zafh net

Large capacity solar adsorption cooling at the Festo company

Dirk Pietruschka, Antoine Dalibard, Ursula Eicker

klimazwei
Risiken mindern · Chancen nutzen

Bundesministerium für Bildung und Forschung

HOCHSCHULE FÜR TECHNIK STUTTGART
STUTTGART UNIVERSITY OF APPLIED SCIENCES

Content

Part A: Solar cooling system

- FESTO office building and cooling system
- Solar collector field
- Research Projects, funding and institutions involved

Part B: Simulation based performance analysis during the planning phase of the solar collector field

- Analysed cases and control options
- Simulation results and conclusions

Part C: Measured performance of the collector field 2008 compared to predicted values

Part D: Online simulation tool

- Comparison online simulation tool / measured performance data

Conclusions and Outlook

A) Office building, FESTO AG & Co. KG

Solar collector field

- 25.000 m² gross floor area
- Heat- and Cold distribution through thermal activated ceilings and ventilation system
- Cold production with three 353 kW MYCOM adsorption chillers and thermally activated bored piles of the buildings foundation
- Utilisation of compressor waste heat

A) Solar collector field; FESTO AG & Co. KG

zafh net

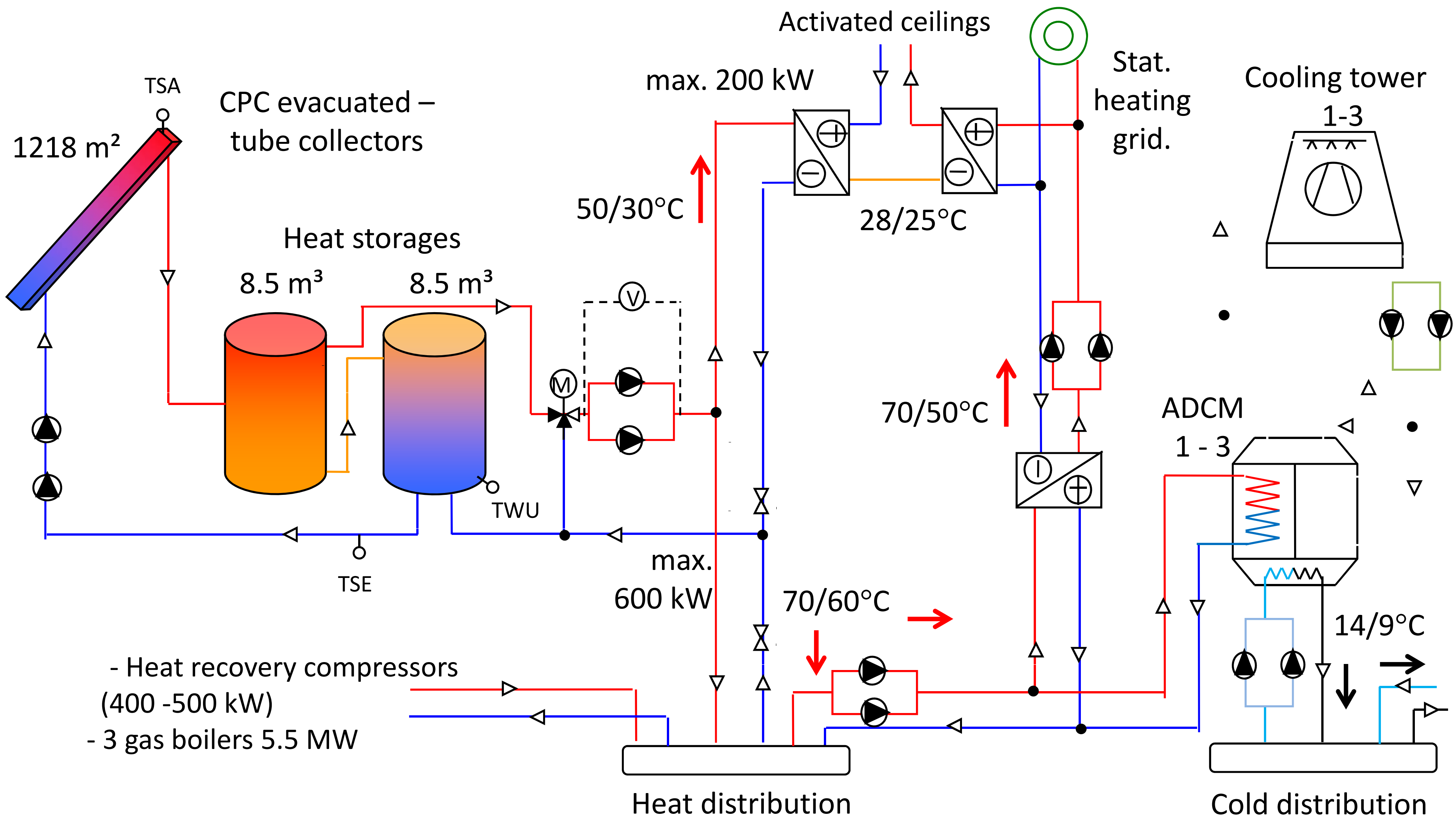
FESTO

Collector area:	1218 m^2 (aperture area) 1330 m^2 (brutto area)
Collector type:	Paradigma CPC collectors with evacuated tubes - 58 Paradigma CPC 30 with 3,0 m^2 aperture area each - 232 Paradigma CPC 45 with 4,5 m^2 aperture area each
Connection:	all parallel
Orientation:	South
Tilt angle:	30°

Guaranteed result: 500 MWh/a

A) Integration of the solar collector field in the existing heat distribution

zafh net



A) Reaserch Projects, Funding and Institutions Involved

zafh net

Solarthermie 2000plus

Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit

Fraunhofer Institut Solare Energiesysteme ISE

Hochschule Offenburg University of Applied Sciences

- Design, implementation and commissioning of the monitoring system of the plant
- Performance analysis and graphical presentation of the monitoring data
- Simulation based performance observation and proof of guaranteed solar energy yield
- Evaluation of optimisation potentials

klimazwei Risiken mindern · Chancen nutzen

Bundesministerium für Bildung und Forschung

Cooperation Project:

Simulation based control optimisation of buildings with sustainable cooling systems

zafh net

FESTO

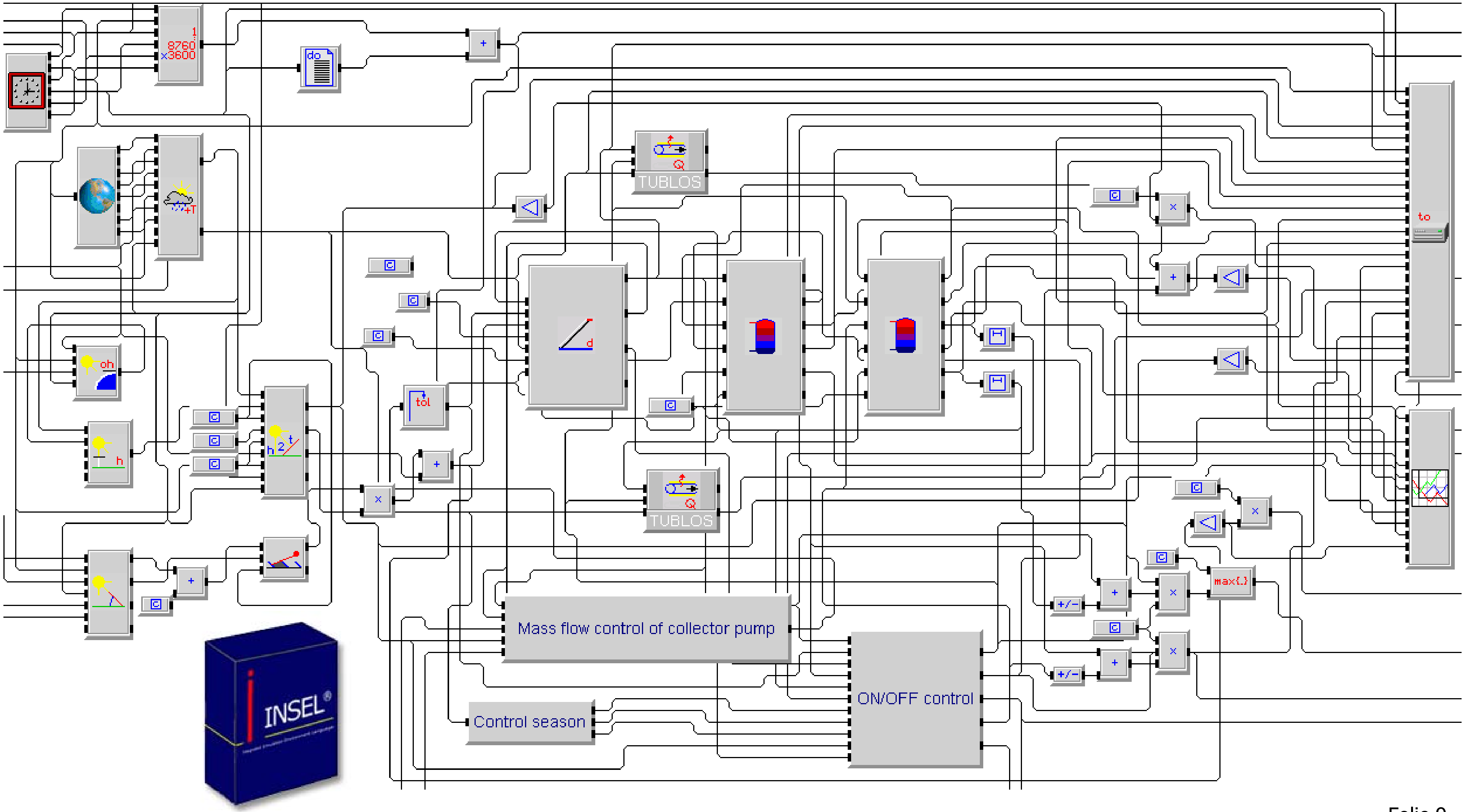
Hochschule Offenburg University of Applied Sciences

