Target/actual comparison and benchmarking used to safeguard low energy consumption in refurbished housing stocks

Tobias Loga | Guillaume Behem
IWU – Institut Wohnen und Umwelt
Institute for Housing and Environment
Darmstadt | Germany

Methodology and results developed within the project:

MOBASY – Modellierung der Bandbreiten und systematischen Abhängigkeiten des Energieverbrauchs zur Anwendung im Verbrauchscontrolling von Wohngebäudebeständen

In cooperation with:
Bauverein AG, Darmstadt
Wohnbau Gießen GmbH
Nassauische Heimstätte Wohnstadt, Frankfurt am Main

Project duration: 11/2017 to 10/2022 / „Verbundvorhaben SolaresBauen“ / Registration number: 03SBE0004A / B / C

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

Challenges

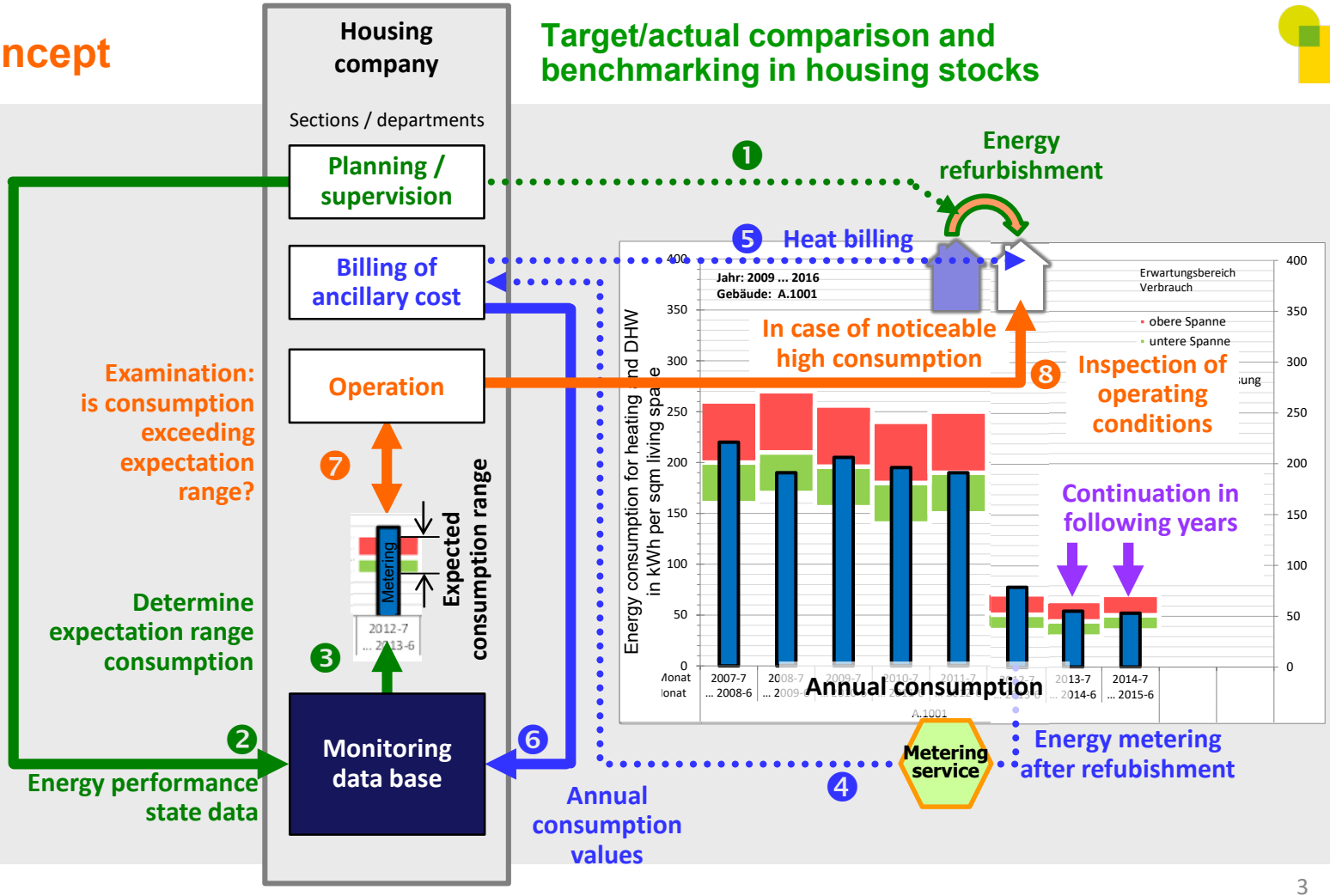
- 40 million homes in Germany, half of them in multi-family houses (MFH)
- Thereof about one third owned by housing companies
- More than 80% of MFH: central heating systems (fuels, district heating)
- Heating bills: usually part of the ancillary cost paid by the tenants
- Many housing companies put a lot of effort into energy refurbishment activities, driven by the challenges of the climate crisis
- Most of them do not systematically track the applied measures and the energy savings

