Impact of a waste heat integration on district heating systems' multi-objective optimization results

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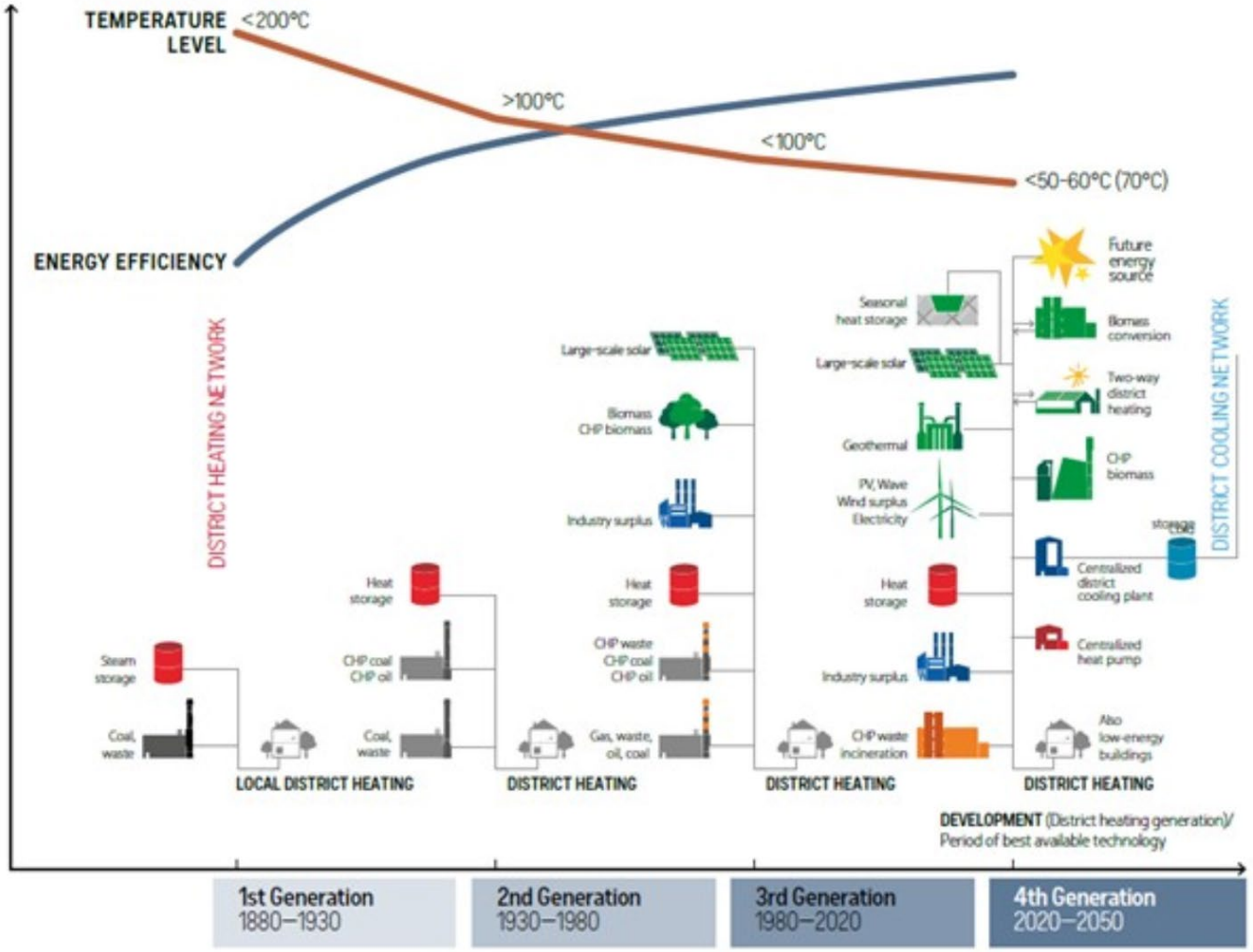
Content