- Simulation based control optimisation of the partly solar driven adsorption chillers of the FESTO AG & Co. KG
- Online simulation based performance observation of the absorption chillers and supporting solar collector field

Questions analysed during the planning phase of the collector field:

- How do different collector start up temperature limits influence the annual performance of the collector field?
- Mass flow control of the collector pump or simple on-/off control?
- Performance improvement through supply temperature reduction in the primary heating circuit of the activated ceilings?

B) Dynamic simulation model in INSEL



B) Analysed control options

Description	Control of the collector pump	Start-up temperature		Supply / return primary solar circuit	
		Winter	Summer	Activated ceilings	Heat distributer
Case 1	ON / OFF	70 °C		50°C / 30°C	70°C / 60°C
Case 2	ON / OFF	50°C	70°C	50°C / 30°C	70°C / 60°C
Case 3	mass flow	50°C	70°C	50°C / 30°C	70°C / 60°C
Case 4	mass flow	**40°C**	70°C	**40°C** / 30°C	70°C / 60°C

B) Boundary conditions of the simulations

Weather data:

1. Annual simulations: Insel Weather data base location Stuttgart

2. Summer 2006: Nearby weather station UNI-Hohenheim

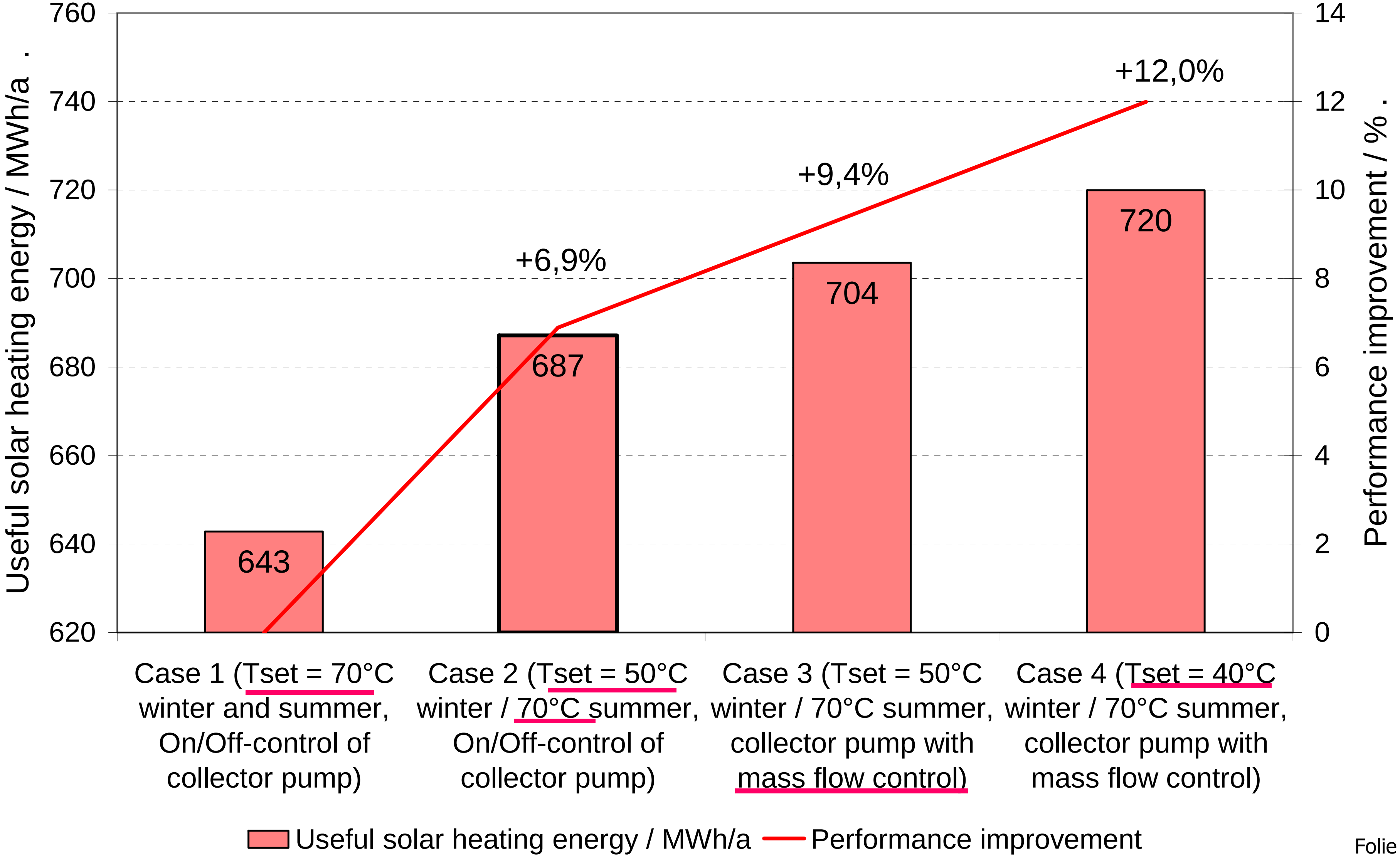
Heating load/degree of utilisation of solar heat:

1. Annual simulations: Assumption: $Q_{h,building} \geq Q_{Collector}$

2. Summer 2006: Real measured heating energy consumption of the three AdCM

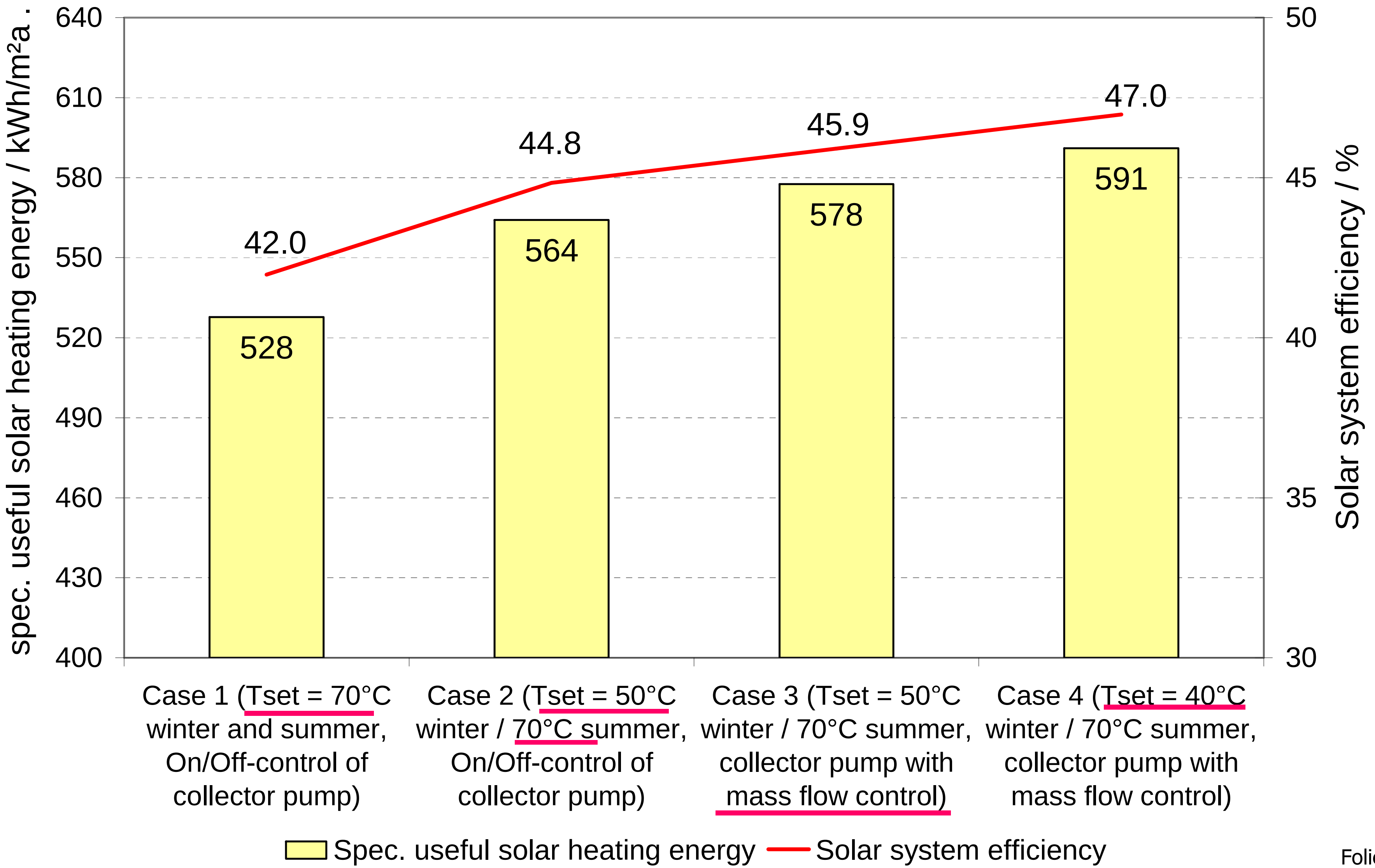
Shading losses: Geometric shading model

B) Results of annual simulations :
- Influence of setpoints and pump control



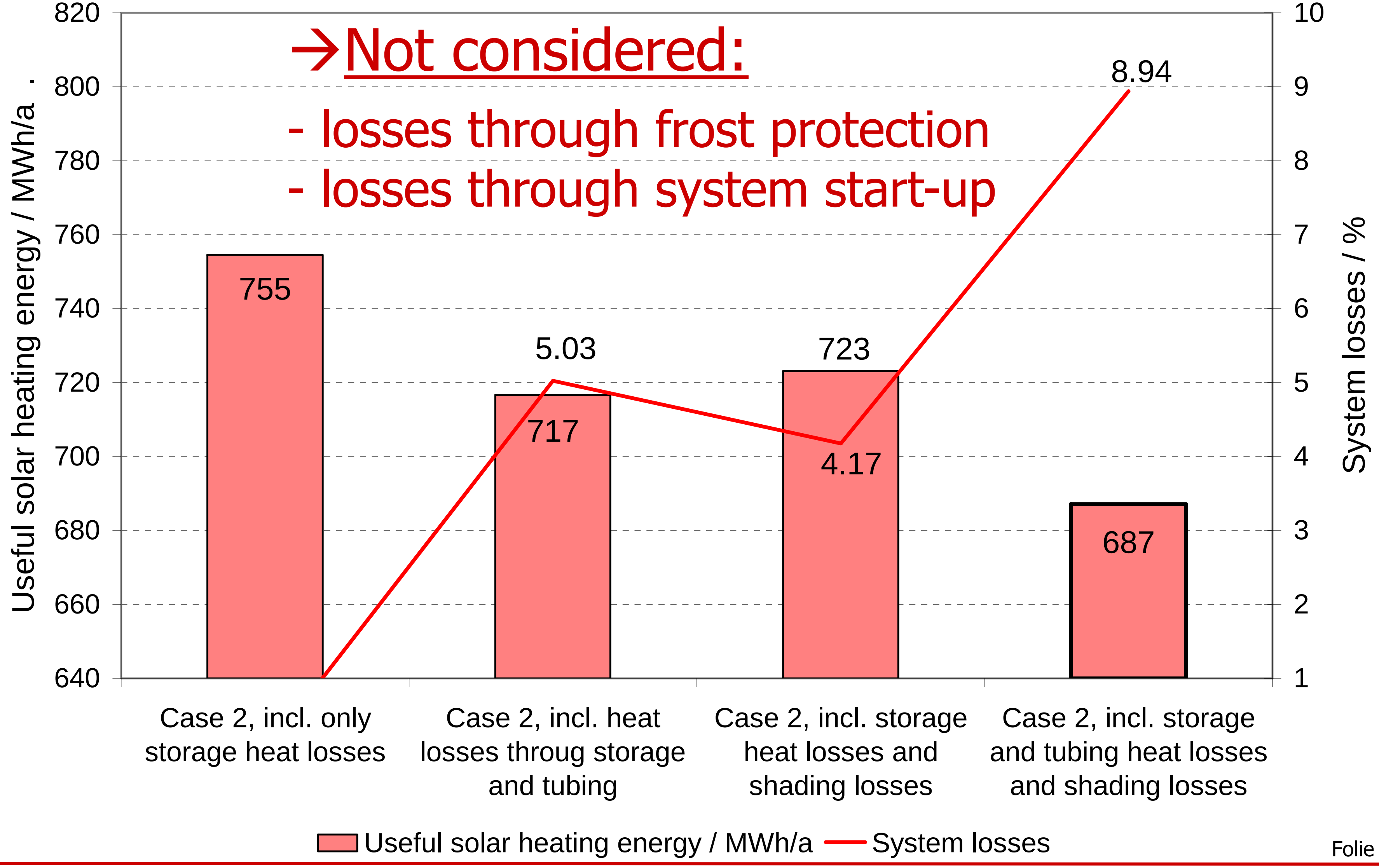
B) Results of annual simulations :

- Influence of setpoints and pump control

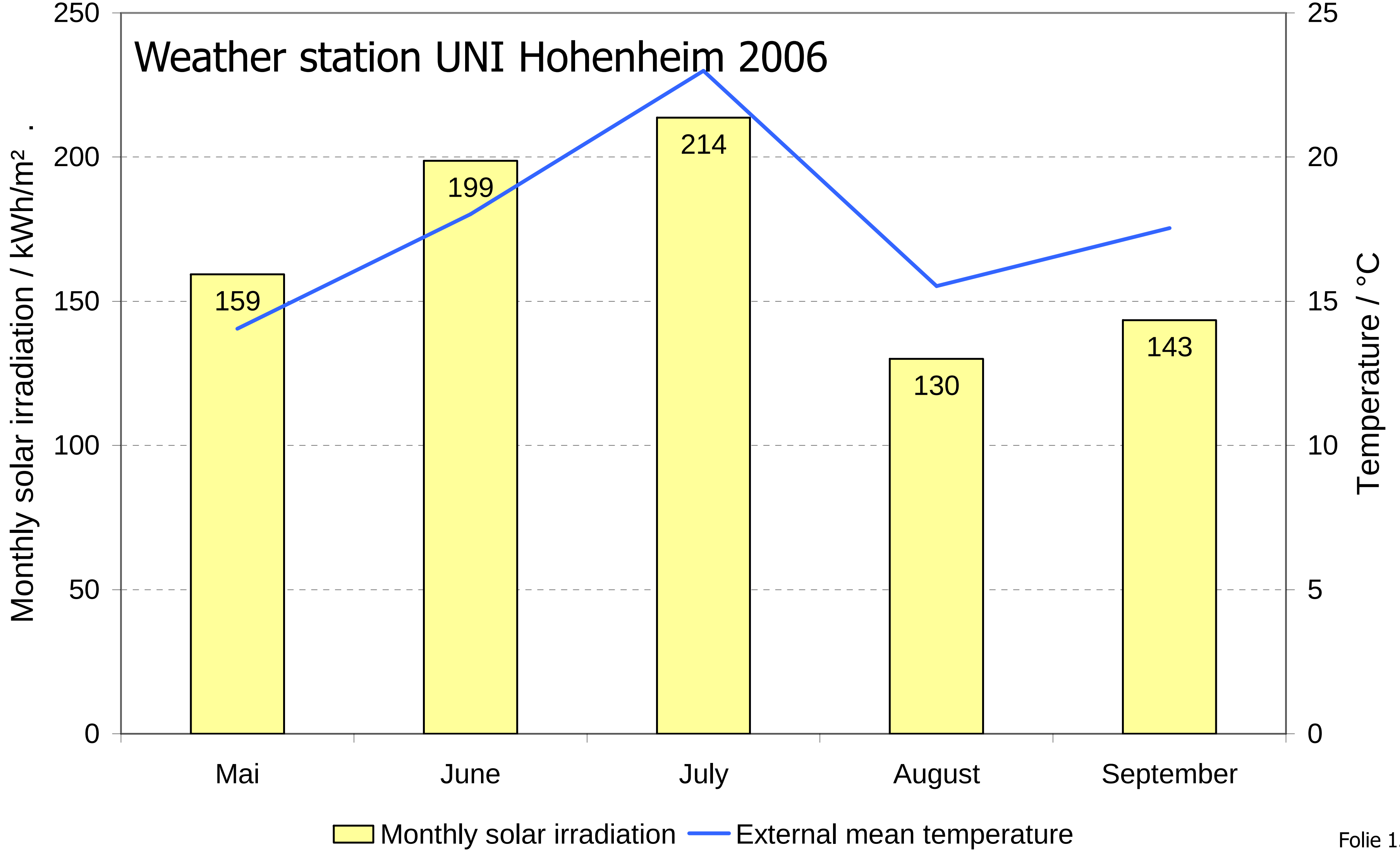


B) Results of annual simulations :

