Theory versus reality

Why do buildings need more thermal energy than designed, and why is it the other way round when it comes to calculating the heating power?

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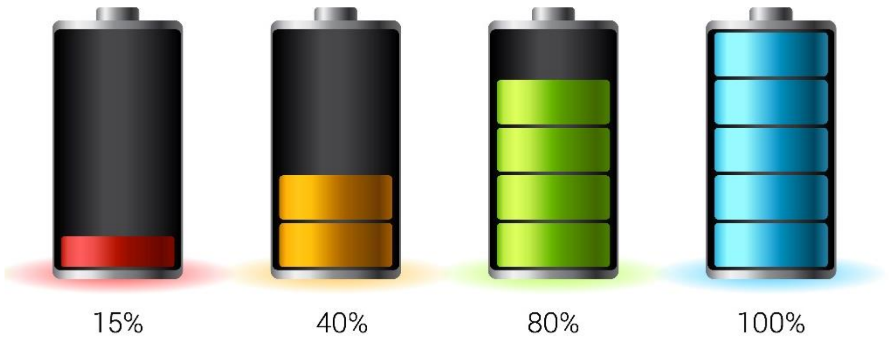
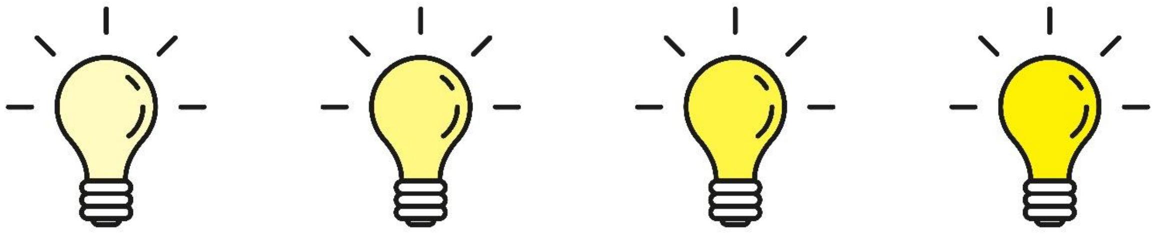
Performance Gap: Energy vs. Power

Energy – Additional demand due real user behaviour



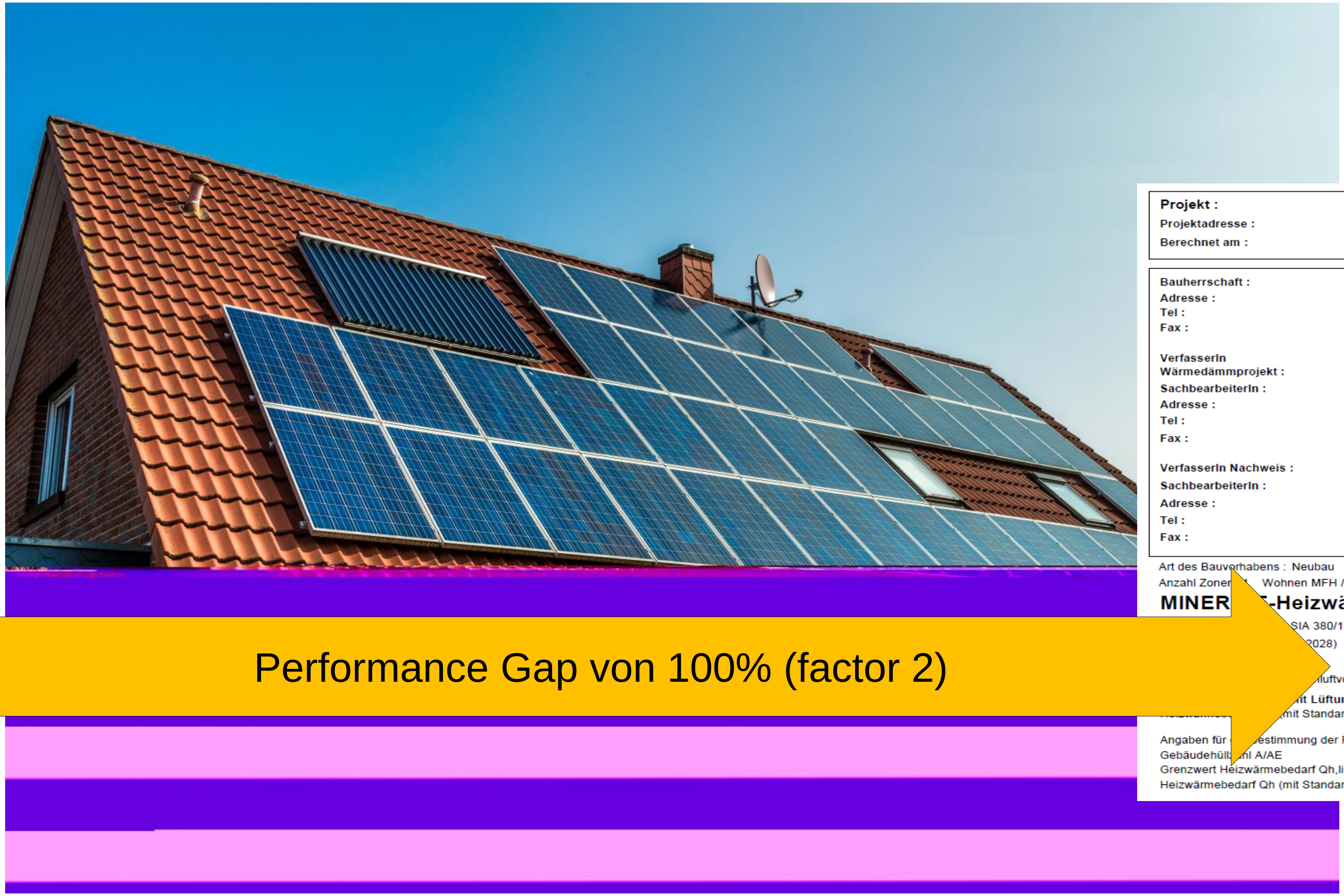
Project VenTSol: www.spf.ch/ventsol

Power – oversizing of heating and cooling systems

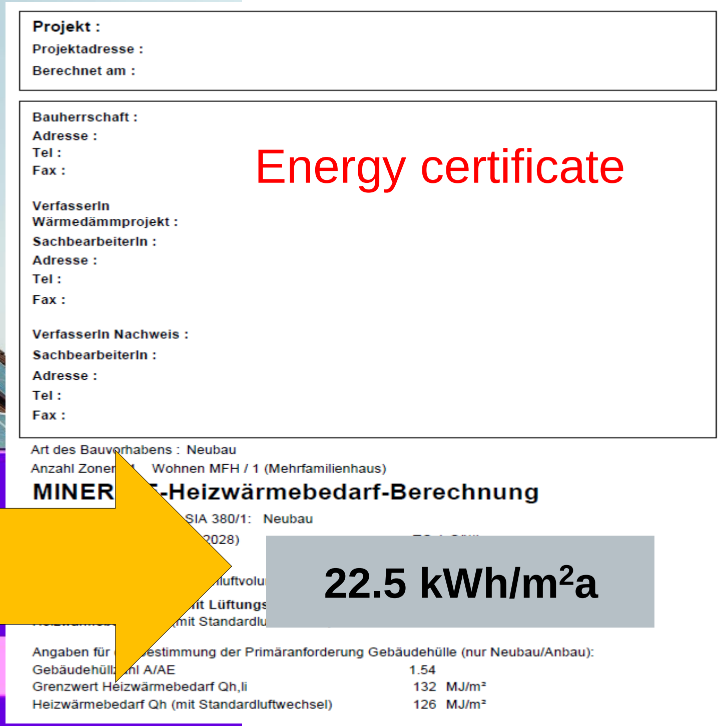


Project OptiPower: www.spf.ch/optipower

Reality versus Theory



Performance Gap von 100% (factor 2)


Projekt :
Projektadresse :
Berechnet am :

Bauherrschaft :
Adresse :
Tel :
Fax :

VerfasserIn Wärmedämmprojekt :
SachbearbeiterIn :
Adresse :
Tel :
Fax :

VerfasserIn Nachweis :
SachbearbeiterIn :
Adresse :
Tel :
Fax :

Art des Bauvorhabens : Neubau
Anzahl Zonen : Wohnen MFH / 1 (Mehrfamilienhaus)

MINER -Heizwärmebedarf-Berechnung

SIA 380/1: Neubau

Angaben für Bestimmung der Primäranforderung Gebäudehülle (nur Neubau/Anbau):

Gebäudehüllzahl A/AE	1.54	
Grenzwert Heizwärmebedarf Qh,li	132	MJ/m²
Heizwärmebedarf Qh (mit Standardluftwechsel)	126	MJ/m²