- 4th generation district heating systems
- Multi-objective optimization – main features
- Method
- Case study
- Results
- Conclusion

4th generation district heating systems – 4DH

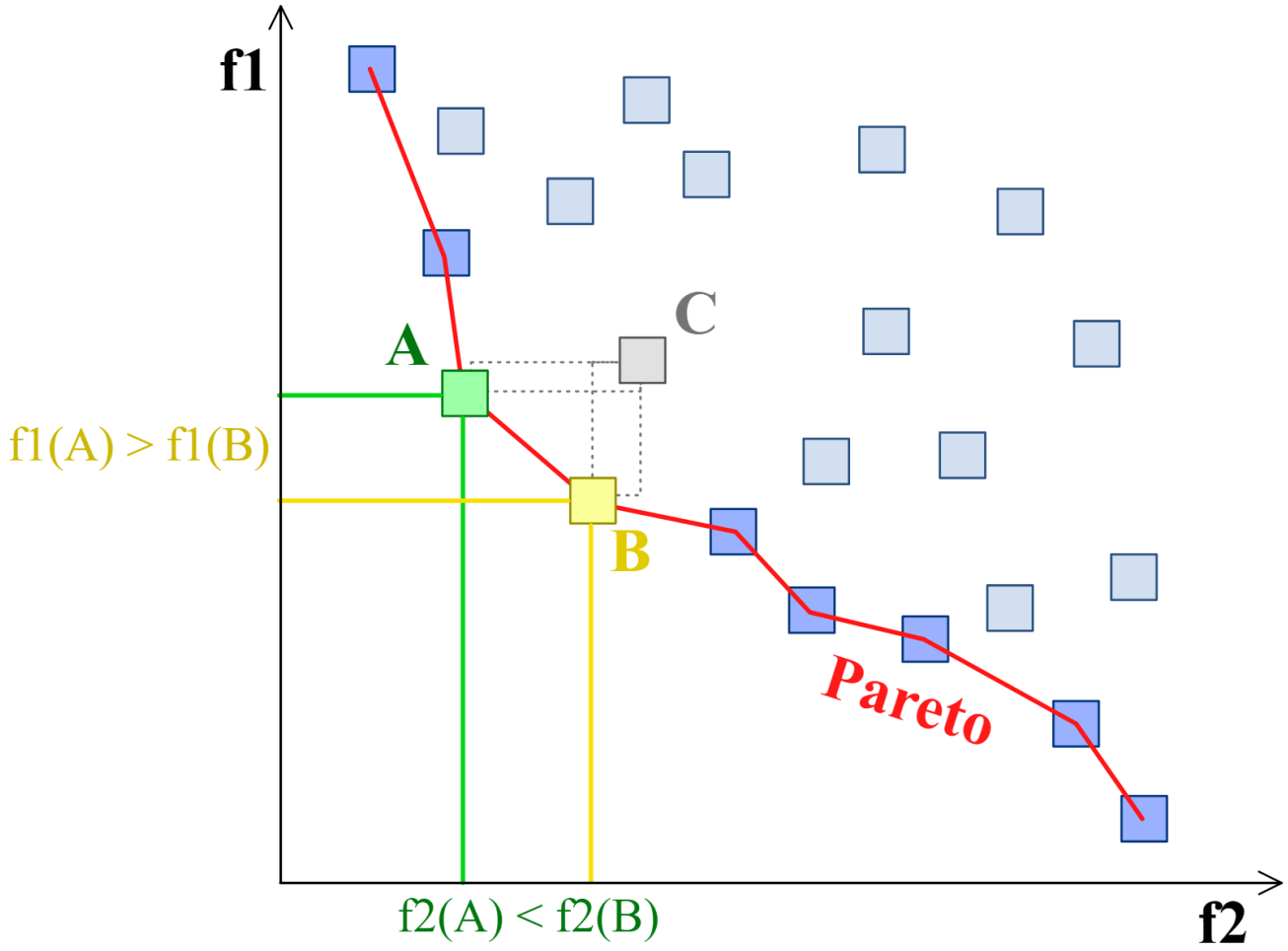
- Integration of heating, cooling and power sector (besides transport and gas grid) → *smart grid*