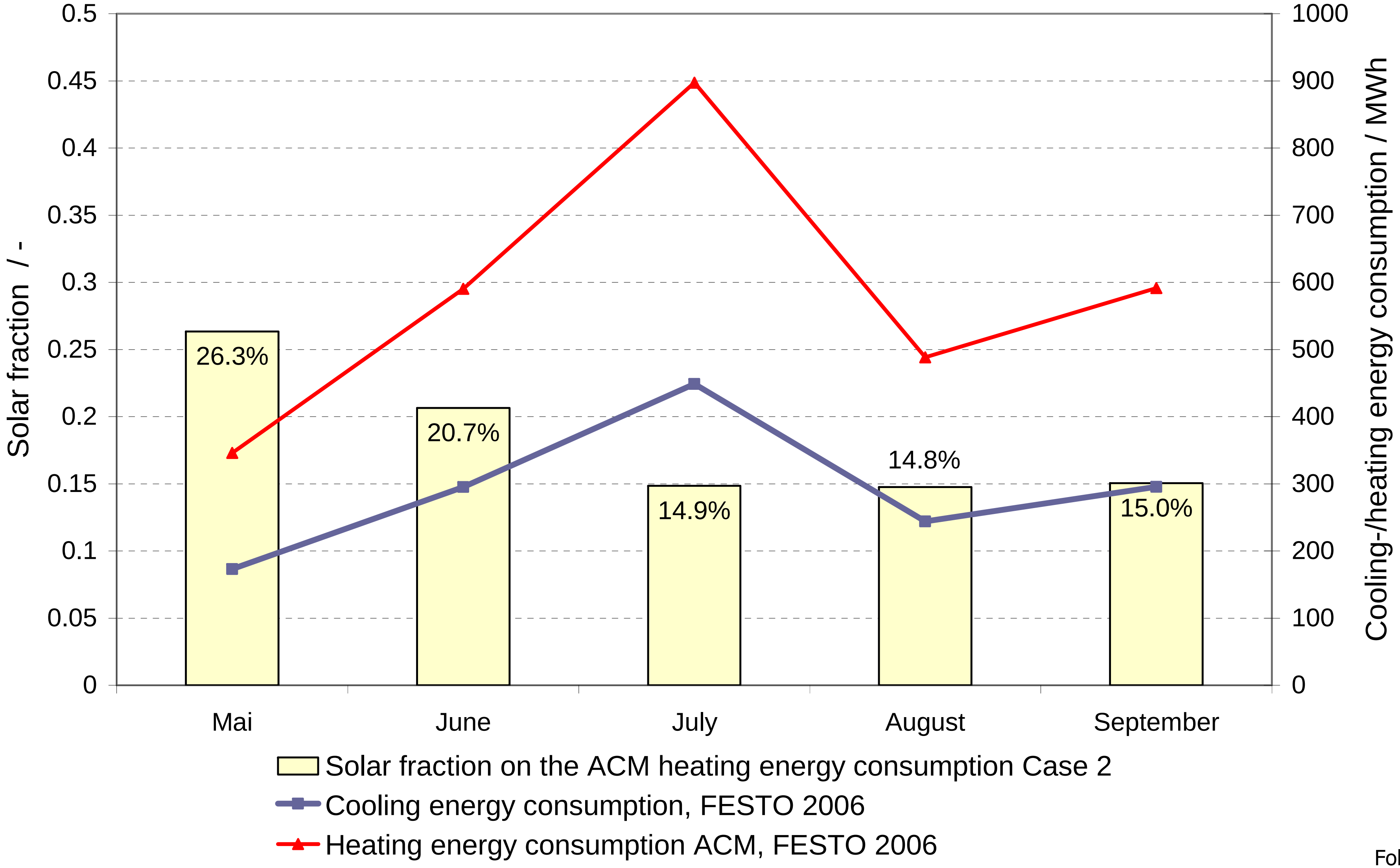
- Influence of different system losses, Case 2



B) Simulation results summer 2006:
- Meteorological conditions



B) Simulation results summer 2006:
- Solar fraction ACM heating energy demand



B) Conclusions

- Due to permanent use of the produced solar heating energy:
  → high specific useful heating energy > 530 kWh/m²a
  → high solar system efficiency 42 – 47 %
- 7 % increase of solar heating energy possible for different collector temperature setpoints for summer and winter operation (70°C summer / 50°C Winter)
- 2,5 % increase in solar heating energy for collector pump with mass flow control instead of On-/Off control
- Temperature reduction in the primary heating circuit of the activated ceilings revels in additional 2,6 % increase of solar heating energy
- 15 to 25 % solar fraction of the heating energy demand of the adsorption chillers expected.

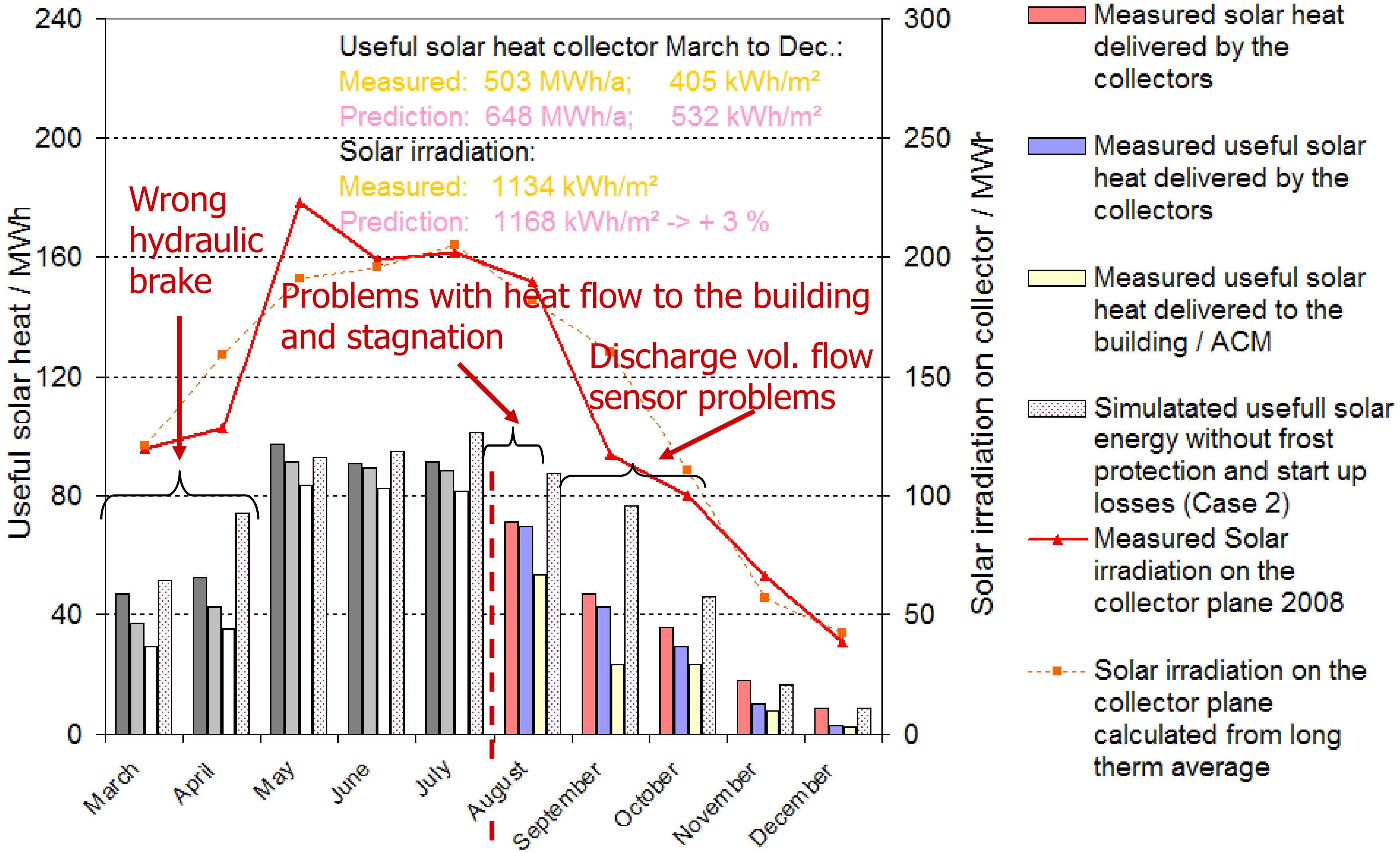
Objectives:

- Demonstration of the quality of dynamic simulation based performance predictions.
  - Prediction with long term weather data (Part B, Case 2)
  - Real measured performance data 2008
- Discussion of possible reasons for deviations between prediction and measured data

Data source:

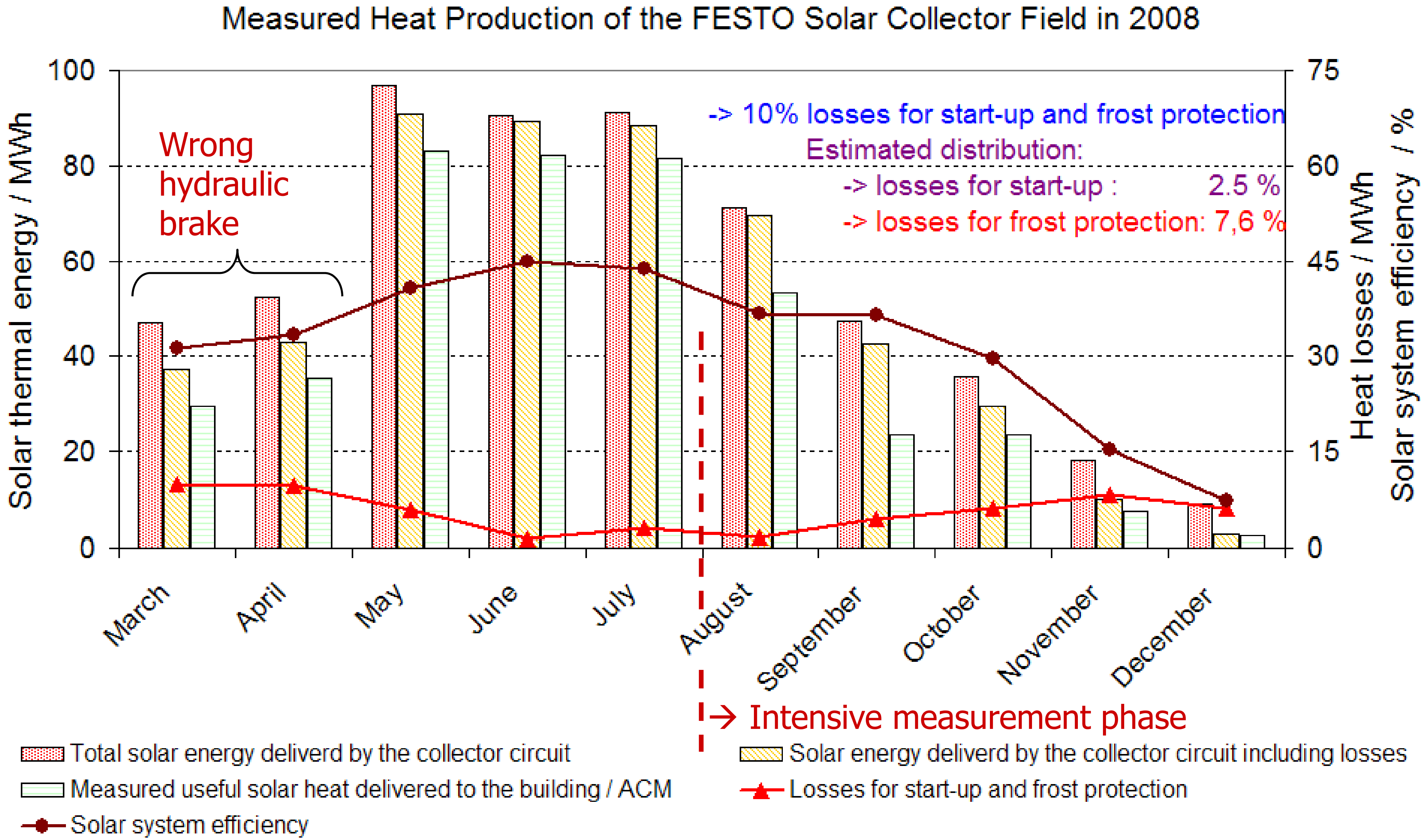
- Measured performance data of the solar collector field from March to December 2008 (Monitoring system: Hochschule Offenburg, Solarthermie 2000plus → 5 min mean values)

C) Measured performance compared to predicted values



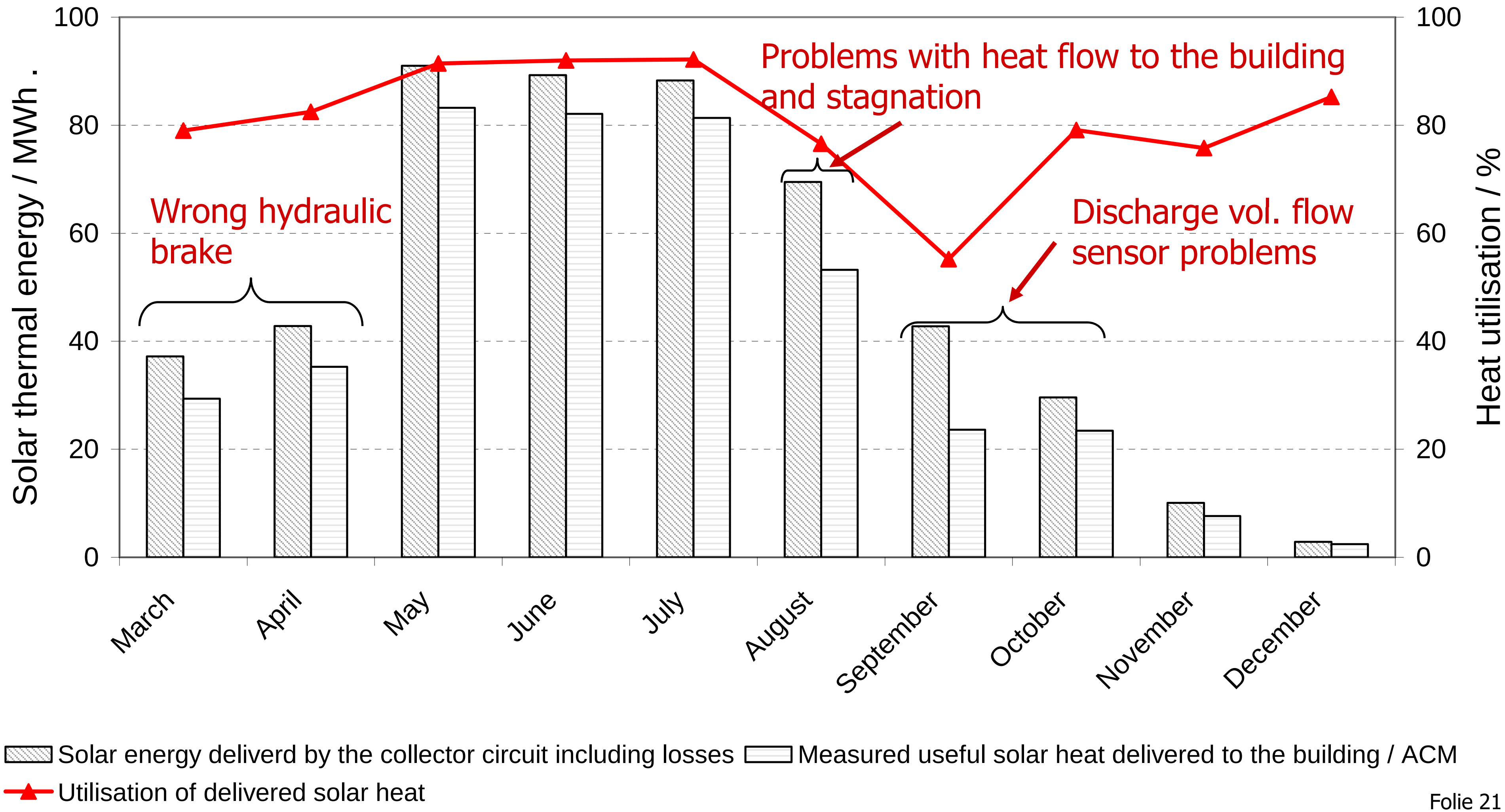
→ Intensive measurement phase Solarthermie 2000plus

