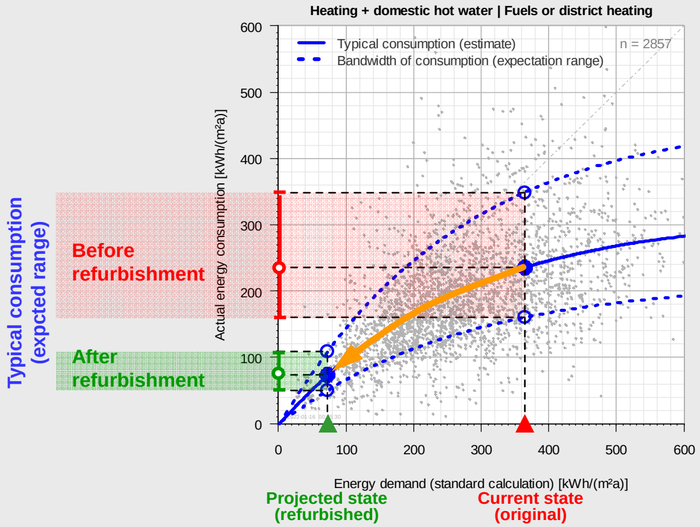
Use of energy performance certificates for realistic prognoses – A method to calibrate the national calculation procedure by the average actual consumption

Tobias Loga / Britta Stein
IWU – Institut Wohnen und Umwelt
(Institute for Housing and Environment)
Darmstadt / Germany



Excerpt of approaches, analyses and results of the project "Consideration of user behaviour in energy refurbishments“

Project title	Berücksichtigung des Nutzerverhaltens bei energetischen Verbesserungen
Project duration	01. Dezember 2016 bis 31. Juli 2018
On behalf of	Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) im Bundesamt für Bauwesen und Raumordnung (BBR) (Federal Institute for Research on Building, Urban Affairs and Spatial Development, Germany)
Project website	https://www.iwu.de/forschung/energie/nutzerverhalten-bei-energetischen-verbesserungen/
Final report	[Loga et al. 2019] available via project website

Challenge: Standard calculation of Energy Performance Certificates (EPCs) – relation to reality

Physical models of heat transfer and energy flow in buildings are used

(1) to understand energy consumption + to make prognoses

(2) for proof of legal requirements and for rating
= energy performance certificates (EPCs)

Focus of this presentation

- Standardisation of calculation rules
  ensures comparability, replicability and verifiability
- Calculation results: discrepancies to actual consumption values
  are reported (individual buildings but also total stock)

Not surprising: A physical model with important input uncertainties

- cannot provide exact prognoses
- is in need for adjustments to reality

Objectives

- **Complement the EPC rating and legal proof of requirements by realistic information about the energy consumption.**
- **In particular: Use of empirical data to assign usual consumption levels to the energy demand calculated by the national standard EPC method.**

Steps

1. Empirical basis: Search for studies that include both metered and calculated consumption and transfer the values into one data table.
2. Discrete estimation model: Pool buildings with similar calculated energy rating and determine averages and standard deviations of measured consumption for these classes.
3. Continuous estimation model: Find a function for estimating the measured consumption and variance.
4. Showcase benefit for energy advice.

