Internal gain assumptions and building size

International Passivhaus conference Aachen 2014

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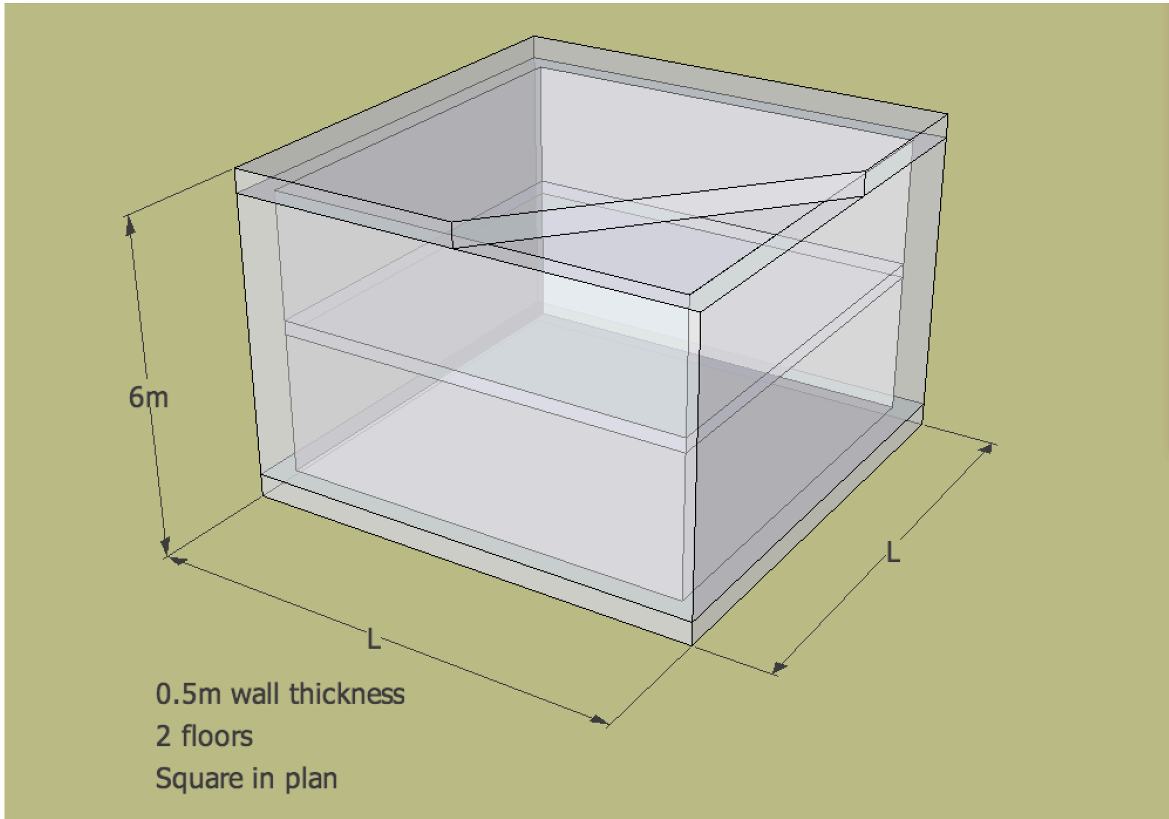
Thanks to members of the Passivhaus Trust for technical review.