C) Possible reasons for large difference between prediction and measured data



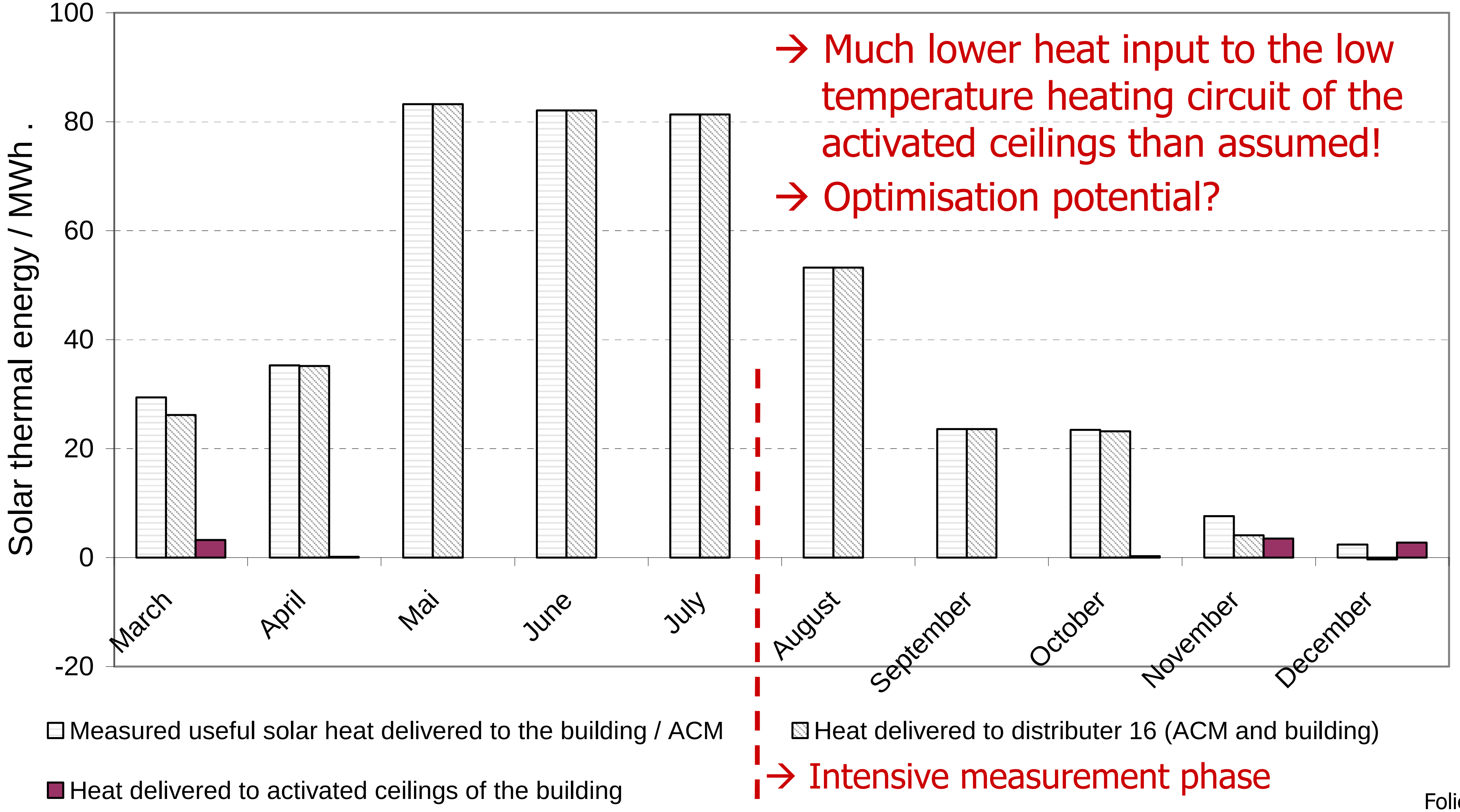
C) Possible reasons for large difference between prediction and measured data

Heat Production and Utilisation of the FESTO Solar Collector Field in 2008



C) Possible reasons for large difference between prediction and measured data

Heat Distribution of the Solar Heat Delivered by the FESTO Solar Collector Field in 2008



C) Conclusions

Reasons for deviations between prediction and measurement:

→Losses through system startup and frost protection not considered in the simulation tool → 10 % heat losses!

→Additional heat losses in March and April due to a wrongly dimensioned hydraulic brake → backflow of warm water into the collector field during night time

→ 3 % lower measured solar irradiation

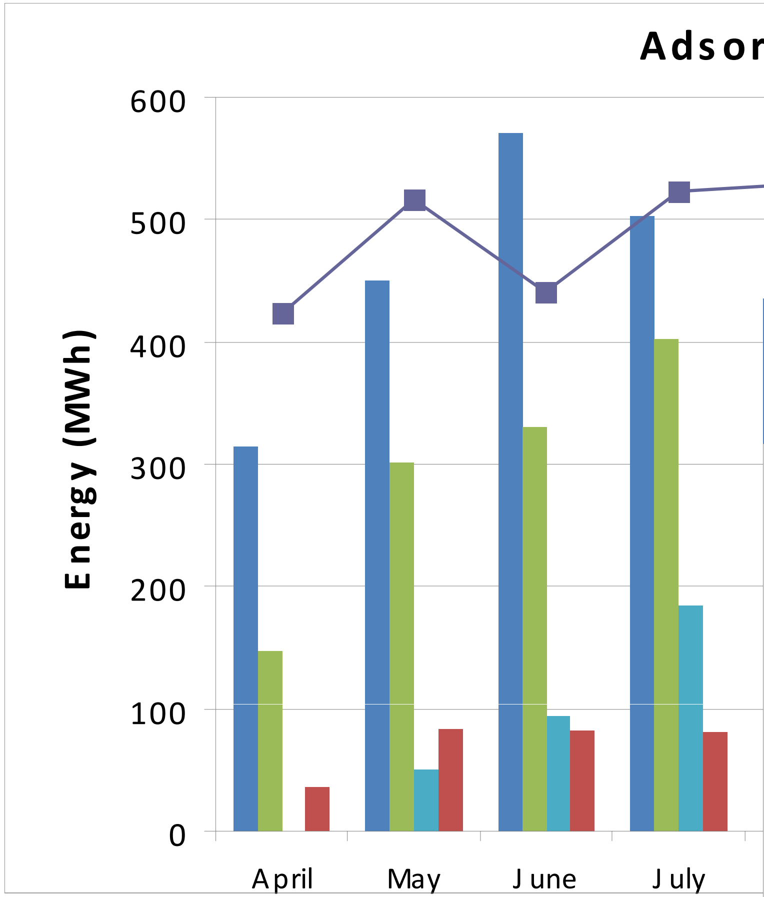
→Problems with the heat flow to the building in August 2008 and resulting stagnation of the collector field → lower efficiency

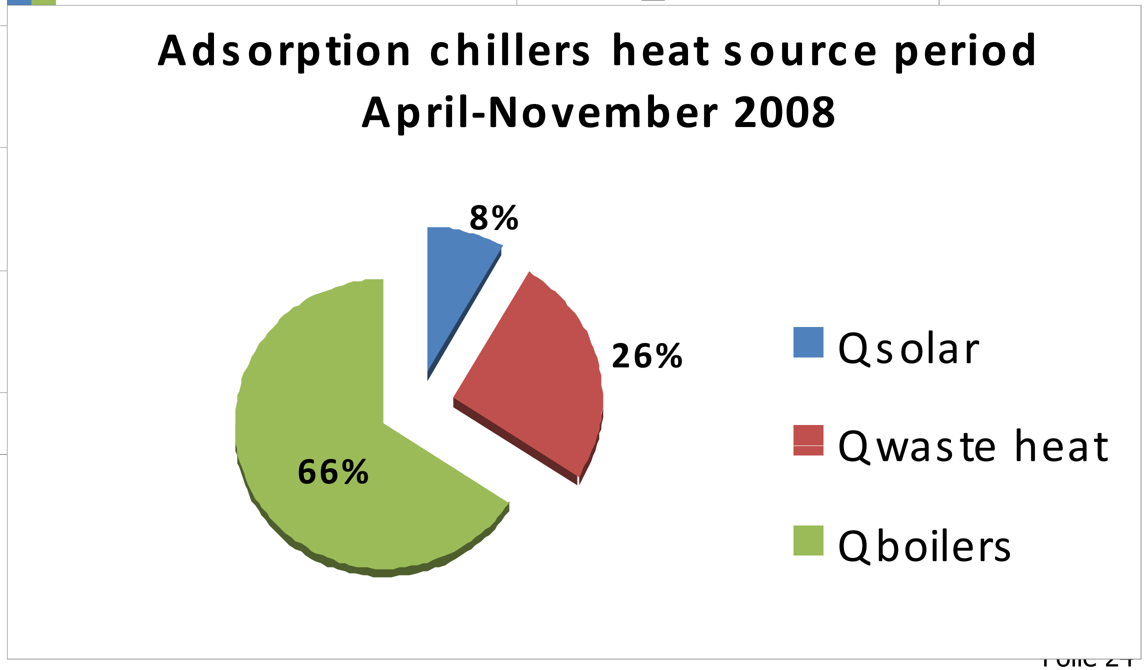
→Much lower heat input to the low temperature heating circuit of the activated ceilings than assumed by the ideal control of the simulation model!