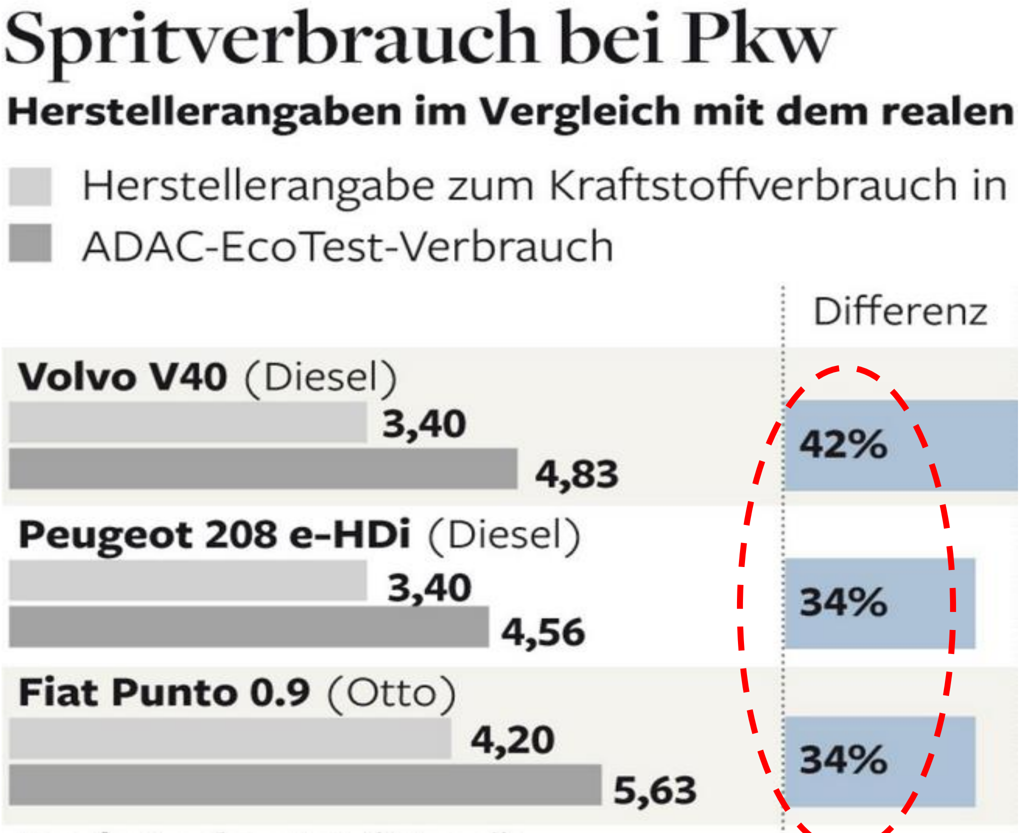
Energy certificate

22.5 kWh/m²a

The same story with the gasoline demand

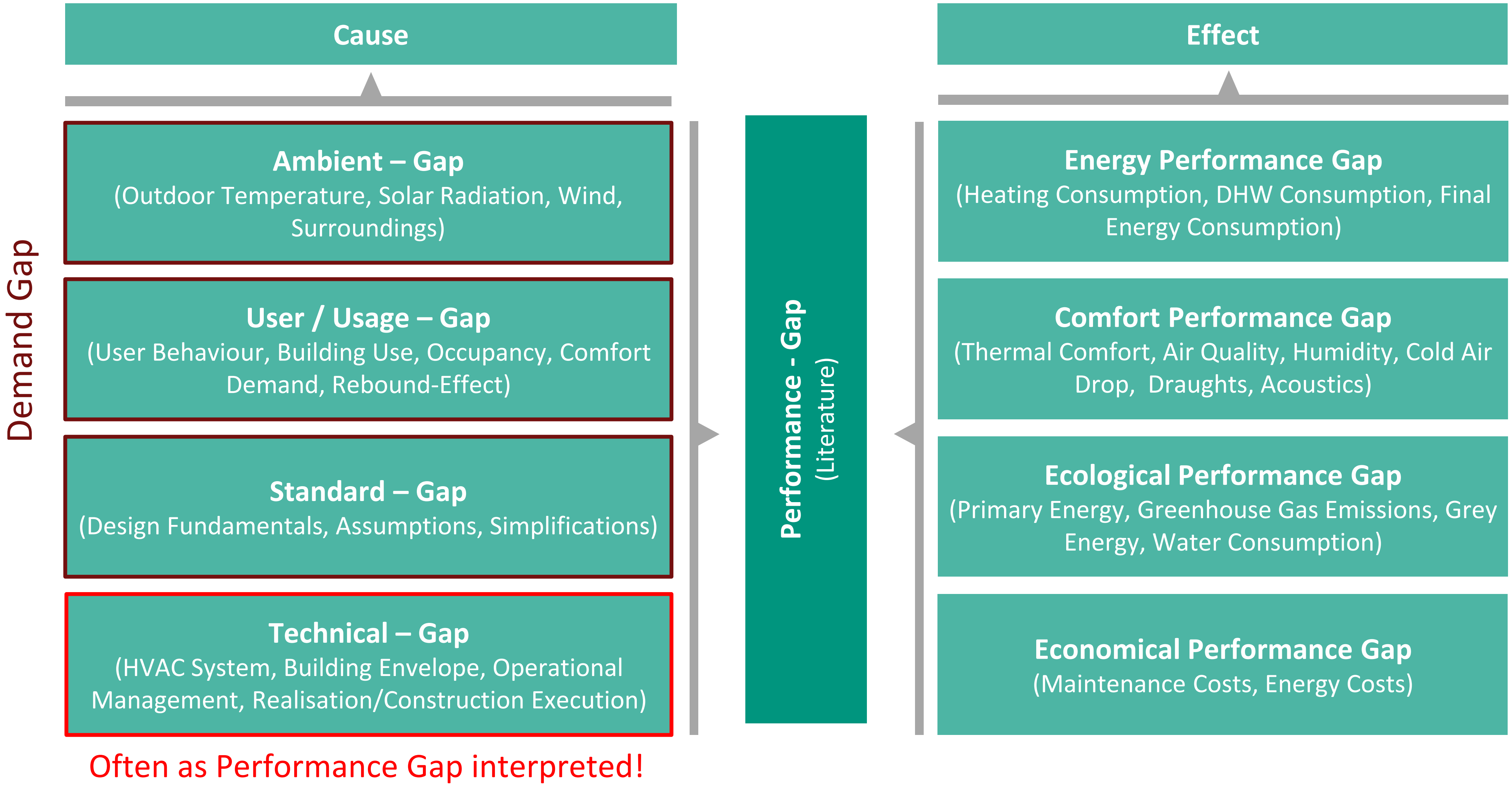
www.welt.de

??????



The idea of standards is not to match reality exactly, but to provide some benchmarks for comparison!

Overview Performance Gap

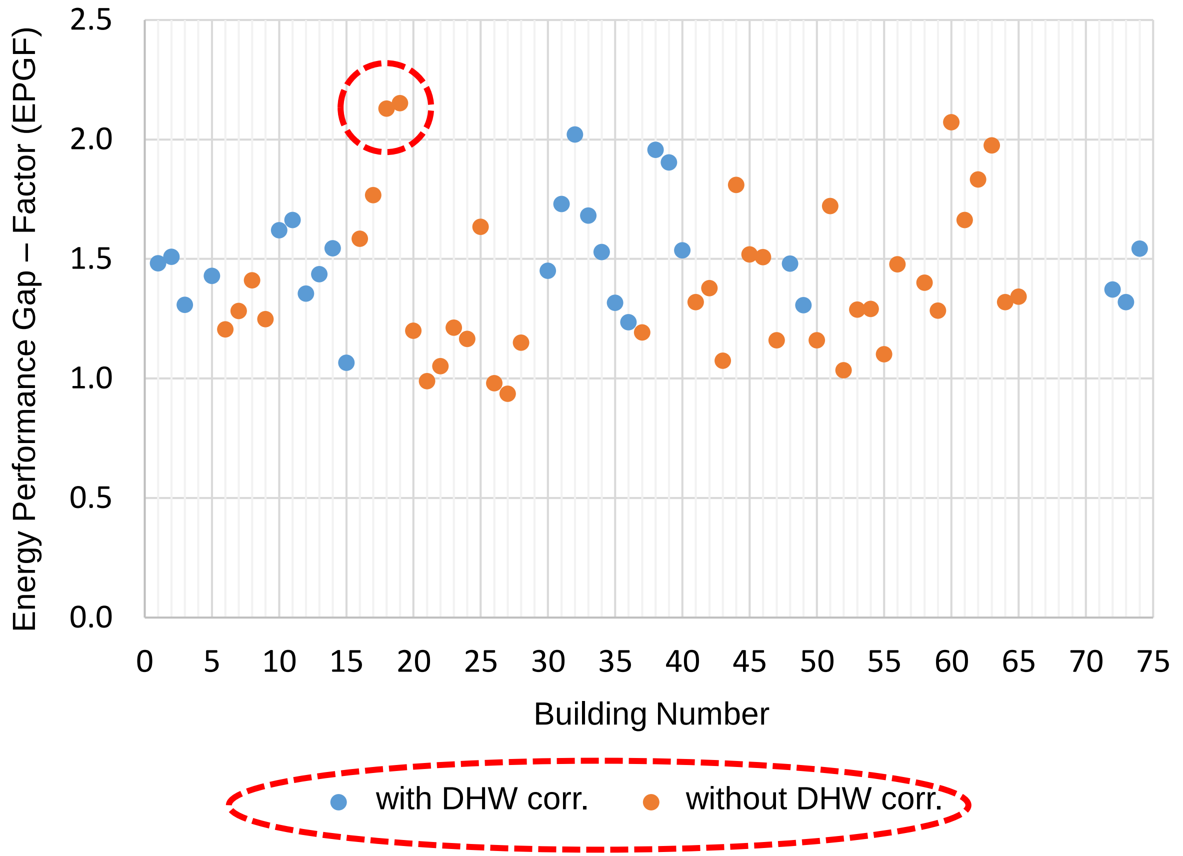


Analysis of 65 multi-family buildings

- Comparison of measured heat consumption (energy) and calculated heat demand (certificate) of 65 MFBs
- Focus on heating energy
- No consideration of final energy (e.g. electricity, gas, etc.) or Minergie KPI's
- Therefore no influence of the efficiency of the heat production
- We only consider the useful heat (what is actually emitted into the home!)
- Weather-adjusted data
- High temporal resolution (15-minute values)

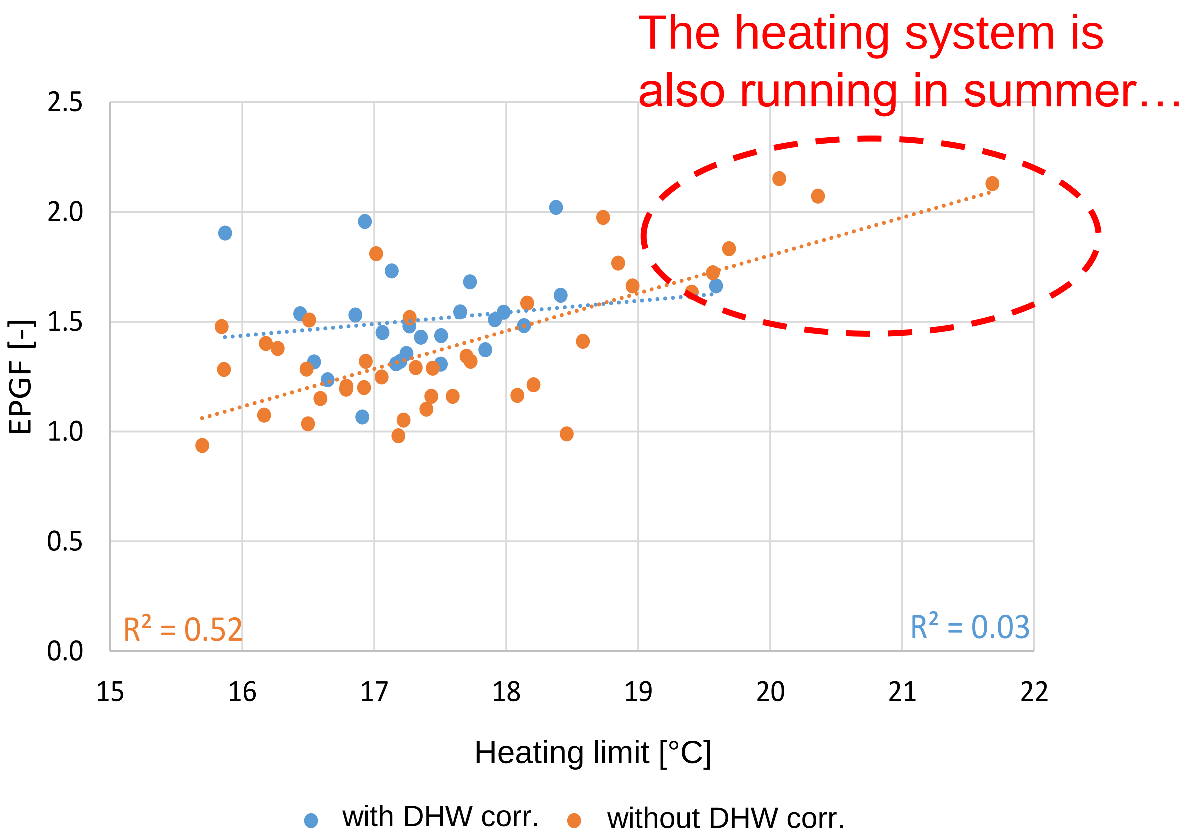
Analysis of the heating demand

- In average +44%
- Worst building with +115%
- Comparison with energy certificate → not ideal, but what else should be used?



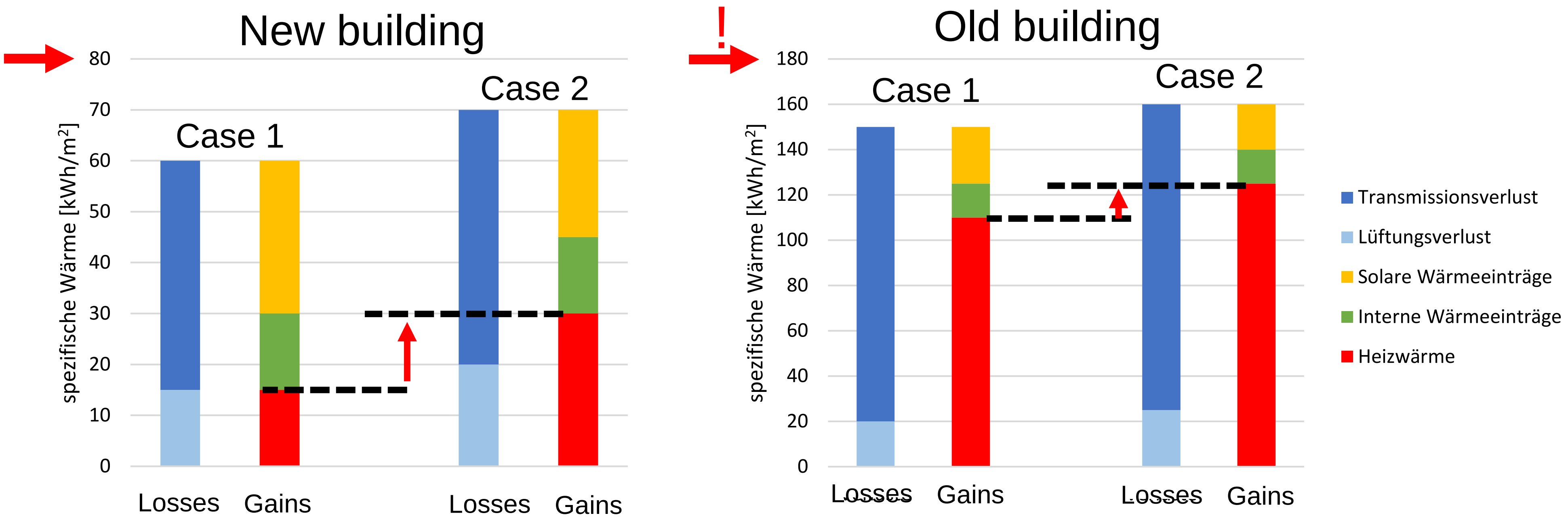
Heating limit – an important parameter

- In theory (e.g standards) a heating limite of 12°C is assumed
- In average the heating limite is around 17°C!
- Some buildings heat also in «summer»!