Focus area

- **Germany**
- **Residential buildings**

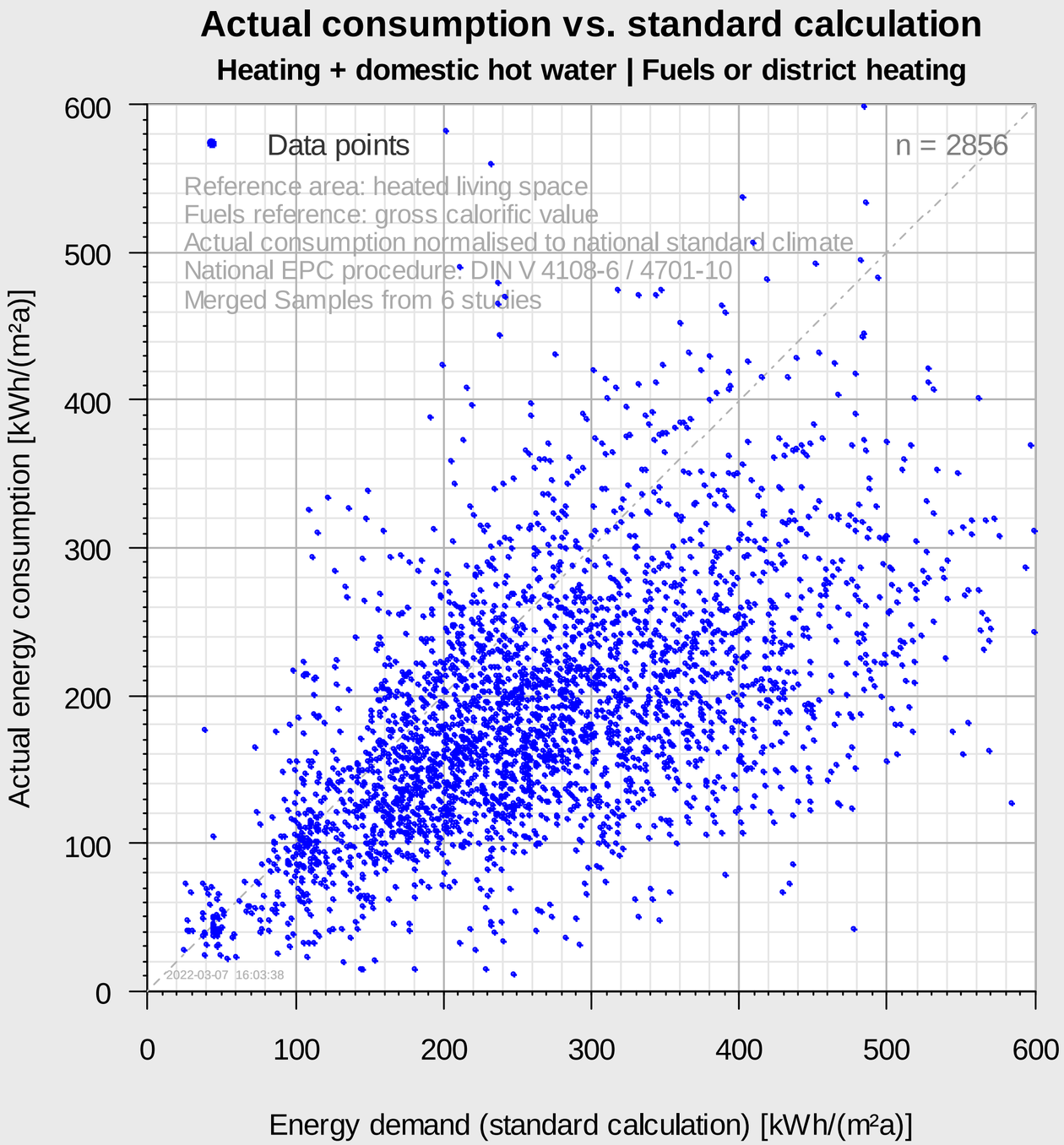
Terms and references

- **“Energy consumption”**
  = actual metered energy consumption, normalised to German standard climate
- **“Energy demand”**
  = theoretical energy consumption calculated by use of an official national EPC rating or legal proof method (“standard calculation”)

Annual values of both quantities refer to:

- Square meter living space
- Final energy (gas, oil, district heating), fuels related to gross calorific value
- Space heating and domestic hot water (DHW)

Empirical basis



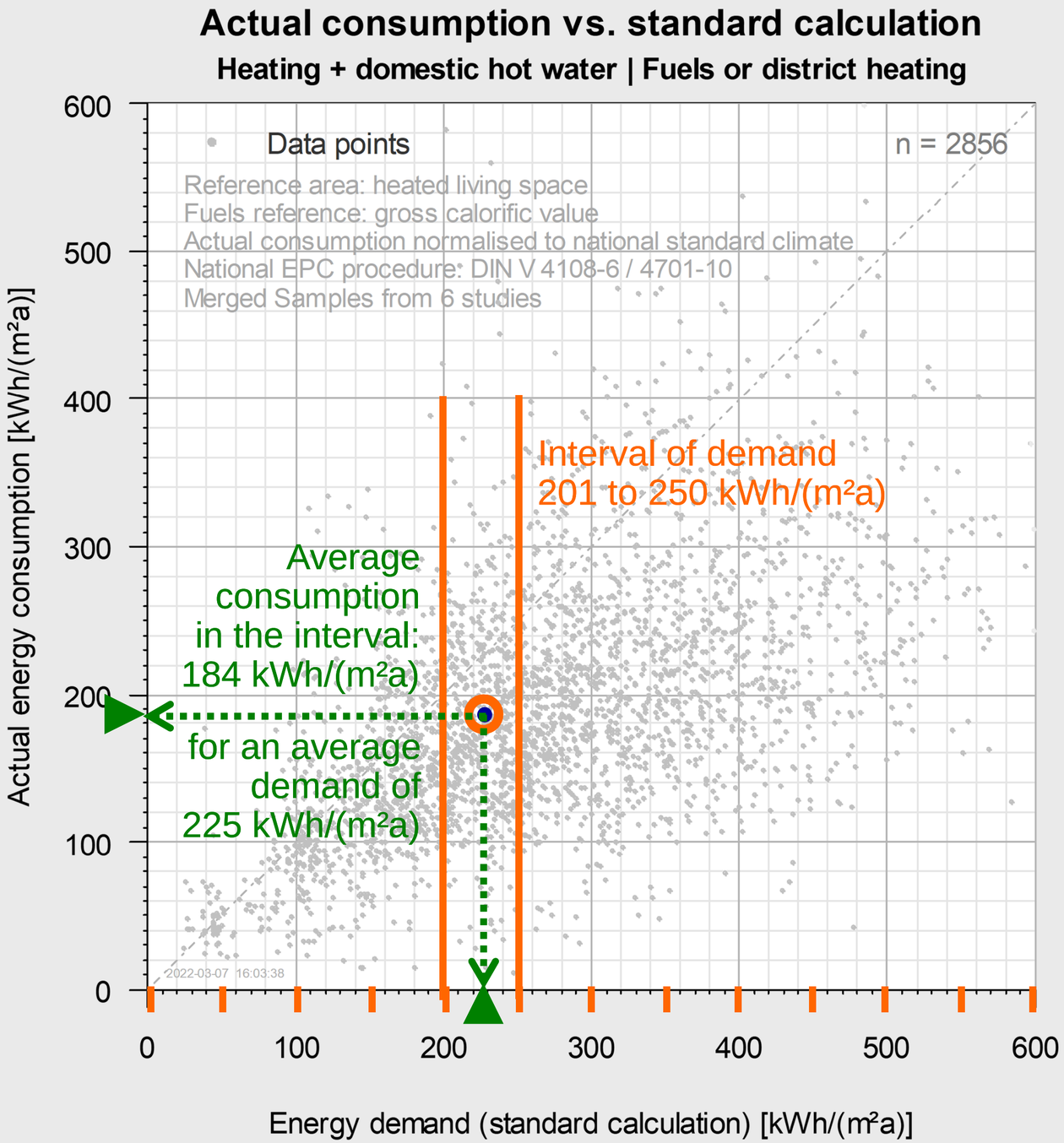
Meta-analysis

Search for studies that include measured energy consumption and calculated energy demand (standard EPC method) for residential buildings in Germany (pilot projects, field tests, energy consulting activities, …)