MOBASY idea

- ► Develop a concept for target/actual comparison and benchmarking
- ► Apply the concept in cooperation with housing companies

Concept

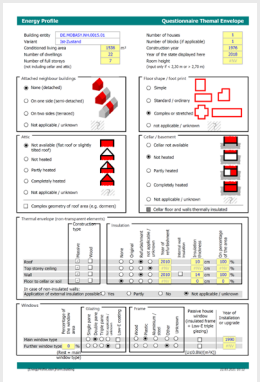
Target/actual comparison and benchmarking in housing stocks



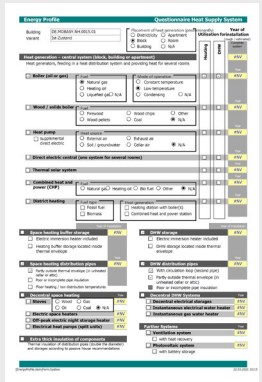
“Energy Profile Monitoring Indicators”

Data acquisition forms:

Building



System



- Specific set of query variables
- Indicators: physical characteristics of a building that have the biggest impact on its energy performance
- Can in principle be collected by on-site inspections or by asking building owners
- Similar to queries used by German energy housing surveys 2009 and 2016

Building form

Geometrical information:

- Living space
- Number of storeys
- Number of attached buildings
- Heating situation attic and basement

Insulation upgrade:

- Thickness
- Area fraction
- Year of installation

Window types:

- Number of panes
- Low-e coating
- Year of installation

Building entity	DE.MOBASY.NH.0015.01	Number of houses	1
Variant	Ist-Zustand	Number of blocks (if applicable)	1
Conditioned living area	1536 m²	Construction year	1976
Number of dwellings	22	Year of the state displayed here	2018
Number of full storeys (not including cellar and attic)	7	Room height (input only if < 2,30 m or > 2,70 m)	#NV

Attached neighbour buildings
- (●) None (detached)
- ( ) On one side (semi-detached)
- ( ) On two sides (terraced)
- ( ) Not applicable / unknown

Floor shape / foot print
- ( ) Simple
- ( ) Standard / ordinary
- (●) Complex or stretched
- ( ) not applicable / unknown

Attic
- (●) Not available (flat roof or slightly tilted roof)
- ( ) Not heated
- ( ) Partly heated
- ( ) Completely heated
- ( ) Not applicable / unknown
- [ ] Complex geometry of roof area (e.g. dormers)

Cellar / basement
- ( ) Cellar not available
- (●) Not heated
- ( ) Partly heated
- ( ) Completely heated
- ( ) Not applicable / unknown
- [■] Cellar floor and walls thermally insulated

Thermal envelope (non-transparent elements)