- Optimization of system capacity and operation presents challenge



Multi-objective optimization

- Optimization → looking for maximum or minimum of the objective function
- Multi-objective optimization? → possible conflict of interest → compromise
- **Pareto front**



Method

- Two objective functions:

$$\min(f_{econ}, f_{ecol})$$

- Total discounted cost

$$f_{economical} = \sum_{i} C_{investment,i} + C_{fuel,i} + C_{O\&M,i} - Income_i$$

- Total CO2 emissions

$$f_{environmental} = \sum_{t=1}^{t=8760} \sum_{i} e_{CO_2,i} \cdot Q_{i,t} / \eta_i$$

- **Optimization variables: supply capacities (including thermal storage size) and hourly operation for a whole year**

Method

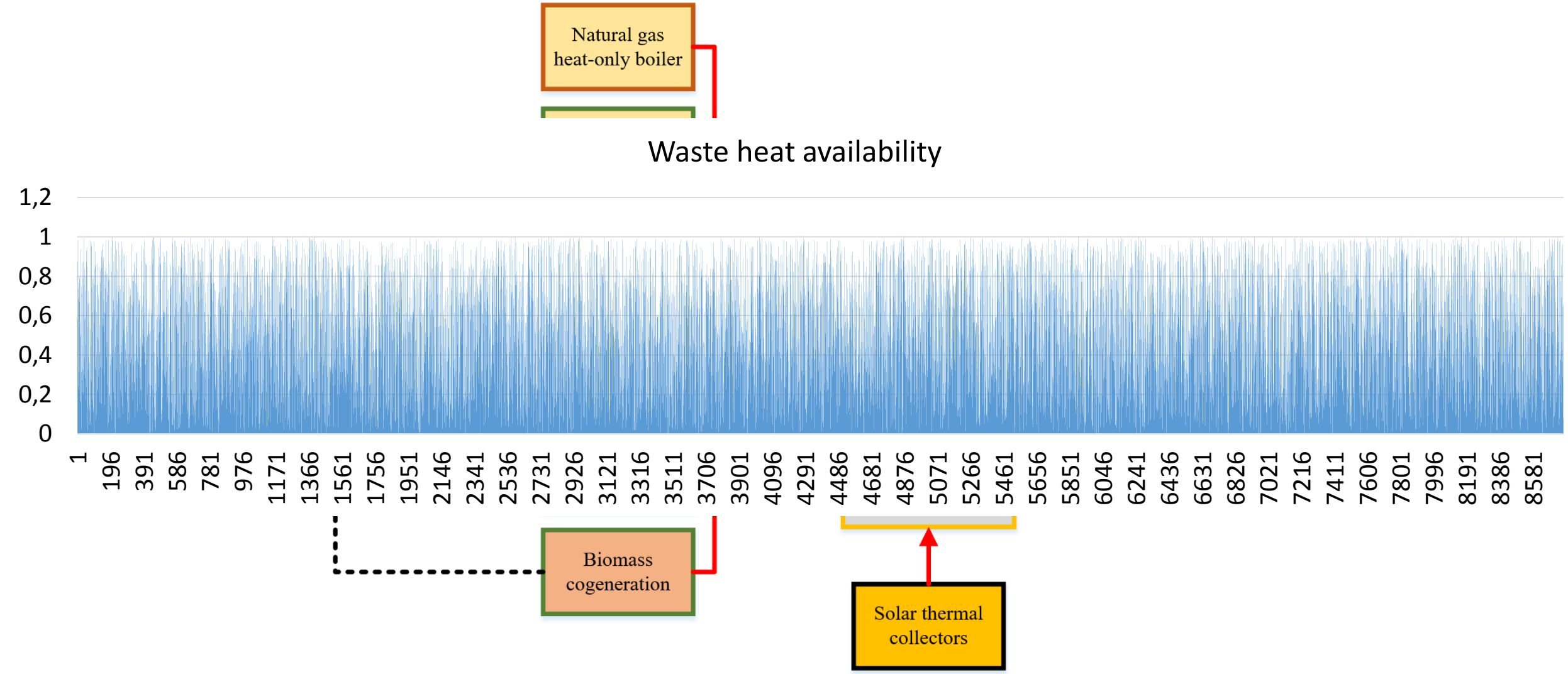