- 6 studies useable (values for heating and domestic hot water DHW, boilers and district heating, without additional heat generators)
- Extraction of value pairs demand / consumption (n = 2856), see chart

x-axis: calculated demand (German standard DIN V 4108-6 / 4701-10)

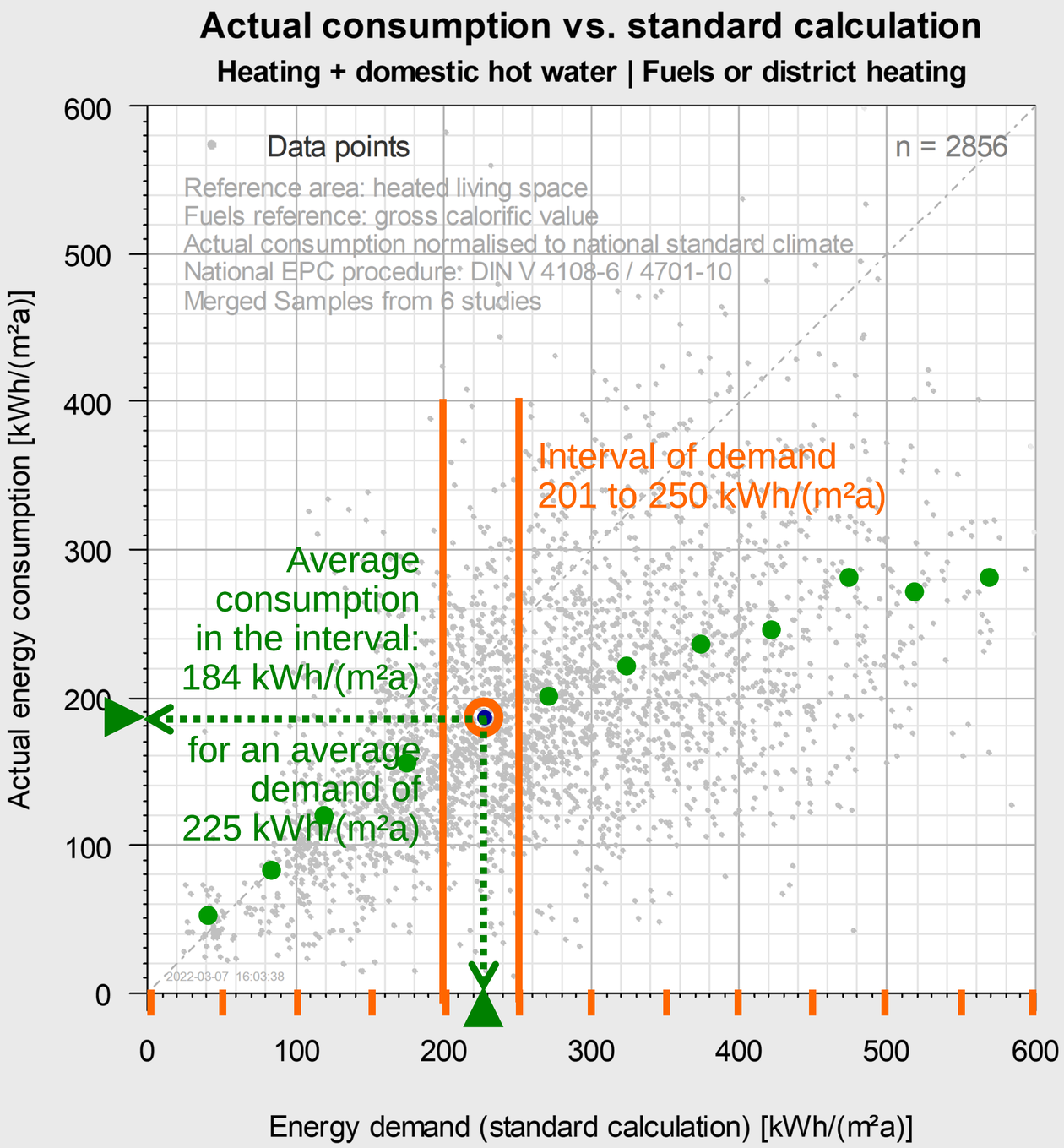
y-axis: measured consumption (corrected to standard climate by degree days ratio)



Discrete model

Average and standard deviation of consumption by energy demand class

Subdivision of demand (x-axis) in classes of 50 kWh/(m²a)