Attention: absolute vs. relative comparison

- Case 2:
  - Higher ventilation losses (open windows), higher losses building envelope
  - Lower solar gains (more window shading)



+15 kWh/m² **(+100%)**

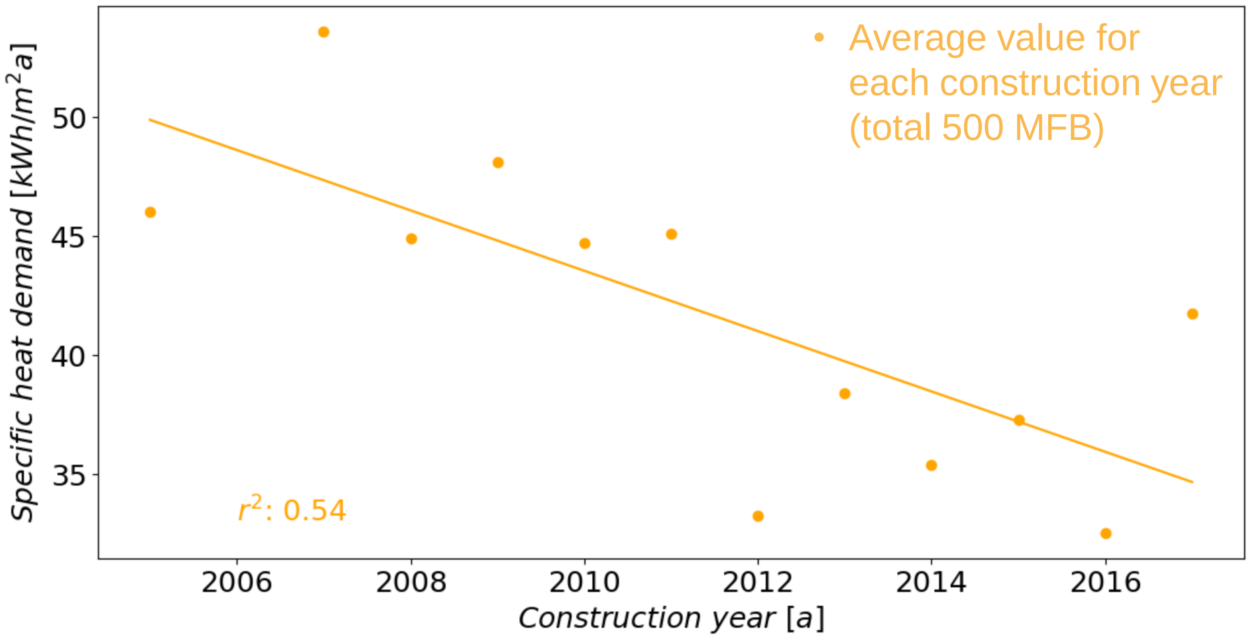
+15 kWh/m² (**+14%**)

Absolute vs. relative comparison

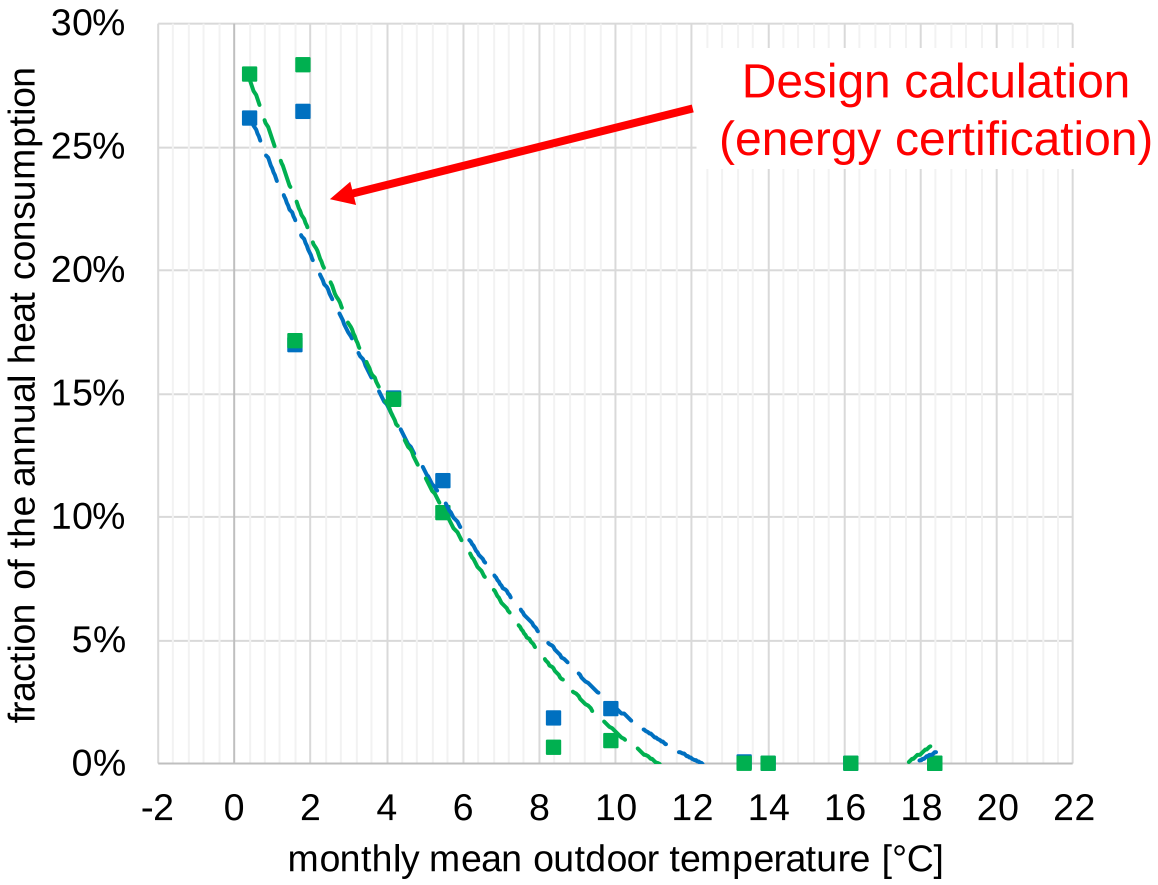
- Small deviations in losses or gains can make deviations shown as a percentage appear very large
- In absolute figures, however, the difference (additional consumption) can be much smaller, or even the same as in the example shown
- Conclusion:
  – Deviations (performance gap) in well-insulated buildings appear much higher! This falsely reinforces the impression that modern buildings do not fulfil what they promise! Wrongly so, because...

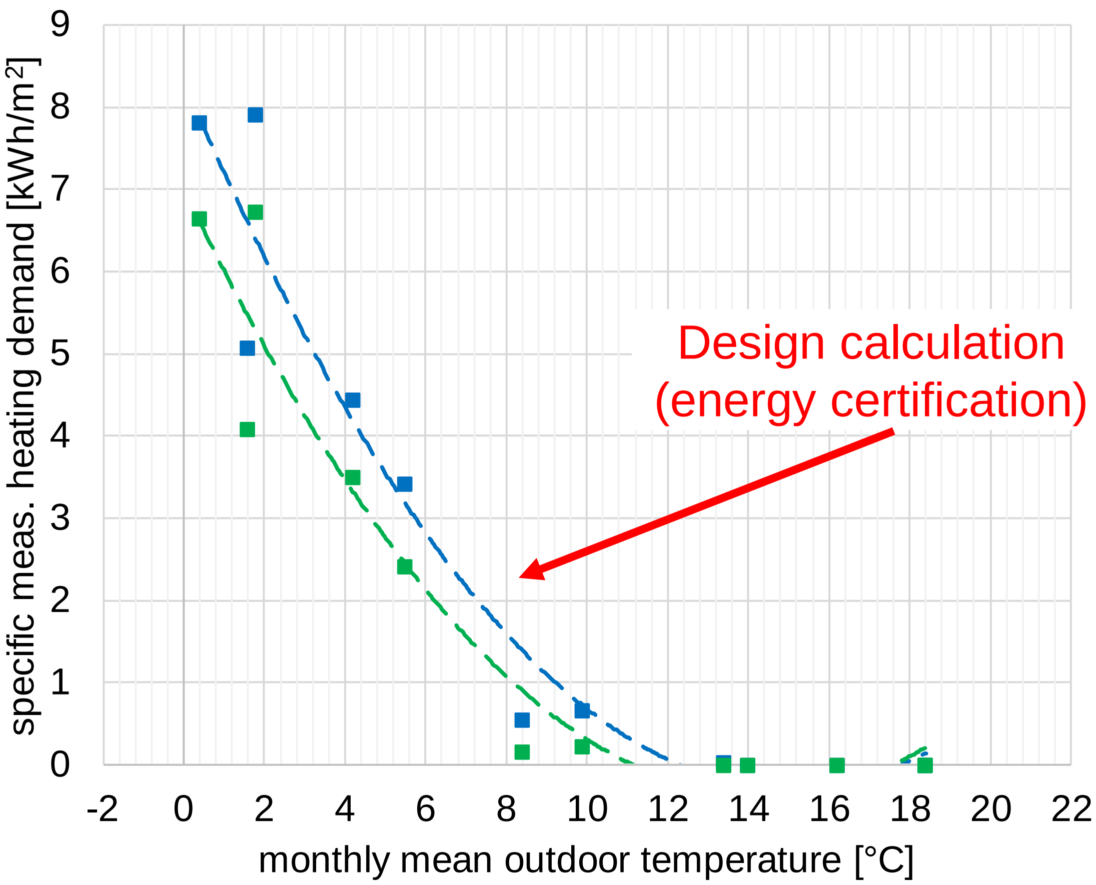
The buildings are improving over time…

- ... the evaluation shows that the heating requirement has fallen significantly over the years!
- The higher requirements for insulation are having a positive effect, despite the performance gap