- **Epsilon constrainted method**

- Translating multi-objective optimization problem to single-objective optimization with additional constraints

- Acquire boundaries of the Pareto surface

$$\min(f_{econ}) \ for \ f_{ecol} = \varepsilon_{ecol}$$

Waste heat integration



Waste heat availability

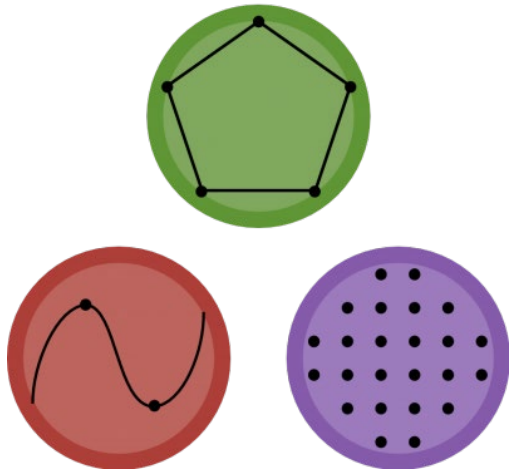
- Ratio of available waste heat and heat demand → $\boldsymbol{\Psi_a} = \frac{Total\ available\ waste\ heat}{Total\ heat\ demand}$
- Ratio of utilized waste heat and heat demand → $\Psi_u = \frac{Total\ utilized\ waste\ heat}{Total\ heat\ demand}$
- Share of utilized and available waste heat → $\Phi_u = \frac{Total\ utilized\ waste\ heat}{Total\ available\ waste\ heat}$

