Differential Impacts of Additional Consumers in DH Systems

Analysis for Absorption Chillers

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Impacts of Absorption Chiller (ACh)

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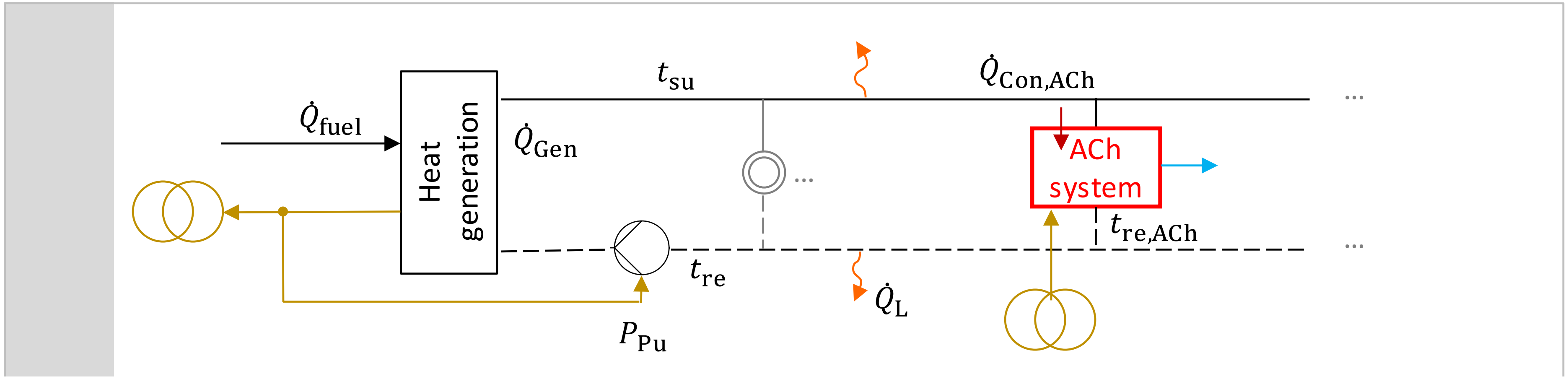

subject matter:

- new generation of ACh (return temperatures 60…70 °C)
- field installations in several district heating systems
- Effects in DH system / relevance of return temp. are discussed but not quantified

Impacts of Absorption Chiller (ACh)

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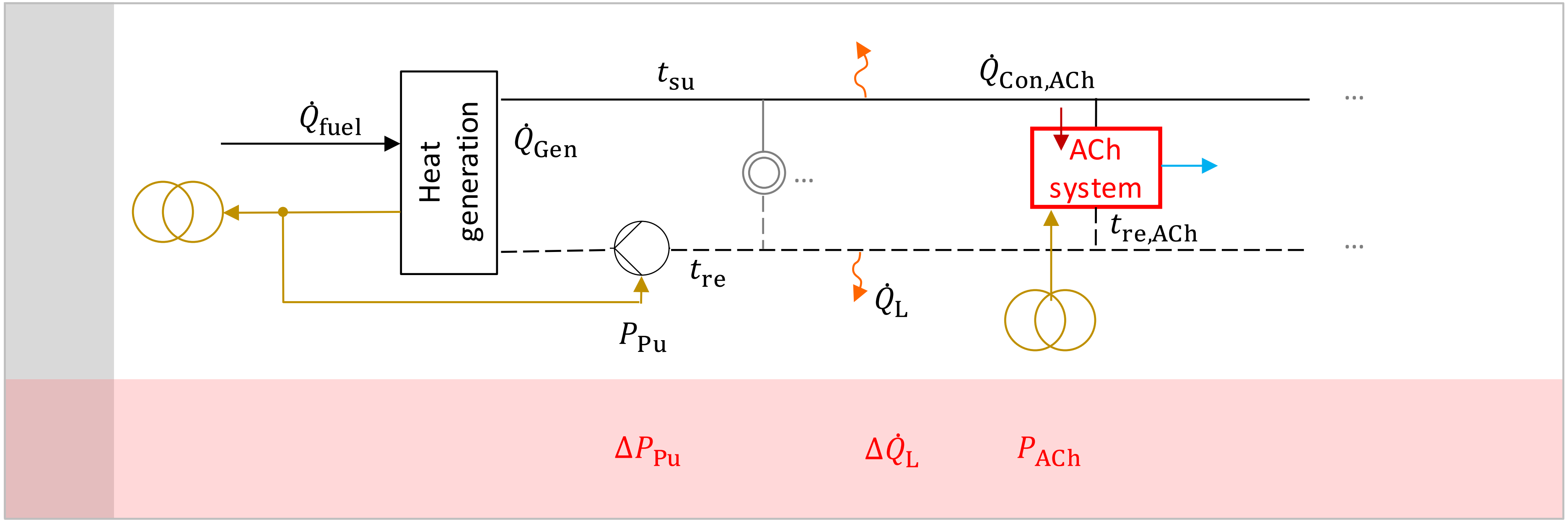

Goal: → estimation of all effects of ACh in DH system

→ total primary energy effort of ACh

Approach: → all additional efforts are allocated to the ACh

→ DH system is not changed (no pipes enlarged, no additional CHP-unit)

Impacts of Absorption Chiller (ACh)

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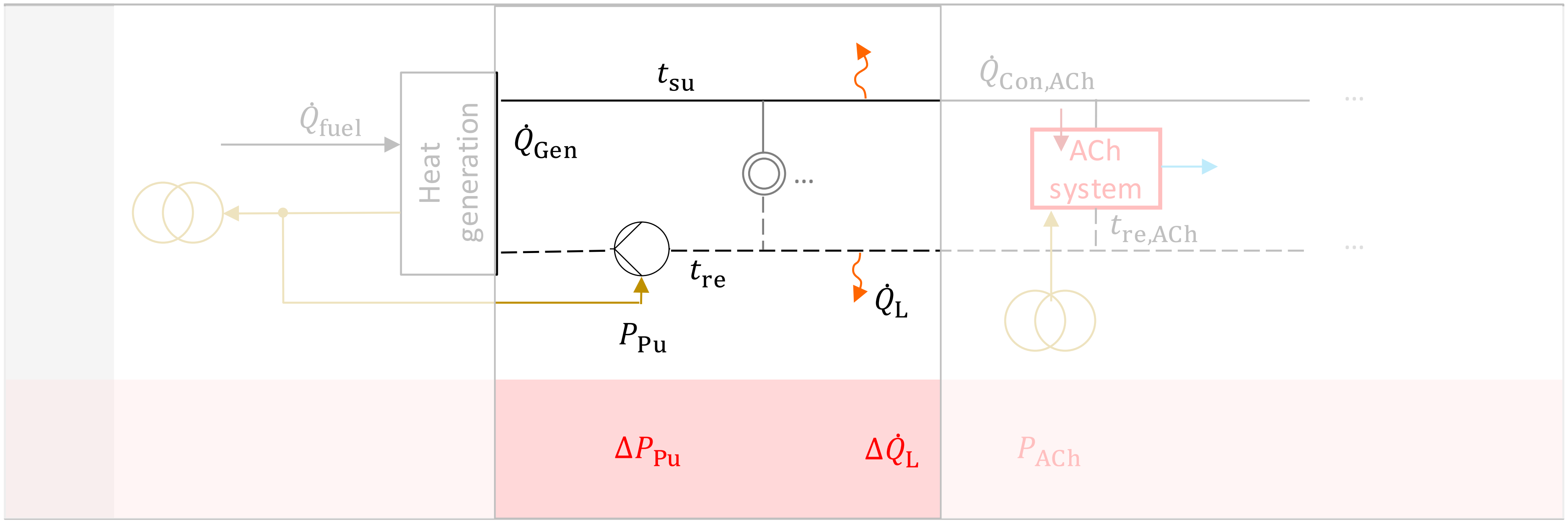