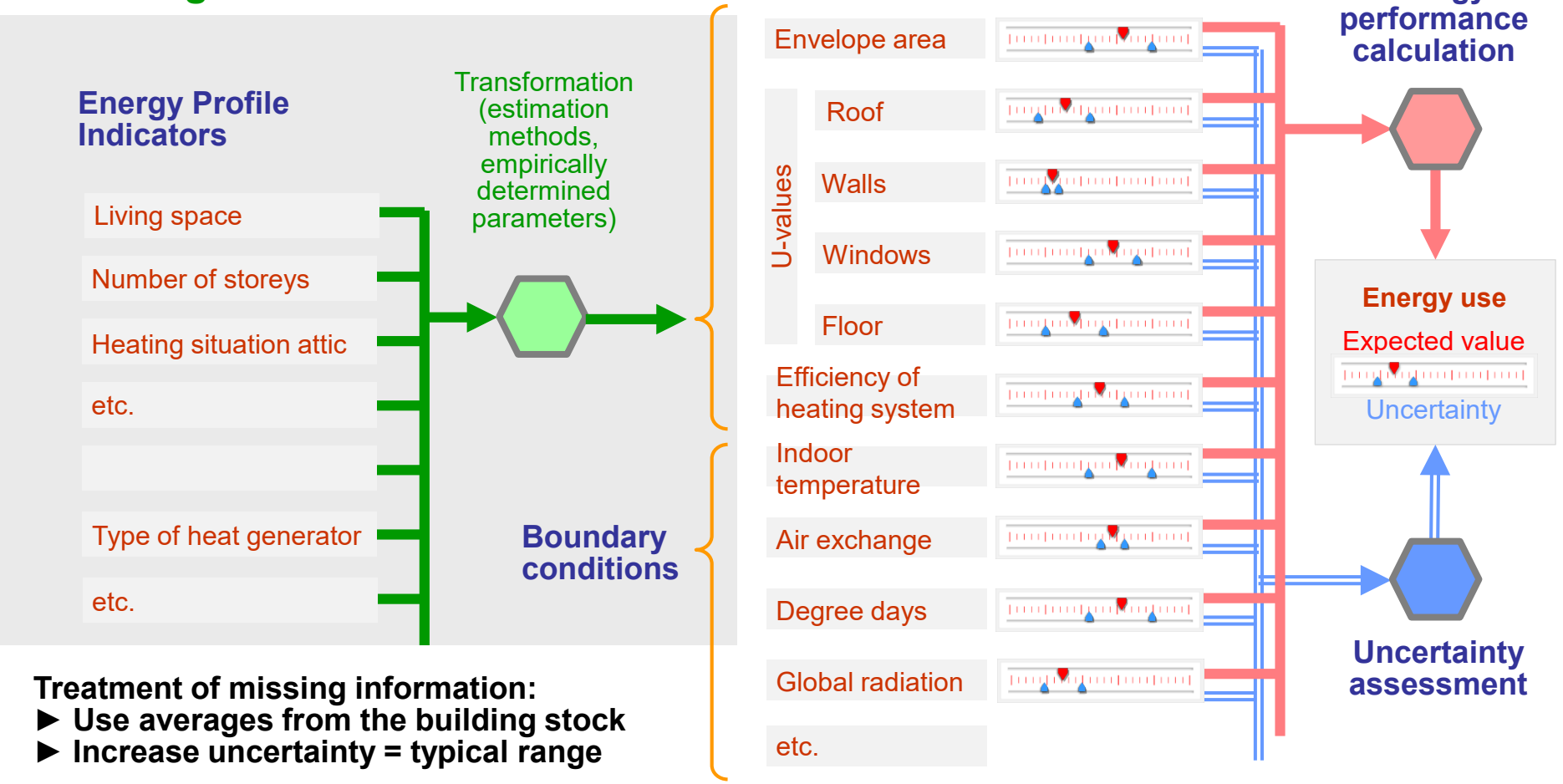
Construction type			Insulation									
	Massive	Wood	None	Original	Refurbishment	not applicable / unknown	Year of refurbishment	Internal wall insulation	Insulation thickness		On percentage of the area	
Roof	☑	☐	○	○	●	○	2010		10	cm	100	%
Top storey ceiling	☑	☐	○	○	○	●	#NV		#NV	cm	#NV	%
Wall	☑	☐	○	○	●	○	2010	☐	14	cm	100	%
Floor to cellar or soil	☑	☐	●	○	○	○	#NV		0	cm	0	%

In case of non-insulated walls:
Application of external insulation possible? ○ Yes ○ Partly ○ No ● Not applicable / unknown

Windows

	Percentage of the window area	Glazing					Frame					Passive house window (insulated frame + Low-E triple glazing)	Year of Installation or upgrade
		Single pane	Double pane	Triple pane	Not applicable / unknown	Low-E coating	Wood	Plastic	Aluminium / steel	Other	Unknown		
Main window type		○	●	○	○	☐	○	●	○	○	○	☐	1990
Further window type	0 %	○	○	○	●	☐	○	○	○	●	○	☐	#NV
	(Rest = main window type)											(U≤0.8W/(m²K))	