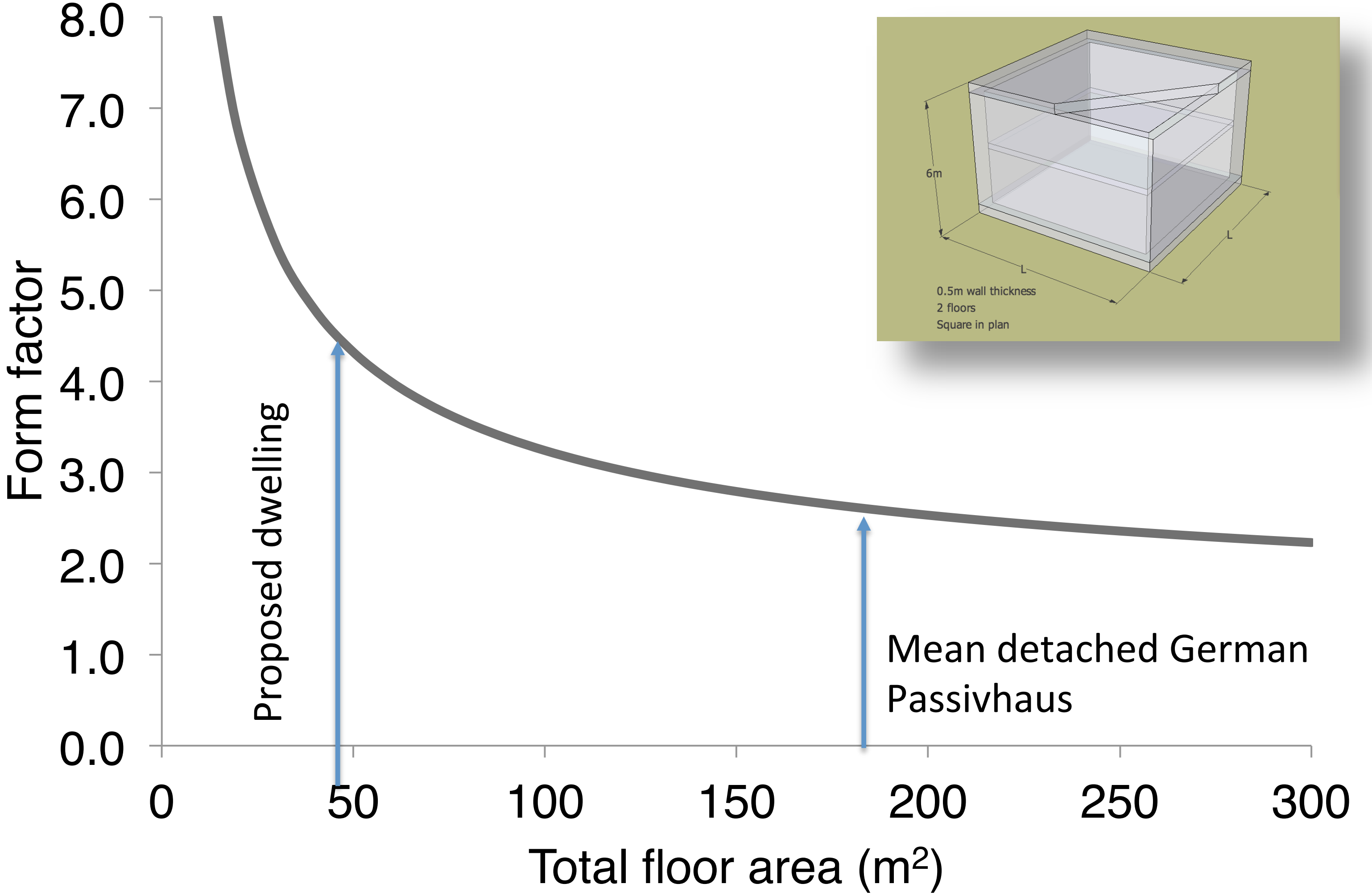
Small is beautiful but tricky in PHPP



Our model building:
2 floors
Square in plan
6m fixed height
0.5m wall, roof and floor thickness
L= 3.6m to 13.3m