Discrete model

Average and standard deviation of consumption by energy demand class

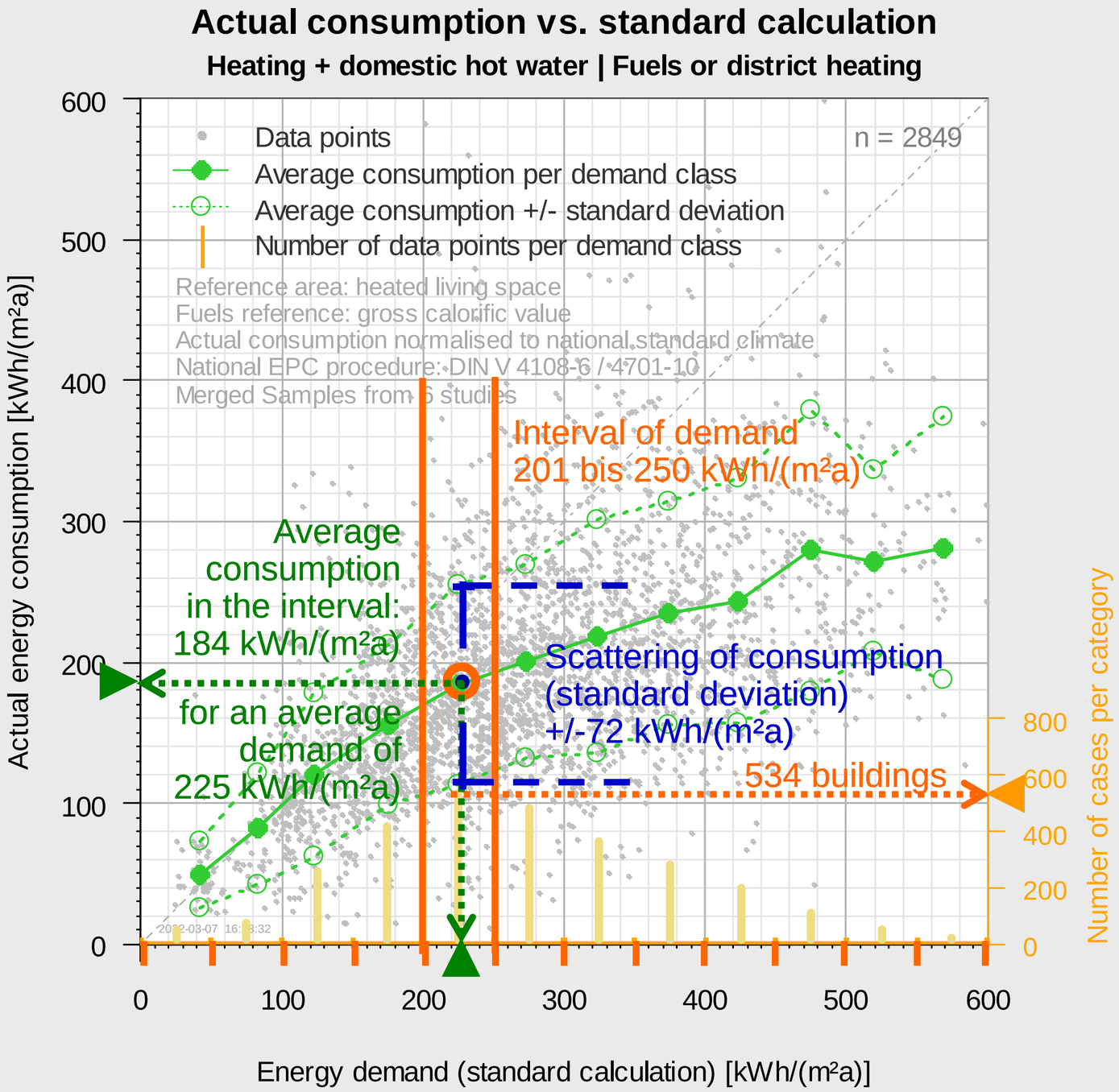
“Consumption Benchmarks”

Subdivision of demand (x-axis) in classes of 50 kWh/(m²a)

Evaluation by demand class:

- Average consumption

Discrete model



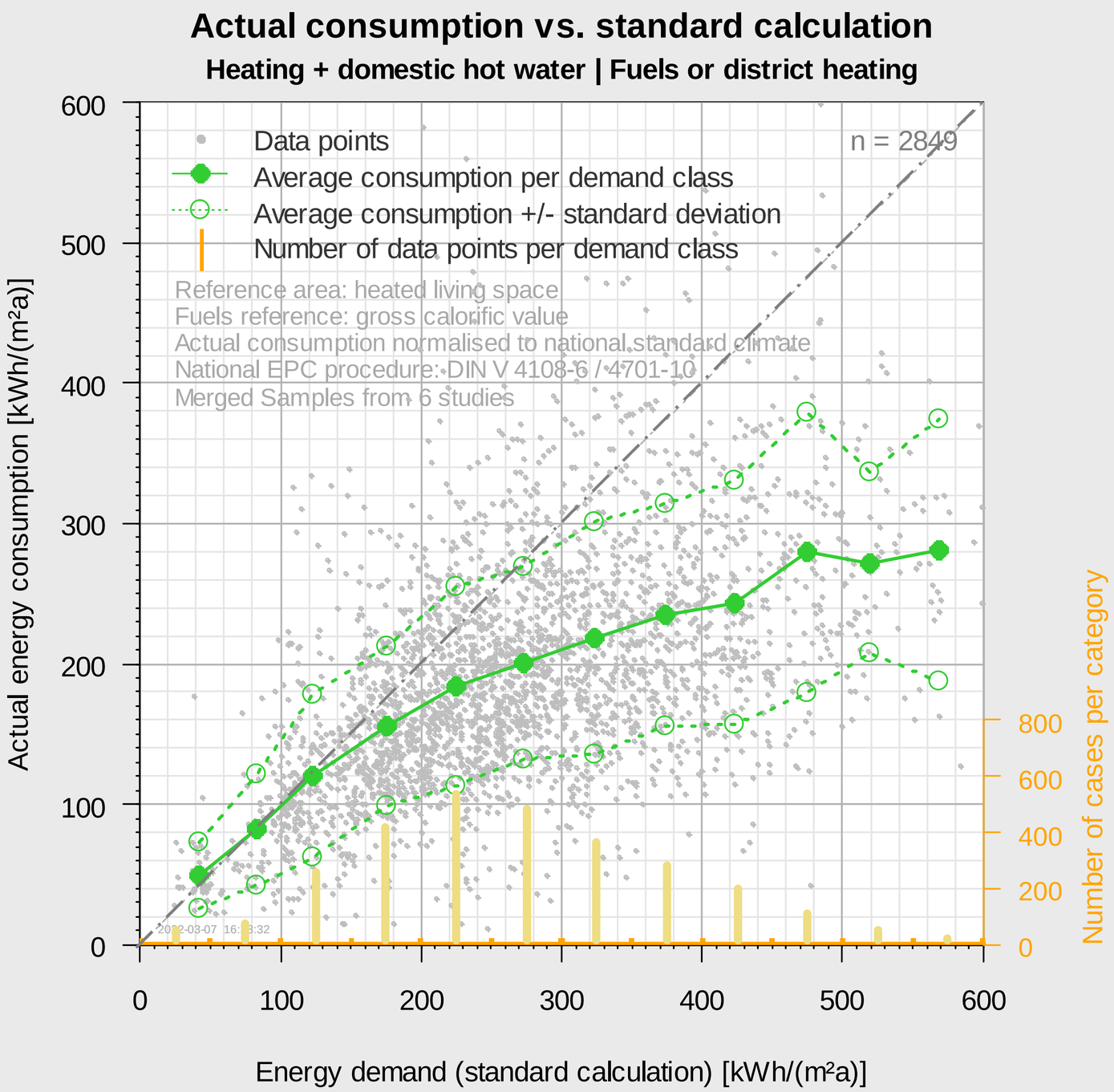
Average and standard deviation of consumption by energy demand class