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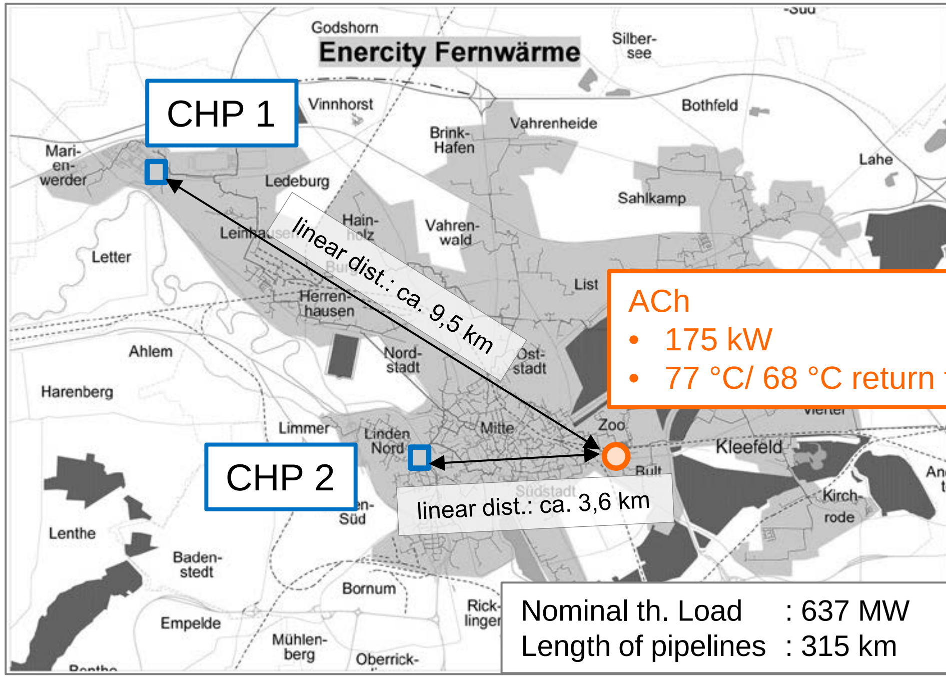
Network simulations



- Network simulations have been conducted for DH-network Hannover (SIR 3S)
- Simulations without and with additional ACh
- 5 representative load situations

Supply Station / ambient temperature	CHP1+2 / -14°C	CHP1+2 / +1°C	CHP1 / +15°C	CHP1 / +30°C	CHP2 / +30°C
Supply temperature at heat generator	120 °C	92 °C	92 °C	92 °C	92 °C
Return temperature at heat generator	60 °C	58 °C	60 °C	64 °C	64 °C
Thermal load	637 MW	394 MW	105 MW	39 MW	38 MW

Summer load case (CHP2 / +30°C)

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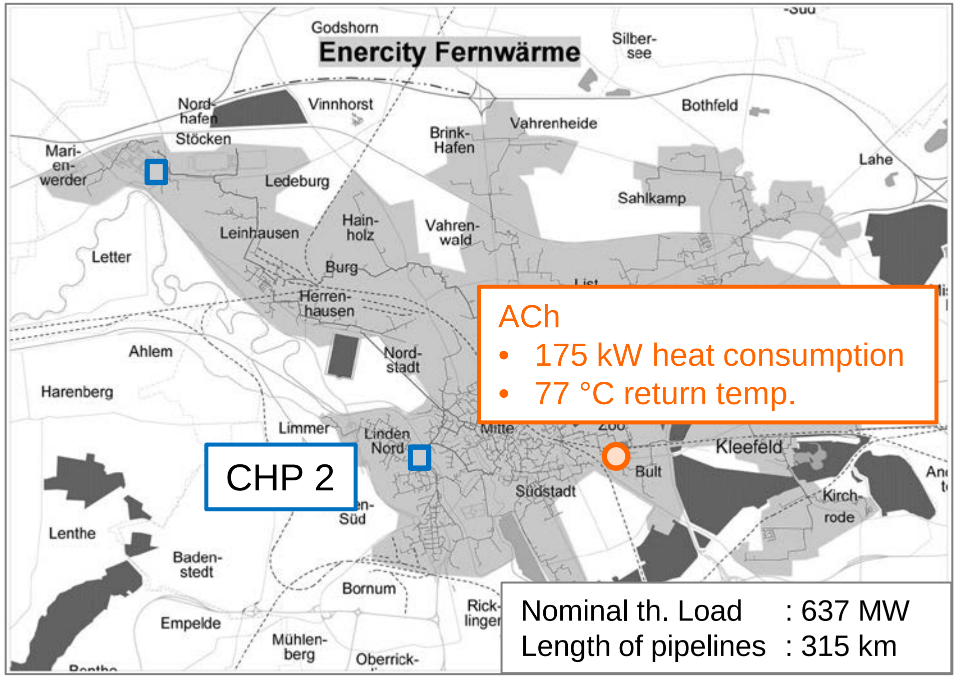

Results of simulation	
Heat loss without ACh	11,573 kW
Heat loss with ACh	11,594 kW
Difference $\Delta\dot{Q}_L$	21 kW
Relative increase of heat loss	+0.18 %

Specific loss ACh:

$$\varphi_{L,ACh} = \frac{\Delta\dot{Q}_L}{\dot{Q}_{Con,ACh}} = \frac{21\ kW}{175\ kW} \quad \mathbf{= 12.1\ \%}$$

Specific loss average consumer (without ACh):

$$\varphi_{L,avg} = \frac{\dot{Q}_L}{\sum\dot{Q}_{Con,i}} = \frac{11{,}573 kW}{26{,}021 kW} \quad = 44.5\ \%$$

- Additional heat loss is small compared to overall heat loss
  → therefore: **specific values** are used!
- Specific heat loss of ACh is lower than average
  → specific overall heat loss with ACh are slightly lower (44.3 %)

Effects on thermal losses

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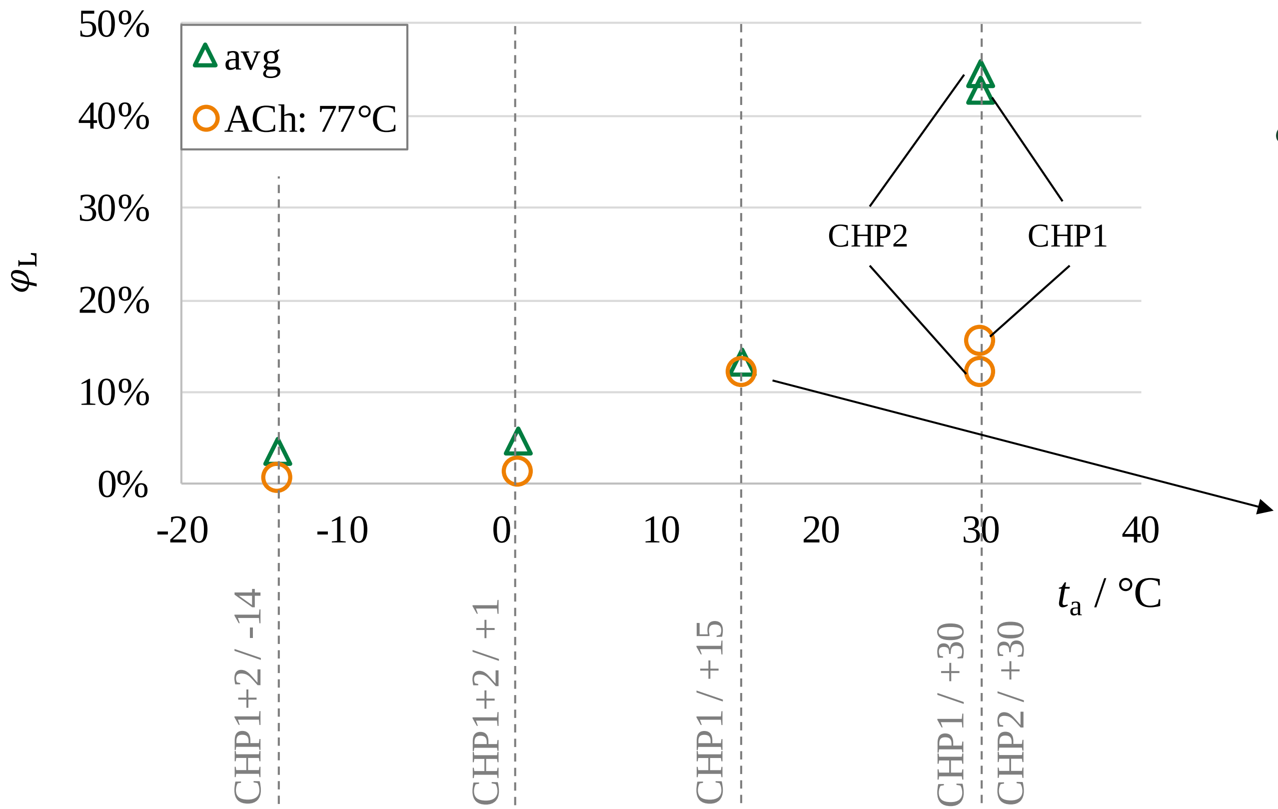