Plotting form factor v Floor area

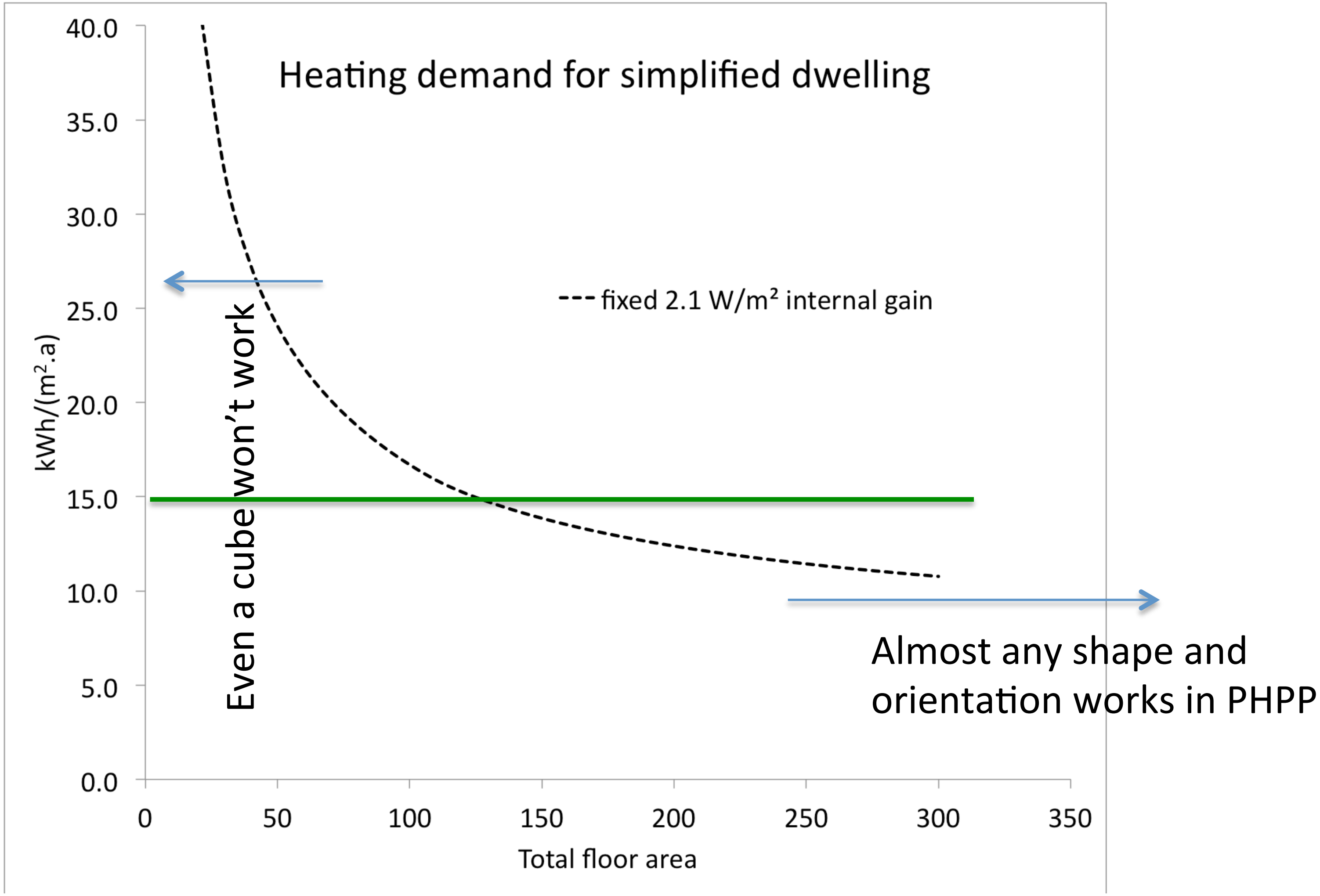
Form factor = heat loss area / floor area