“Consumption Benchmarks”

Subdivision of demand (x-axis) in classes of 50 kWh/(m²a)

Evaluation by demand class:

- Average consumption —●—
- Standard deviation - - o - -
- Frequencies ▮
  (numbers at the right vertical axis)



Discrete model

Average and standard deviation of consumption by energy demand class

“Consumption Benchmarks”

Subdivision of demand (x-axis) in classes of 50 kWh/(m²a)

Evaluation by demand class:

- Average consumption —●—
- Standard deviation - - o - -
- Frequencies ▮
  (numbers at the right vertical axis)
- Bisecting line – · – · – ·
  (consumption = demand)

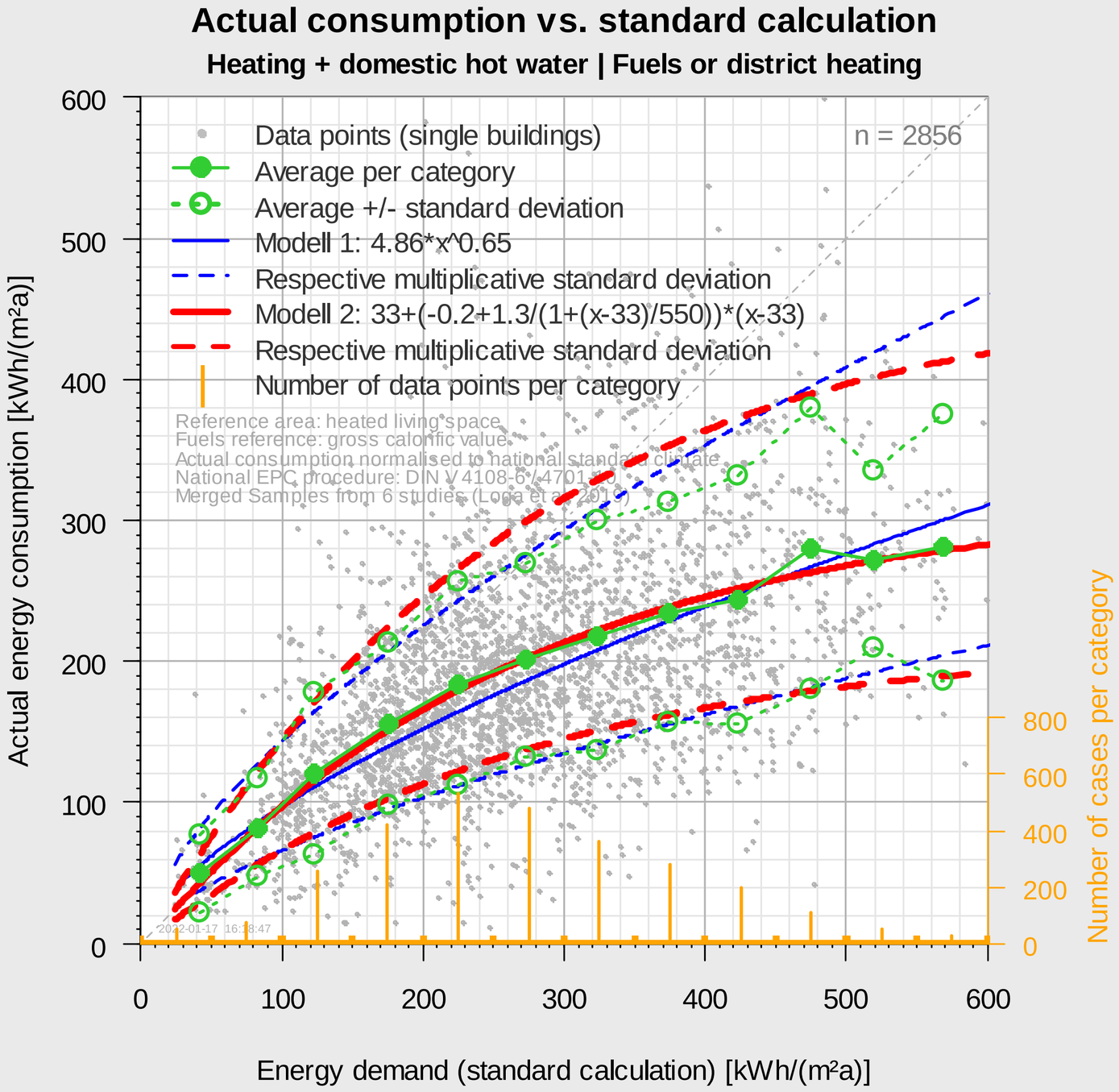
Benchmark table

Combined systems for heat supply: space heating + domestic hot water

Natural gas / heating oil / district heating (for fuels related to gross calorific value H_s)

Theoretical energy demand (standard calculation) * related to heated living space		Sample	**Actual energy consumption** related to heated living space				
			Average	Calibration factor: Ratio actual consumption to theoretical demand		Standard deviation of the actual consumption	Model uncertainty (uncertainty of the determined average consumption)
Interval	Average	Number of buildings		Average	Relative standard deviation		