$$\Phi_u = \frac{\Psi_u}{\Psi_a}$$

- **Analyse increase of $\boldsymbol{\Psi_a}$ → from 0% to 60%**

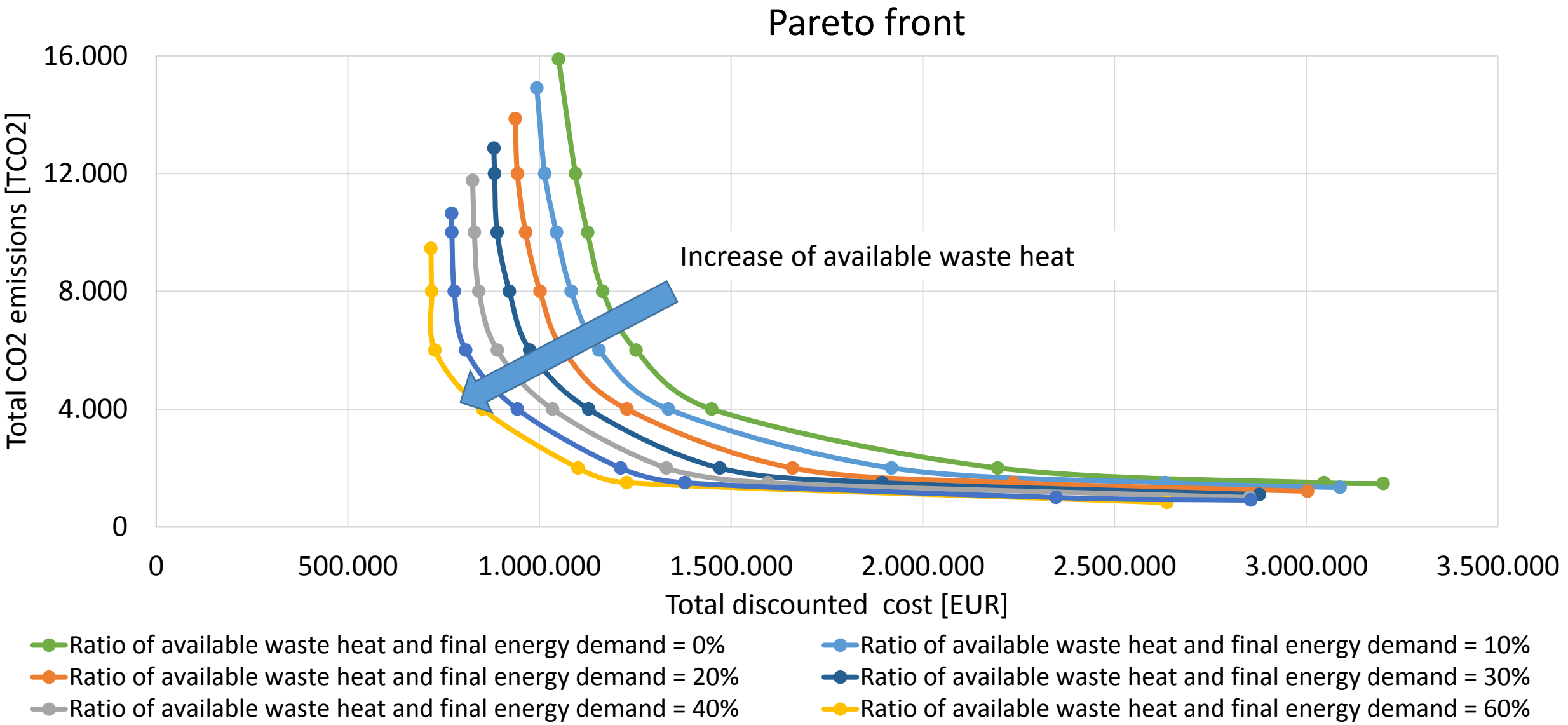
Programming tools

- Linear programming
- Julia programming language, JuMP package
- Clp solver

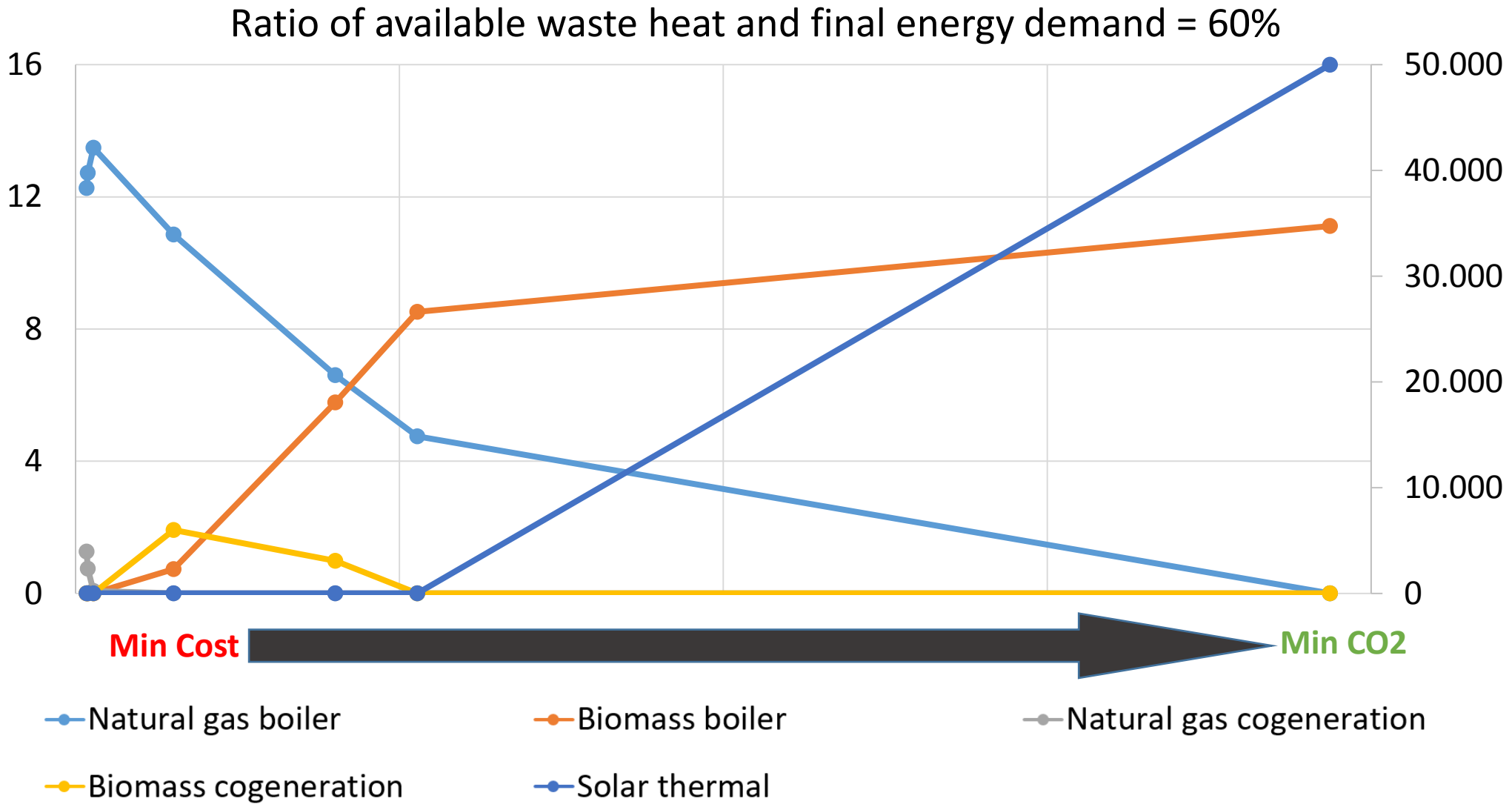


julia