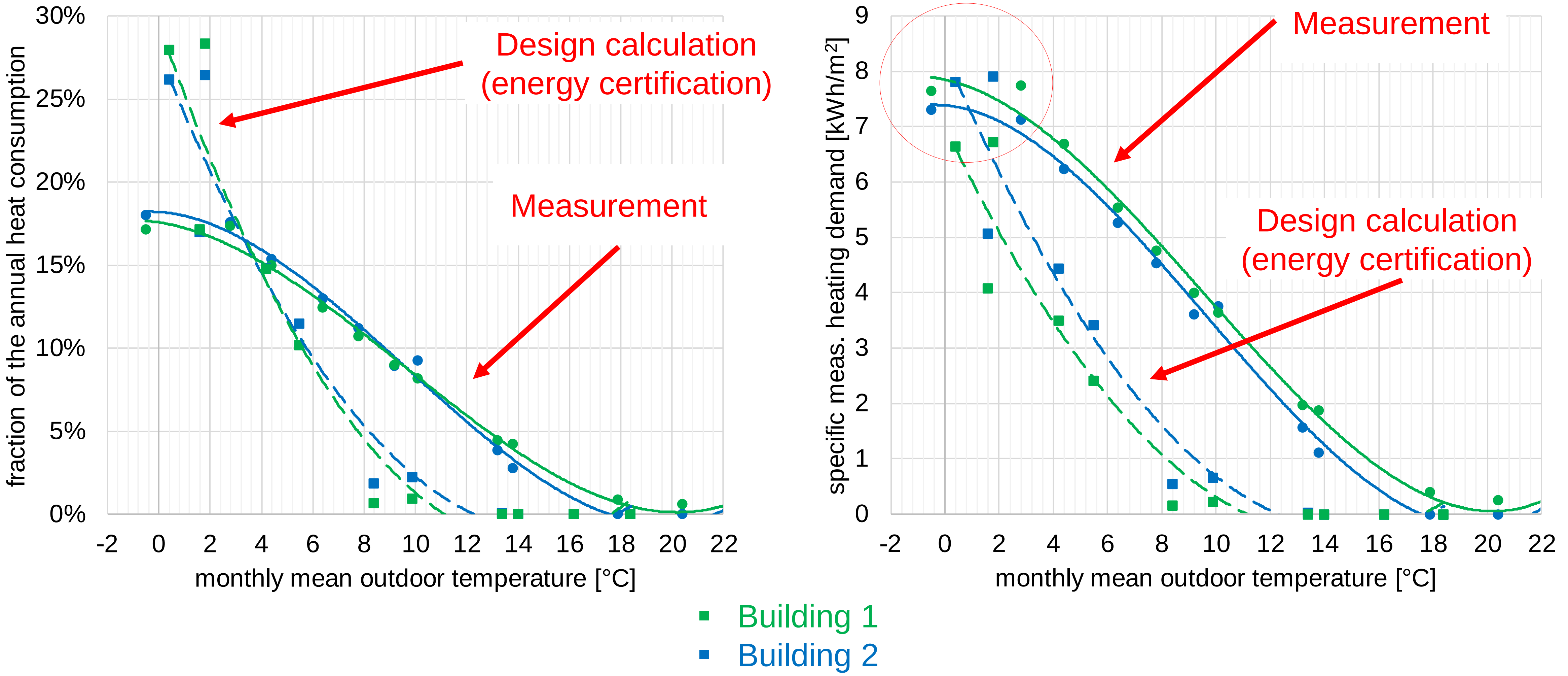
Theory (standard) vs. real measured data





- Building 1
- Building 2

Theory (standard) vs. real measured data

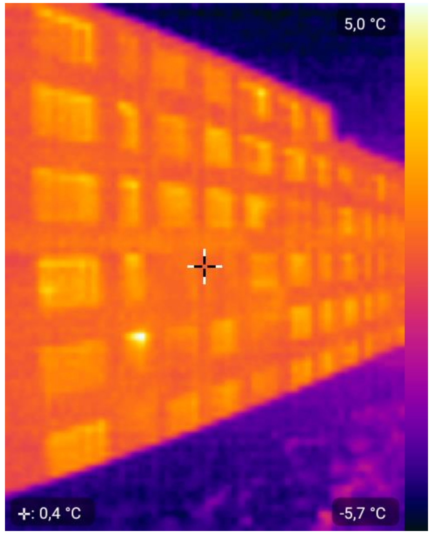


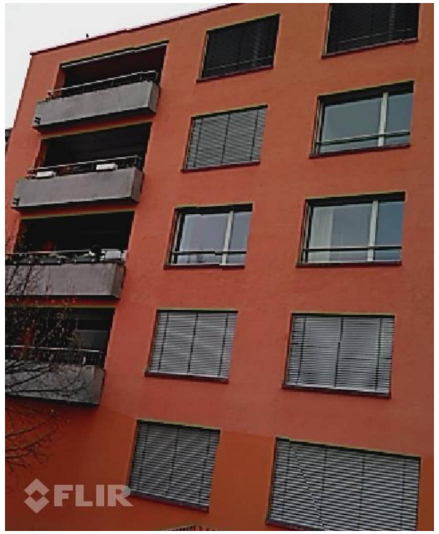
VenTSol SFOE project

- Can the theory proposed in ImmoGap that user behaviour is mainly responsible for the additional demand be confirmed?
- There have been many studies on user behaviour, but none have examined all the important parameters at the same time

Analysis of the user behaviour

- Image of facades using photo- and thermography
  - Automated evaluation of the images
- High temporal resolution (ideally every 15 minutes)
- Recording of room temperature, relative humidity and CO2 concentration (IoT-Sensors)





Thermography – lessons learned

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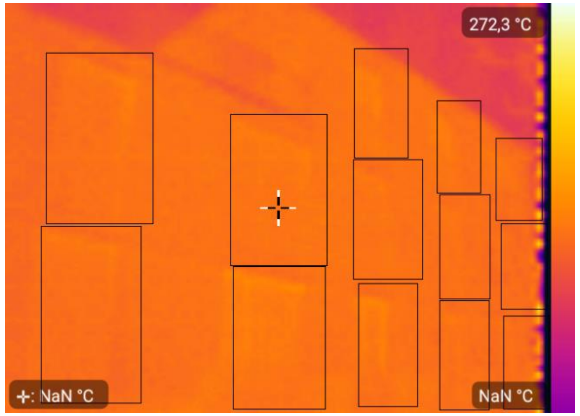
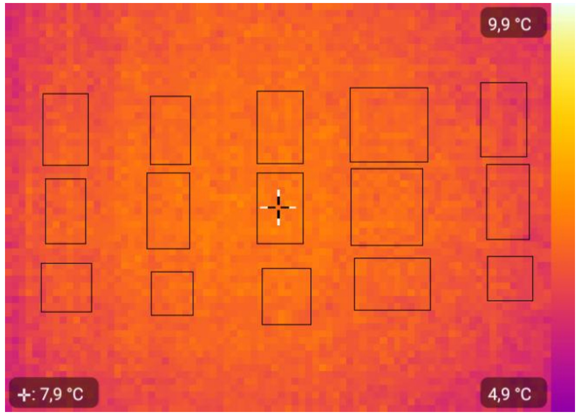
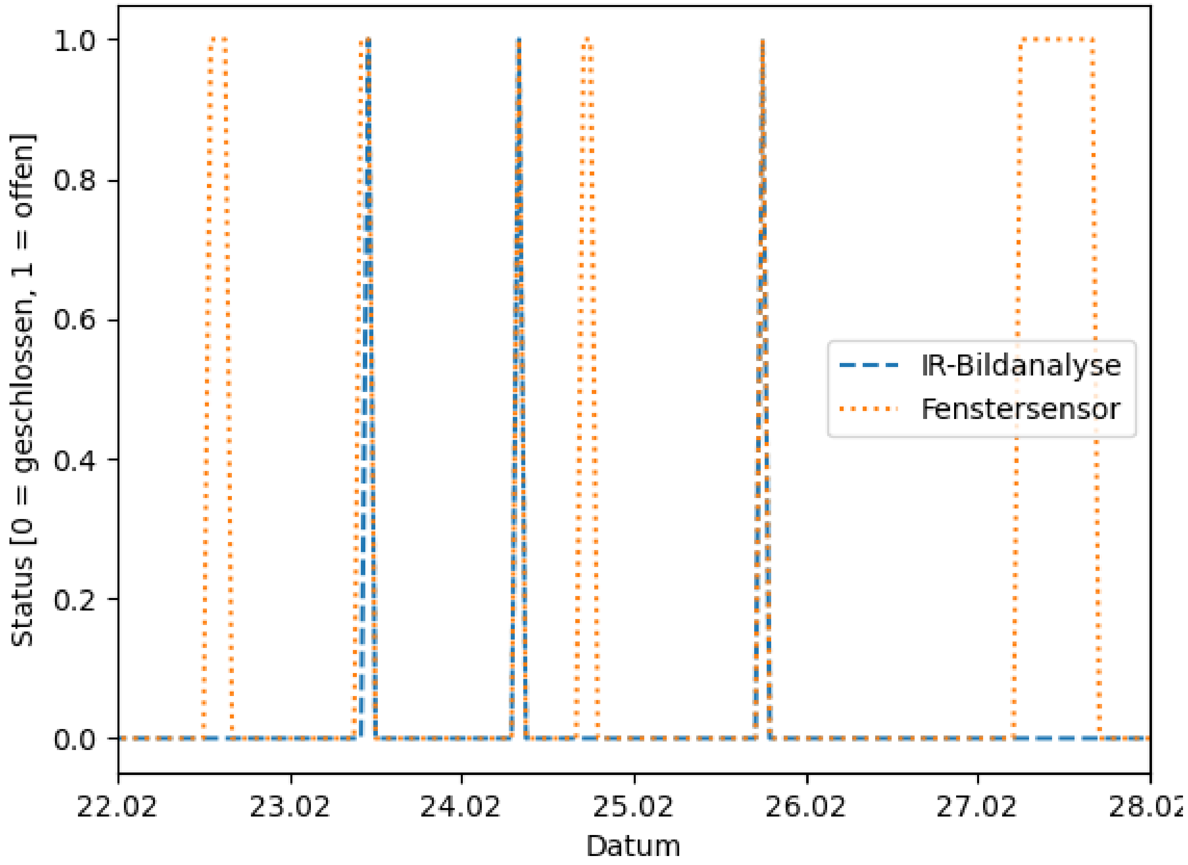
- Method using thermography delivered unsatisfactory results
- Some images completely unusable (e.g. due to the device)
- Large error at higher outside temperatures
- Possibly higher resolution and better app could lead to much better results





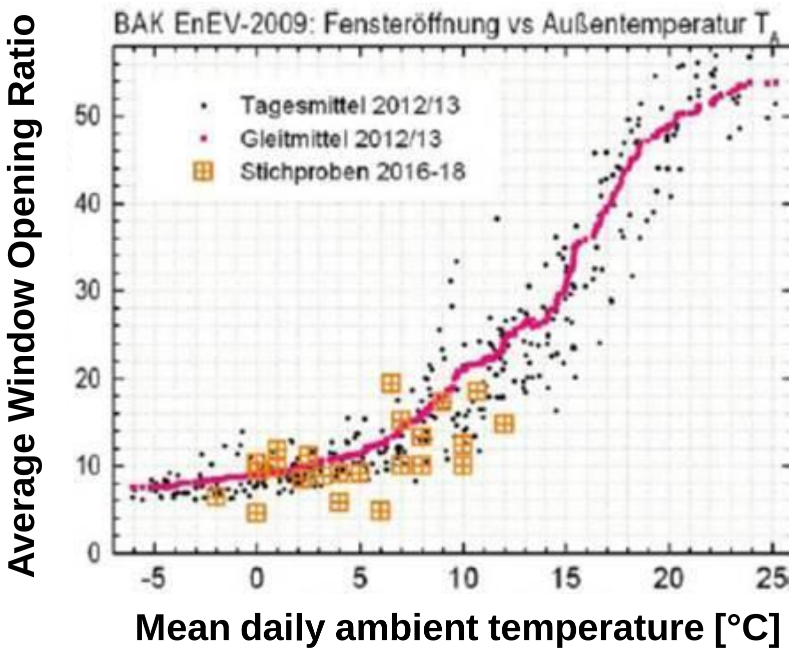
Thermography vs. contact sensors

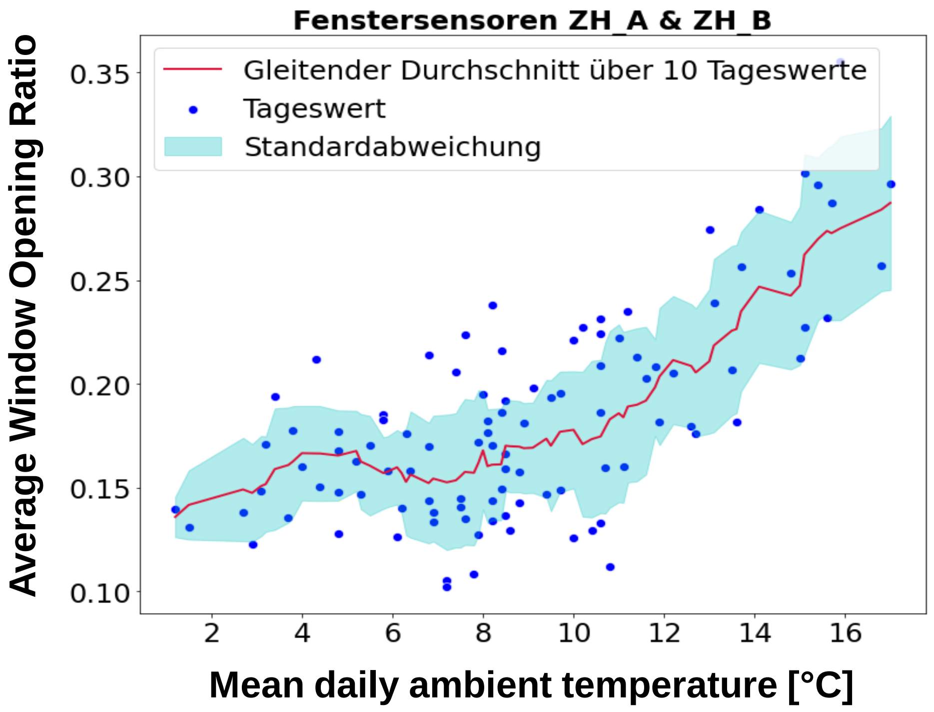
- IoT contact sensors mounted directly on the window
- Total of 20 sensors
- Windows that are regularly opened
- Comparison of IR and contact sensor
- Many false negative results with IR



