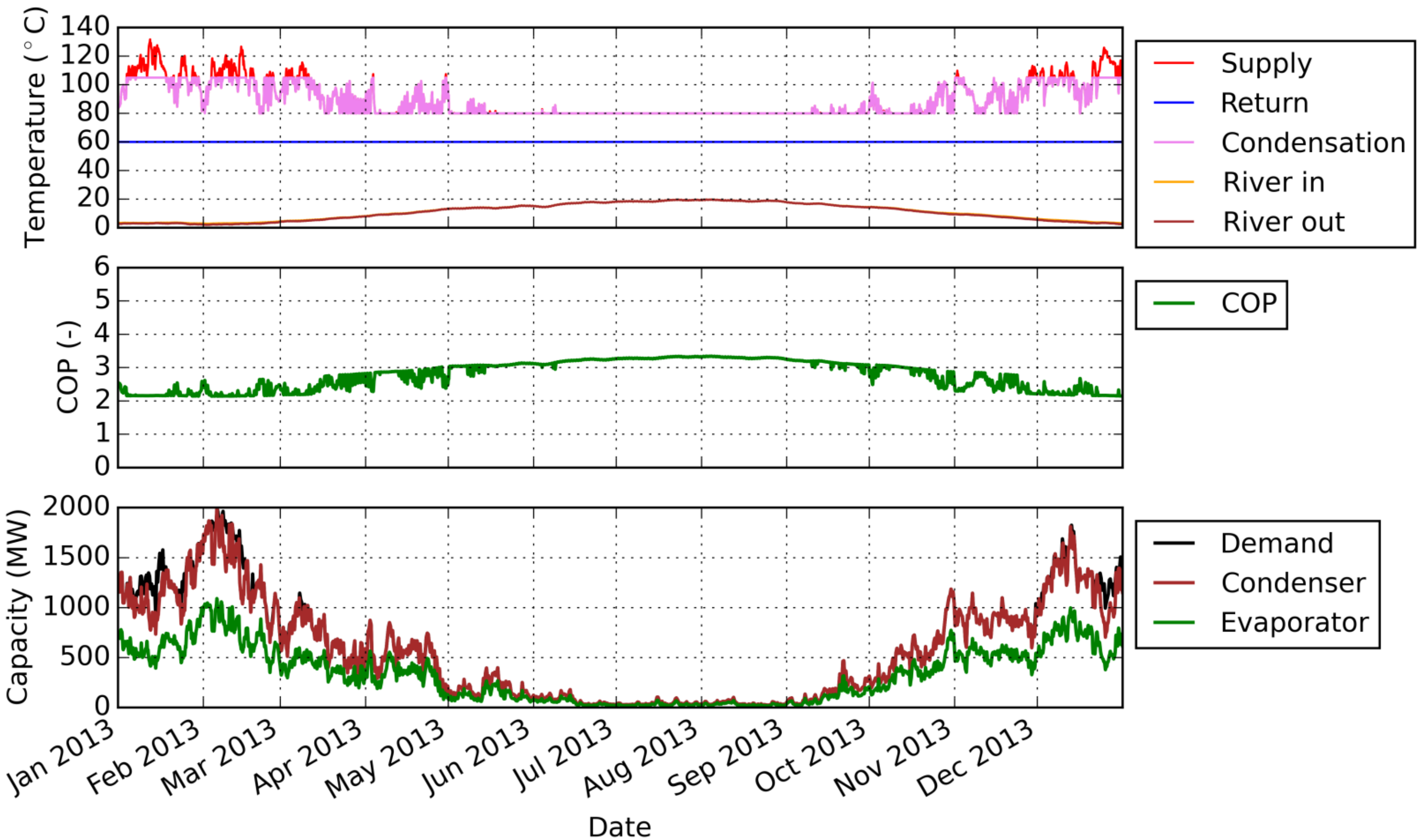
- comparison to the backup system
  - gas boiler
  - electric heater
- environmental aspects
  - CO_2 emissions
- economic aspects
  - investment and operation costs



Highest CO_2 emission reduction

- CO_2 emissions calculated according to EN15601
  - natural gas: 277 g/kWh
  - electricity: 617 g/kWh (European electricity mixture)
- SPF > 2.2 to allow for CO_2 emission reduction

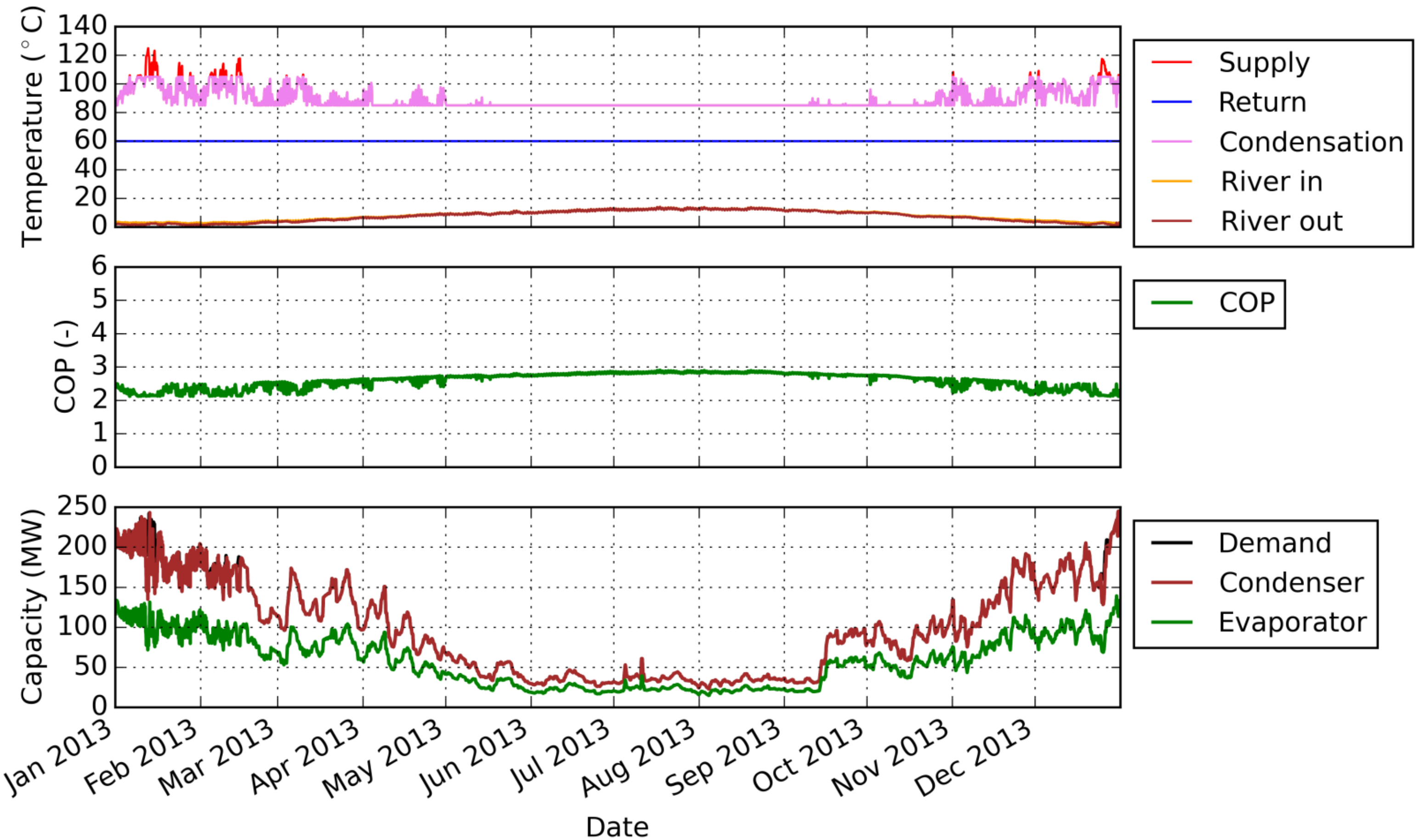
River A: highest CO_2 emission reduction



