
Building energy **Performance Gap**– possible causes and the role of users, operators and design standards



Performance Gap

Performance Gap?

«Performance gap» is the term used to describe the difference between the theoretical and actual energy consumption of buildings.

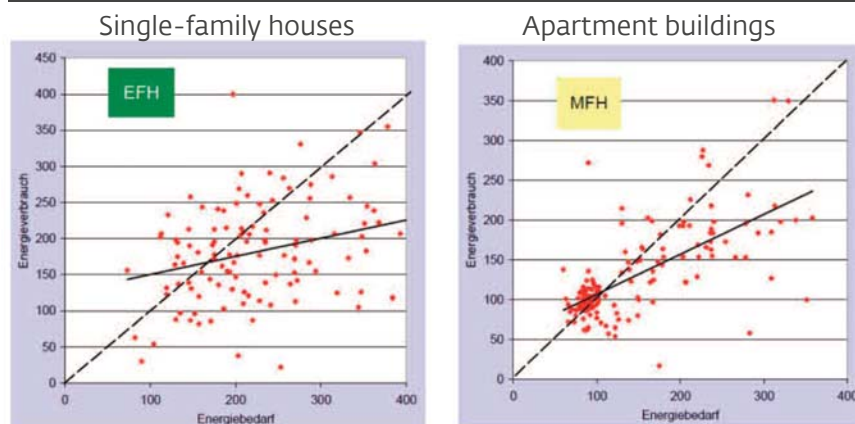
Internationally, the performance gap has been an issue of debate for over 5 years now.

The performance gap has also gained importance in Switzerland since the IBPSA paper at the brenet status-seminar of 2014 and the current call for proposals of the BFE energy efficiency research program.

Performance Gap Agenda

1. International state of research
2. Swiss research studies
3. Possible causes of the performance gap
4. The role users, operators and design standards
5. Conclusion and outlook

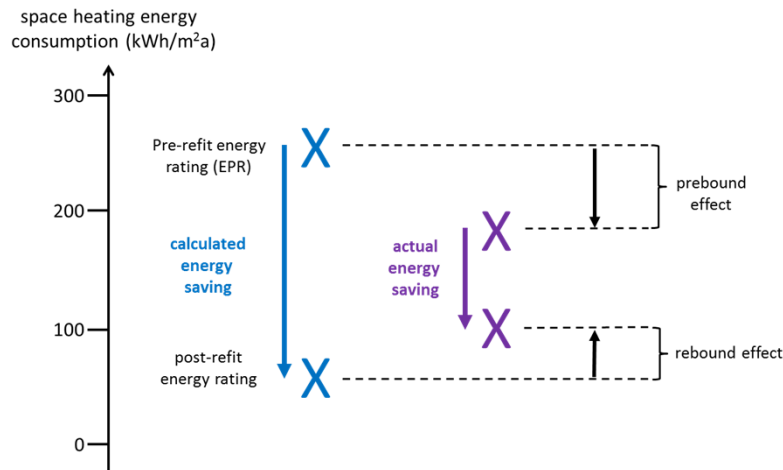
Performance Gap – International German energy certificates – performance of 3400 dwellings



Source: M. Sunikka-Blank & R. Galvin (2012): Introducing the prebound effect: the gap between performance and actual energy consumption, *Building Research & Information*, 40:3, 260-271

Performance Gap – International

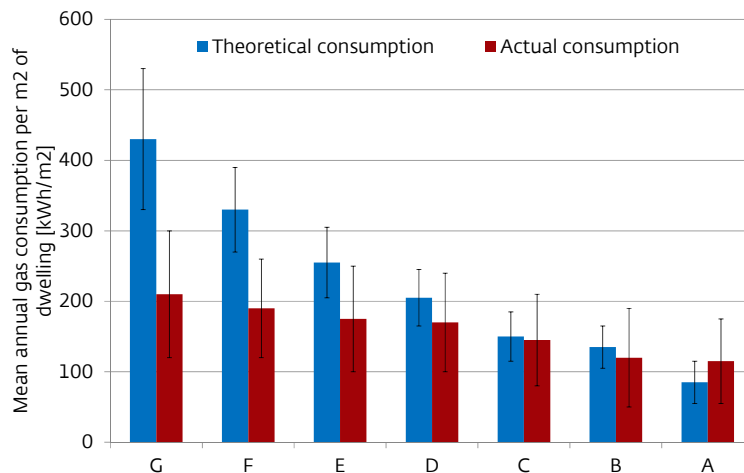
German energy certificates – performance of 3400 dwellings



Source: M. Sunikka-Blank & R. Galvin (2012): Introducing the prebound effect: the gap between performance and actual energy consumption, *Building Research & Information*, 40:3, 260-271

Performance Gap – International

Gas consumption of 200'000 Dutch dwellings



Remodelled chart based on source : D. Majcen et al.: Theoretical vs. Actual energy consumption of labelled dwellings in the Netherlands: Discrepancies and policy implications, *EnergyPolicy*54(2013)125-136