Reality-based physical model including uncertainties



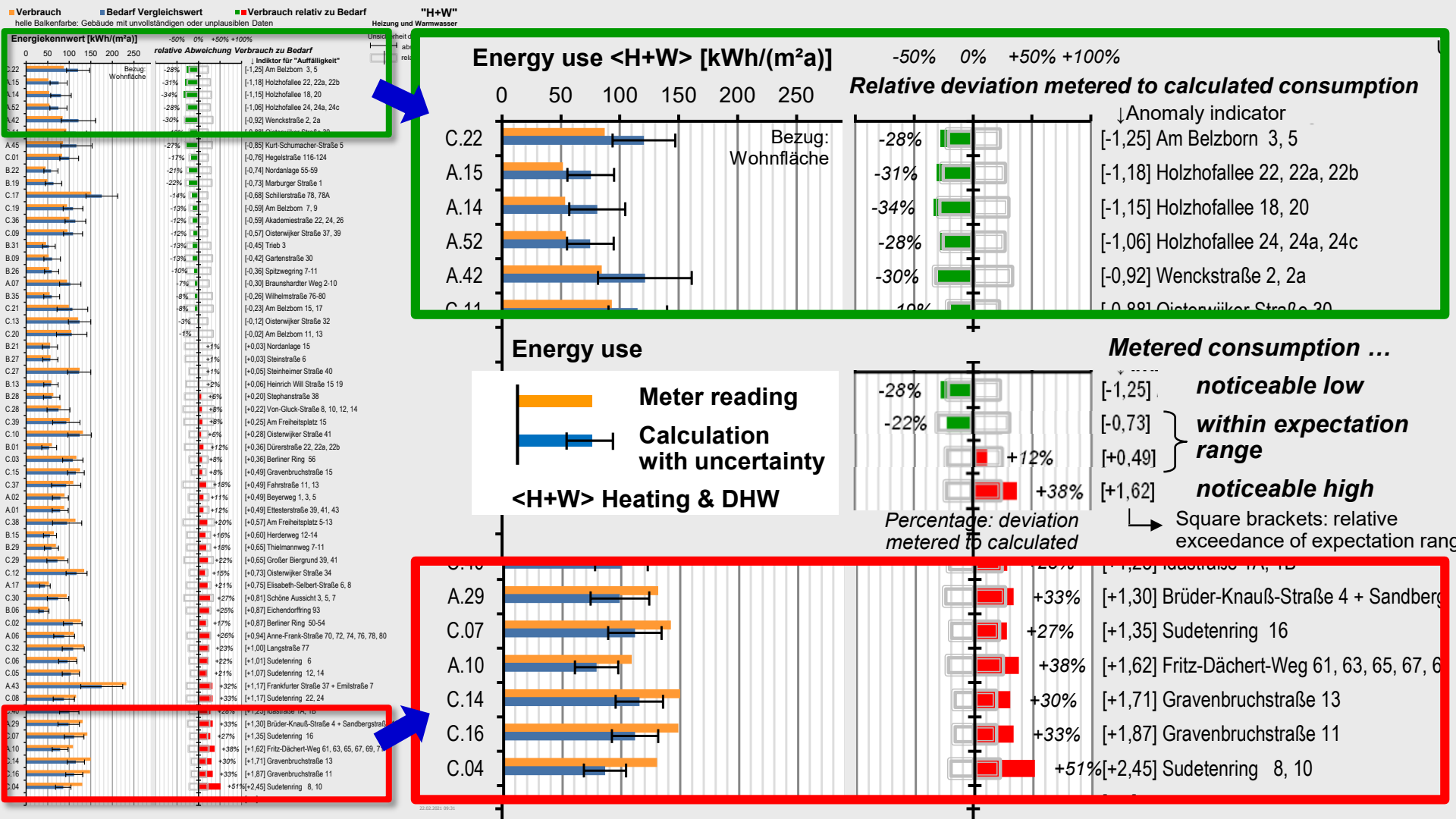
Treatment of missing information:

- ► **Use averages from the building stock**
- ► **Increase uncertainty = typical range**

Investigated housing stock subsets

Group	Shortcut	Housing company	Datasets / building entities	Apartment blocks	Houses*	Dwellings	Living space
A	„BV upgraded“	Bauverein AG	53	63	156	1 376	91 308 m²
B	„WBG upgraded“	Wohnbau Gießen	35	35	58	718	47 041 m²
C	„NHW upgraded“	Nassauische Heimstätte Wohnstadt	41	41	85	822	53 735 m²
D	„NHW original“		26	26	42	413	27 023 m²
Total			155	165	341	3 329	219 106 m²
Thereof datasets with meter readings		Metering scope**					
		<H+W>	85	94	196	2 080	132 667 m²
		<H>	82	90	176	1 958	128 348 m²