→ Higher collector temperatures and lower system efficiency
→ Possible optimisation potential for the implemented control

→Together around 30% losses not considered in the simulations

C.1) Measured performance of the adsorption chillers 2008





D) Online simulation tool and measured performance data

zafh net

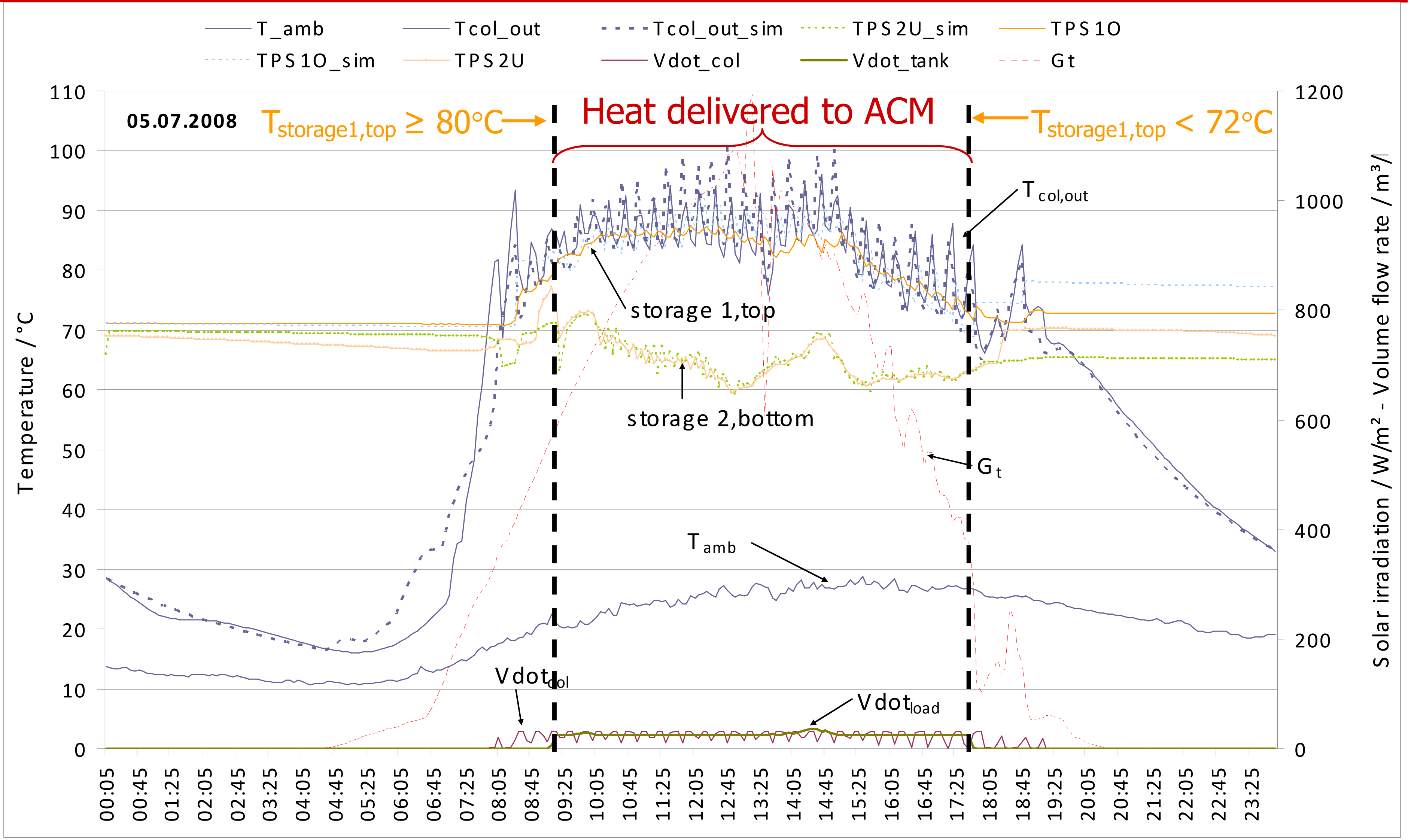
Objectives:

- Validation of the simulation models (collector field and ACM)
- Implementation of an online simulation based performance observation
- Simulation based control optimisation of the ACM cascade

Data source:

- Measured performance data of the solar collector field from April to December 2008
  (Monitoring system: Hochschule Offenburg, Solarthermie 2000plus
  → 5 min mean values)
- Measured detailed performance data of the adsorption chillers
  (FESTO building management system, 10 s mean values)

D.1) Validation dynamic solar system model
Example, one day in July



5. CEP 2009, Stuttgart Januar 2008
M.Sc. Dirk Pietruschka
www.zafh.net

Zentrum für angewandte Forschung an Fachhochschulen
Nachhaltige Energietechnik

D.1) Validation dynamic solar system model
Results and conclusions

- Comparison of measured and simulated results

	Qsol	Qcol_m	Qcol_sim	Qload_m	Qload_sim	Dev. col	Dev. load
	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²	%	%
5th July	8.04	4.32	4.17	3.92	4.04	-3.2	+3.1

- Conclusions
  - Good representation of the solar system performance by the developed dynamic system model
  - Improvements:
    - shorter time steps 10 s instead of 5 min mean values
      → Data transfer via OPC and Labview from the BMS
    - Improvement of the stratified solar storage model
      → fixed heat input at predefined storage layers

D.2) Development and validation adsorption chiller model

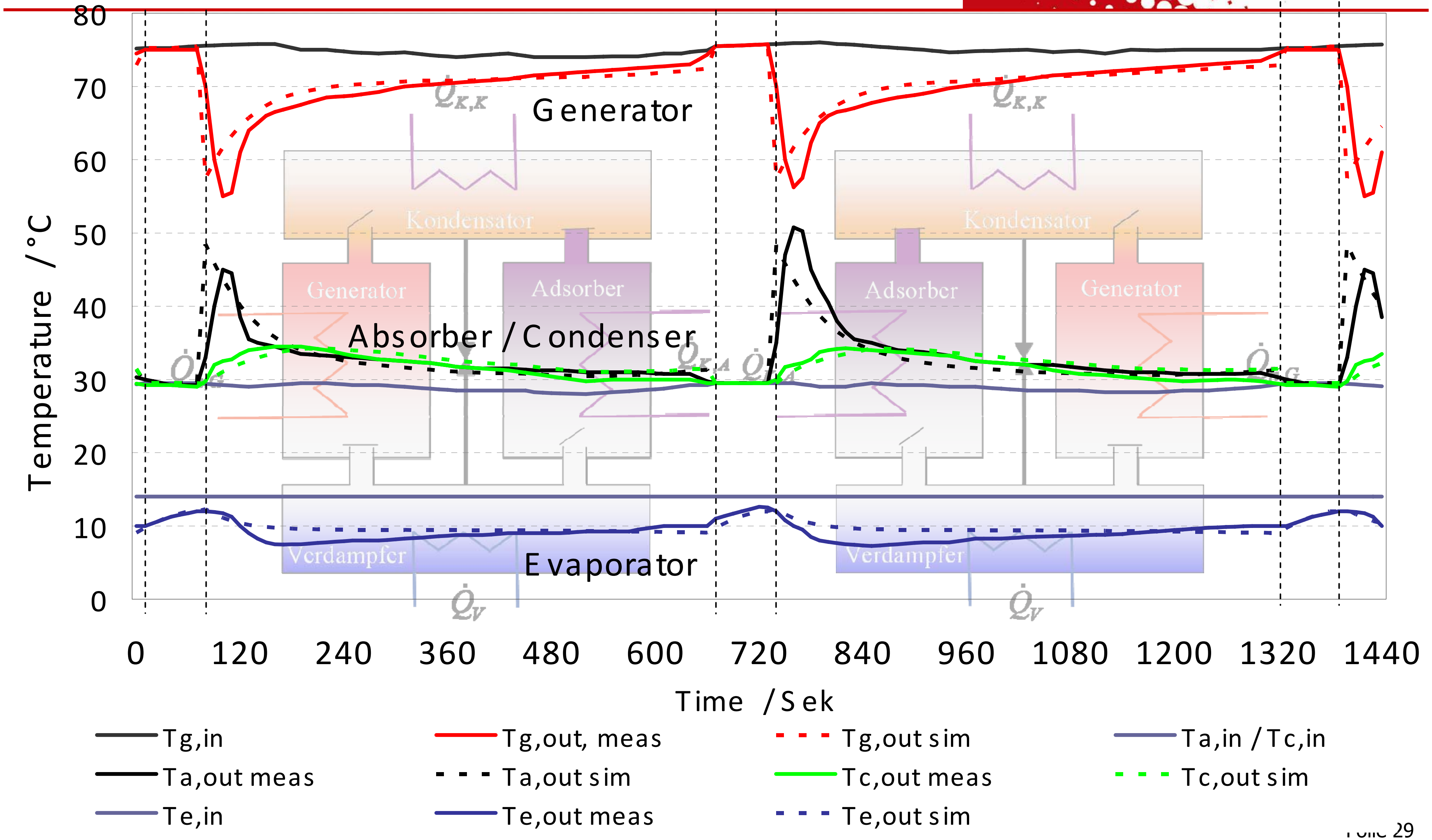
Problem:

- Discontinuous dynamics of adsorption/desorption cycle causes variable cooling effects
  → Dynamic model required which accounts for the transient behaviour [Saha 1995 + simplified silicagel model according to Henry's law proposed by Ng and Chua 2001]