Performance Gap - Switzerland

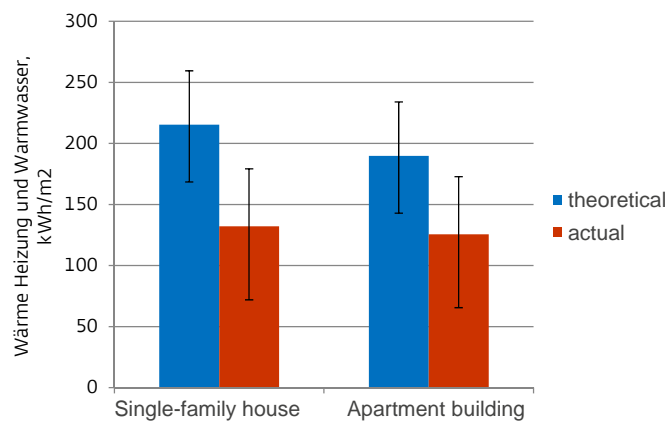
Current Swiss studies

1. Results of the Energie Coaching by the City of Zurich
2. BFE «Erfolgskontrolle Gebäudeenergiestandards» (*DemoSCOPE, econcept, Lemon Consult*)
3. AWEL «Untersuchung Wärmeverbrauchsdaten von Neubauten» (*sustech*)
4. «Offene Fragen beim Einsatz der SIA 380/1 als Prognoseinstrument bei Bestandsgebäuden» (*FHNW, Lemon Consult*)

Performance Gap - Switzerland

1. Energy-Coaching of Zurich: Evaluation of 65 dwellings

Space heating energy and warm water consumption (kWh/m²)



Performance Gap - Switzerland

2. BFE Study "Performance control of building energy standards" - Scope

First overall performance control of "Minergie" standards in comparison to "MuKE" standard on behalf of the federal bureau of energy (BFE):

- Interviews
- Energy consumption evaluations

3 building categories:

- Single-family houses
- Apartment buildings
- Offices

6 building energy standards:

- Minergie new construction
- Minergie renovation
- Minergie-P new construction
- Minergie-A new construction
- MuKE new construction
- MuKE renovation

Performance Gap - Switzerland

Goals and target groups

Goals:

- Find drivers behind the construction and use of Minergie houses
- Evaluate experiences in different stages (planning, construction, operation)
- Assess customer satisfaction

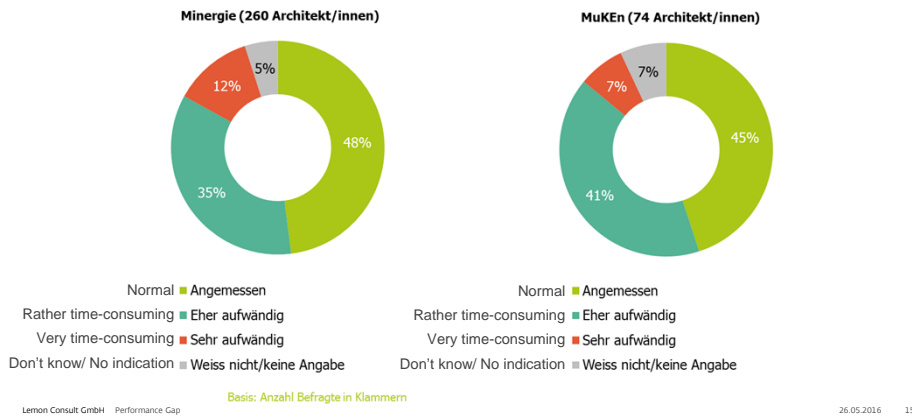
Target groups:

- Builders
- Architects
- Planners
- Operators
- Users

Performance Gap - Switzerland

Evaluation of the certification and verification process

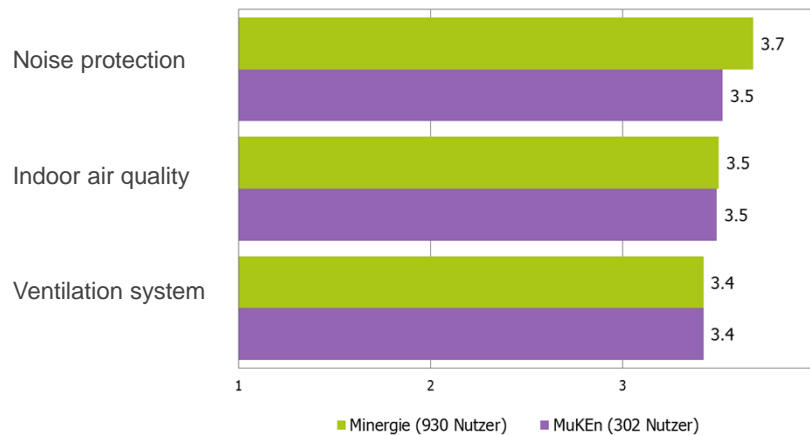
Q15 (Minergie): In retrospect, how would you evaluate the certification process?
 Q15 (MuKE): In retrospect, how would you evaluate the energetic verification process during the construction permit procedure?



Performance Gap - Switzerland

Satisfaction with indoor air quality and noise protection

How satisfied are you with the following conditions (1: not at all, 4: very much)?



Performance Gap - Switzerland

Evaluation goals

Do the evaluated buildings adhere to the energetic requirements?