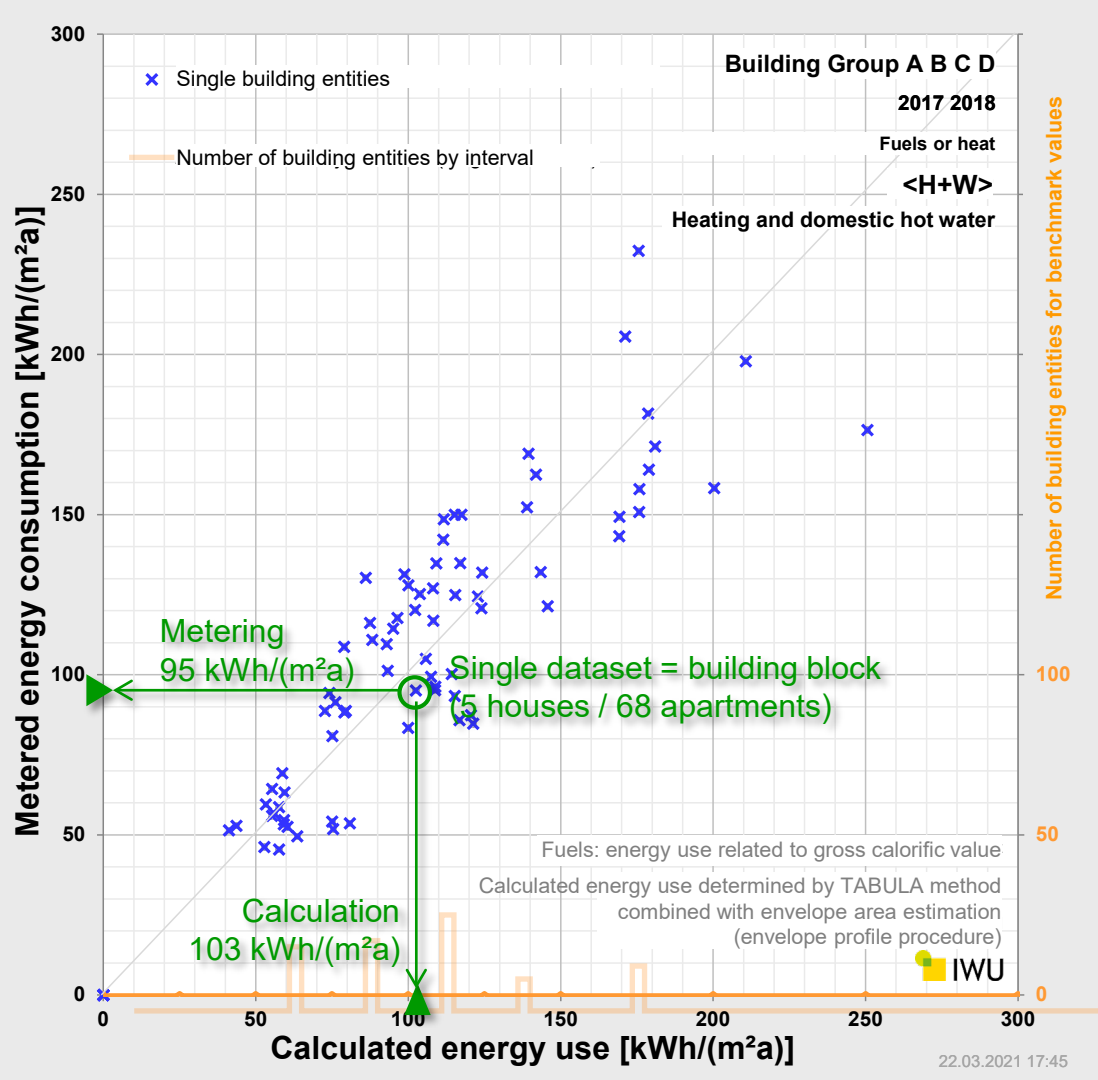
*) “House” = a building unit with a separate entrance, staircase and/or address (street + house number)
**) Shortcuts for metering scope: <H+W> = heating and domestic hot water (DHW); <H> = only heating


Verbrauch
Bedarf Vergleichswert
Verbrauch relativ zu Bedarf
"H+W"
Heizung und Warmwasser
helle Balkenfarbe: Gebäude mit unvollständigen oder unplausiblen Daten
Energiekennwert [kWh/(m²a)]
relative Abweichung Verbrauch zu Bedarf
↓ Indiktor für "Auffälligkeit"
Bezug: Wohnfläche
[-1,25] Am Belzborn 3, 5
[-1,18] Holzhofallee 22, 22a, 22b
[-1,15] Holzhofallee 18, 20
[-1,06] Holzhofallee 24, 24a, 24c
[-0,92] Wenckstraße 2, 2a
[-0,85] Kurt-Schumacher-Straße 5
[-0,76] Hegelstraße 116-124
[-0,74] Nordanlage 55-59
[-0,73] Marburger Straße 1
[-0,68] Schillerstraße 78, 78A
[-0,59] Am Belzborn 7, 9
[-0,59] Akademiestraße 22, 24, 26
[-0,57] Oisterwijker Straße 37, 39
[-0,45] Trieb 3
[-0,42] Gartenstraße 30
[-0,36] Spitzwegring 7-11
[-0,30] Braunshardter Weg 2-10
[-0,26] Wilhelmstraße 76-80
[-0,23] Am Belzborn 15, 17
[-0,12] Oisterwijker Straße 32
[-0,02] Am Belzborn 11, 13
[+0,03] Nordanlage 15
[+0,03] Steinstraße 6
[+0,05] Steinheimer Straße 40
[+0,06] Heinrich Will Straße 15 19
[+0,20] Stephanstraße 38
[+0,22] Von-Gluck-Straße 8, 10, 12, 14
[+0,25] Am Freiheitsplatz 15
[+0,28] Oisterwijker Straße 41
[+0,36] Dürerstraße 22, 22a, 22b
[+0,36] Berliner Ring 56
[+0,49] Gravenbruchstraße 15
[+0,49] Fahrstraße 11, 13
[+0,49] Beyerweg 1, 3, 5
[+0,49] Ettesterstraße 39, 41, 43
[+0,57] Am Freiheitsplatz 5-13
[+0,60] Herderweg 12-14
[+0,65] Thielmannweg 7-11
[+0,65] Großer Biergrund 39, 41
[+0,73] Oisterwijker Straße 34
[+0,75] Elisabeth-Selbert-Straße 6, 8
[+0,81] Schöne Aussicht 3, 5, 7
[+0,87] Eichendorffring 93
[+0,87] Berliner Ring 50-54
[+0,94] Anne-Frank-Straße 70, 72, 74, 76, 78, 80
[+1,00] Langstraße 77
[+1,01] Sudetenring 6
[+1,07] Sudetenring 12, 14
[+1,17] Frankfurter Straße 37 + Emilstraße 7
[+1,17] Sudetenring 22, 24
[+1,30] Brüder-Knauß-Straße 4 + Sandbergstraße
[+1,35] Sudetenring 16
[+1,62] Fritz-Dächert-Weg 61, 63, 65, 67, 69, 71
[+1,71] Gravenbruchstraße 13
[+1,87] Gravenbruchstraße 11
[+2,45] Sudetenring 8, 10
Energy use <H+W> [kWh/(m²a)]
Relative deviation metered to calculated consumption
↓Anomaly indicator
Energy use
Meter reading
Calculation with uncertainty
<H+W> Heating & DHW
Metered consumption …
noticeable low
within expectation range
noticeable high
Percentage: deviation metered to calculated
Square brackets: relative exceedance of expectation rang