Tcond = 105 °C
ΔT = 2 K
slip stream = 20 %

SPF = 2.36
5002 GWh/a
96 % of district heating demand

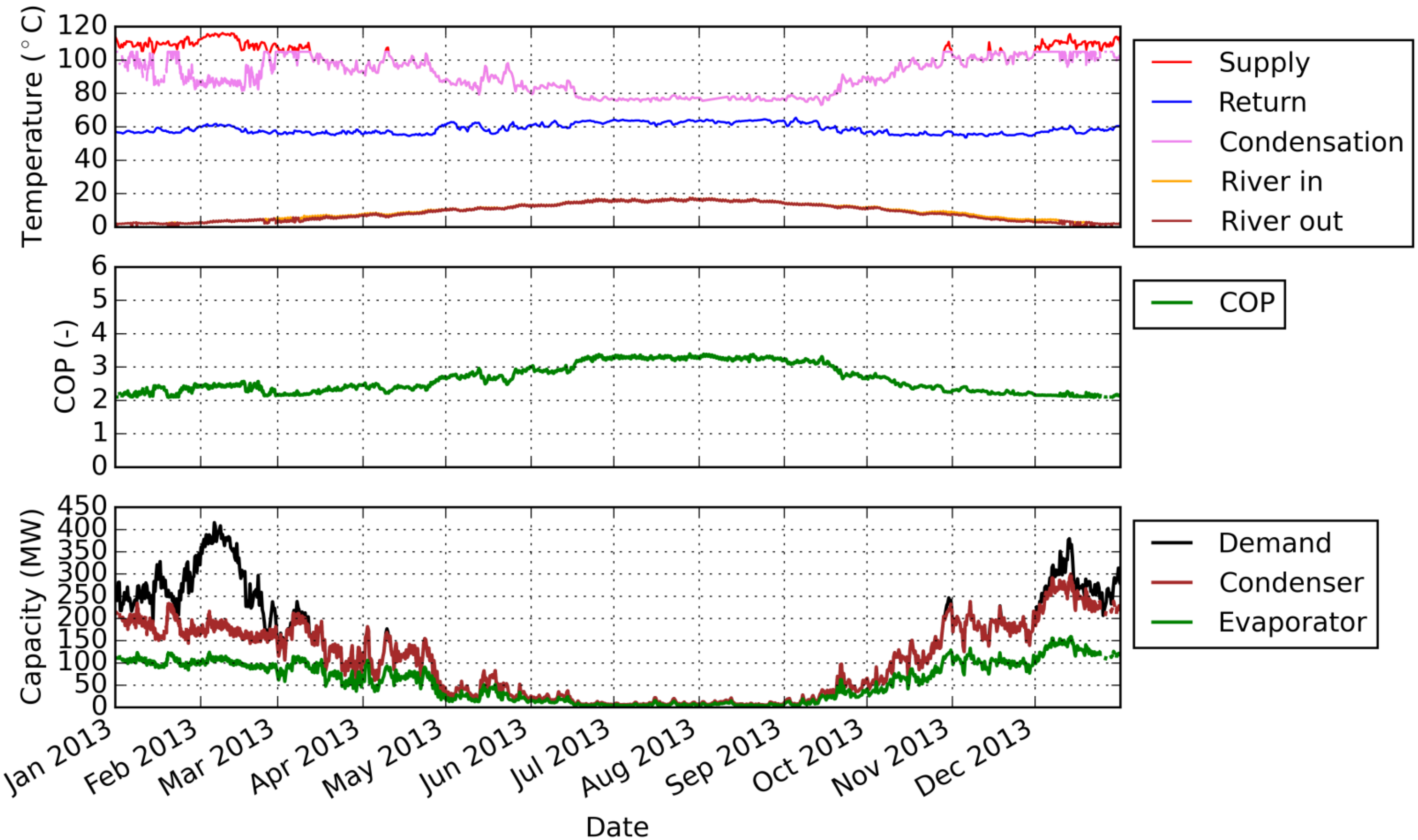
River B: highest CO_2 emission reduction