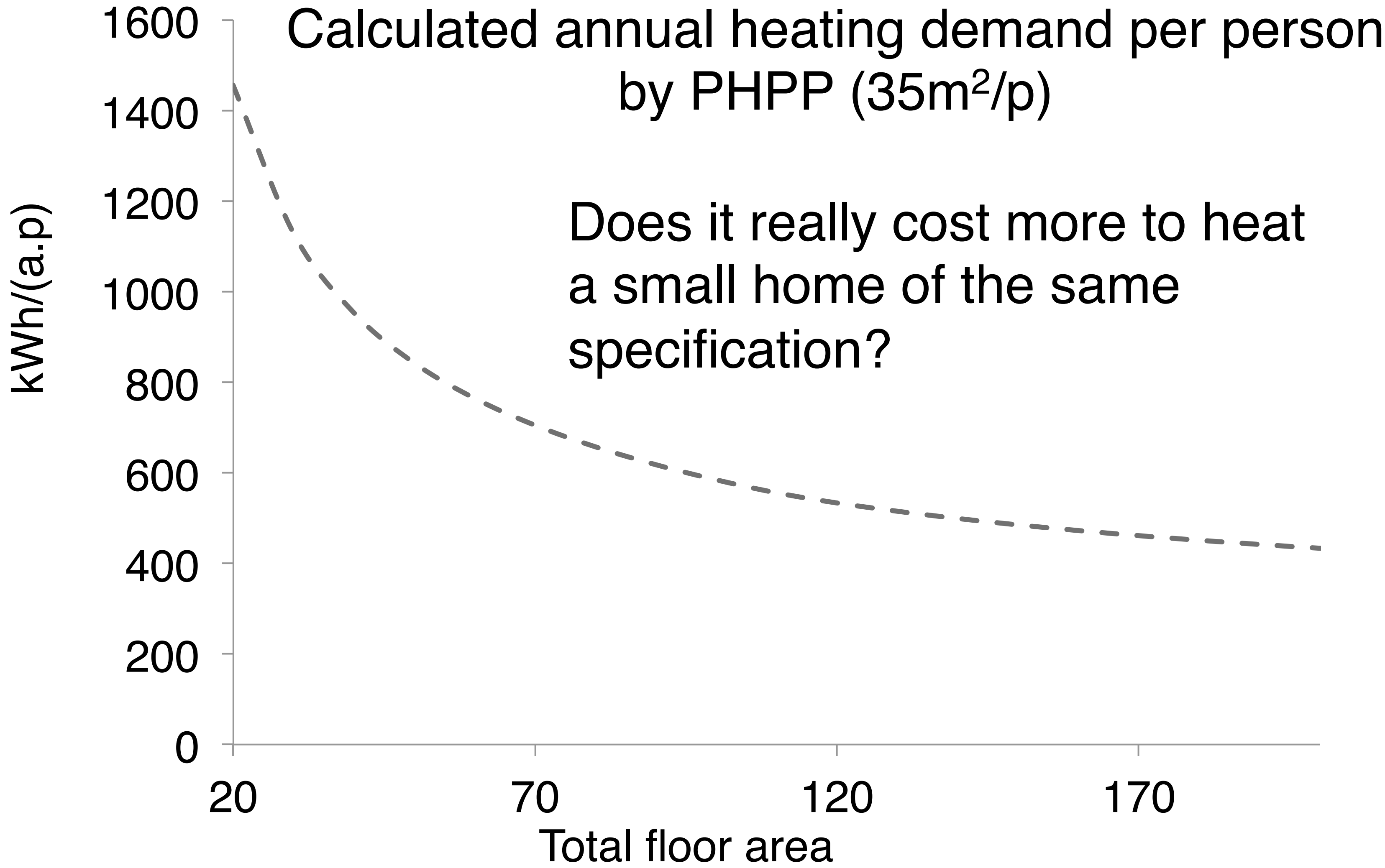
Plotting Annual heat v floor area

smaller dwellings appear less efficient

0.1 U values, PH vent and glazing, simplest form etc, same for all sizes



But small area so should still use less?



This doesn't fit my anecdotal experience:

15m^2 living off grid for 7 years, 100mm insulation & double glazed but cosy warm with twigs and body heat.