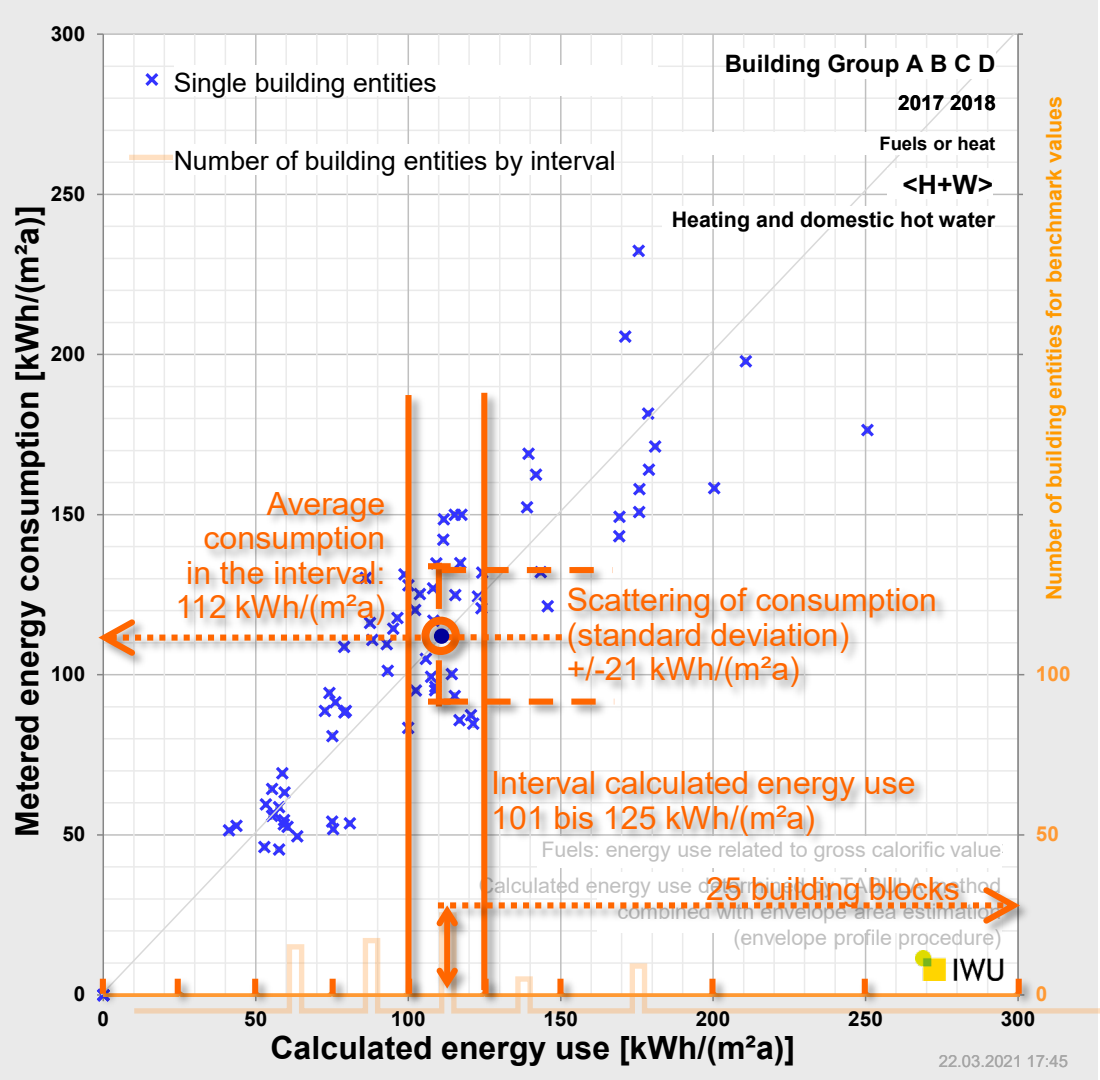
Buildings with suspiciously high or low energy consumption: Next steps “check and fix”