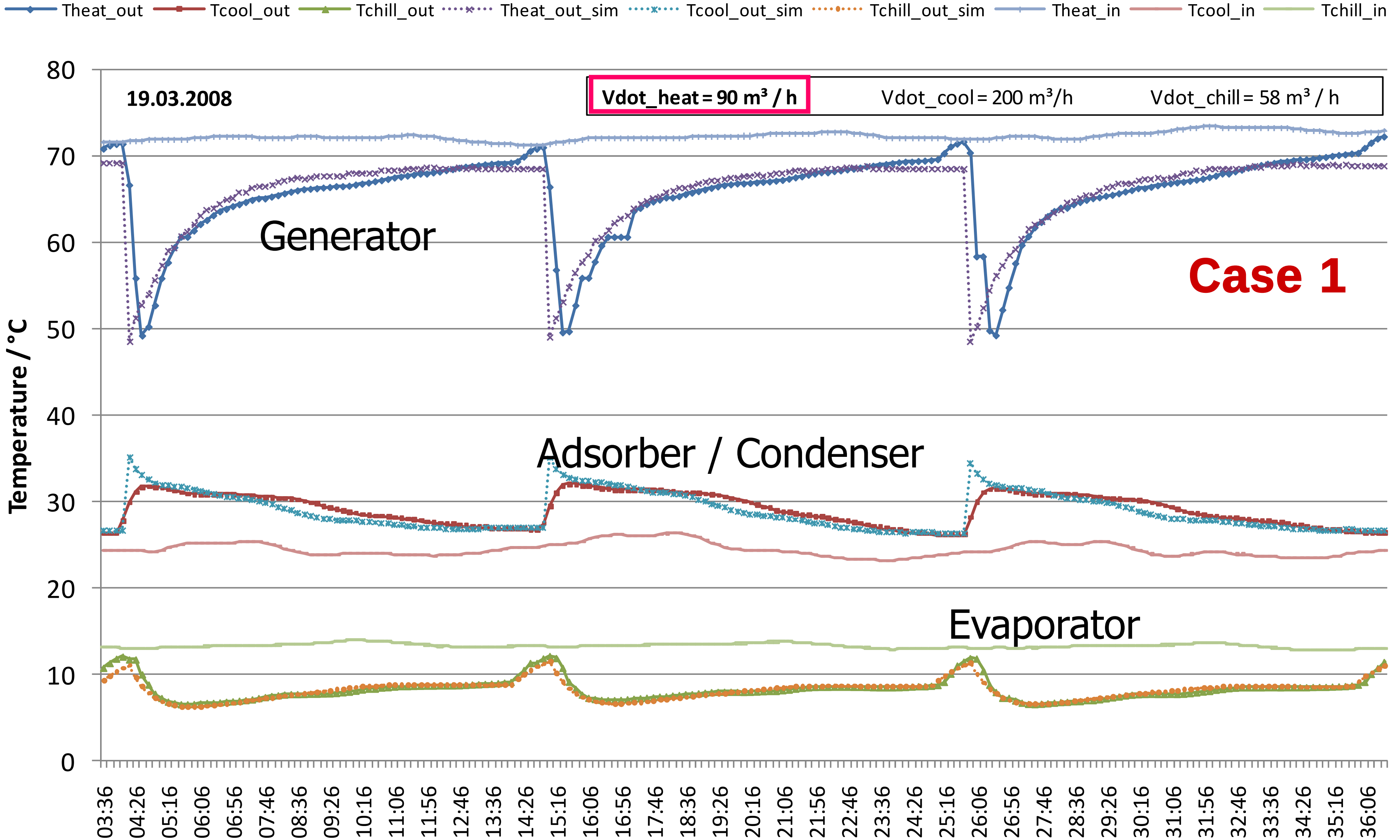
Objectives:

- Analysis of optimisation potentials through the implementation of variable cycle times in the ACM control
- Implementation of an online simulation tool for plant observation and control optimisation with e.g. variable generator mass flow rates at part load or optimised control of the chiller cascade

D.2) Comparison to measured data at standard operation conditions



D.2) Comparison to real measured data with different generator volume flow rates



D.2) Comparison of results and conclusions

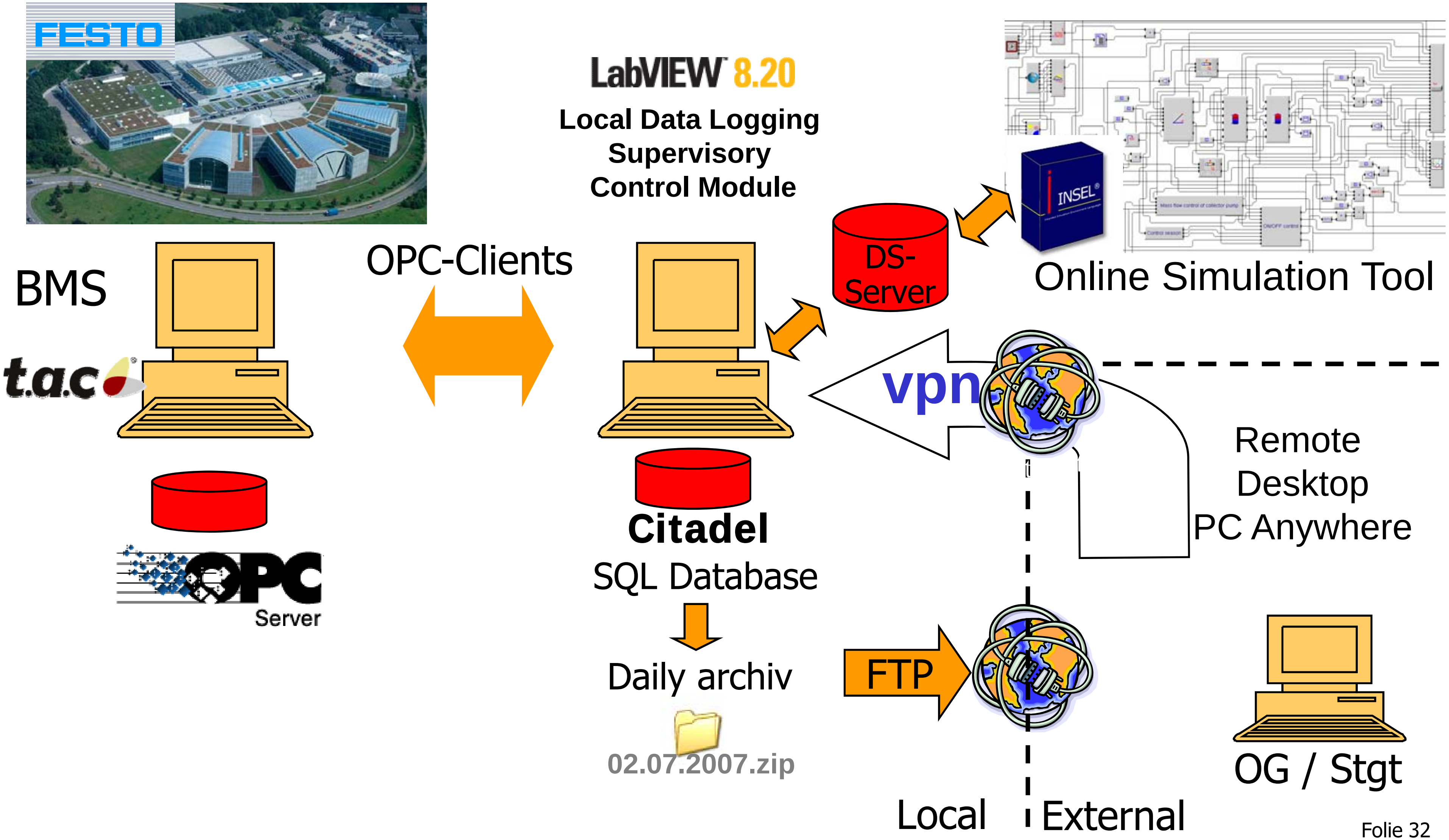
- Comparison of measured and simulated data

	Theat_in	Vdot_heat	P_cool,m	P_cool,sim	COP_m	COP_sim	Dev. Pcool	Dev. COP
	°C	m³/h	kW	kW	-	-	%	%
Case 1	70-72	90	338.7	346.3	0.49	0.52	+ 2.3	+ 6.3
Case 2	78-80	65	360.6	358.0	0.458	0.476	- 0.7	+ 3.9
Case 3	68-70	50	304.3	295.6	0.49	0.54	- 2.8	+ 11.7

- Conclusions

- Very good agreement between simulation model and measurement also for variable operation conditions
- Implementation as online simulation tool in February 2009

D.3) Implementation of online simulation tools in the local BMS



Outlook

- Automated data-transfer between BMS and online simulation tool with high time resolution (OPC-interface, LabView, DataSocket) → finished
- Implementation of a permanent and automated performance observation of solar plant and adsorption chillers → February / March 2009
- Primary energy optimised simulation based control of the adsorption chillers including all subsystems → May / June 2009