kWh/(m²a)	kWh/(m²a)		**kWh/(m²a)**			kWh/(m²a)	kWh/(m²a)
1 … 50	41	n=49	**50**	1.20	± 55 %	± 27	± 3.9
51 … 100	83	n=76	**82**	0.98	± 42 %	± 35	± 4.0
101 … 150	123	n=257	**121**	0.98	± 48 %	± 57	± 3.6
151 … 200	176	n=421	**156**	0.89	± 37 %	± 57	± 2.8
201 … 250	225	n=534	**184**	0.82	± 39 %	± 72	± 3.1
251 … 300	274	n=482	**201**	0.74	± 34 %	± 69	± 3.1
301 … 350	324	n=364	**218**	0.67	± 37 %	± 82	± 4.3
351 … 400	374	n=281	**235**	0.63	± 33 %	± 78	± 4.7
401 … 450	424	n=199	**244**	0.58	± 36 %	± 88	± 6.3
451 … 500	475	n=109	**280**	0.59	± 36 %	± 100	± 9.5
501 … 550	519	n=52	**272**	0.52	± 23 %	± 63	± 8.7
551 … 600	569	n=25	**281**	0.49	± 34 %	± 95	± 18.9

*) Theoretical demand calculated according to the German standards DIN V 4108-6 + DIN V 4701-10



Continuous model

Regression analyses: Function for estimating consumption and variance

Functional model 1:
Estimate: ———— / estimation range: - - - -
A power function with real exponent *

Proposed for further use

Functional model 2:
Estimate ——— / estimation range: — — —
A linear function with a multiplicative correction term **

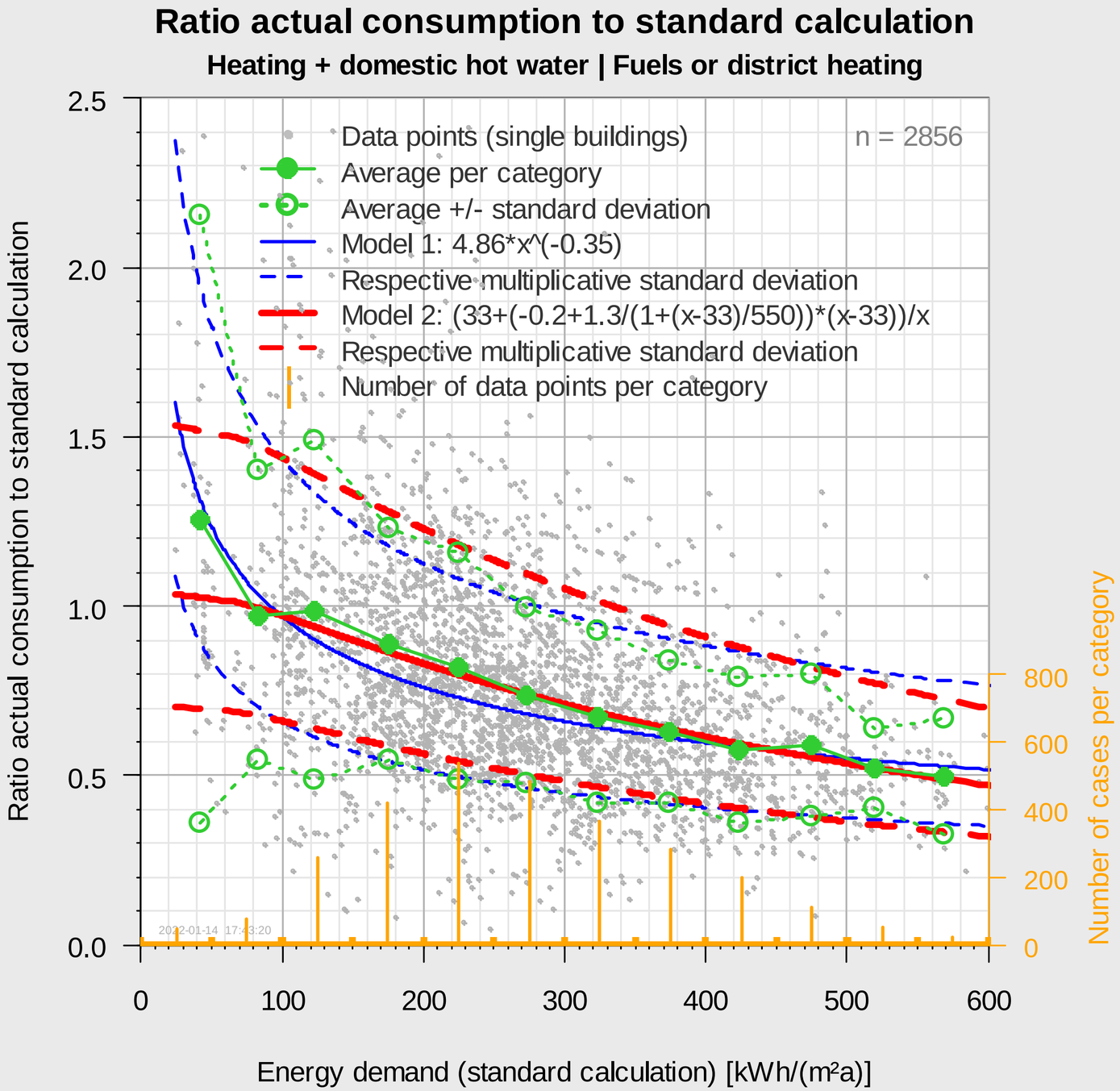
R^2 = 0.39 for both formulas (coefficient of determination of the logarithmised values)