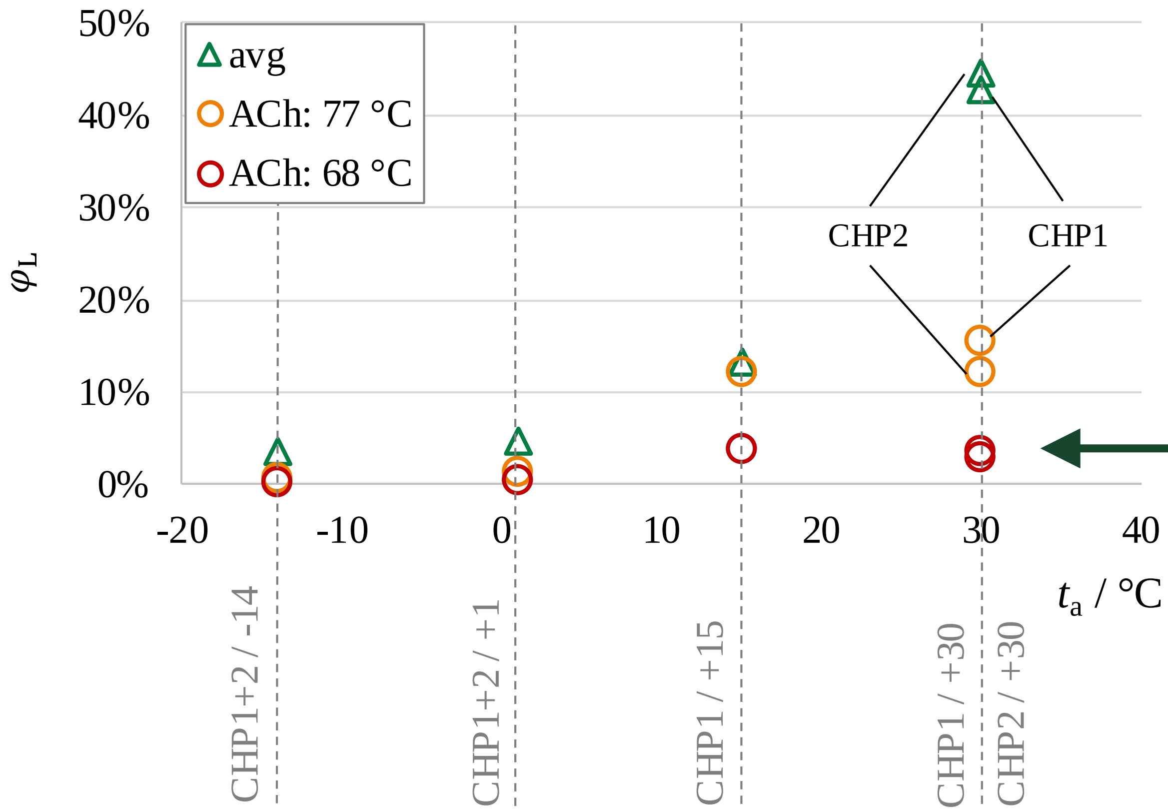
$$\varphi_{L,avg} = \frac{\dot{Q}_L}{\sum \dot{Q}_{Con,i}}$$

$$\varphi_{L,ACh} = \frac{\Delta \dot{Q}_L}{\dot{Q}_{Con,ACh}}$$

possible reason: ACh keeps nearby pipes warm

→ Specific heat losses caused by ACh are smaller than those of average consumer! (despite high ACh return temperature)

Effects on thermal losses

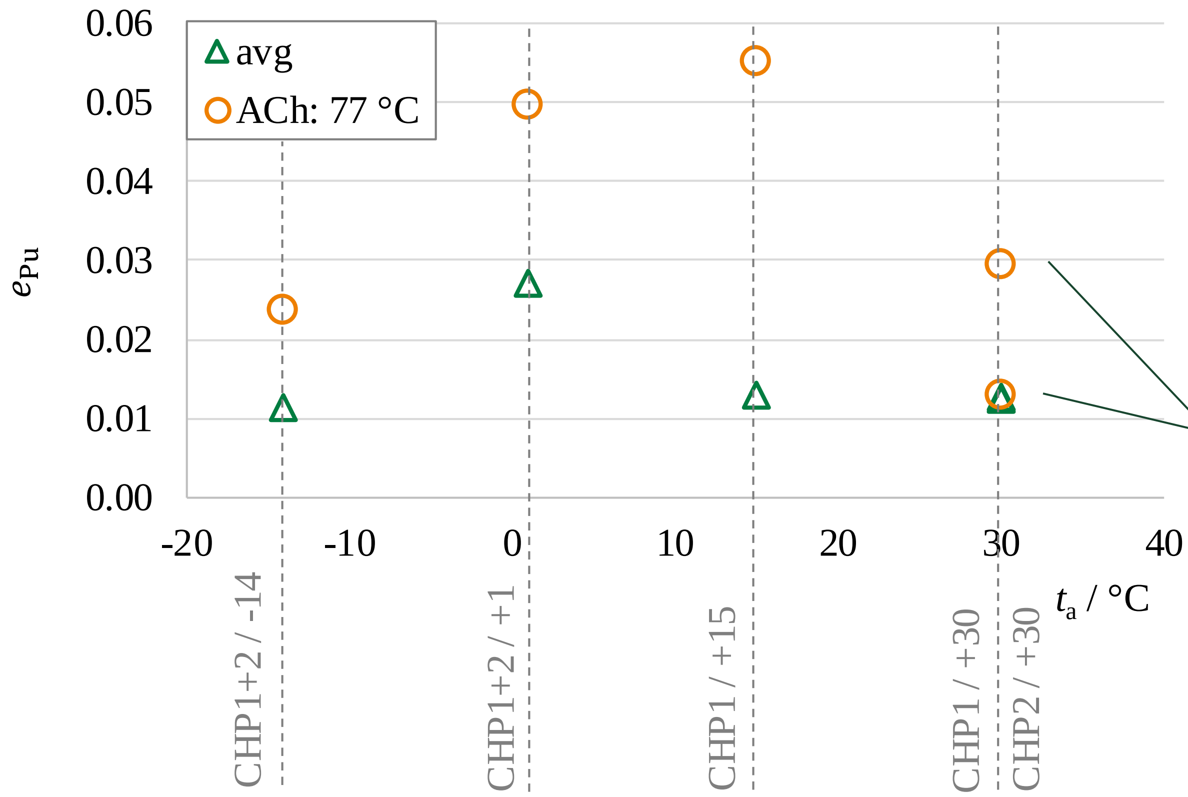


$$\varphi_{L,avg} = \frac{\dot{Q}_L}{\sum \dot{Q}_{Con,i}}$$

$$\varphi_{L,ACh} = \frac{\Delta \dot{Q}_L}{\dot{Q}_{Con,ACh}}$$

New ACh generation can reduce specific heat losses especially in spring and summer!

Effects on pumping electricity



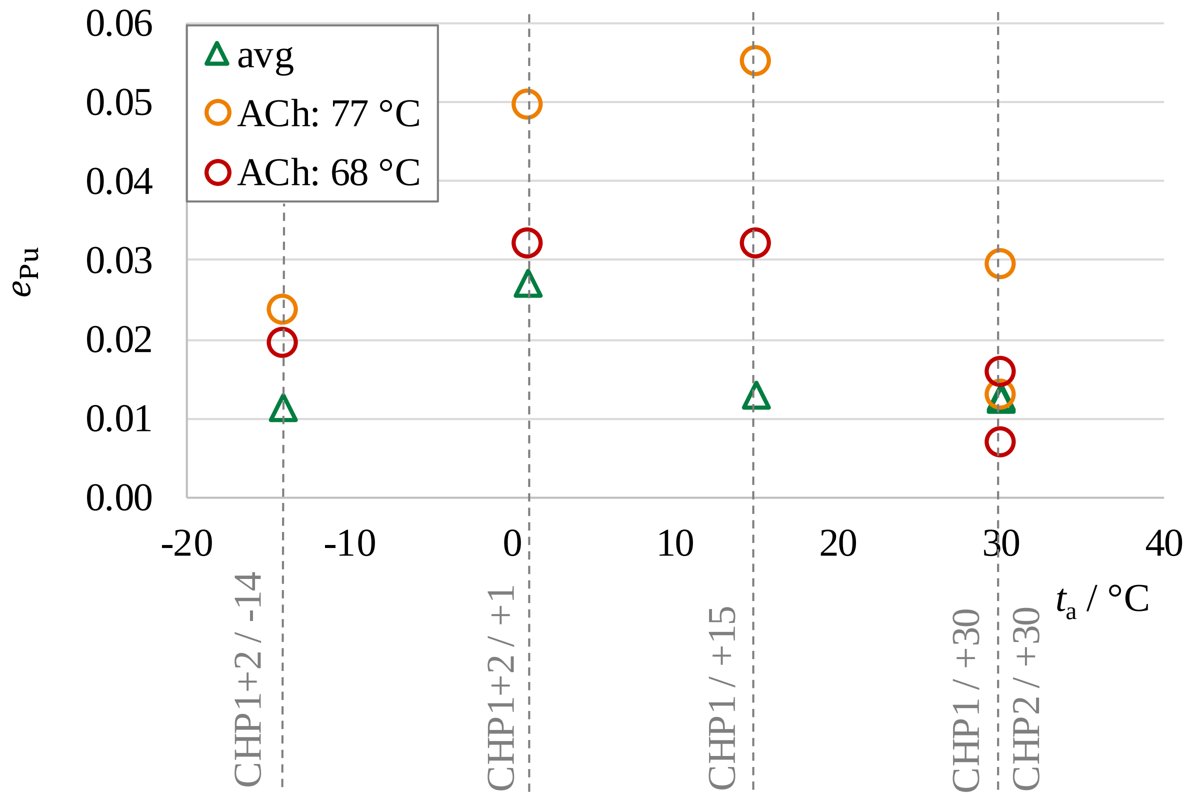
$$e_{\mathrm{Pu,avg}} = \frac{P_{\mathrm{Pu}}}{\sum \dot{Q}_{\mathrm{Con},i}}$$

$$e_{\mathrm{Pu,ACh}} = \frac{\Delta P_{\mathrm{Pu}}}{\dot{Q}_{\mathrm{Con,ACh}}}$$

different results for CHP1 & CHP2:
→ Location of heat generator & ACh has big influence!