Tcond = 105 °C
ΔT = 2 K
slip stream = 25 %

SPF = 2.41
860 GWh/a
99 % of the district heating demand

River C: highest CO_2 emission reduction



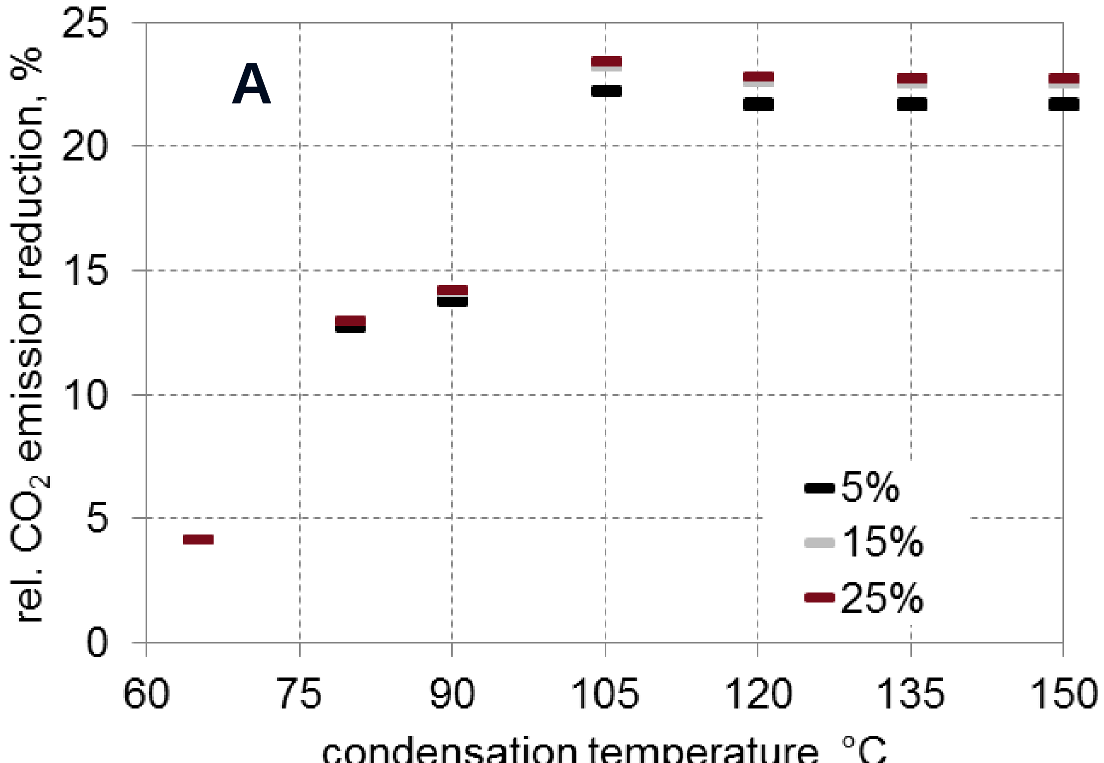
Tcond = 105 °C
ΔT = 2 K
slip stream = 25 %

SPF = 2.28
834 GWh/a
77 % of the district heating demand

Maximum CO_2 emission reduction

Gas boiler

- all scenarios allow for CO_2 emission reductions
- maximum in all cities at T_{cond} = 105 °C
- T_{cond} > 105 °C: CO_2 emission reduction decreases slightly because of SPF



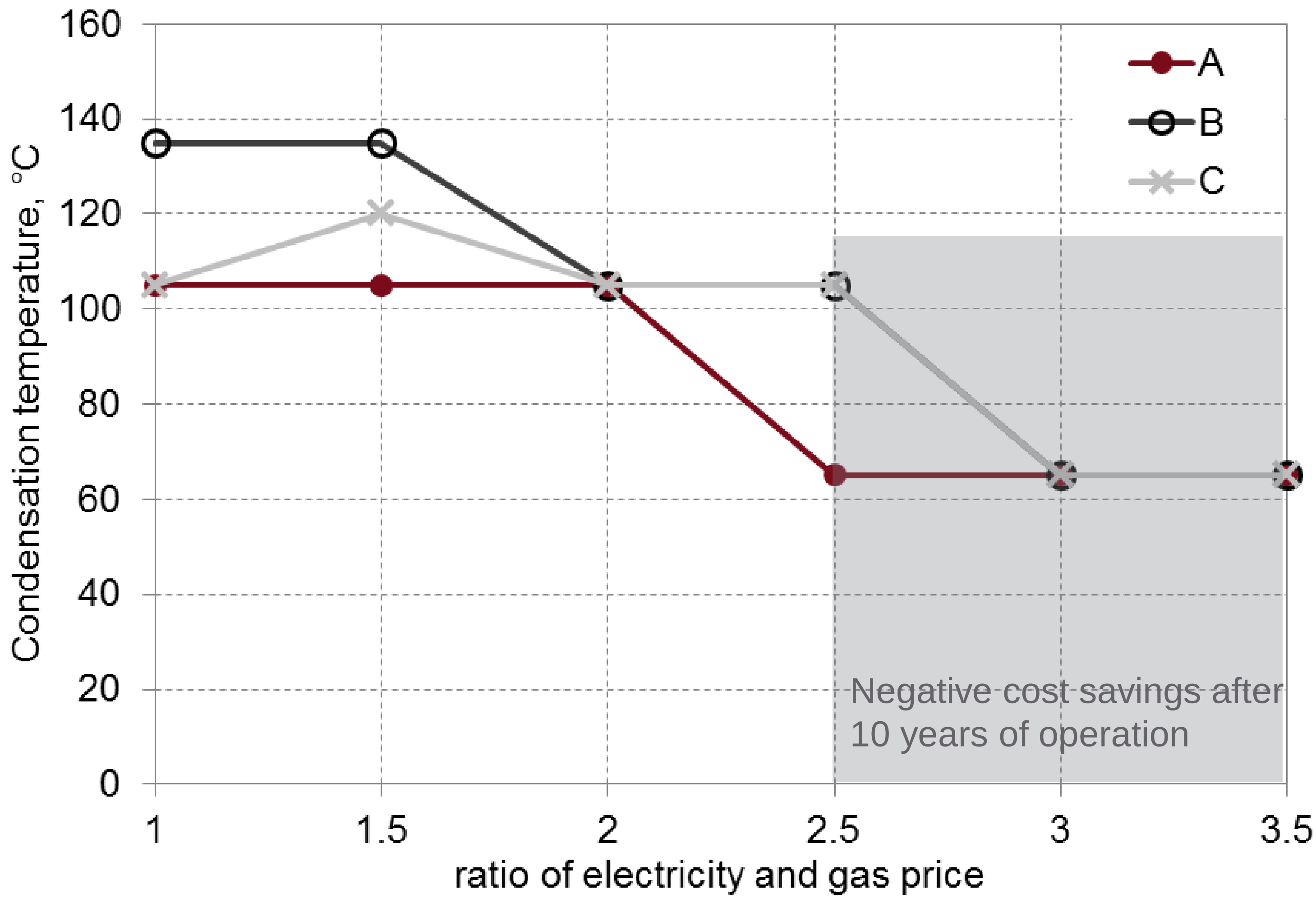
Economic aspects

Gas boiler

- investment costs:
  - gas boiler: 20 €/kW heating capacity
  - heat pump: 250 – 400 €/kW heating capacity
  - without river intake structure
  - without district heating infrastructure