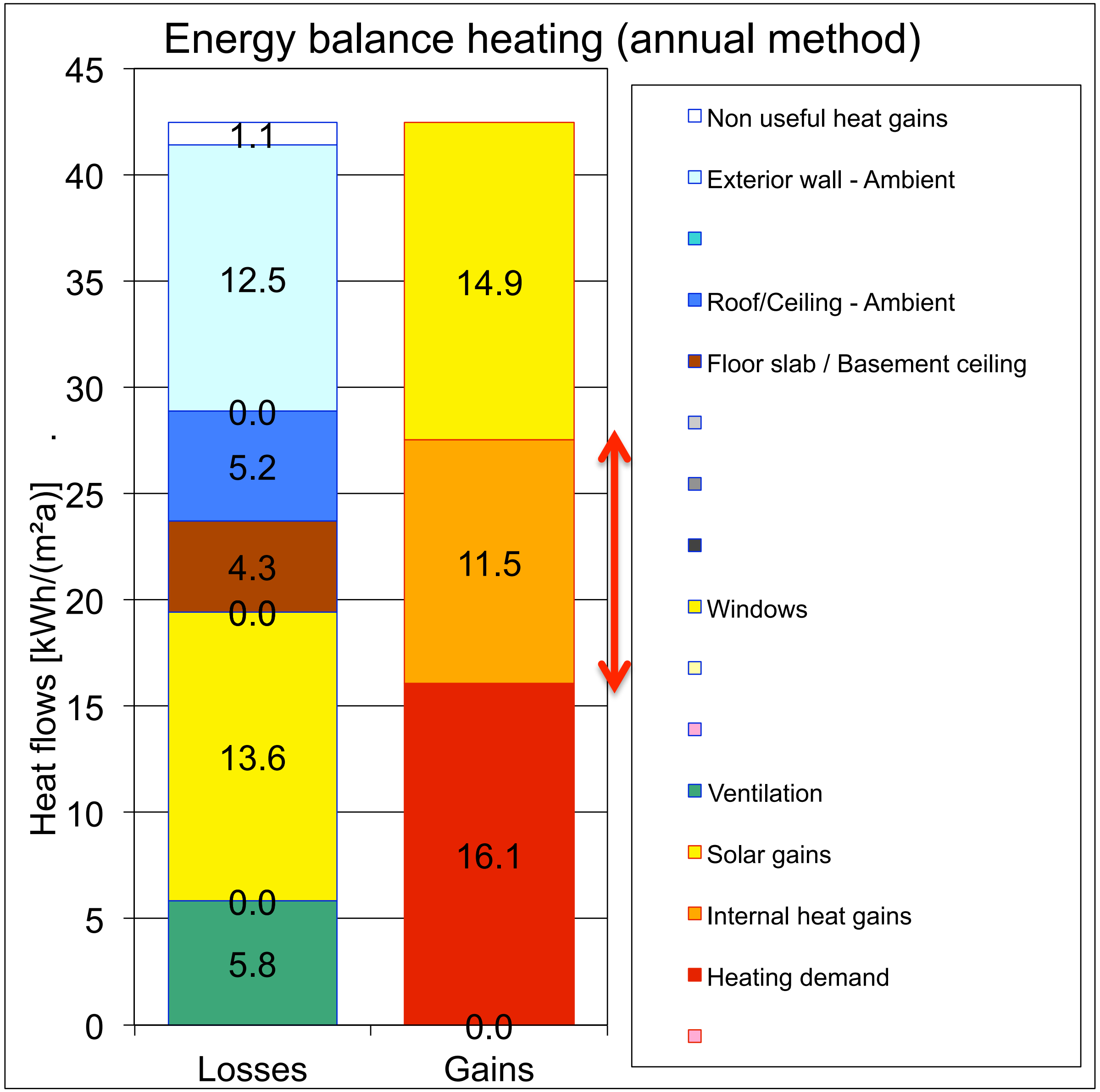
1/3 not 3x the fuel to heat our larger super-insulated house

What about a tiny envelope, in an extreme climate?

Is high form factor compensated by higher specific gains?

National Geographic

About a third ± PH heating is from IHGs



2.1 W/m^2 IHG breakdown:

Calculated in PHPP IHG sheet (DHW not included):

Per person:
Metabolic, lighting people, drying towels, some appliances

≅ 54W/p

Per m^2:
Aux electric, lighting space, DHW distribution, pot plant evaporation?