- Step 1: Check building data
- Step 2: Check heat billing data
- Step 3: On-site inspection of the thermal properties of building fabric and heat supply system
- Step 4: On-site examination of the operating conditions / user behavior

- Improvement of data quality
- Improvement of operation conditions

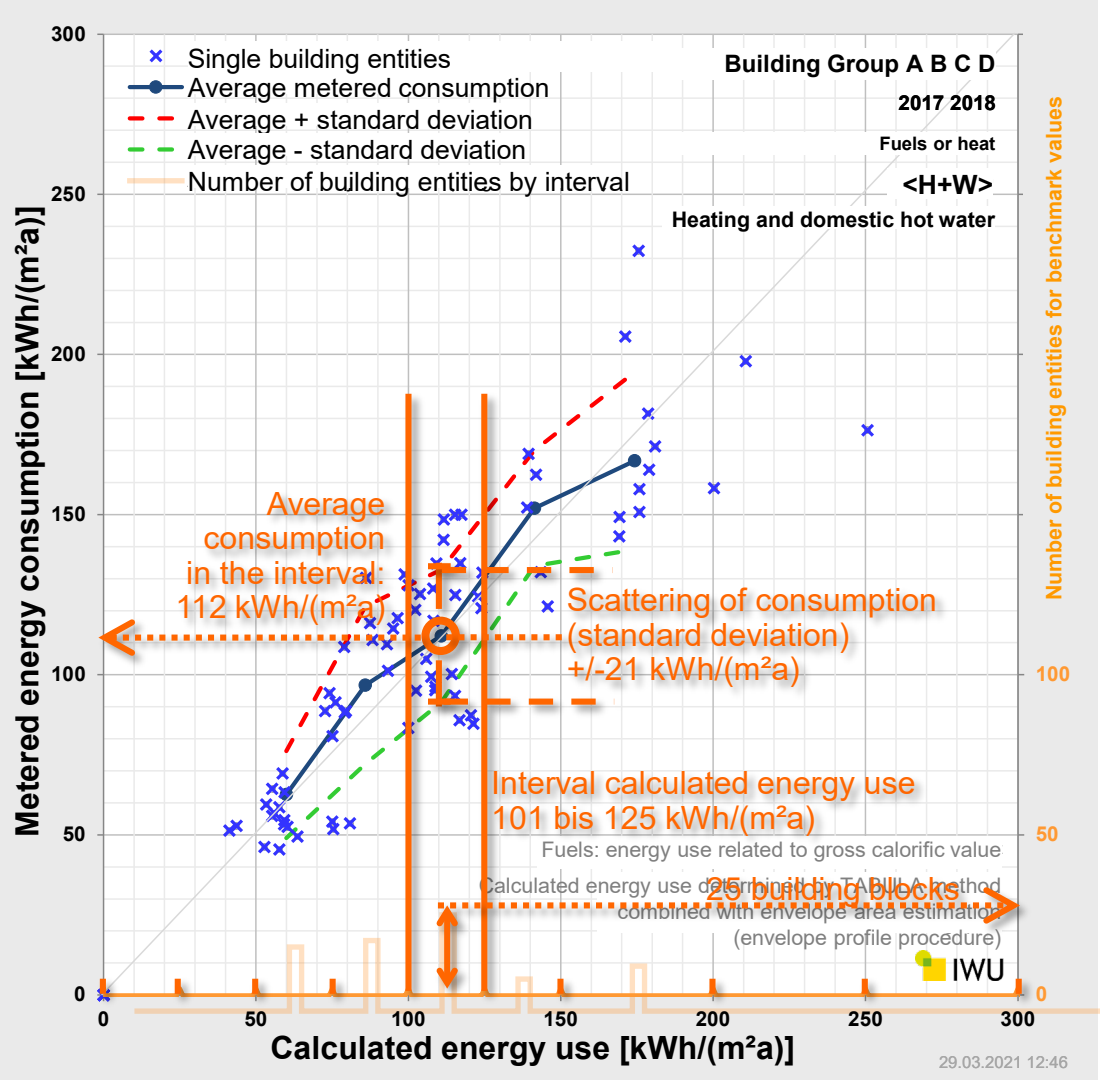


Coherence of reality-based physical model and actual consumption

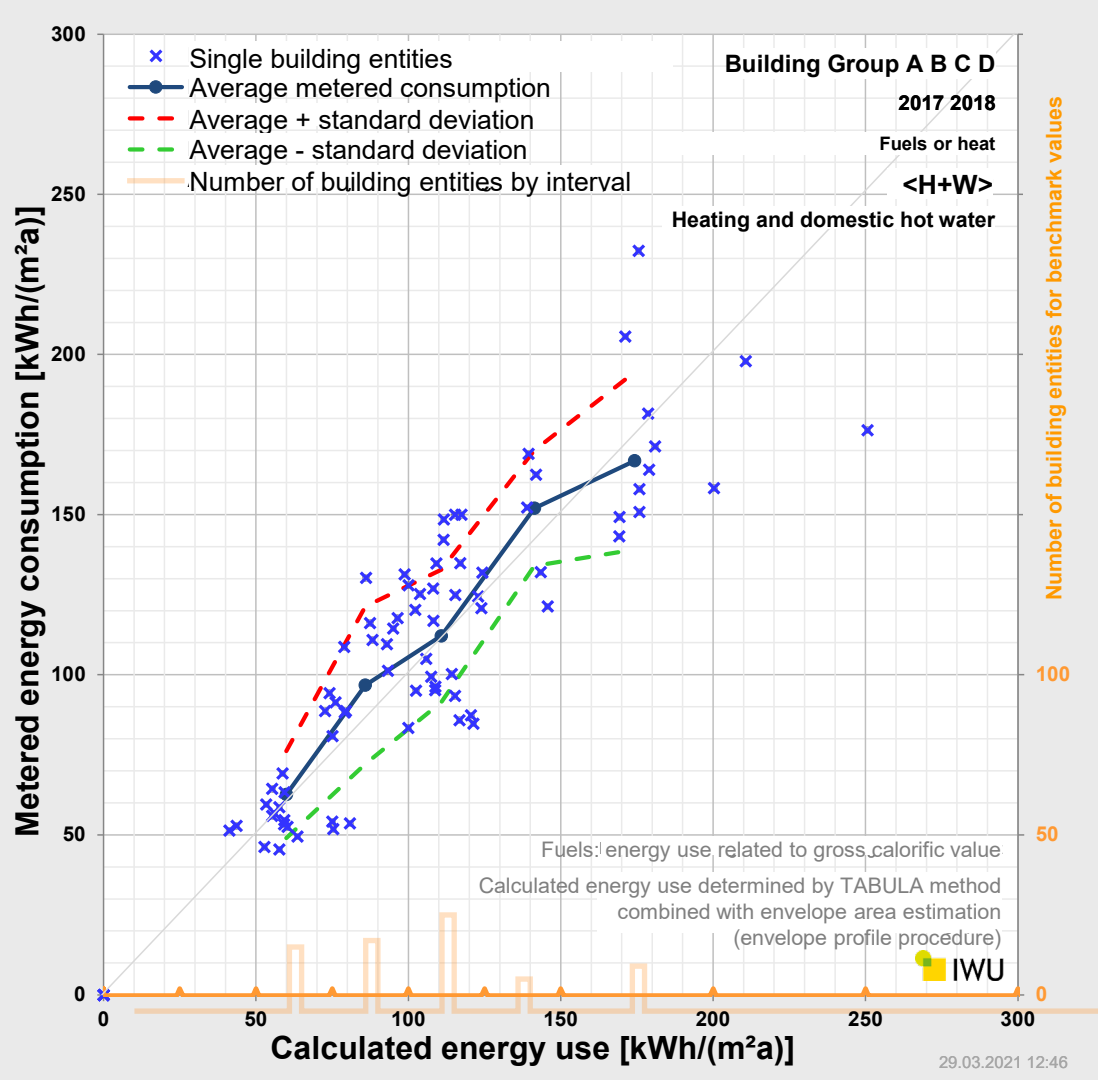


Coherence of reality-based physical model and actual consumption

Examination:
Average consumption per interval of calculated energy use
➔ systematic deviations?



Average consumption and standard deviation per interval of calculated energy use



Average consumption and standard deviation per interval of calculated energy use

- Rather good coherence (no strong systematic deviation for non-refurbished buildings as known from EPC calculation)

Résumé

Target/actual comparison and benchmarking in housing companies

Methodology: monitoring table, energy profile indicators, reality-based physical model, treatment of missing information, uncertainty assessment <developed>

Application to a collection of datasets of about 150 apartment blocks <done>

→ Reliable physical model: expected energy consumption <yes>

→ Improve data validity <yes> + Improve non-optimal operating conditions <tbd>

Perspectives:

- Extension of database / continuation on annual basis
- Energy management in housing companies (challenge: additional staff)
- Strategic portfolio management towards carbon neutral housing stocks (refurbishment rates / tracking of GHG emission reduction, …)