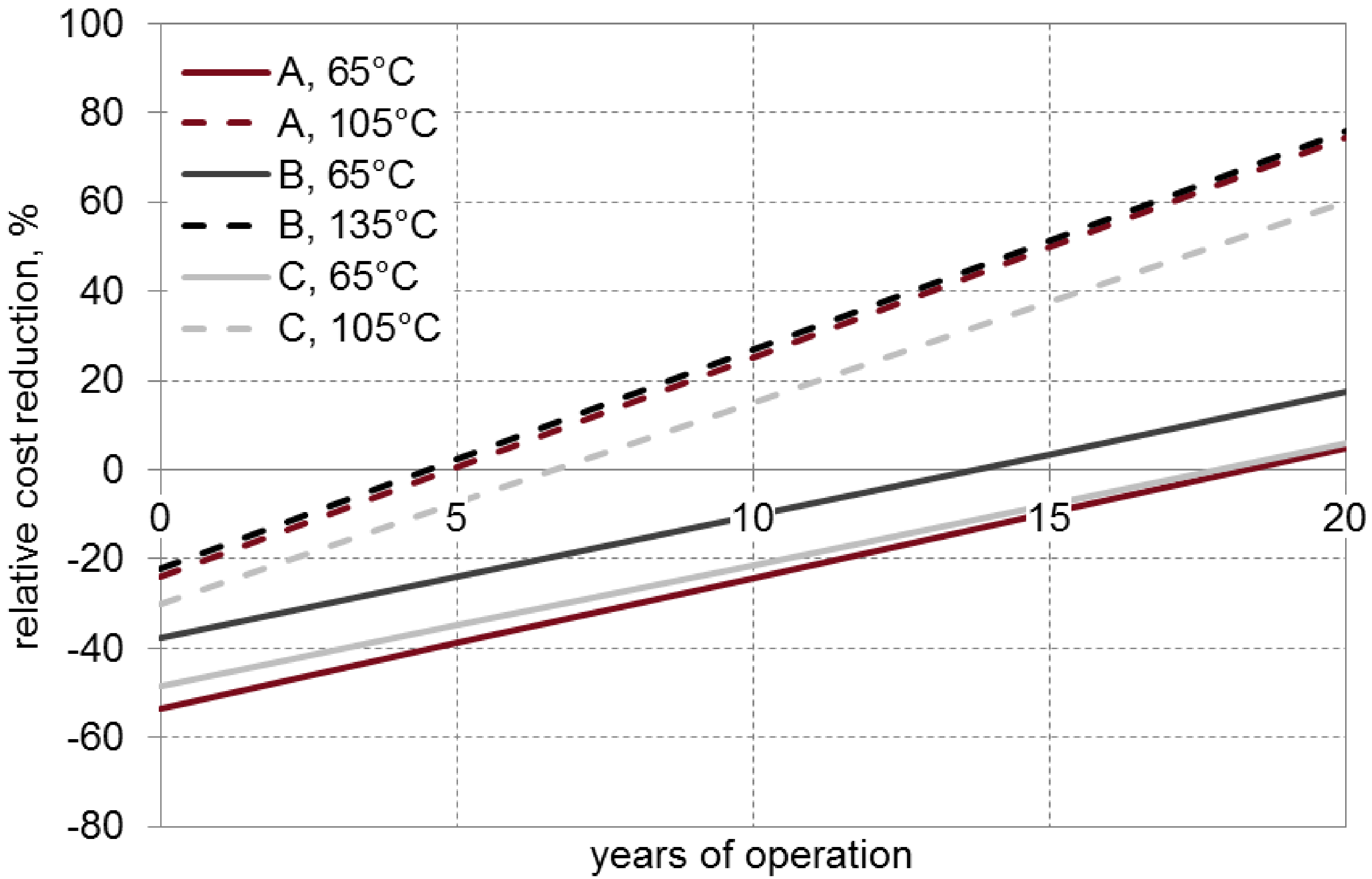
- operation costs:
  - ratio of electricity and gas prices: 1 … 3.5

Maximum savings



heat pump investment cost = 300 €/kW heating capacity
at maximum cost savings after 10 years of operation

Development of relative cost reduction with time



year 0 = investment costs

maximum savings at S/G = 3 → T_{cond} = 65 °C and at S/G = 1.5 → T_{cond} = 105…135 °C

Conclusions

- base load scenarios with T_{cond} = 65 °C allow for high SPF and are more economic
- high shares of heat pumps in the district heating grid require low electricity prices (or high gas prices)
- T_{cond} = 105 °C is sufficient to achieve maximum CO_2 emission reductions
- rivers are suitable ambient heat sources for heat pumps in alpine regions
- icing at the evaporator is a major concern that requires control strategies