- Evaluation of the **actual** weighed energy consumption
- Evaluation of the deviation of the energy consumption from the individual limit of the respective building energy standard.

In addition to earlier performance evaluations:

- Energy consumption was **verified** on-site.
- During verification on-site, possible causes for the deviation of the energy consumption could be made out.

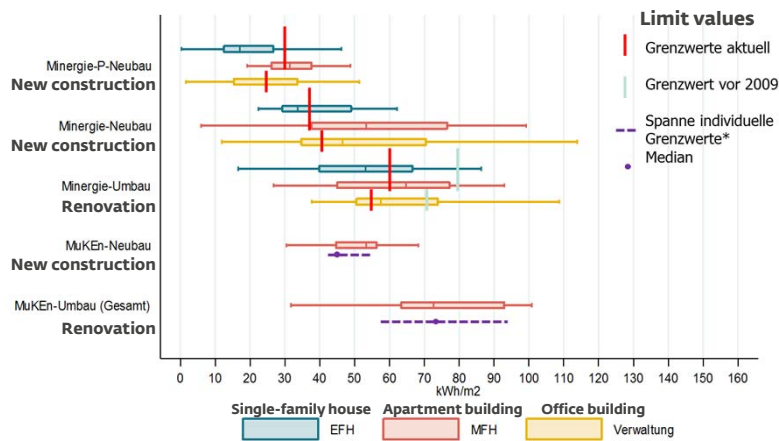
Performance Gap - Switzerland

Difficult building recruitment process

Builders	Minergie Neubau	Minergie Umbau	Minergie- P Neubau	Minergie- A Neubau	MuKEN Neubau	MuKEN Umbau	Total
Addressed	766	791	1'010	51	1'524	1'517	5'659
Participants in Online-survey	250 (33%)	319 (40%)	396 (39%)	22 (43%)	108 (7%)	132 (9%)	1'227 (22%)
ready for on-site Inspection	105 (42%)	182 (57%)	235 (59%)	8 (36%)	27 (25%)	34 (26%)	591 (48%)
Share of drop-outs due to missing or non-usable data	60%	60%	79%	75%	74%	71%	69%
Accomplished inspections	54	68	44	5	19	24	214

* nach Bereinigung um überzählige EFH in den Kategorien Minergie-Umbau und Minergie-P-Neubau und inklusive nachrekrutierte Objekte (insbesondere in den MuKEN-MFH-Kategorien).

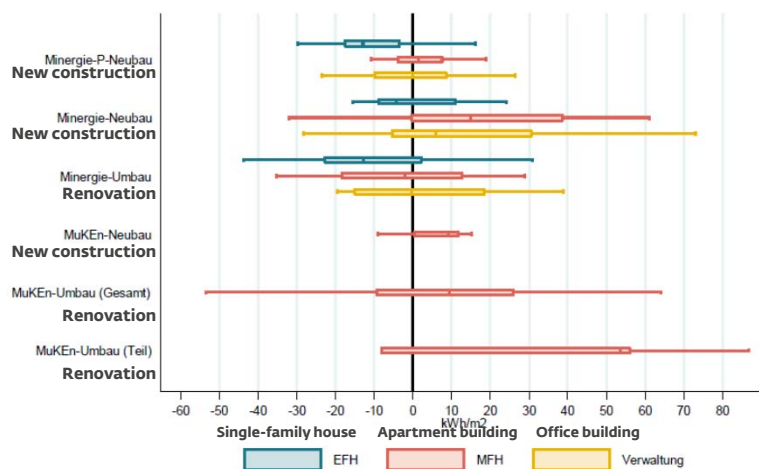
Performance Gap - Switzerland Energy consumption index (kWh/m²)



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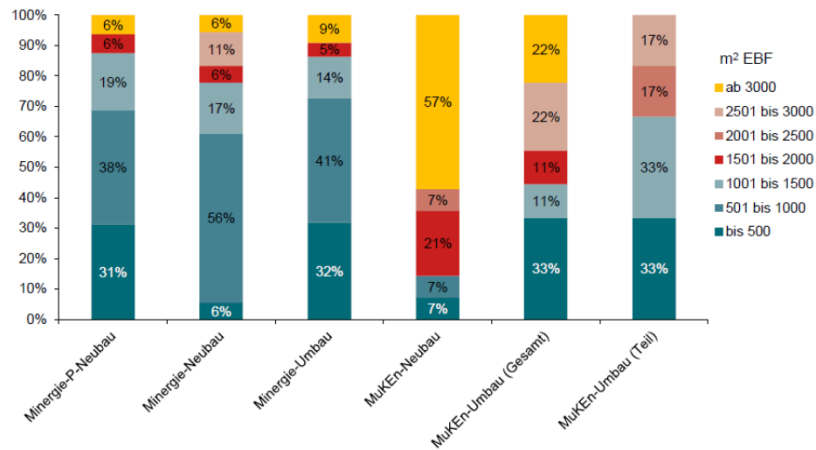
Performance Gap - Switzerland Weighted energy consumption index – Deviation from limit values