Window opening depends on outside temperature

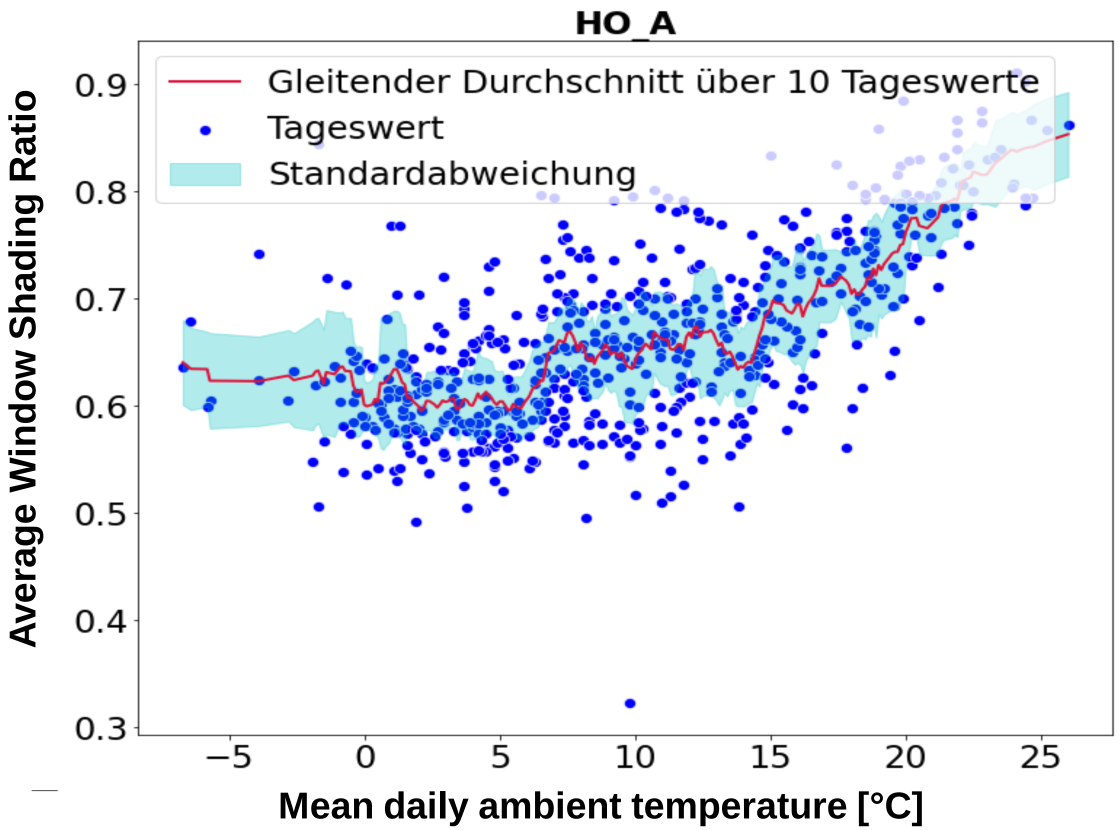
- Results from Germany can also be confirmed with our data
- Similar trend, higher values in ZH (but selected windows that are opened more frequently, not the entire number of windows taken into account!)

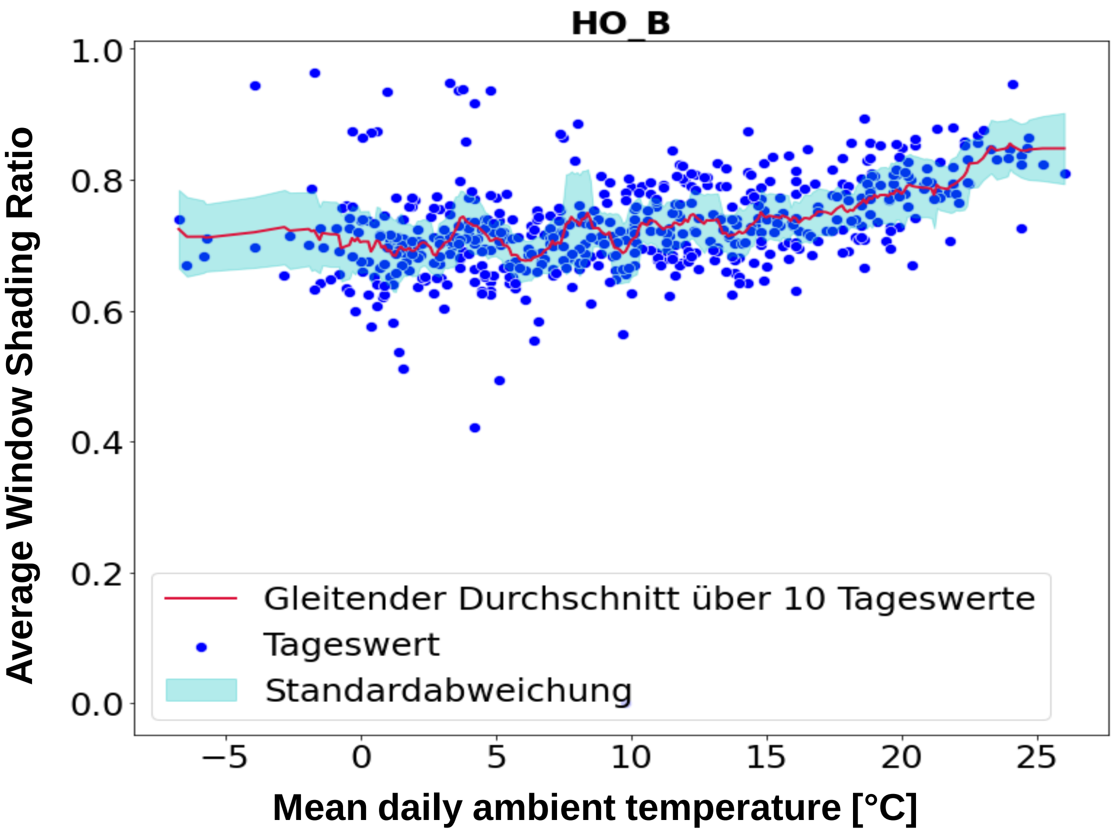




Shading rate surprisingly high

- Results of the photography recordings





Shading in winter

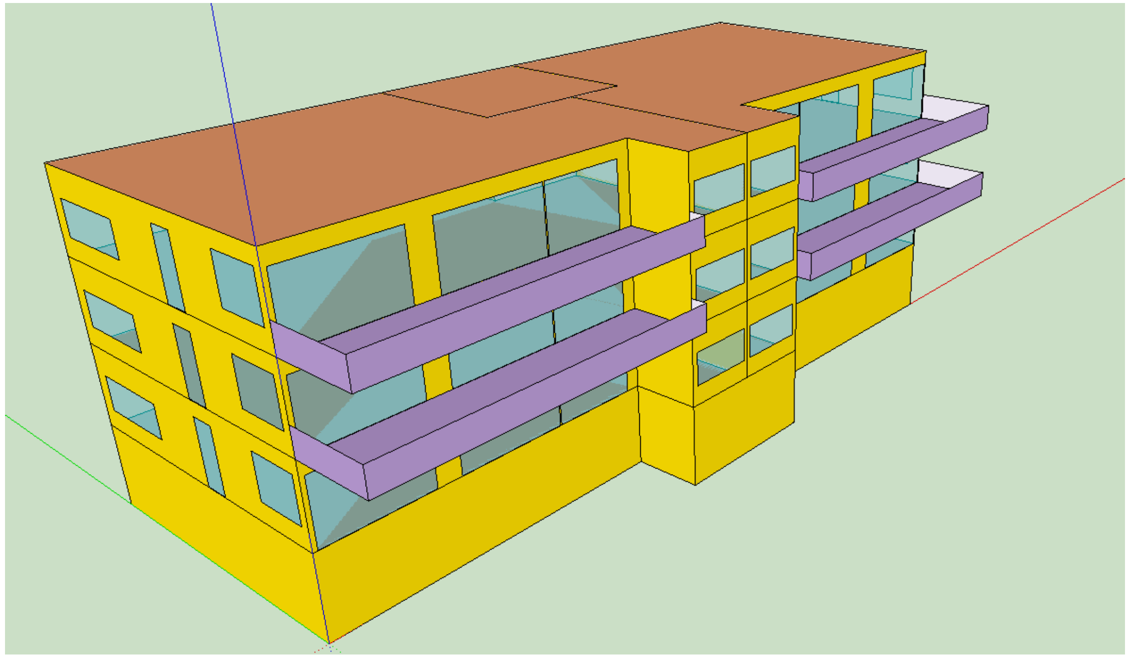
- Common situation in winter if you are aware of the issue

Evaluation of other weather parameters

- Global radiation and outside air temperature have an influence, whereby the outside air temperature has a greater coefficient of determination (R^2)
- The other weather parameters (rain, humidity) show no significant influence
- Despite some difficulties, we have generated enough results to carry out a parameter study with simulations and measurement data