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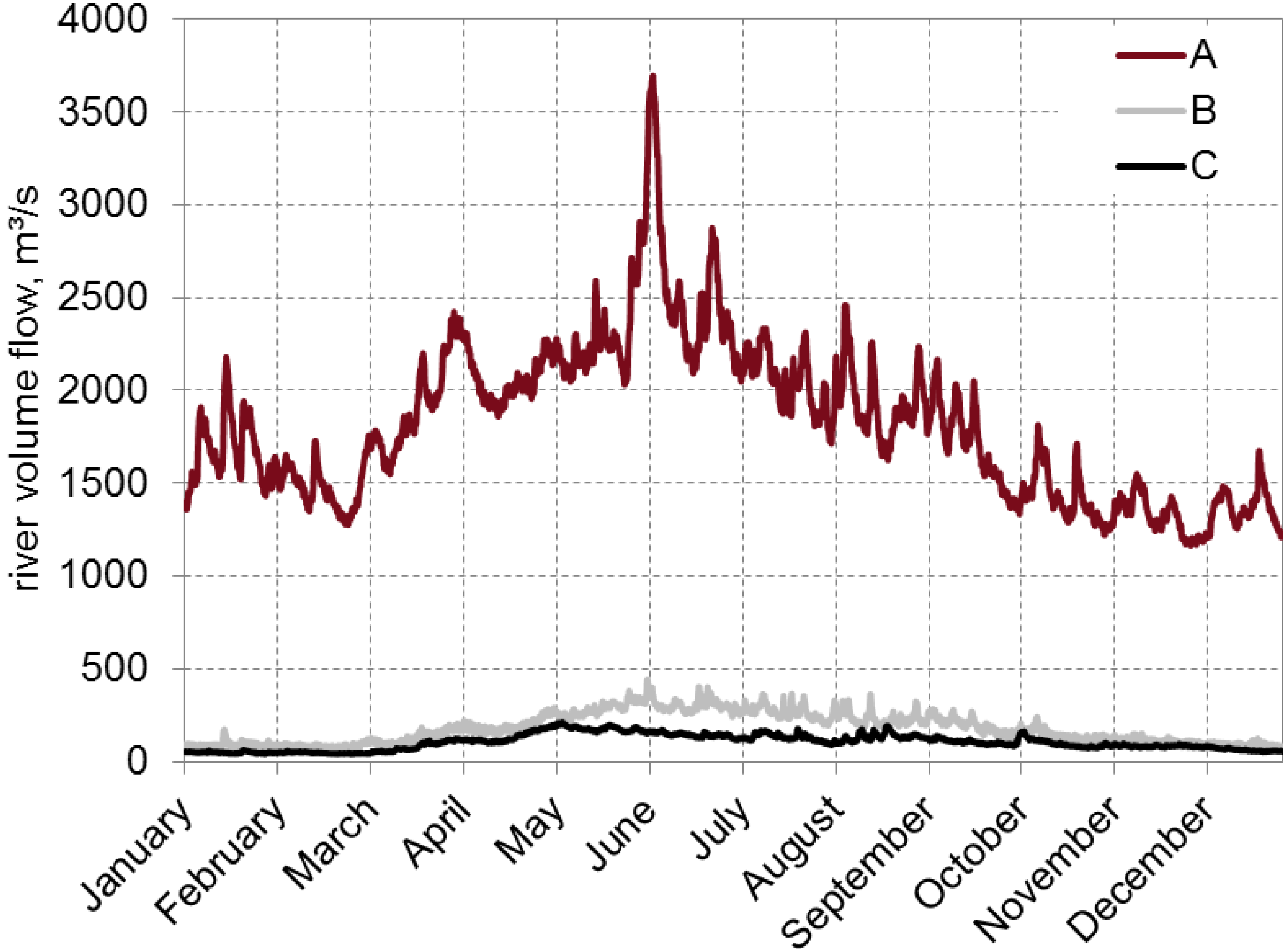
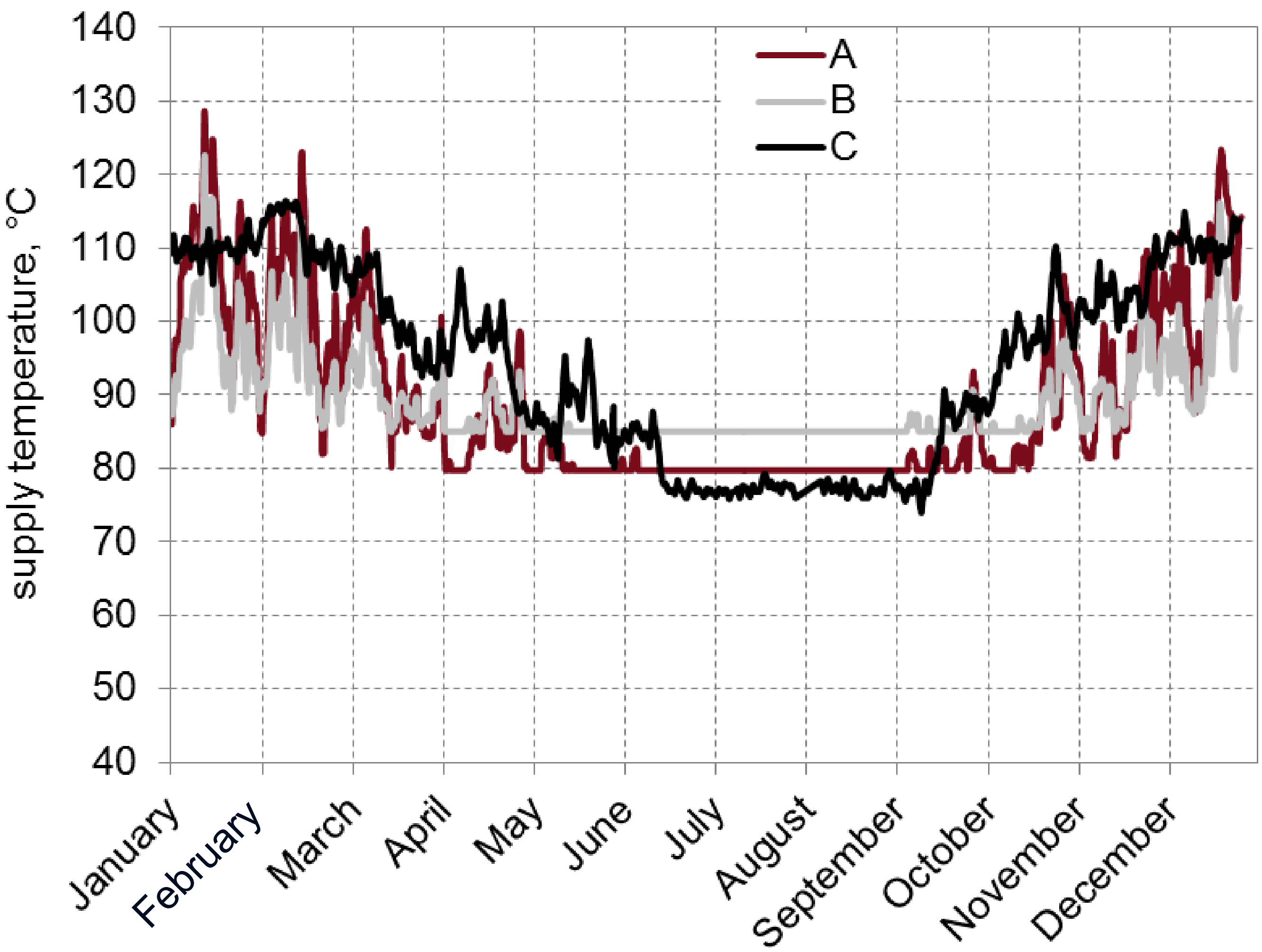
River water as heat source: volume flow