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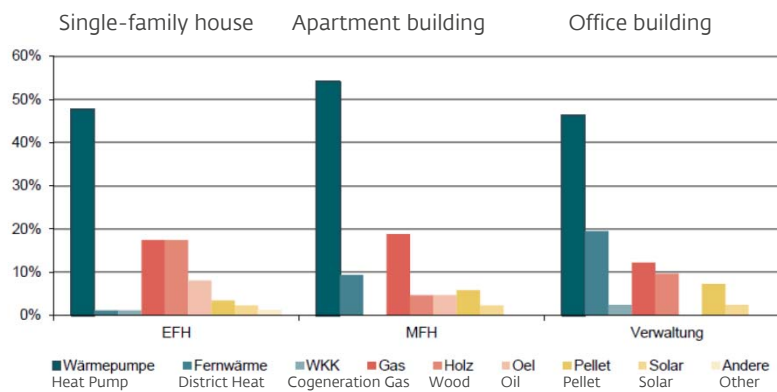
Performance Gap - Switzerland Distribution of building size (energy ref. area)



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Performance Gap - Switzerland Distribution of heating systems

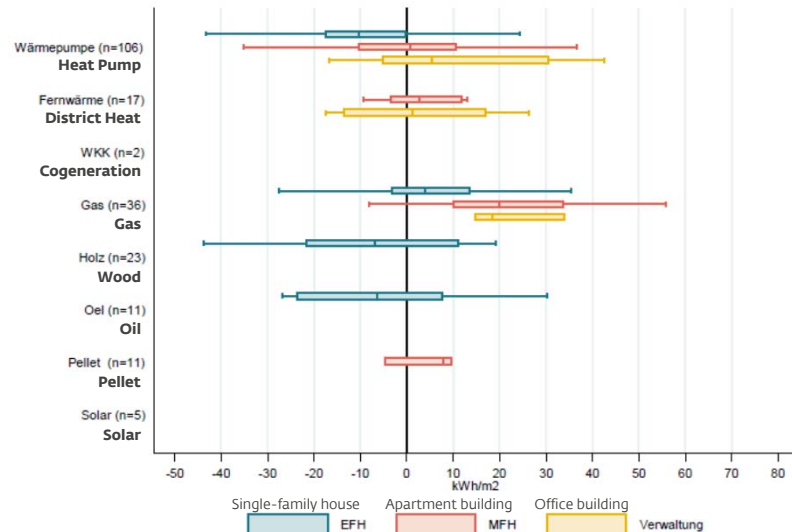


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Performance Gap - Switzerland

Energy consumption index vs. heating system



Performance Gap - Switzerland

Possible causes for the exceeding energy consumption in apartment buildings

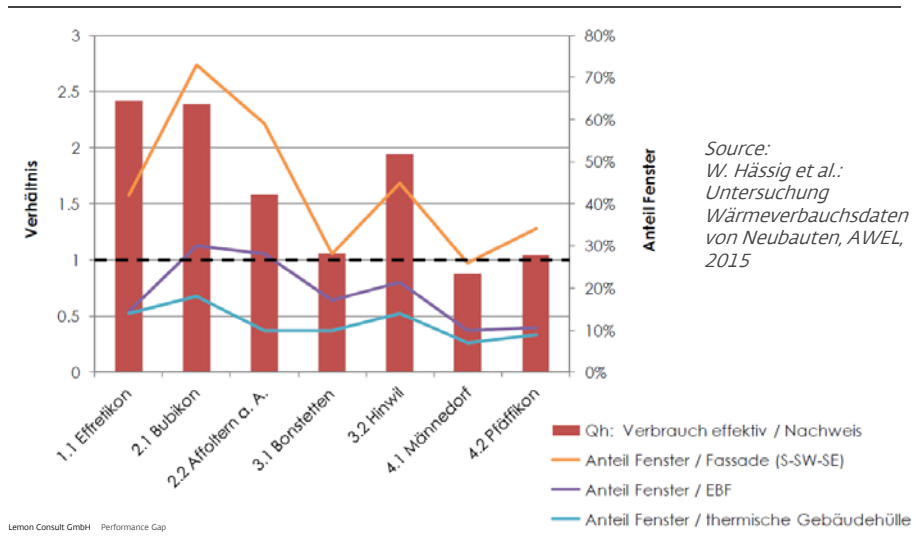
Observations during on-site inspections:

1. Functional problems or faulty settings in the building systems
2. Low efficiency level of the heating system (high supply or boiler temperatures)
3. High energy consumption due to heat tape ("bande chauffante") and heating rods in boilers.

➤ Conclusion: By setting the basic parameters of the heating- and ventilation systems, operators have a *much bigger influence* on the level of overall energy consumption than the users.