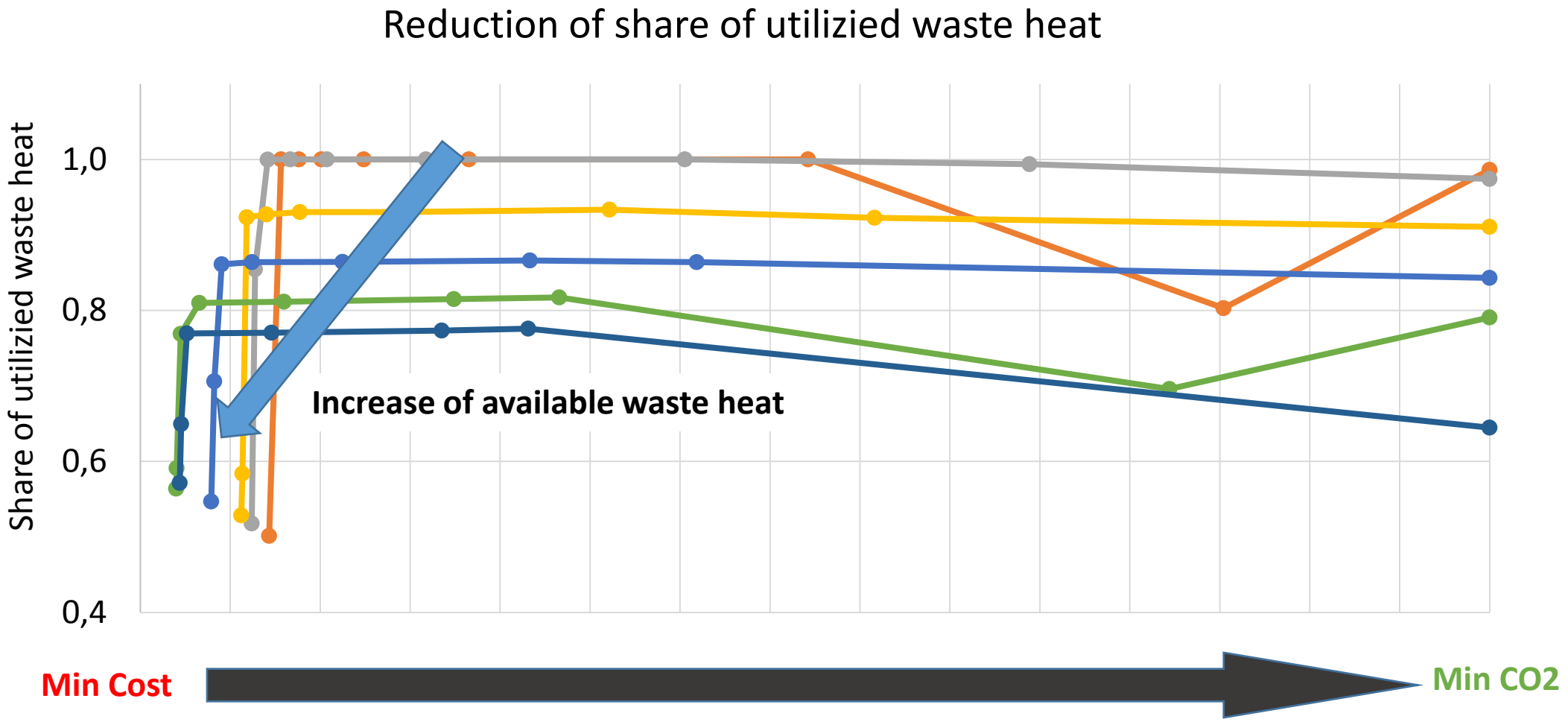
Results


Pareto front
16.000
12.000
8.000
4.000
0
Total CO2 emissions [TCO2]
0
500.000
1.000.000
1.500.000
2.000.000
2.500.000
3.000.000
3.500.000
Total discounted cost [EUR]
Increase of available waste heat
Ratio of available waste heat and final energy demand = 0%
Ratio of available waste heat and final energy demand = 10%
Ratio of available waste heat and final energy demand = 20%
Ratio of available waste heat and final energy demand = 30%
Ratio of available waste heat and final energy demand = 40%
Ratio of available waste heat and final energy demand = 60%