- Specific pumping electricity of ACh is higher than network average
- Hydraulic effects can not be neglected!

Effects on pumping electricity



$$e_{\mathrm{Pu,avg}} = \frac{P_{\mathrm{Pu}}}{\sum \dot{Q}_{\mathrm{Con},i}}$$

$$e_{\mathrm{Pu,ACh}} = \frac{\Delta P_{\mathrm{Pu}}}{\dot{Q}_{\mathrm{Con,ACh}}}$$

- New ACh generation with lower return temperatures can reduce pumping electricity especially in transitional season

Conclusion: network effects

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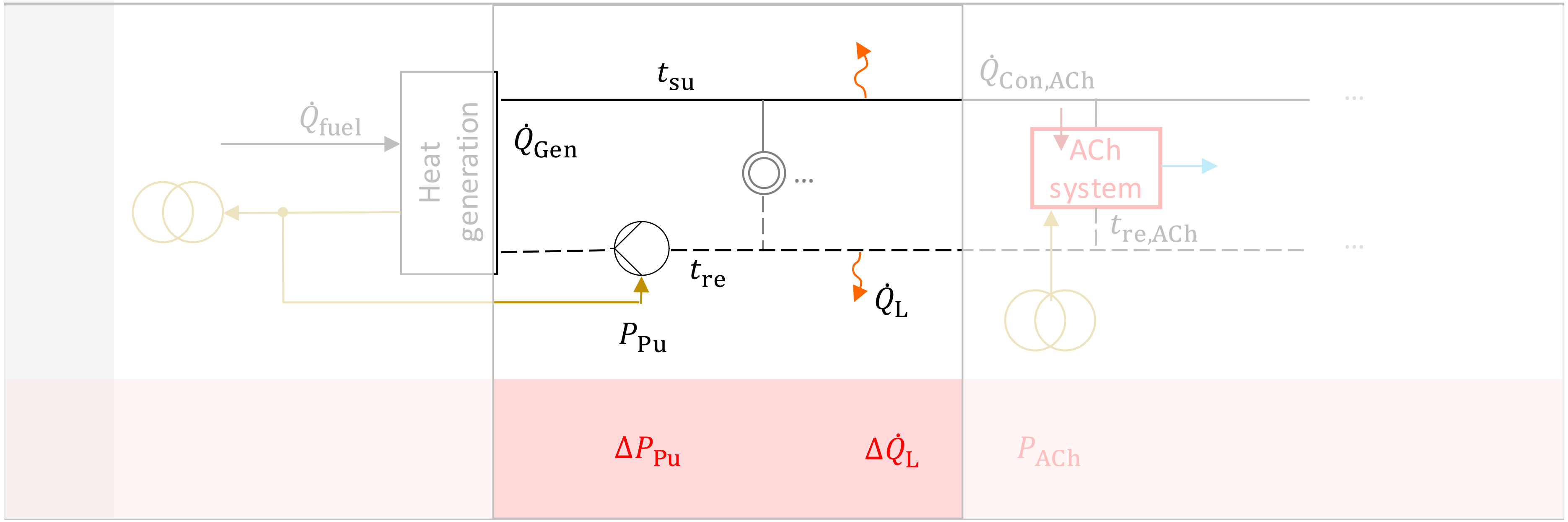
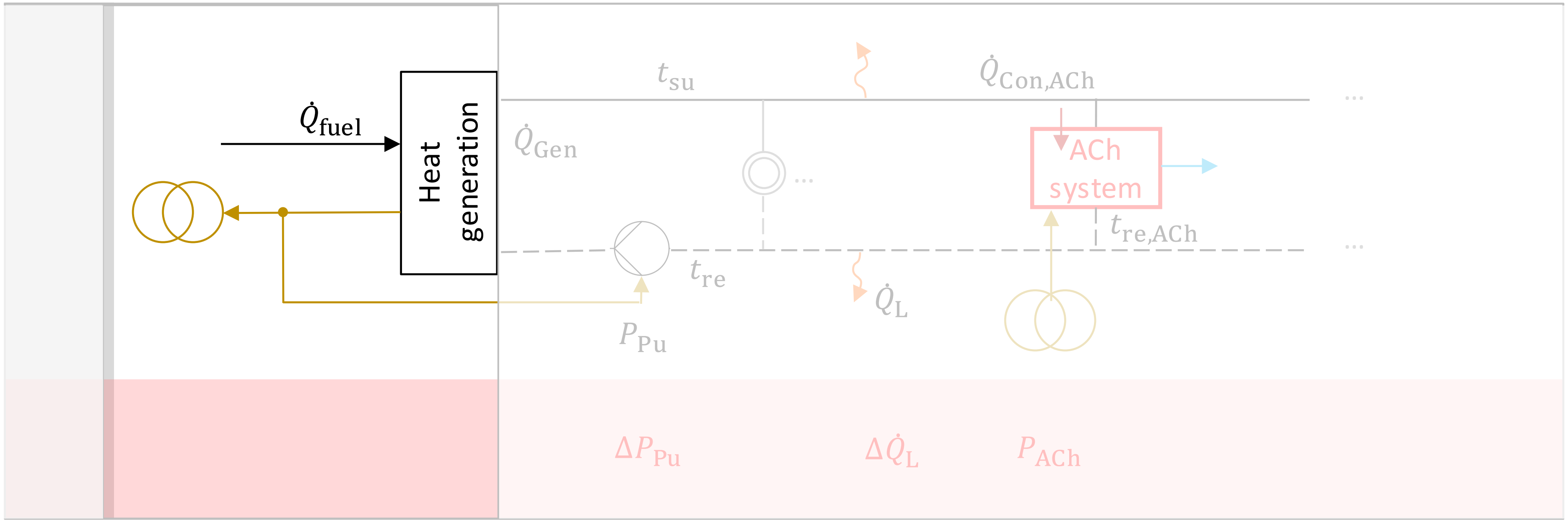


- Additional heat losses are low, Additional pumping electricity is relevant
- Drop of return temp. (77 → 68 °C) strongly reduces heat and electricity demand
- Do equal simulations for long-term strategy DH temperatures!

Impact on heat generation



- CHP and boiler: estimate additional power generation and fuel demand
- key figures to characterize additional heat generation needed:

Diff. CHP share:

$$x_{CHP,ACh} = \frac{\Delta Q_{CHP}}{\Delta Q_{CHP} + \Delta Q_{Boiler}}$$

Diff. CHP coefficient:

$$\sigma_{CHP,ACh} = \frac{\Delta W_{CHP}}{\Delta Q_{CHP}}$$

Heat generator set-up

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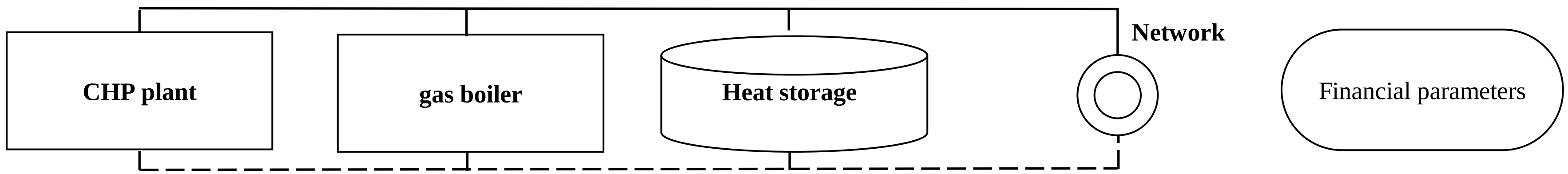
Construed example (data security reasons):

year: 2016



16.25 $MW_{th,nominal}$
- part load 38..100 %
- Switch-on costs 80 €

65 $MW_{th,nominal}$
- η = 90 %
- part load 0..100 %

50 MWh
- losses: 0,02 %/h

65 $MW_{th,nominal}$
- DH load profile

- time series of prices for gas, electricity, CO_2
- gas tax
- CHP bonus

simulation sequence: one week (7x24 time steps)
MILP problem → CPLEX solver used

- Mode of operation has high impact on key figures!
- How to create realistic operation sequence?