Performance Gap – New constructions

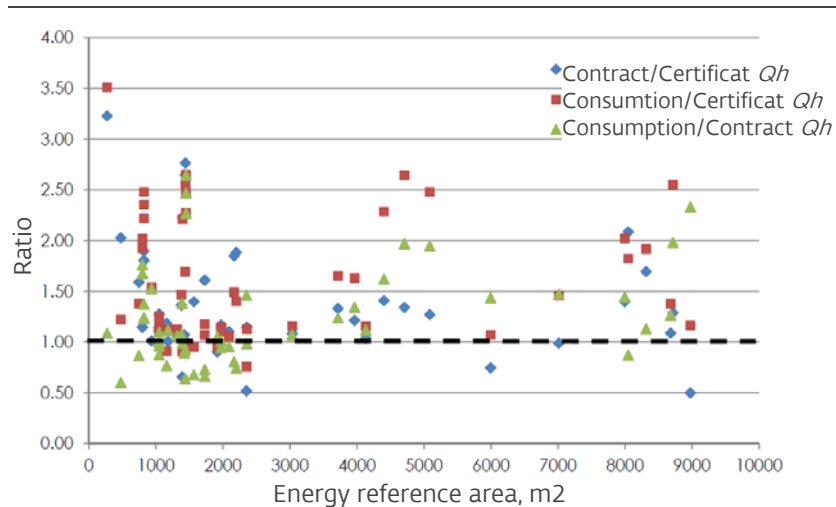
3. AWEL-Study: Analysis of contractor data



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Performance Gap – New constructions

Analysis of contractor data - heating

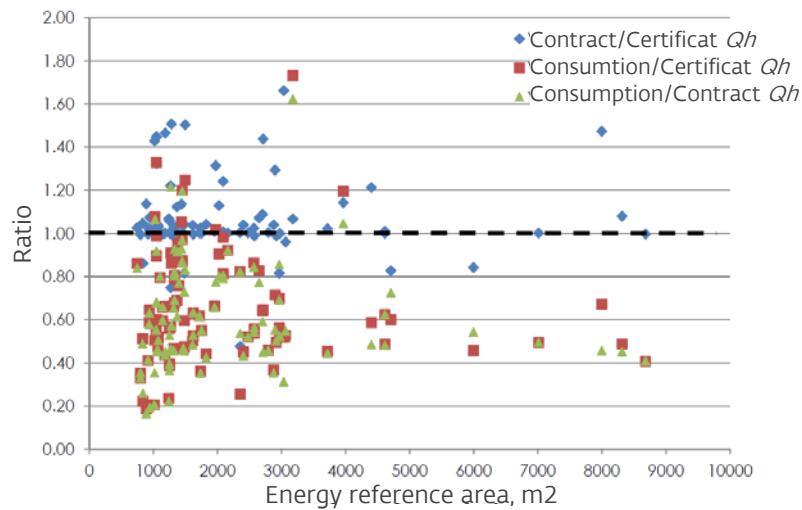


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Performance Gap – New constructions

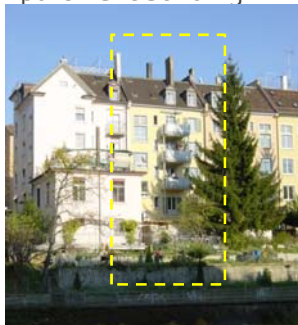
Analysis of contractor data – hot water



Performance Gap – Existing buildings

4. «SIA 380/1 as a forecast tool for existing buildings»

Apartment building



Hönggerstr. 23, 8037 Zürich
built in 1894

Office building



Sumatrastr. 10, 8006 Zürich
built in 1951

Performance Gap – Existing buildings Methods

IR-Sensors ($\rightarrow Q_p$)



Solarlog ($\rightarrow Q_A + Q_D$)
Load profiles



Shading ($\rightarrow Q_s$)



Indoor Air quality ($\rightarrow Q_v$)

- CO₂
- Rel. Feuchte
- Temperatur



Heat transition coefficient ($\rightarrow Q_T$)
greenTEG



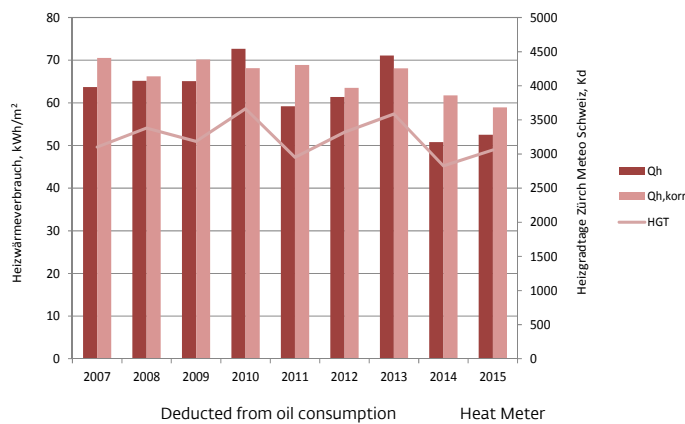
Flow meter ($\rightarrow Q_f$)



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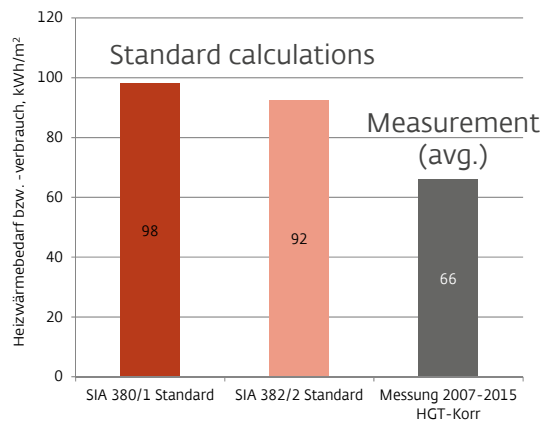
Performance Gap – Existing buildings Apartment building - Actual heating consumption