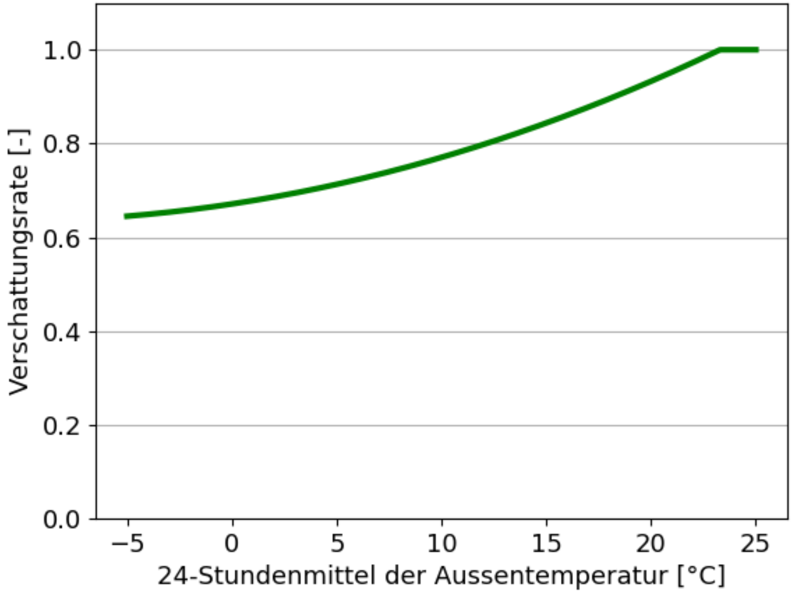
Parameter simulation

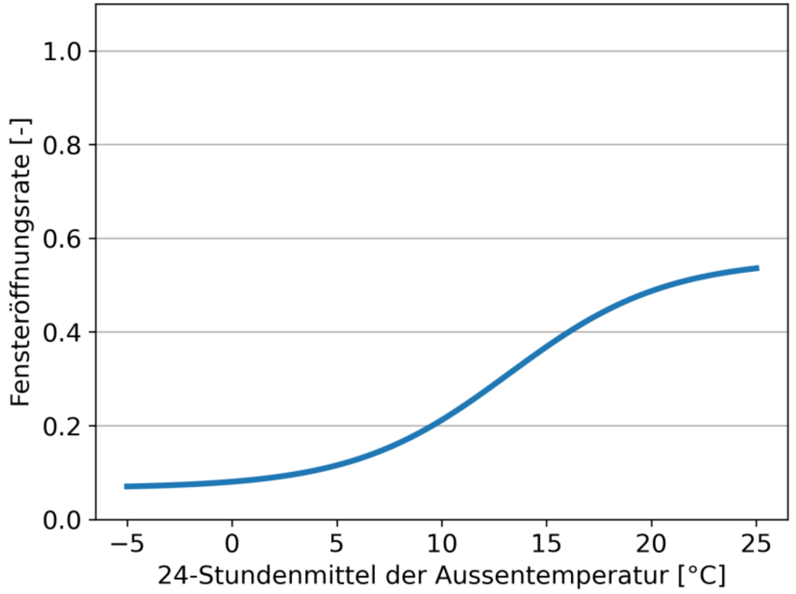
- Simulation of 1500 variants (TRNSYS)
- Variation of user behavior
- Window opening
- Shading (with blinds)
- Room temperature setpoint
- SPF reference building (new construction)
- Validation with data of 40 multi-family buildings



Determined values for real user behaviour

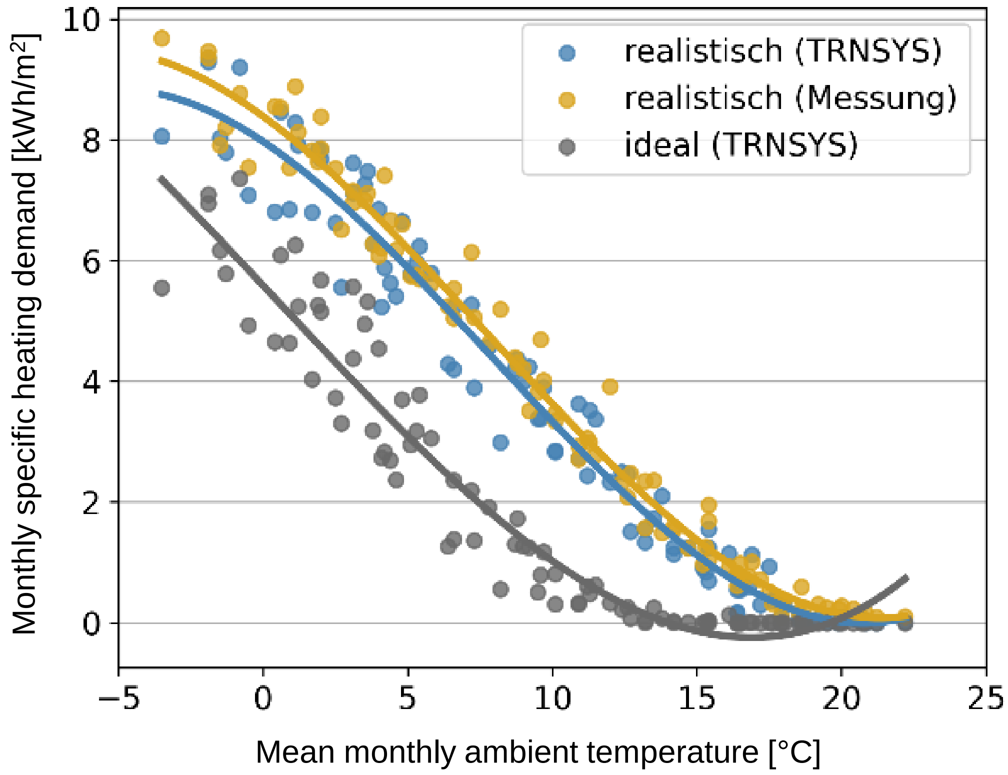
- Room setpoint temperature 23°C ($T_{sp,3}$)
- Shading with g-multiplication factor 0.31 ($f_{g,2}$)
- Shading rate as function of the ambient temperature ($f_{shd,4}$), see top figure
- Window opening rate as function of the ambient temperature ($f_{win,5}$), see bottom figure
- Infiltration rate through the windows according to the formula of Weber (2005)





The new model fits well with real data

- Simulation reference building (gray & blue)
- Measurement data (yellow): 40 MFB, eight years of measured data (2009-2015 und 2018)



Relevance for the energy sector

- Passive solar gains are overestimated and ventilation losses are underestimated, resulting in higher heating demand
- Underestimated potential of solar systems (e.g. self-consumption)

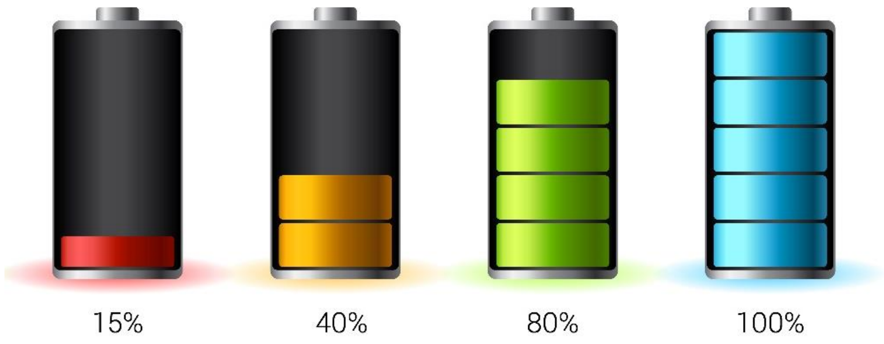
  → better cost/benefit ratio for project planning
- Higher heat extraction from geothermal probes

  → deeper geothermal probes required or regeneration

  → However, oversizing in the field mitigates this situation somewhat

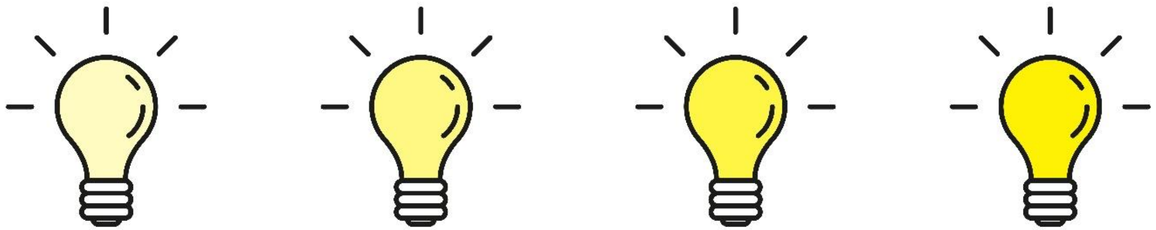
Performance Gap: Energy vs. Power

Energy – Additional demand due real user behaviour



Project VenTSol: www.spf.ch/ventsol

Power – oversizing of heating and cooling systems



Project OptiPower: www.spf.ch/optipower

Situation in Switzerland?

Data used

- 341 Heating systems (95% MFB)
- Only heat pump systems
- New buildings (2005 – 2017)
- Measurement data: 3-15 years

Data used

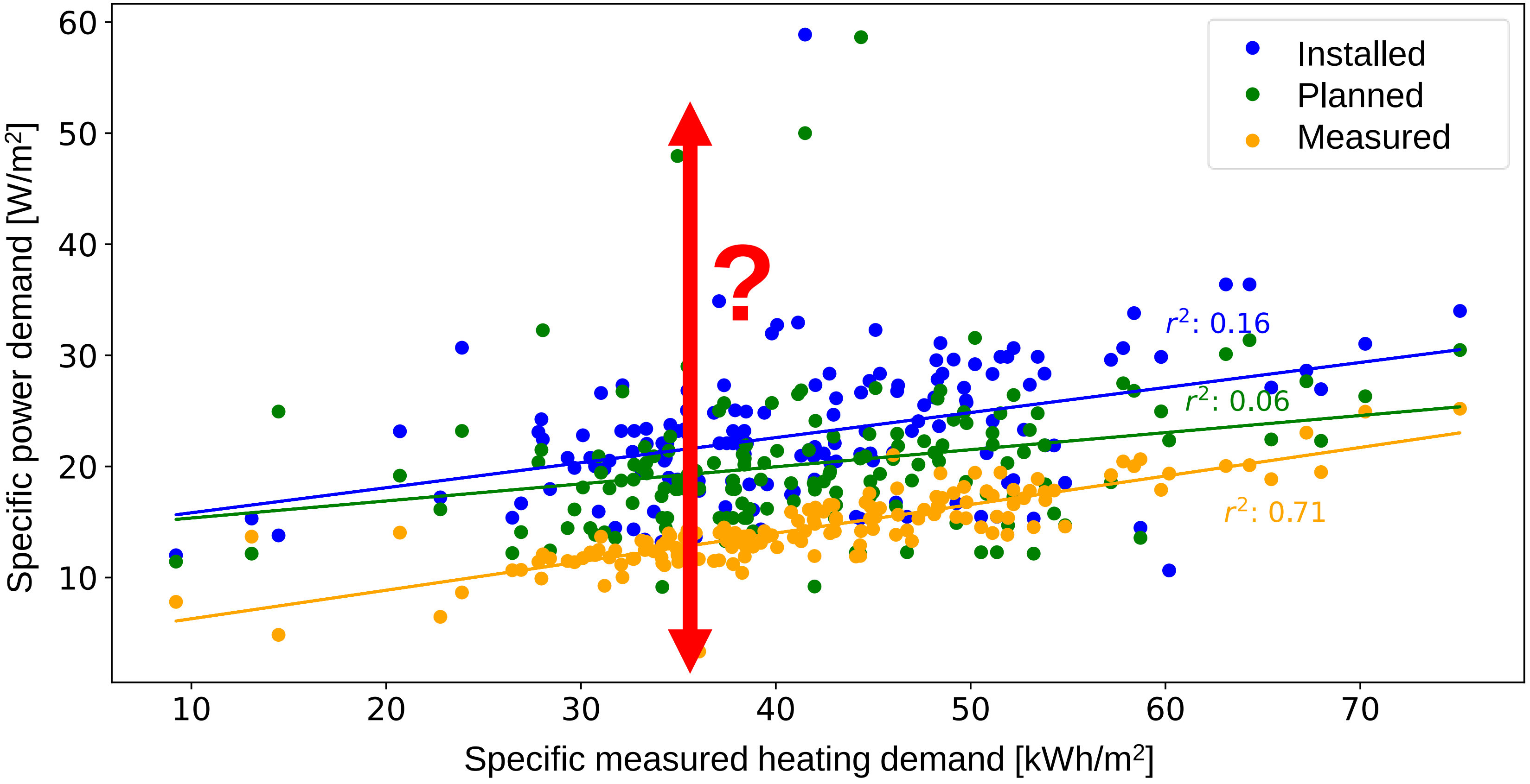
- 10 office buildings
- Three of them were studied in detail
- SFOE pilot and demonstration projects