*) see Hörner et al. 2016 and Hörner / Lichtmeß 2017;
= straightforward method when variables are logarithmised due to heteroskedastic variance

**) see Loga et al. 2011/2015, Sunikka-Blank / Galvin 2012, and Pehnt et al. 2015
= model oriented at assumed physical effects

Note: Simple linear regression not allowed due to very different scattering for small and high demand values!

“Calibration factor”



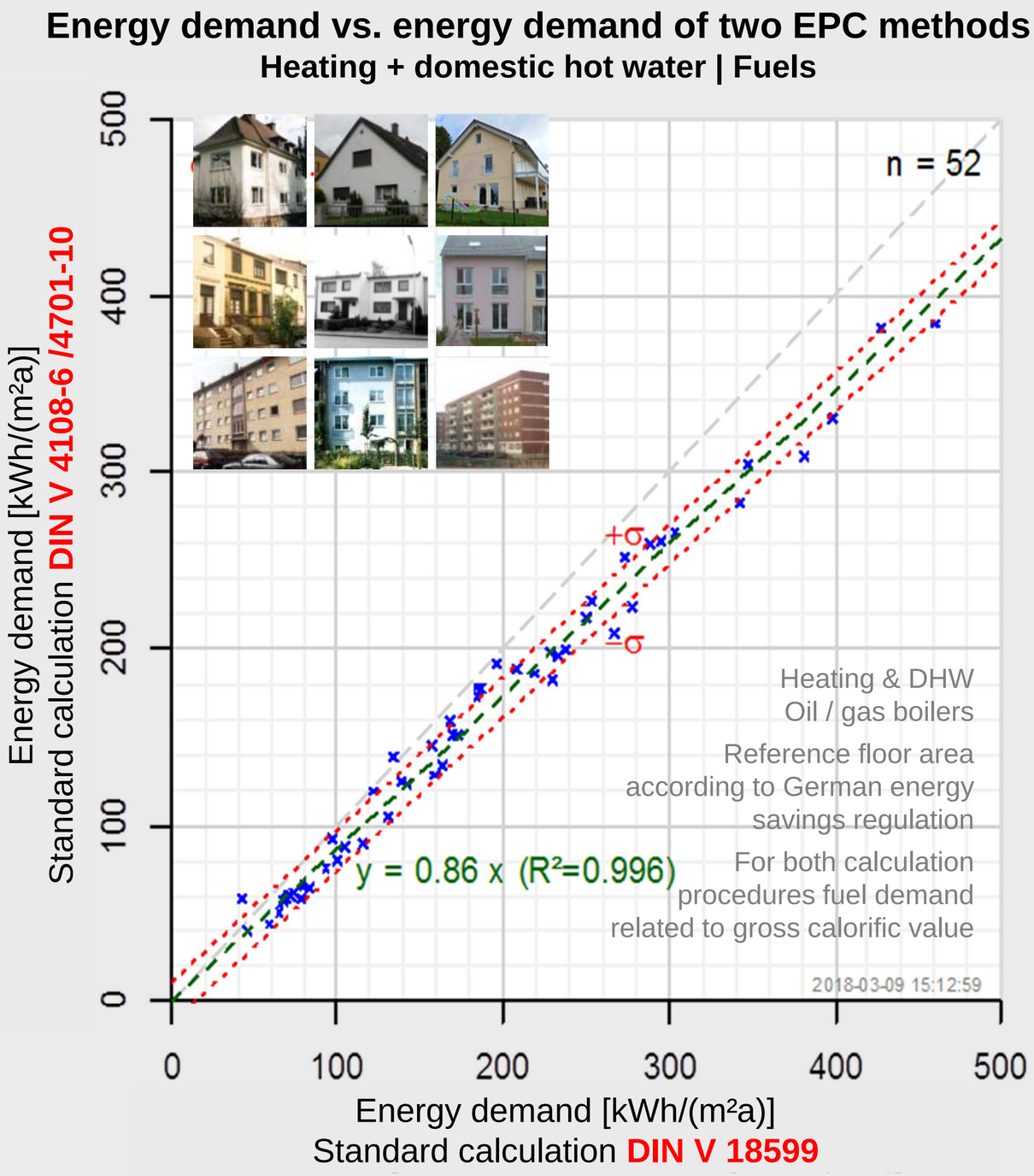
Ratio consumption to demand vs. demand

- **Factor directly applicable to energy demand**
  (result of standard energy performance calculation)