→ Optimization of generator operation: minimize total operating costs

A: Simulation without ACh
B: Simulation with ACh, 175 kW

} Effects of ACh = difference B - A !

Simulation periods: 4 x 1 week

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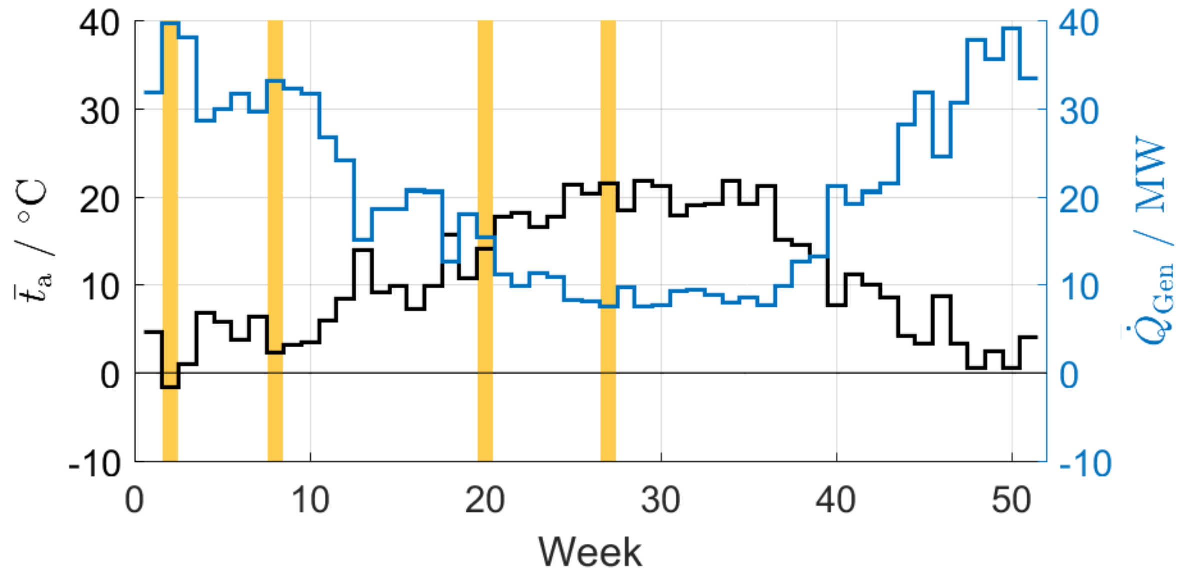
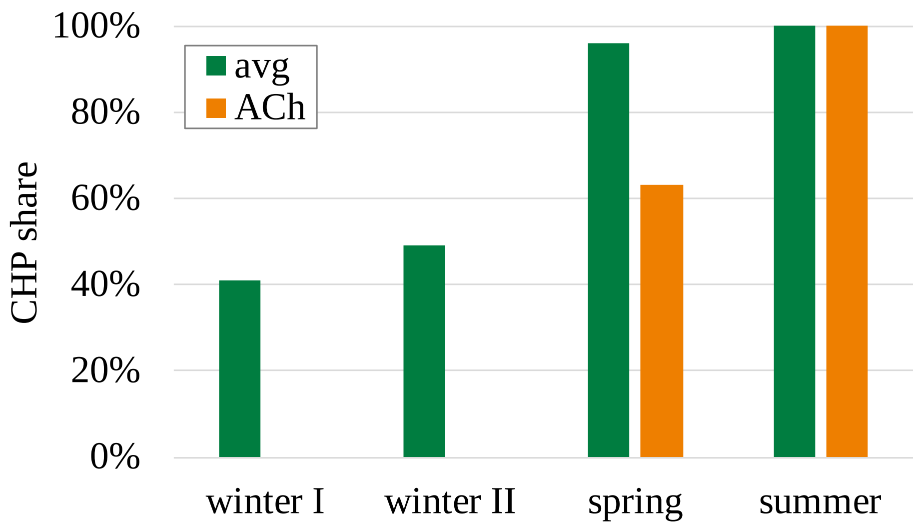
year: 2016



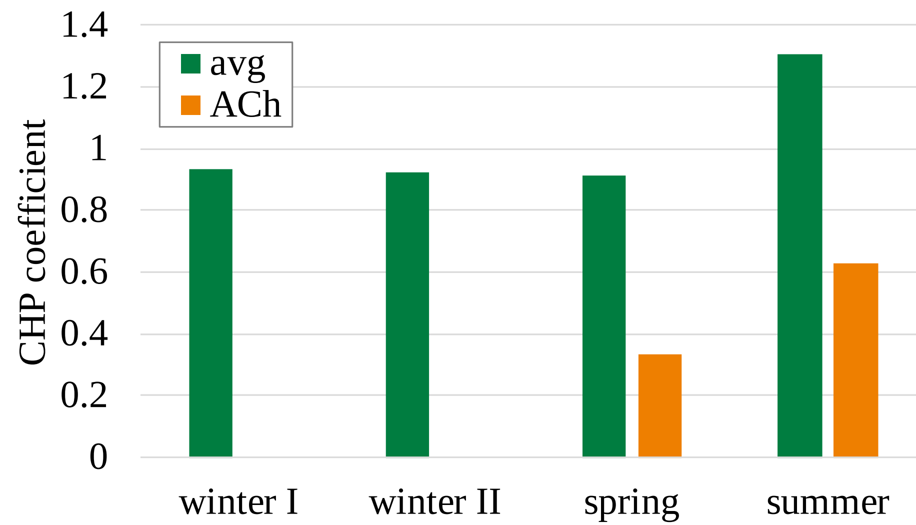
	winter I	winter II	spring	summer
Week	2	8	20	27
$\bar{t}_a$	-1.6 °C	2.3 °C	14.1 °C	21.5 °C
$\bar{\dot{Q}}_{Gen}$	39.7 MW	33.2 MW	15.4 MW	7.5 MW
Load percentage	61.1 %	51.1 %	23.7 %	11.6 %

Characteristic key figures

CHP share $x_{CHP} = \frac{\text{CHP heat}}{\text{CHP heat + Boiler heat}}$



CHP coefficient $\sigma_{CHP} = \frac{\text{CHP Electricity}}{\text{CHP Heat}}$



Characteristic key figures

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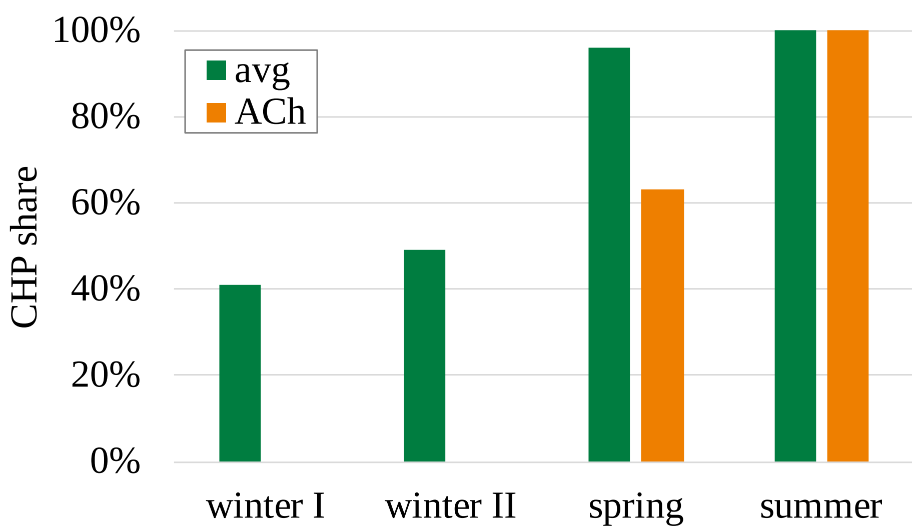