Method

Theory versus reality

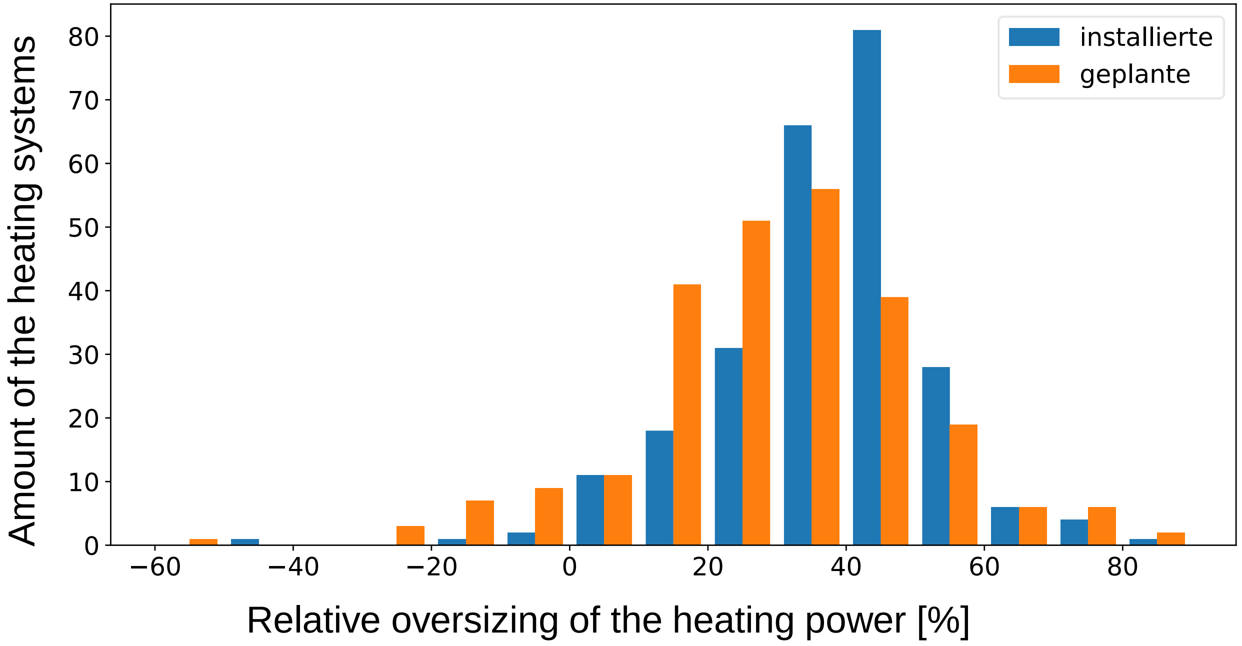
- Usually, the calculation of the heating power is not directly linked with the heating demand in practice (even done by different companies)
- The decoupling of these calculations can lead to problems, as in reality these values are very dependent on each other…

Results MFB: clear oversizing



Detailed results MFB

- Additional power on top of the planning: 2.8 W/m^2 (+12%)
- „Anxiety surcharges“
- Next machine size
- Faulty calculation
- Domestic hot water
- No consideration of internal loads



The 40% oversizing «fits» the 40% surplus heating demand due to the energy performance gap!

Plausibility check of the calculation for practical use (e.g. integration to WPesti)

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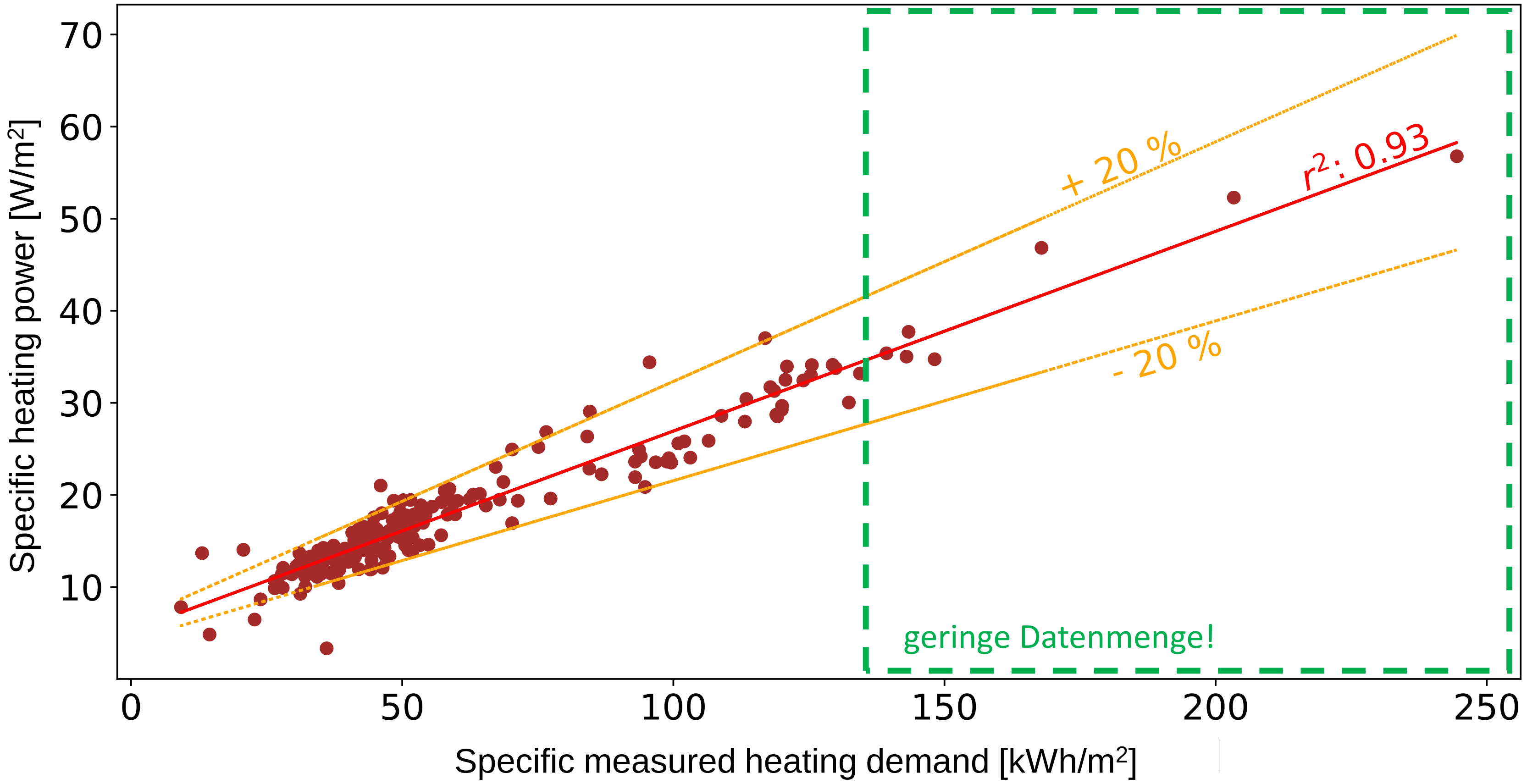
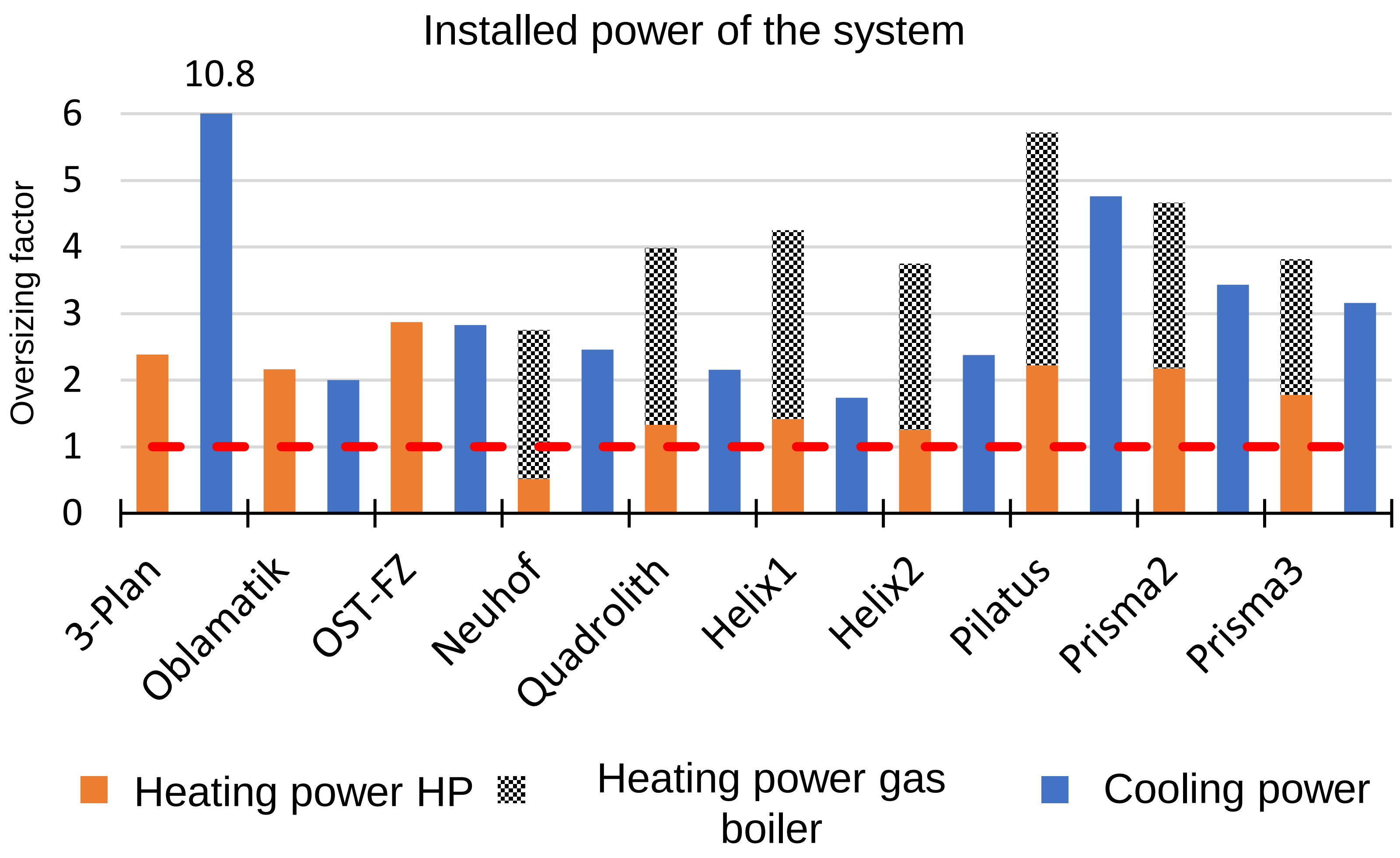


The final report also contains a simple formula!