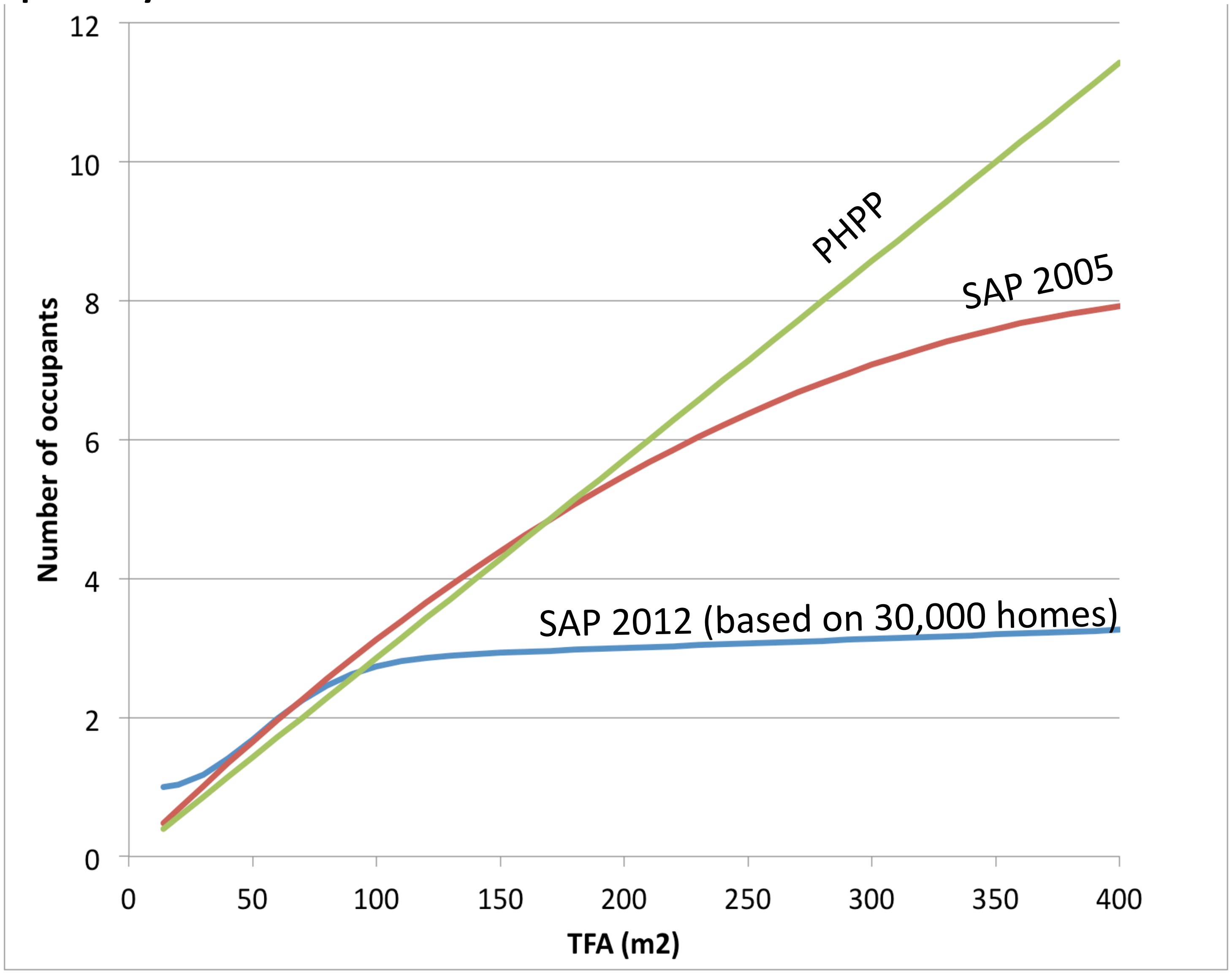
≅ 0.1W/m^2

Per dwelling:
Fridge, freezer, appliances, boiler DHW base storage

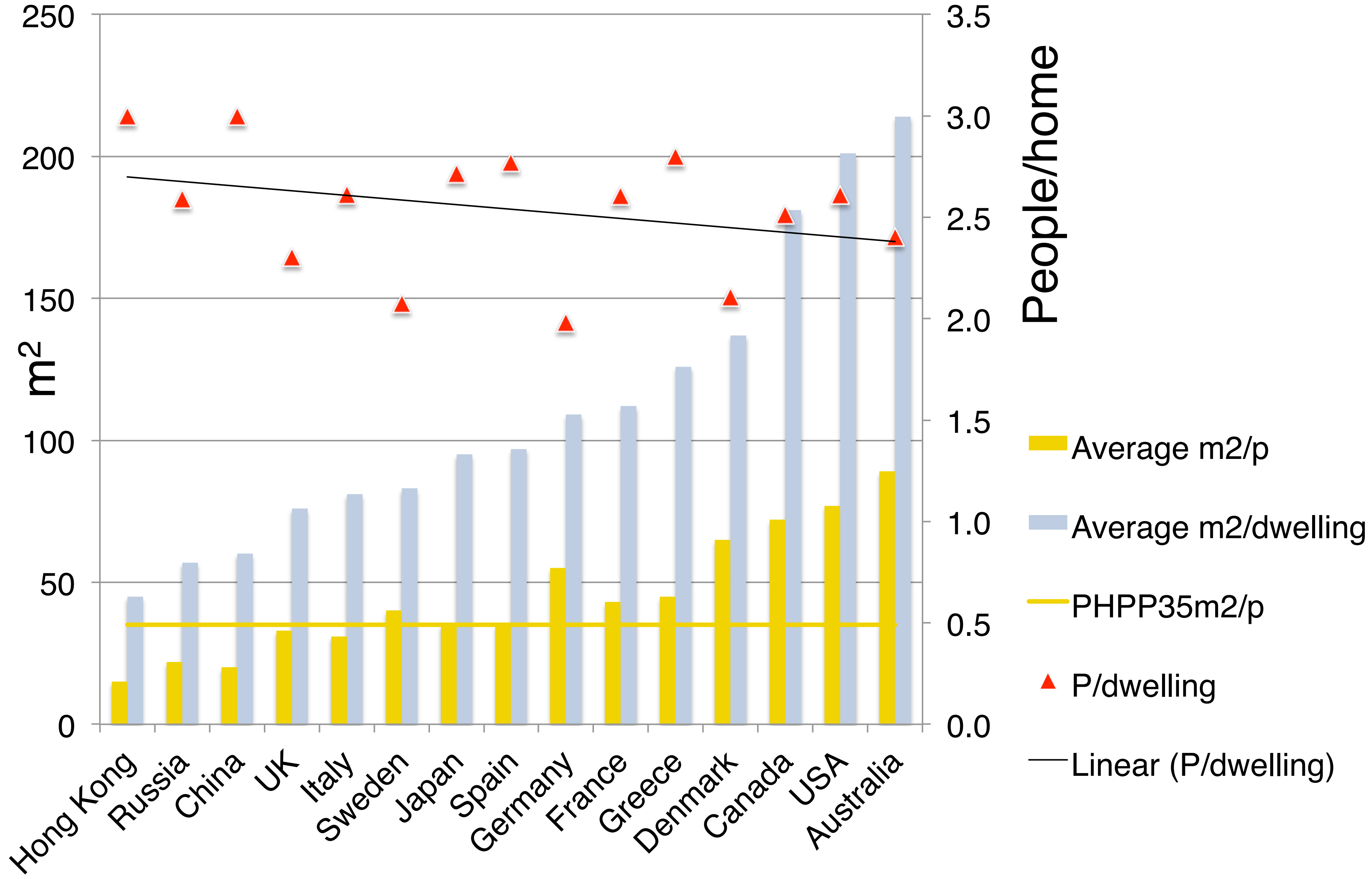
≅105W/dwelling

But how many people?

Occupancy v TFA



Is UK occupancy data relevant?



IHG calculated using PHPP assumptions with BRE occupancy rate.