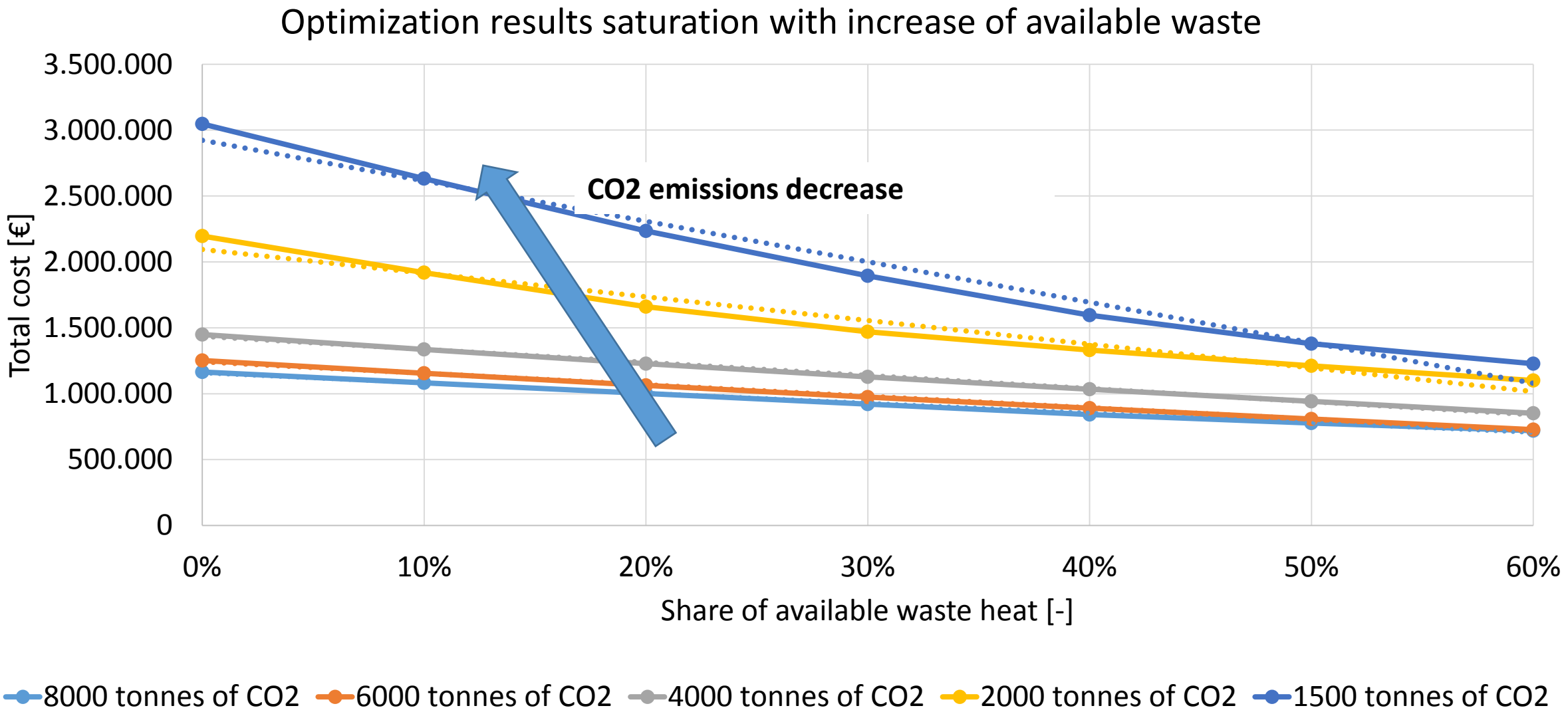
Results


Ratio of available waste heat and final energy demand = 60%
16
12
8
4
0
50.000
40.000
30.000
20.000
10.000
0
Min Cost
Min CO2
Natural gas boiler
Biomass boiler
Natural gas cogeneration
Biomass cogeneration
Solar thermal

Results


Reduction of share of utilizied waste heat
Share of utilizied waste heat
1,0
0,8
0,6
0,4
Increase of available waste heat
Min Cost
Min CO2
Ratio of available waste heat and heat demand
10%
20%
30%
40%
50%
60%

Results


Optimization results saturation with increase of available waste
3.500.000
3.000.000
2.500.000
2.000.000
1.500.000
1.000.000
500.000
0
Total cost [€]
CO2 emissions decrease
0%
10%
20%
30%
40%
50%
60%
Share of available waste heat [-]
8000 tonnes of CO2
6000 tonnes of CO2
4000 tonnes of CO2
2000 tonnes of CO2
1500 tonnes of CO2

Conclusion

- Multi-objective optimization
- Waste heat in conflict with CHP which receives feed-in premium
- Saturation of multi-objective optimization results has been observed

Thank you for your attention

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