Model	Estimation value	Estimation range
Discrete	—●—	- - o - -
Function 1	– – – – –	- - - - -
Function 2	– – – –	– – –

To be noted (for discussion):

- A comparative use of more than one model and a critical discussion of their features (also with respect to fit criteria) can be helpful.
- Criteria for model fit can be quite different
  (discrete model: minimised sum of linear differences; functional models: minimised sum of squared differences of logarithmised values)



Coping with change of standard calculation procedure

Parameter study

- Apply both calculation methods for a large variety of buildings and building features
- Chart: Energy demand of old versus energy demand of new German standard method (old: DIN V 4108-6 / 4701-10 new: DIN V 18599)
- Displayed case:
  Heating systems with boilers
  Derived conversion model:
  Factor **0.86**
  (Uncertainty for application to a single building: +/-11 kWh/(m²a))

Showcase: Benefit in energy advice

Example: single-family house

Actual consumption vs. standard calculation

Heating + domestic hot water | Fuels or district heating

Case 1:

Information about actual consumption not available

Showcase: Benefit in energy advice

Example: single-family house

Case 2:
Information about actual consumption available

Showcase: Benefit in energy advice

Example: single-family house

Case 3:

Information about actual consumption available + change of users

Perspectives

Fields of application

Estimation of actual consumption based on EPC rating

- Energy advice: assess and interpret actual consumption + reliable prognoses
- Scientific studies on political instruments (legal requirements, funding schemes, promotion of energy advice, …)
  - design + optimisation of the programmes
  - evaluation of the programmes
- Energy management and controlling (e.g. housing companies, …)

Link with policies in Germany

Addendum to

- EPC rating / legal proof **recommended**
- “Individual refurbishment roadmap” for residential buildings (“Sanierungsfahrplan”) **implemented**

[dena / ifeu / PHI 2017]

Scientific topics

- Extension to heat pumps + direct electric heating
- Differentiation by building size
- Practical application of method / communication of estimation ranges to owners and residents

Sources / Literature

[dena / ifeu / PHI 2017] dena – Deutsche Energie-Agentur GmbH; ifeu – Institut für Energie- und Umweltforschung; PHI - Passivhaus-Institut (2017): Mein Sanierungsfahrplan - Handbuch für Energieberater. Publisher: Bundesministerium für Wirtschaft und Energie (BMWi), Berlin. https://www.gebaeudeforum.de/fileadmin/gebaeudeforum/Downloads/iSFP-Publikation/iSFP-Handbuch-21-12.pdf

[Hörner et al. 2016] Hörner, M.; Cischinsky, H.; Lichtmeß, M. (2016): Analyse der Diskrepanz von Energiebedarf und -verbrauch bei Energiepässen von Wohngebäuden in Luxemburg; Teil1: Methode der multiplen linearen Regression; Bauphysik 38 (2016). Heft 3. http://dx.doi.org/10.1002/bapi.201610016

[Hörner / Lichtmeß 2017] Hörner, M.; Lichtmeß, M. (2017): Energy performance of buildings: A quantitative approach to marry calculated demand and measured consumption; eceee 2017 Summer Study Proceedings https://www.researchgate.net/publication/324504381_Energy_Performance_of_Buildings_A_quantitative_approach_to_marry_calculated_demand_and_measured_consumption

[Loga et al. 2011 / 2015] Loga, Tobias; Stein, Britta; Diefenbach, Nikolaus; Born, Rolf: Deutsche Wohngebäudetypologie. Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden; Broschüre erarbeitet im Rahmen der EU-Projekte TABULA und EPISCOPE; 1. und 2. erweiterte Auflage; Institut Wohnen und Umwelt, Darmstadt 2011 und 2015 doi.org/10.13140/RG.2.2.11714.50881

[Loga et al. 2019] Loga, T.; Stein, B.; Hacke, U.; Müller, A.; Großklos, M.; Born, R.; Renz, I.; Cischinsky, H.; Hörner, M.; Weber, I. (2019): Berücksichtigung des Nutzerverhaltens bei energetischen Verbesserungen; Publisher: Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR); BBSR-Online-Publikation 04/2019; https://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/BBSROnline/2019/bbsr-online-04-2019-dl.pdf

[Pehnt et al. 2015] Pehnt, M.; Mellwig, P.; Duscha, M.; von Oehsen, A.; Diefenbach, N.; Enseling, A.; Großklos, M.; Loga, T.; Born, R.; Boermans, T.; Bettgenhäuser, K.; Artz, M. (2015): Weiterentwicklung des bestehenden Instrumentariums für den Klimaschutz im Gebäudebereich / AP 2: Elemente der Entwicklung eines gebäudeindividuellen Sanierungsfahrplans / Teil I Methodische Vorüberlegungen; Studie im Auftrag des Bundesministerium für Wirtschaft und Energie (BMWi); ifeu - Institut für Energie- und Umweltforschung / IWU - Institut Wohnen und Umwelt / Ecofys Germany / Universität Bielefeld, Fakultät für Rechtswissenschaft / ifeu http://www.iwu.de/fileadmin/user_upload/dateien/energie/Sanierungsfahrplan_AP_2_Teil_I_final.pdf

[Sunikka-Blank / Galvin 2012] Sunikka-Blank, M.; Galvin, R. (2012): Introducing the prebound effect: the gap between performance and actual energy consumption, Building Research & Information 2012, 40:3, 260-273 http://dx.doi.org/10.1080/09613218.2012.690952

More literature references can be found in the conference paper.