Office building: 100 – 300% oversizing



Real example calculation heating power

Dimensionierung Wärmeerzeugung Heizung

Wärmebedarf Heizung	θa	Φ HL,Geb
	[°C]	[kW]
Gebäudeheizlast SIA 384.201 ¦ 18.07.2017	-7	**73.678**

Standard calculation heating power

Wärmebedarf Warmwasser	θa	θ KW	θ WW	c	WP Laufzeit	Φ WW
	[lt]	[°C]	[°C]	[kJ/kg*K]	[h]	[kW]
	2000	10	50	4.187	20	**4.652**

Real example calculation heating power

Dimensionierung Wärmeerzeugung Heizung

Wärmebedarf Heizung	θa	Φ HL,Geb
	[°C]	[kW]
Gebäudeheizlast SIA 384.201 ¦ 18.07.2017	-7	73.678

Standard calculation heating power

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	[lt]	[°C]	[°C]	[kJ/kg*K]	[h]	[kW]
	2000	10	50	4.187	20	4.652

Wärmebedarf Lüftung	Luftmenge	θa	θ LE ein	θ LE aus	Φ LE Frost	Φ LE normal	Φ LE -7
	[m3/h]	[°C]	[°C]	[°C]	[kW]	[kW]	[kW]
Lager / Produktion HZ=32.7	6850	-14	16.1	21	32.70	10.74	8.593
Büro / Sitzungsraum HZ=39.3	9220	-14	15	29	39.30	41.31	34.581
Aufenthaltsräume / Nebenräume HZ=50.4	9920	-14	13.9	21	50.40	22.54	18.031
Küche HZ=25.6	5750	-14	15.2	20	25.60	8.83	7.014
Restaurant HZ=18.8	3480	-14	13.2	21	18.80	8.69	6.949
Lager	4260	-14	15.8	26	22.70	13.90	11.471
					189.50	**106.01**	**86.64**
Wärmebedarf Lüftung bei Gleichzeitigkeitsfaktor					0.6	86.639	51.983

Interconnected system

Real example calculation heating power

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Dimensionierung Wärmeerzeugung Heizung

Wärmebedarf Heizung	θa [°C]	Φ HL,Geb [kW]
Gebäudeheizlast SIA 384.201 ¦ 18.07.2017	-7	73.678

Standard calculation heating power

Wärmebedarf Warmwasser	θa [lt]	θ KW [°C]	θ WW [°C]	c [kJ/kg*K]	WP Laufzeit [h]	Φ WW [kW]
	2000	10	50	4.187	20	4.652

Wärmebedarf Lüftung	Luftmenge [m3/h]	θa [°C]	θ LE ein [°C]	θ LE aus [°C]	Φ LE Frost [kW]	Φ LE normal [kW]	Φ LE -7 [kW]
Lager / Produktion HZ=32.7	6850	-14	16.1	21	32.70	10.74	8.593
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					189.50	**106.01**	**86.64**
Wärmebedarf Lüftung bei Gleichzeitigkeitsfaktor					0.6	86.639	51.983

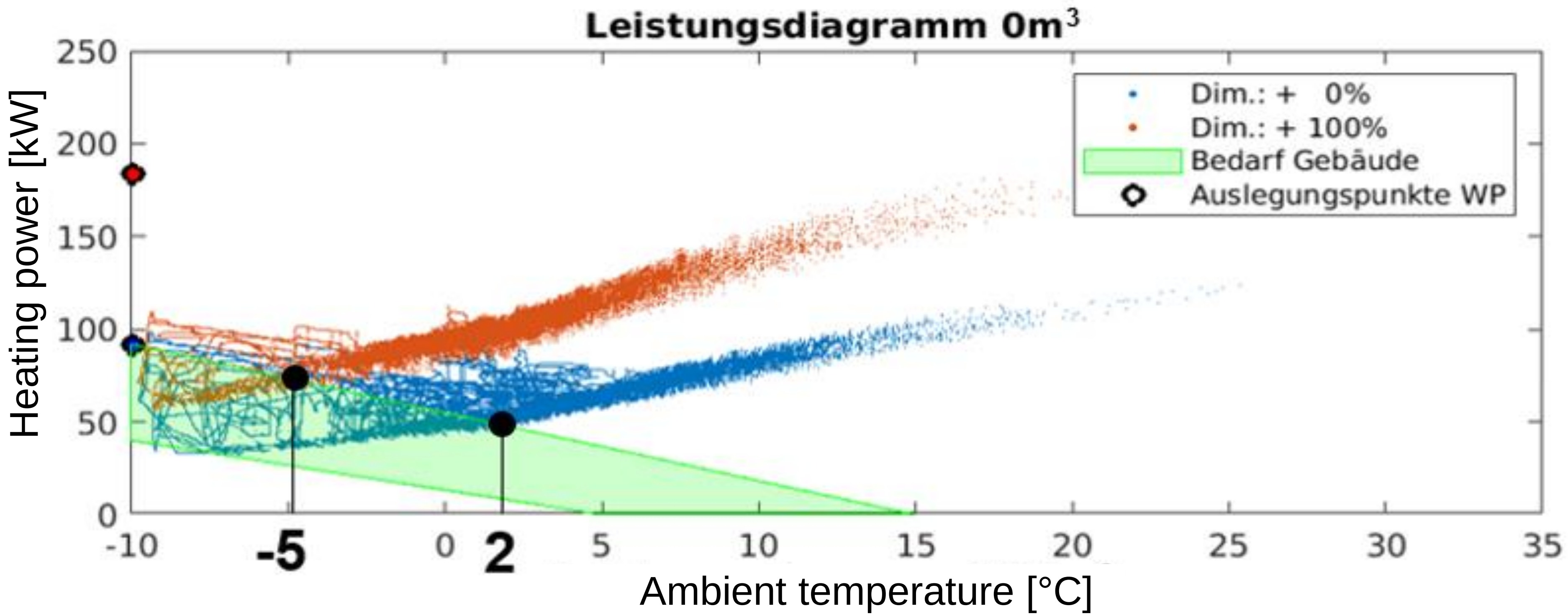
Interconnected system

Erforderliche Heizleistung ohne Sperrzeiten		[kW]
Wärmebedarf Heizung	Φ HL,Geb	73.678
Wärmebedarf Warmwasser	Φ WW	4.652
Wärmebedarf Lüftung	Φ LE -7	51.983
Ergebnis	**Φ WP**	**130.313**

Total oversizing +100%

Impact on the heat pump?

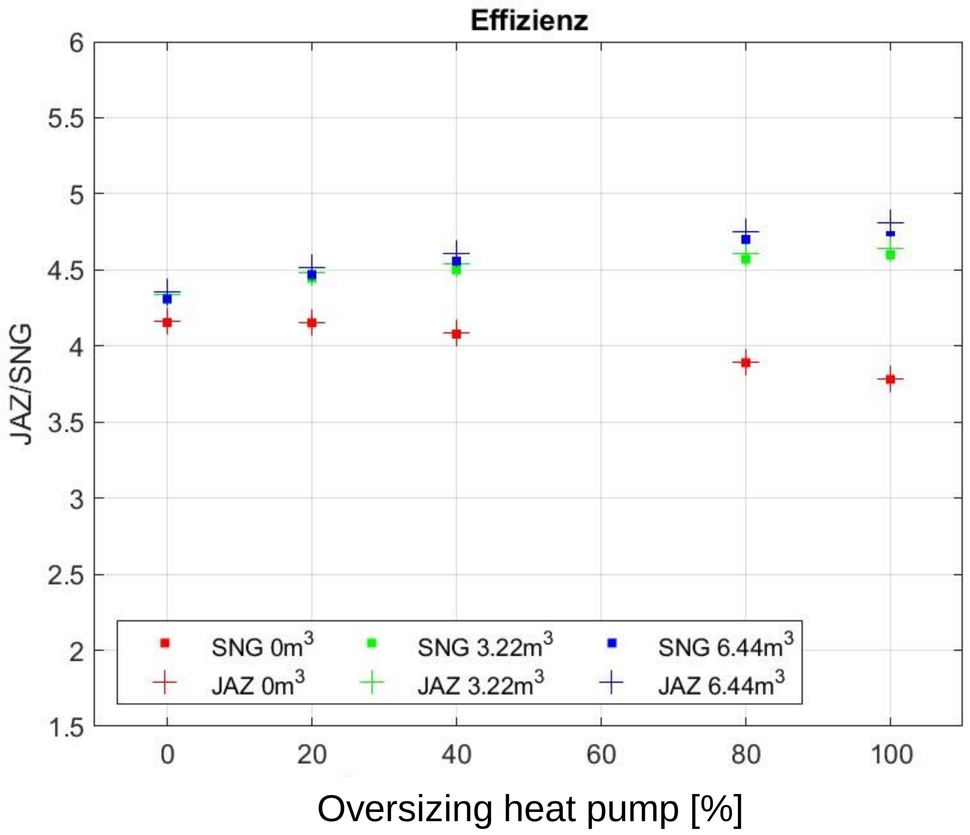
Air-source HP: very quickly outside the control range (despite speed control compressor)



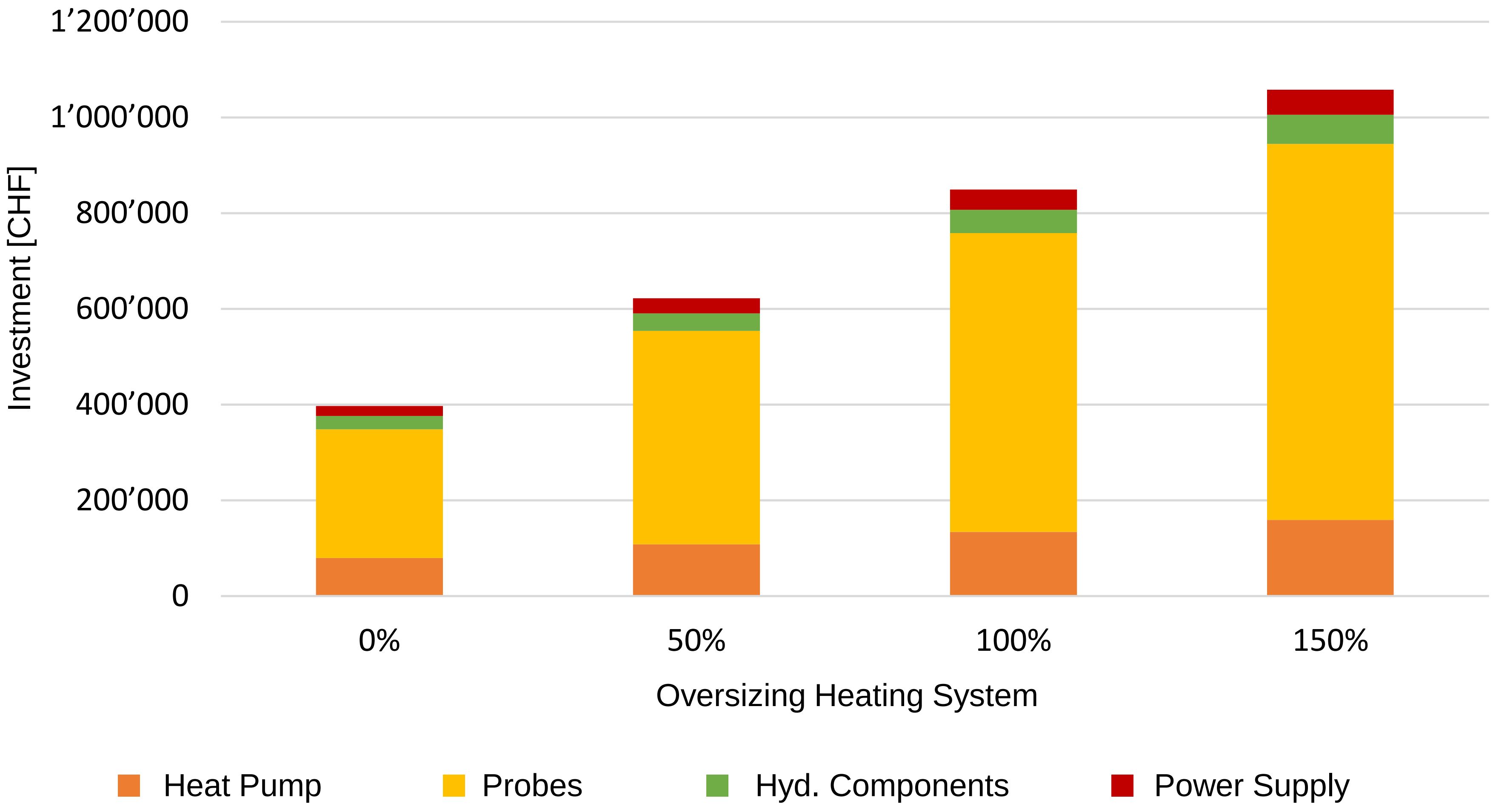
On/Off cycle = min. 1 hour of run time (Info Scheco AG)
An oversizing by 100% increase the operating hours by 20-40%!

Brine-source HP: higher efficiency due higher source temperature

- reduced electricity demand by 10%/a
  – Due higher source temperature
- plus 160% investment costs (factor 2.6)
- To compensate the additional investment the electricity prize must be around 100 Rp/kWh



Brine-source HP: investment costs depend mainly on the geothermal probes



Conclusion

- For MFB, excessive oversizing can be avoided by a simple validation (see final report) of the standard heat load calculation
- For more complex buildings (e.g. office buildings), it is worth carrying out a dynamic building simulation → The study was able to show that the new SIA382/2:2022 is very well suited for this purpose
- Additional costs of overdimensioning exceed the simulation costs many times over
- Select suitable power grading (cascading) of the heat pumps to significantly increase the energy efficiency and service life of the systems (especially air-source-HP)

- **... and many more tips in the final report (OptiPower)!**

Kontakt

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