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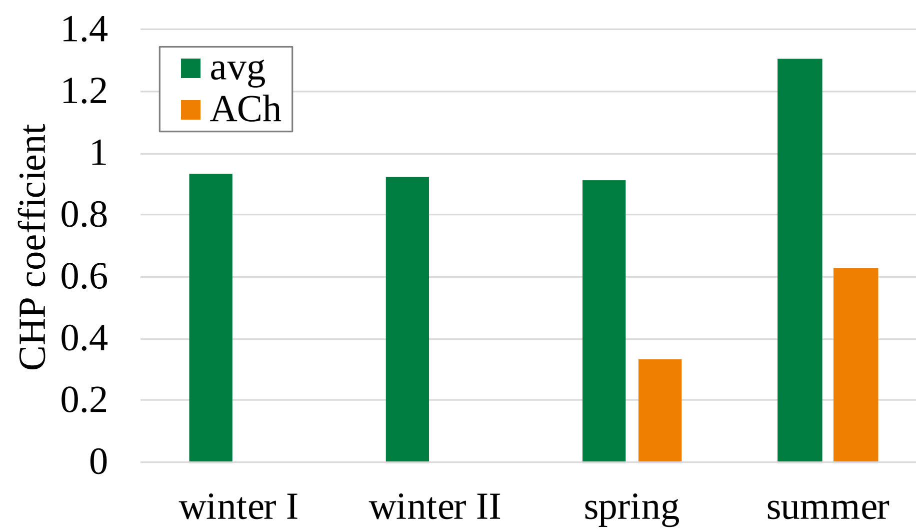

→ Spring: 37 % operation of gas boiler for ACh

→ Winter: Additional heat generation provided only by gas boiler

Characteristic key figures

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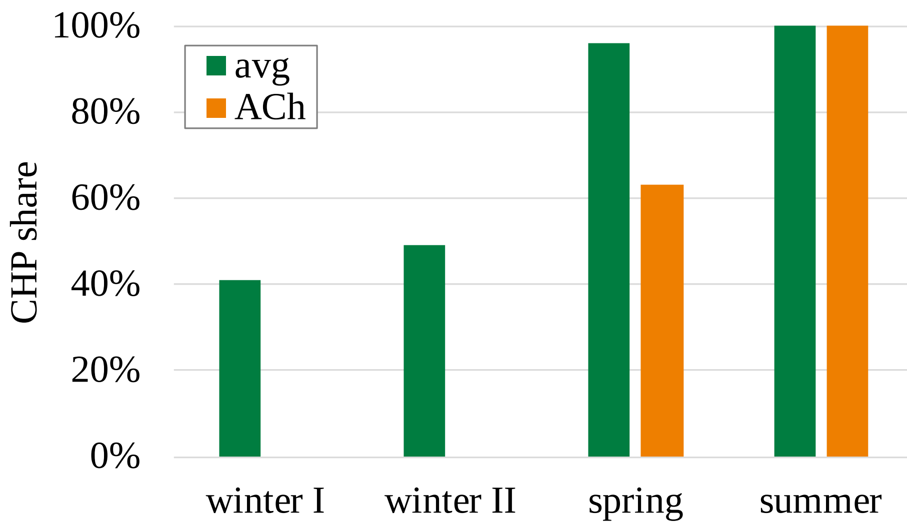
CHP share $x_{\mathrm{CHP}} = \frac{\text{CHP heat}}{\text{CHP heat + Boiler heat}}$



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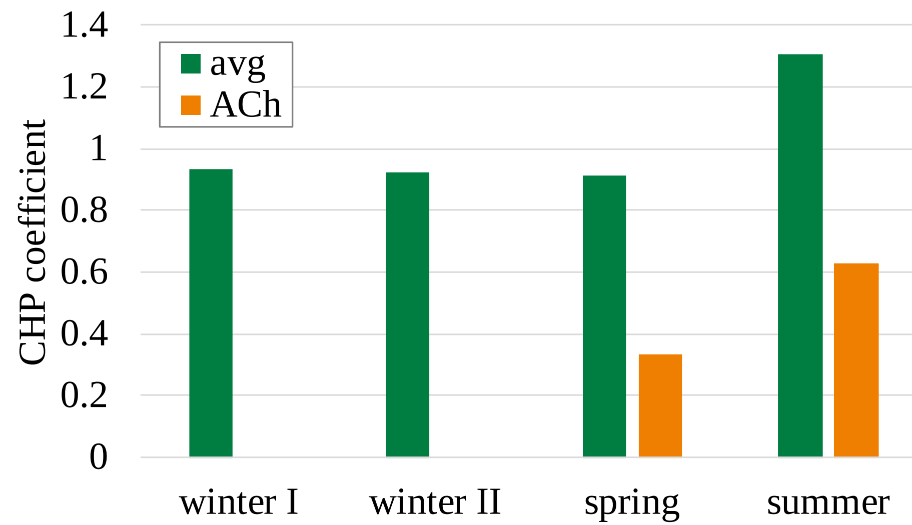
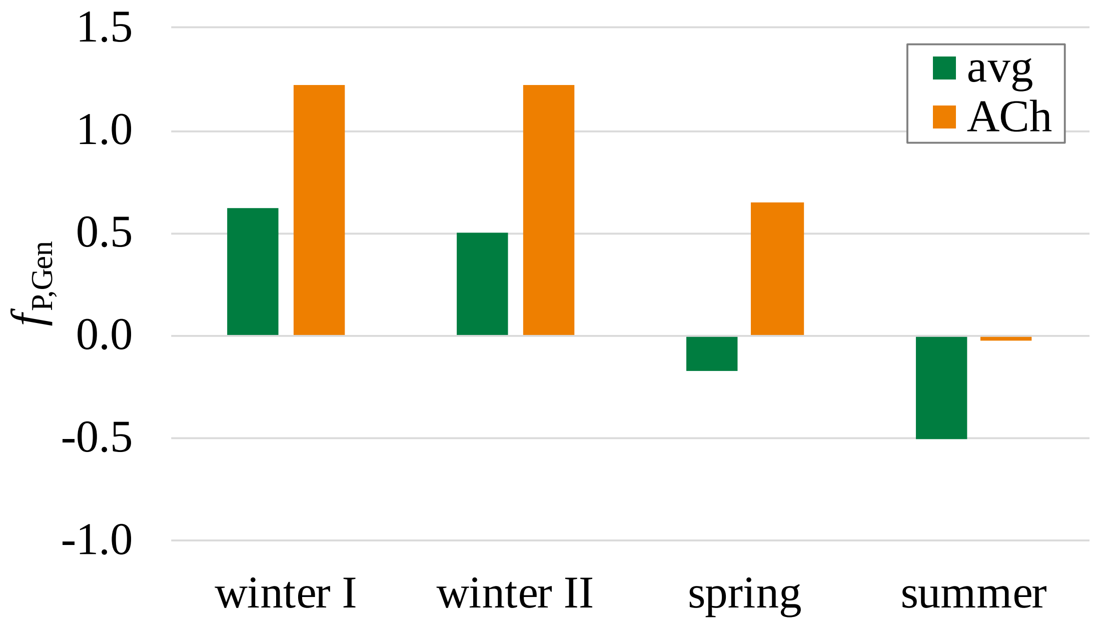


Spring: 37 % operation of gas boiler for ACh

Winter: Additional heat generation provided only by gas boiler

Spring and summer: operation of CHP gets less efficient with additional ACh

Primary energy: generated heat



$$f_{P,Gen,avg} = \frac{1.1 \cdot \dot{Q}_{fuel} - 2.8 \cdot P_{CHP}}{\dot{Q}_{Gen}}$$

$$f_{P,Gen,ACh} = \frac{1.1 \cdot \Delta\dot{Q}_{fuel} - 2.8 \cdot \Delta P_{CHP}}{\Delta\dot{Q}_{Gen}}$$

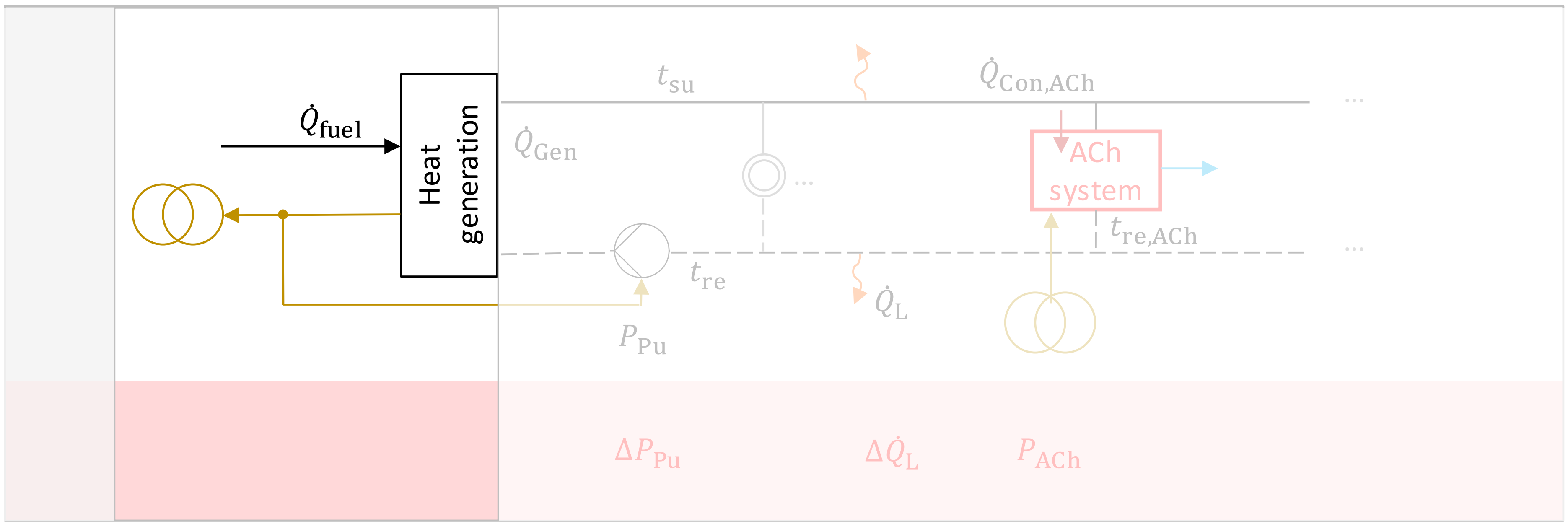
negative $f_{P,Gen}$ are permitted for scientific analysis