Supply temperature in district heating grids



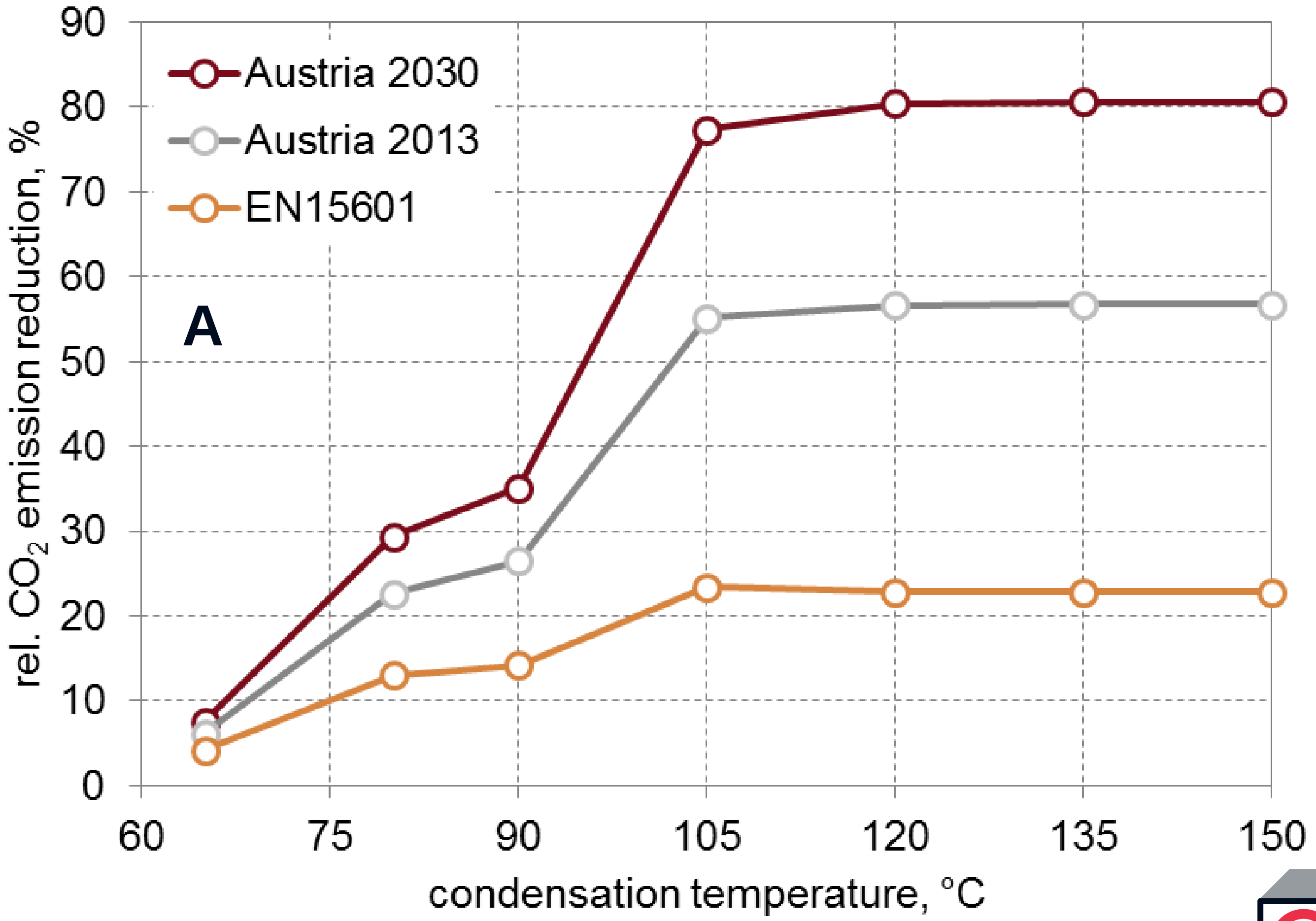
T_{max}

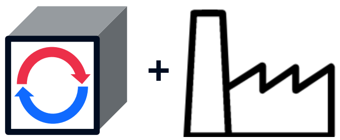
A = 129 °C

B = 123 °C

C = 116 °C

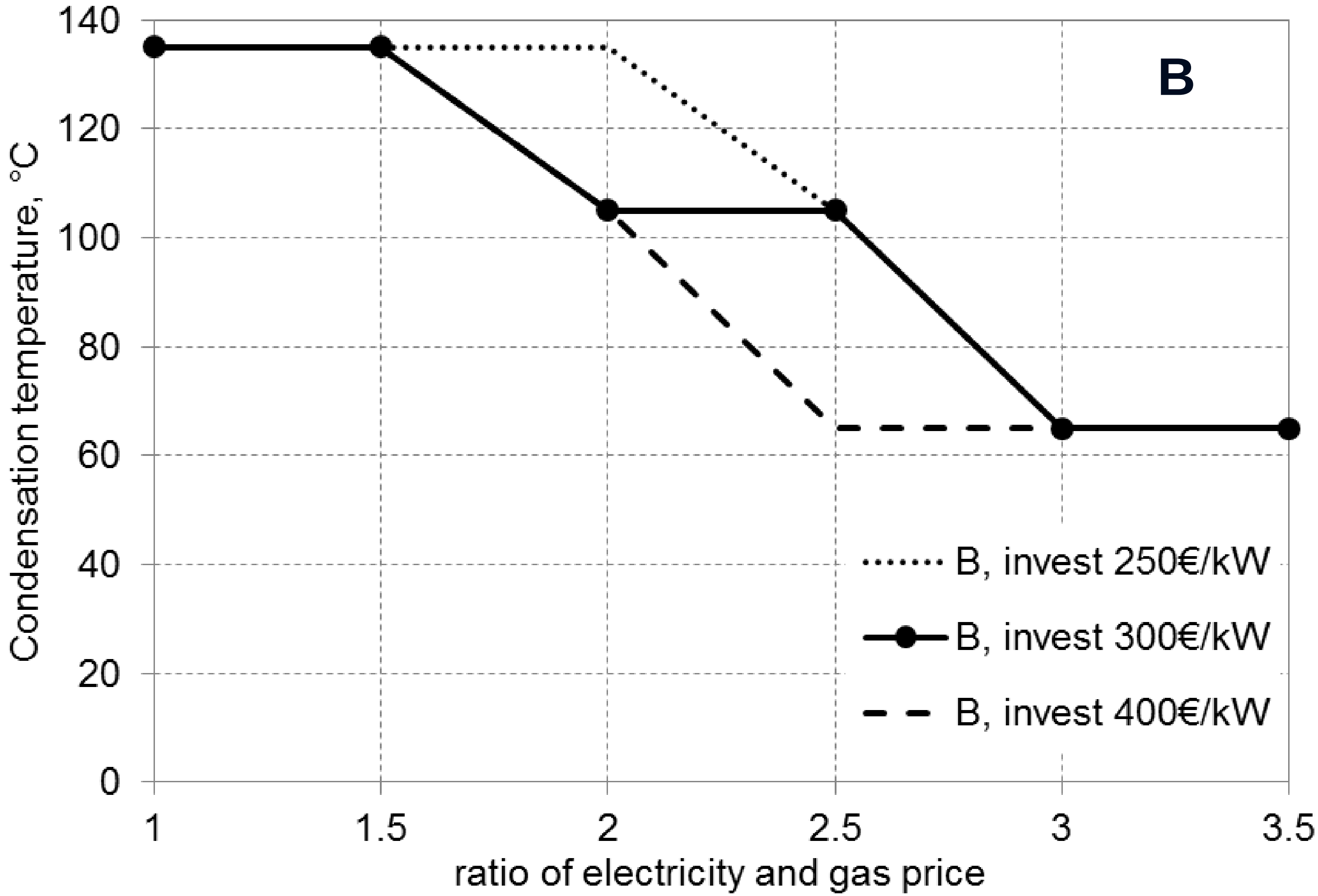
Comparison of different CO_2 factors





Austria 2013: Gas = 225 g/kWh, electricity = 281 g/kWh (ref: Gemis)
Austria 2030: Gas = 225 g/kWh, electricity = 126 g/kWh (ref: EU Energy trends 2050)