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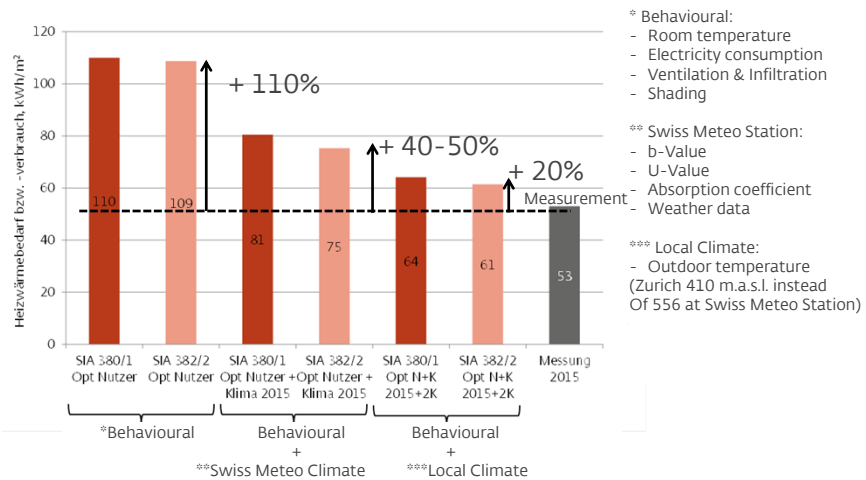
Performance Gap - Existing buildings Apartment building – Standard calculations vs. actual heating consumption



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Performance Gap - Existing buildings Apartment building – Calculations based on measured data

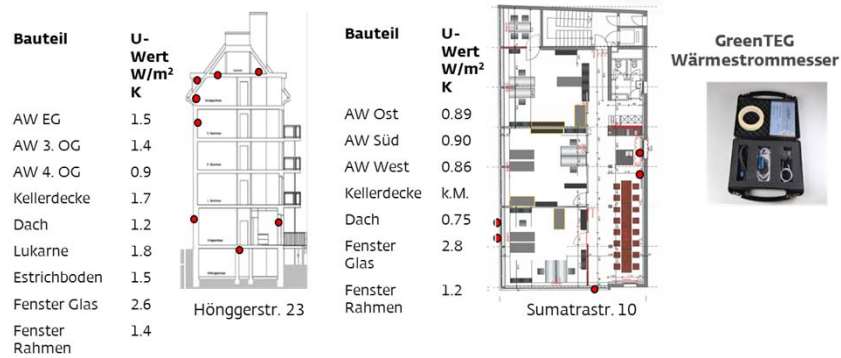


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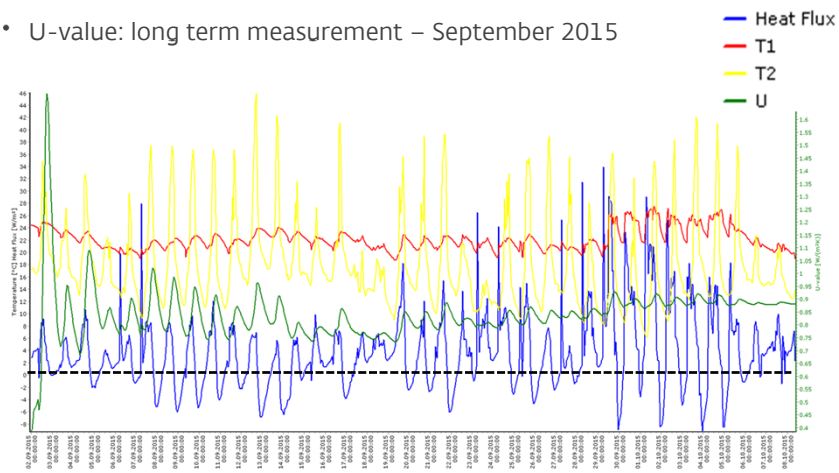
Performance Gap - Existing buildings U-Value Measurements with greenTEG