Primary energy factor of ACh is higher than average consumer's value

→ **ACh increases primary energy factor of network**

Results may vary widely with different heat generation and heat load constellations!

Impact on heat generation



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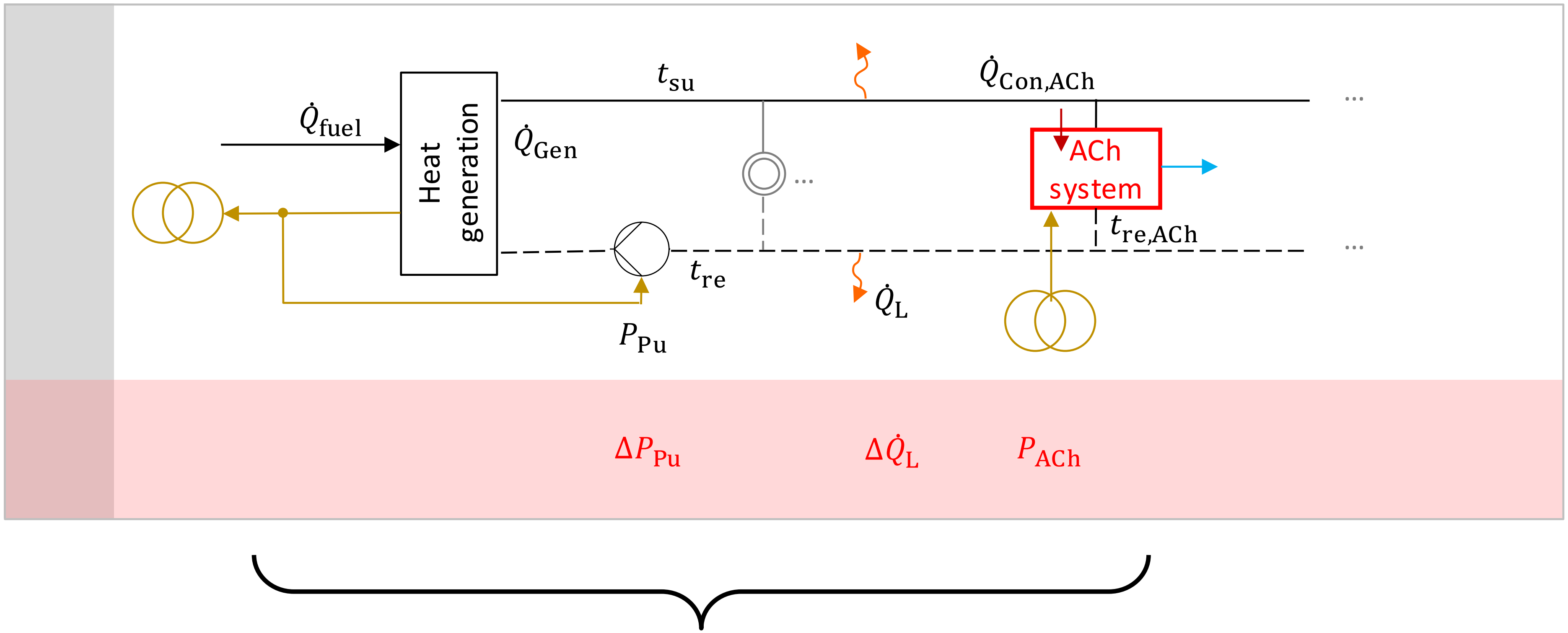
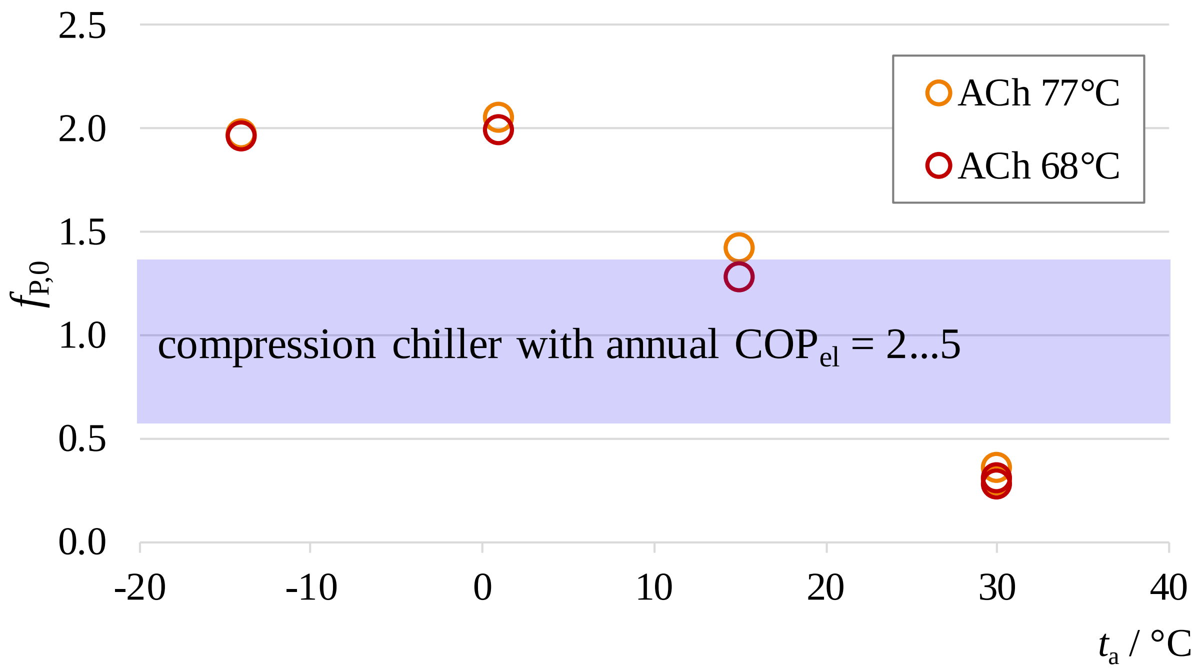
Evaluation of overall system



Total effort for produced cold $\dot{Q}_0$

→ Combination of network effects (load points) and optimization (week simulations)

Evaluation of produced cold



	COP_{th}	COP_{el}
ACh	0.75	10

- ACh has better primary energy efficiency than compression chiller in summer
- Effects of lower ACh return temperature look small but primary energy factor can be lowered by about 0.1 to 0.15

Conclusion

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- Method developed for quantifying effects of additional ACh
- In given example:
  - Add. heat losses are small, add. pumping electricity can not be neglected
  - Comparison to compression chiller: ACh has better primary energy efficiency (only) in summer
  - Heat generation set-up and operation have big influence on primary energy efficiency
- Results can not be generalized!
- DH companies can use presented method to evaluate ecological and economic sense of ACh in existing systems

Thank you for your attention!