Variation of investment cost



at maximum cost savings after 10 years of operation

Economic aspects

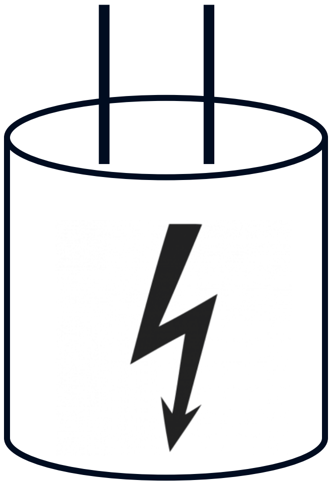
Gas boiler

- base load scenarios economically feasible
  at ratios of electricity and gas price ≈ 2

- significant shares of heat pumps economically feasible
  - low electricity prices (surplus energy?)
  - high gas prices (political situation?)

- lower investment costs allow for larger investments
  - learning curve

Comparison to electric heater as a backup system



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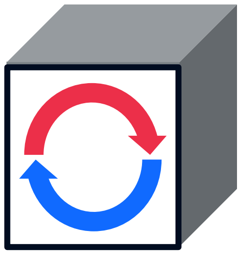

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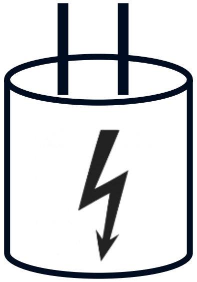


Economic aspects

Electric heater

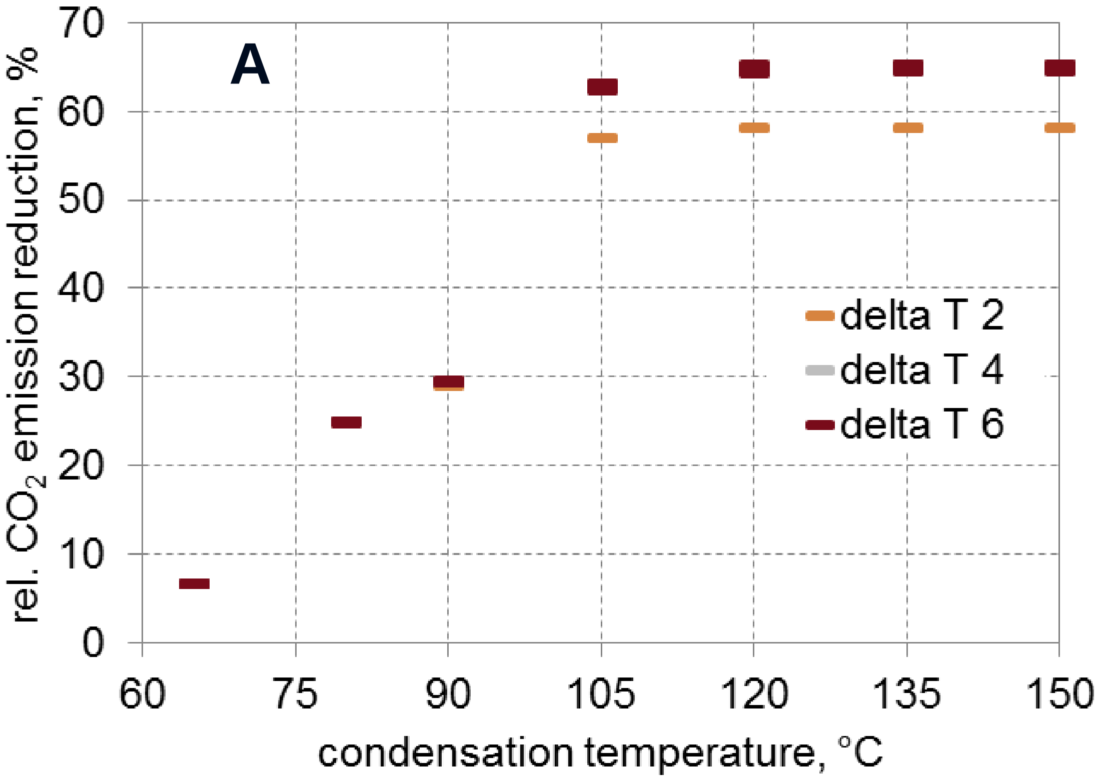
- Investment costs:
  - Electric heater: 60 €/kW heating capacity (electrode boiler)
  - Heat pump: 300 €/kW heating capacity
  - without river intake structure
  - without district heating infrastructure