- Measurement sites: Facade, basement and roof



Performance Gap - Existing buildings U-Value Measurements with greenTEG

- U-value: long term measurement – September 2015



Performance Gap - Existing buildings

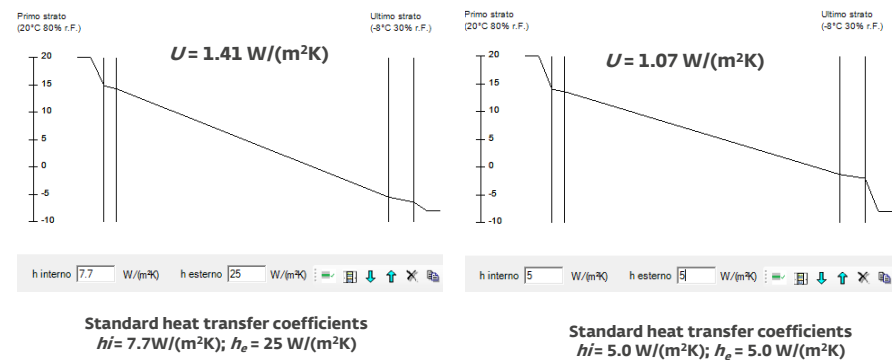
U-Value - Measurement vs. Calculation

Method	Absorption coefficient	Heat transfer coefficient h_i / h_e W/m ² K	U-Value W/m ² K
Messung dT gemessen 2015/16	-	-	1.40
Messung dT Standard SMA 2015/16	-	-	1.05
Berechnung statisch	-	7.7 / 25	1.37
Berechnung statisch	-	5.6 / 4.0	1.01
WUFI Simulation Putz hell	$\alpha = 0.3$	5.6 / 4.0	0.96
WUFI Simulation Putz dunkel	$\alpha = 0.6$	5.6 / 4.0	0.86

Facade
Concrete 15 cm
Cork 2 cm
Brick 5 cm
Plaster 2 cm

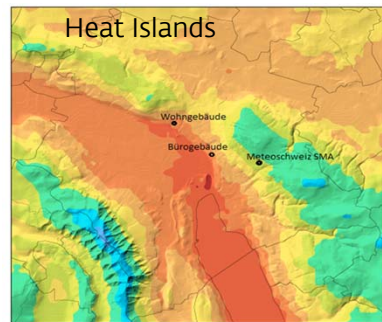
Performance Gap - Existing buildings

U-Value – Importance of Heat transfer coefficients

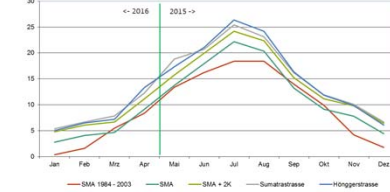


Performance Gap - Existing buildings

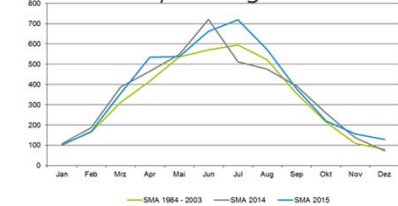
Local Climate 2015 + Urban Heat Islands



Monthly averaged temperatures



Monthly averaged radiation



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Performance Gap - Existing buildings

Conclusions from this study

Calculated («theoretical») heating consumption:

- Based on *standard parameters* (both SIA 380/1 and SIA 382/2) results in **performance gap + 40 to 50%**
- Based on *measured parameters (incl. user behaviour)* makes it even worse -> **performance gap + 110%**
(This is mostly caused by higher indoor temperatures and lower internal gains even though ventilation losses were lower than the standard.)
- Based on *measured parameters (incl. user behaviour and local climate)* -> **performance gap + 20%**

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Performance Gap – Possible causes

Hypotheses on the heat demand

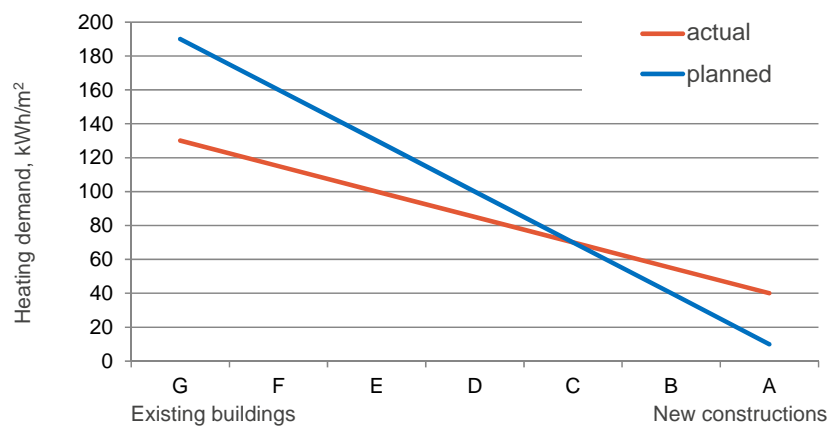
1. New constructions: The calculated heat demand is too low because of higher indoor air temperatures and sun shading in winter.
2. Existing buildings: The calculated heat demand is too high because of overestimated b-Values and U-Values and the neglect of solar gains through opaque construction elements, warmer outdoor climate in urban areas.
3. The heat demand for domestic hot water is often over-estimated because of lower occupancy rates.

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Performance Gap – Possible causes

Hypotheses on the heating demand

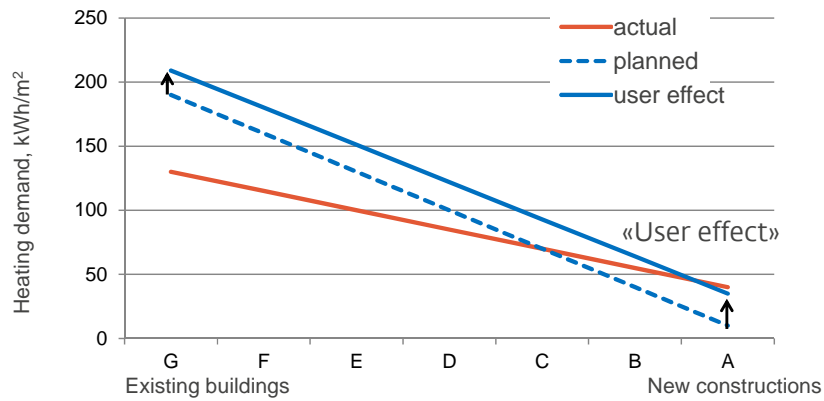


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Performance Gap – Possible causes