Project: **EnEff: Wärme –**
Feldtest Absorptionskälteanlagen für KWKK-Systeme
Research project founded by the Federal Ministry for Economic Affairs and Energy following a resolution of the German Bundestag
FKZ: 03ET1171B

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

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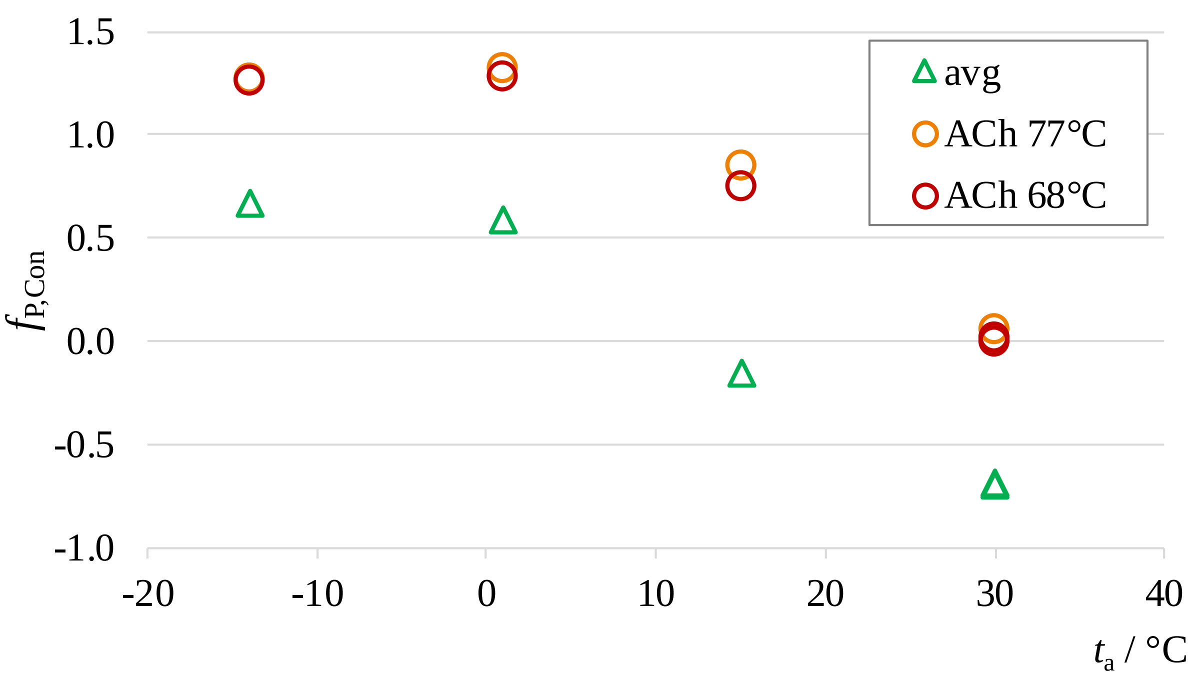
Technische Universität Dresden

Institute of Power Engineering

Chair of Building Energy Systems and Heat Supply

Evaluation of add. consumer heat

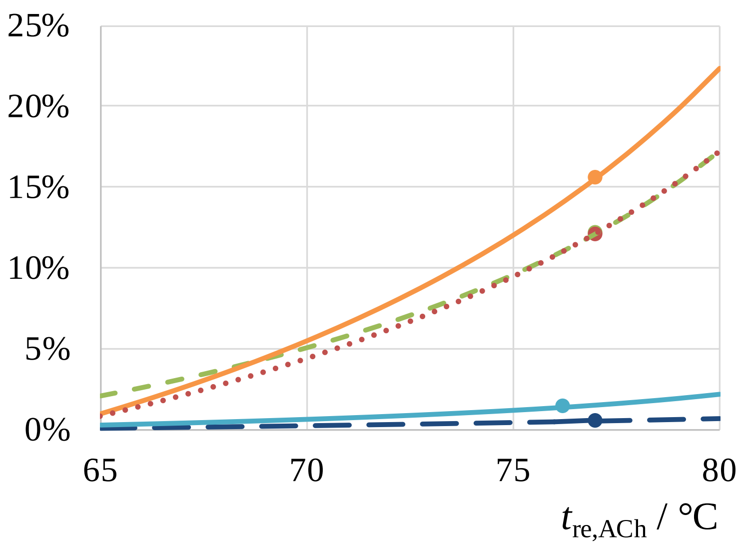
- Combination: Network effects + key figures of heat generation

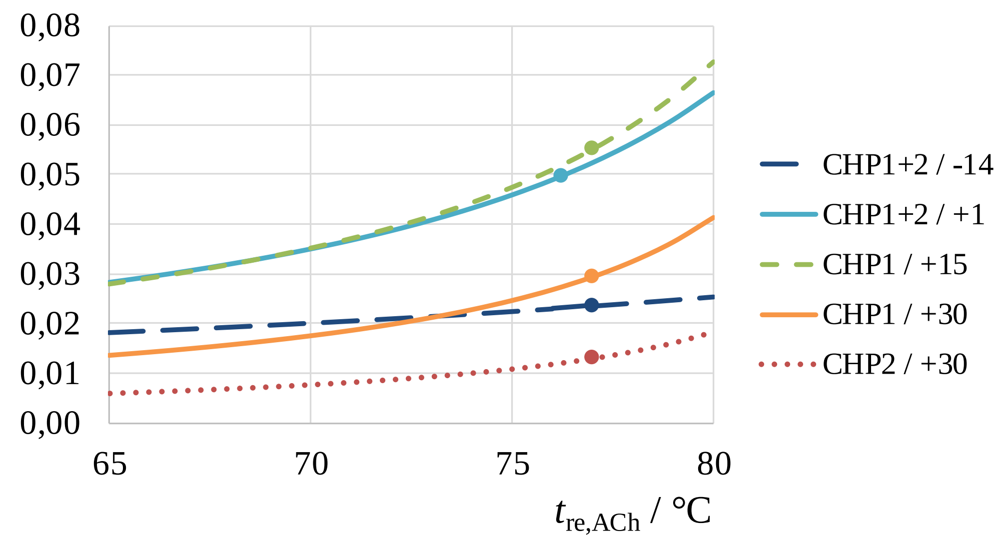


- ACh values higher than those of average consumer
- Highest primary energy factors in winter to spring

Network effects

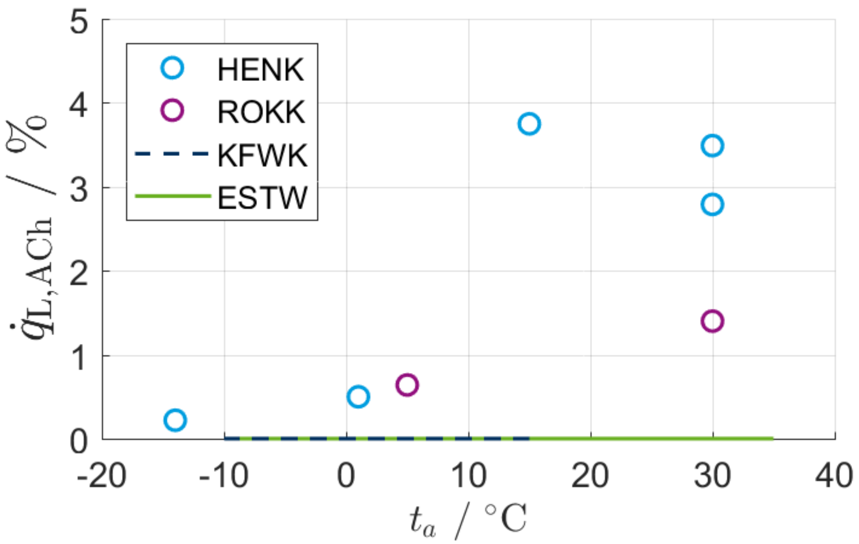
For different ACh return temperatures

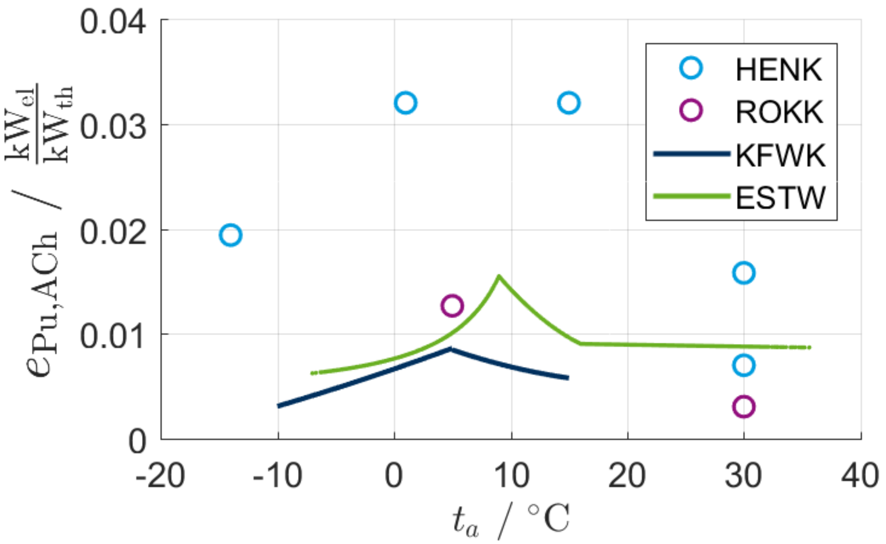




Network effects

For different ACh installations





P-Q-diagram of evaluated CHP plant