- Operation costs:
  - electricity price: 1 … 11 ct/kWh

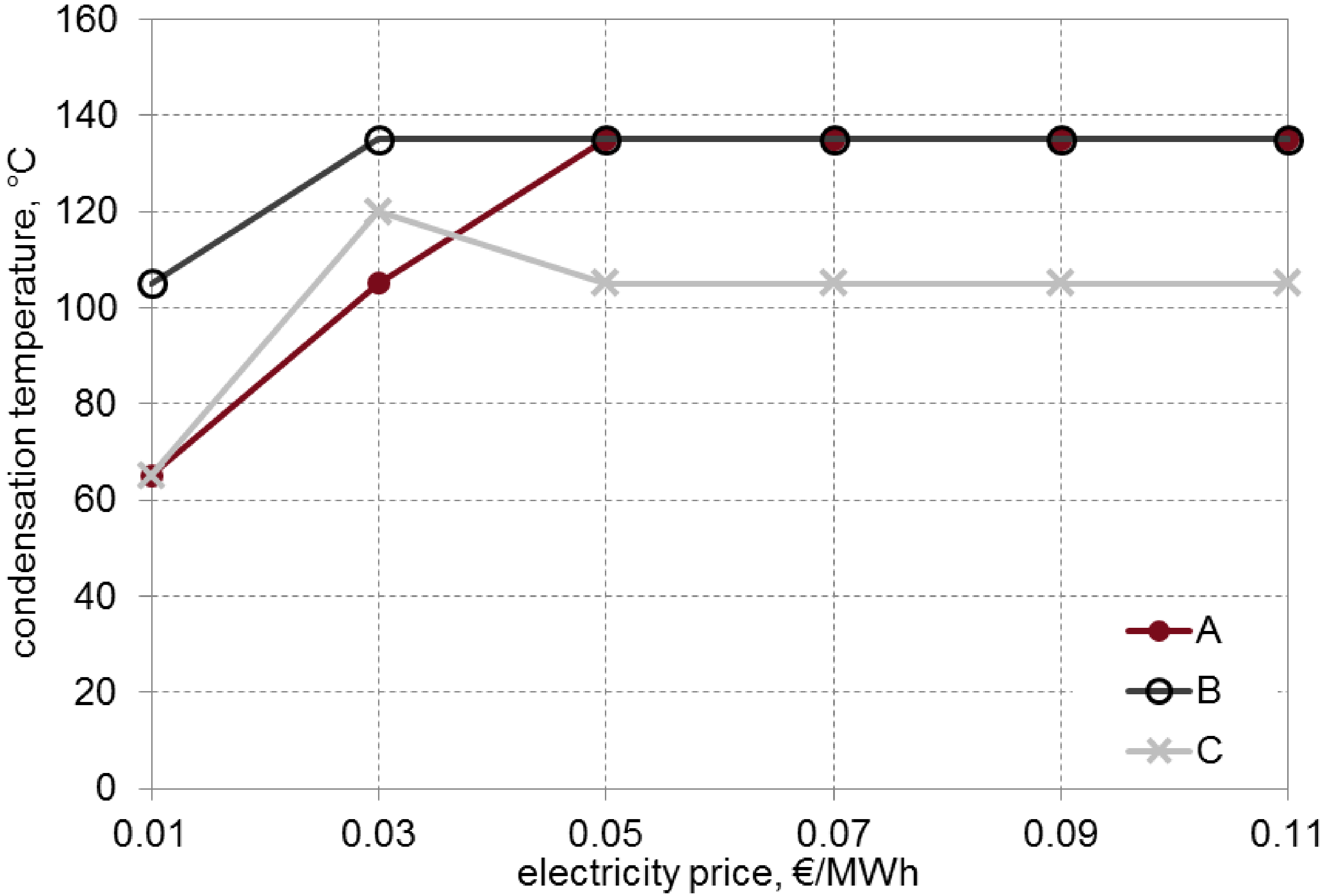
Maximum CO_2 emission reduction

Electric heater

- all scenarios allow for CO_2 emission reductions
- reductions significantly higher compared to gas boiler
- maximum at T_{cond} = 135 °C (city A and B) and 120 °C (city C)



Maximum cost reduction



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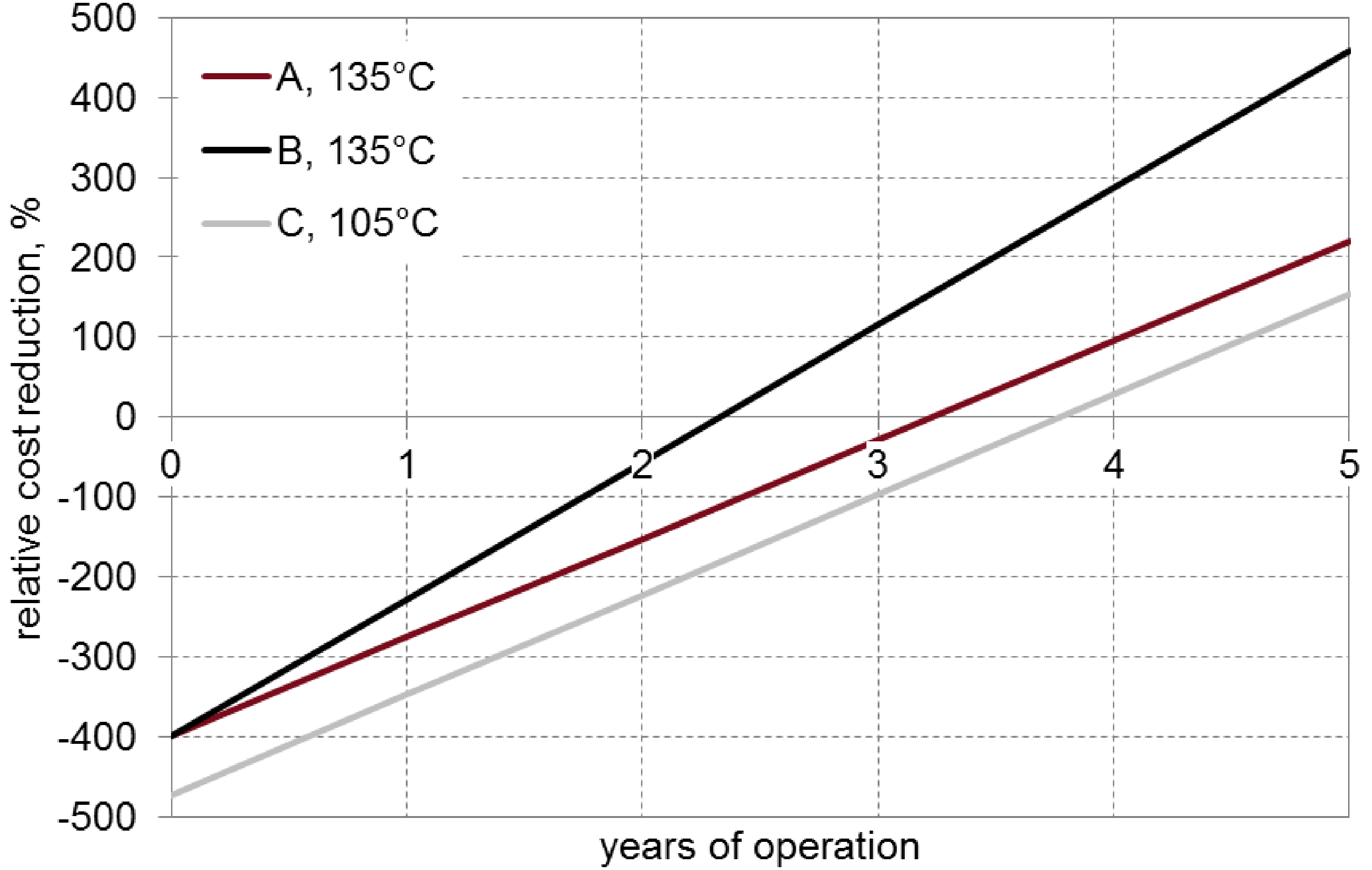

year 0 = investment costs

maximum savings at electricity price of 0.05€/MWh → T_{cond} = 105…135°C

Economic aspects

Electric heater

- low investment costs of the electric heater
- heat pump significantly more efficient during operation
- cumulated costs of the heat pump lower than of the electric heater after 4 years of operation at the latest