Hypotheses on the heating demand

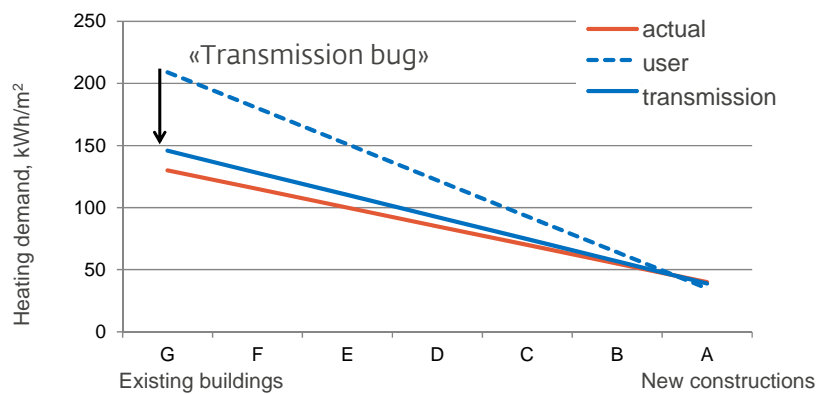


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Performance Gap – Possible causes

Hypotheses on the heating demand



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Performance Gap – Possible causes

Hypotheses on the heat production side

1. Heat pumps: COP are too high in heating mode and too low in domestic hot water mode. This partially compensates the deviations on the heat demand side. The importance of the legionella protection increases.
2. Heating systems (Oil, gas, wood): overestimated degree of utilization.
3. Solar thermal energy: Lower hot domestic water demand results in overestimation of solar thermal production.

Performance Gap – Possible causes

Hypotheses on the heat production side (AWEL)

$$E_{h+ww} = E_h + E_{ww} = \frac{Q_h - Q_{h,sol}}{\eta_h} + \frac{Q_{ww} - Q_{ww,sol}}{\eta_{ww}}$$

Bsp. MFH

Theoretical consumption Heat pump	$\frac{150+0}{4} + \frac{75+0}{2.5} = 68 \text{ MJ/m}^2$ $= 37.5 \text{ kWh/m}^2$
Actual consumption Heat pump	$\frac{250+0}{4.5} + \frac{35+0}{2.5} = 70 \text{ MJ/m}^2$ $= 38.6 \text{ kWh/m}^2$
Theoretical consumption Gas + solar	$\frac{100-10}{0.95} + \frac{75-40}{0.92} = 133 \text{ MJ/m}^2$ $= 36.9 \text{ kWh/m}^2$
Actual consumption Gas + solar	$\frac{180-20}{0.90} + \frac{35-25}{0.87} = 189 \text{ MJ/m}^2$ $= 52.6 \text{ kWh/m}^2$

Performance Gap – Possible causes

Conclusions – the role of users

- User behaviour is fundamental for the actual consumption of buildings (indoor temperature, window ventilation, solar protection, ...)
- User behaviour is difficult to change (low energy prices, life style driven, ...)
- Smart but “simple” buildings might help, e.g. automation system optimises energy consumption when user is absent

Performance Gap – Possible causes

Conclusions – the role of operators

- Especially in large buildings, the role of the building operator becomes more important
- Usually service companies are in charge for heating and ventilation
- Service companies tend to impose very conservative control settings (less complaints = higher revenue), leading to substantially higher actual energy consumptions
- The “operator effect” has to be considered

Performance Gap – Possible causes

Conclusions – the role of design standards

By defining non-representative standard parameters, design standards contributes substantially to the performance gap.

The following corrections are suggested:

- Higher indoor air temperatures, e.g. 22 instead of 20°C
- Reduction of solar gains due to shading in winter
- Lower b-Values against unheated spaces
- Lower heat transfer coefficients, e.g. outside 5 instead of 25 W/(m²K)
- Climate correction for heat islands in urban areas
- Lower occupancy rates
- Lower demand of domestic hot water

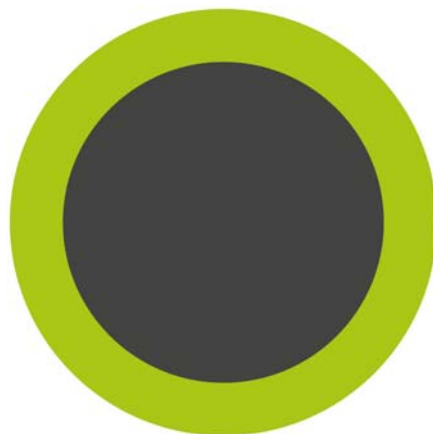
Performance Gap – Possible causes

Open Discussion – what do **you** think?

– ...

– ...

Thank you for the discussion



Harmonisation of standard values

Deadlines & dependencies