Passive House planning: **INTERNAL HEAT GAINS**

Building: Slate Cottage

Utilisation pattern: Dwelling | 2.10 W/m²

Type of values used: Standard | 3.22 W/m² in summer | No data input necessary | 1.99 W/m²

Go to utilisation pattern selection

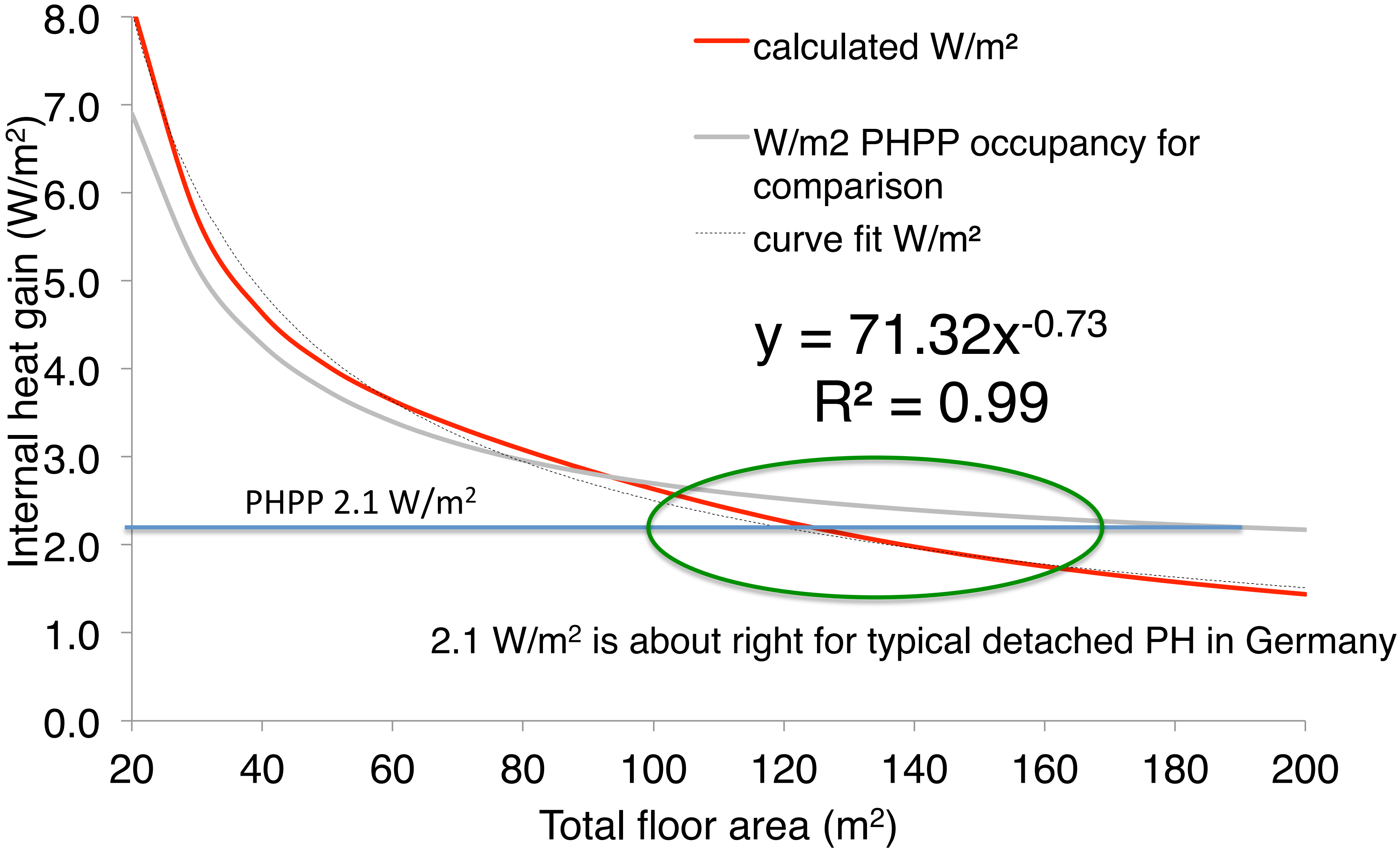
Calculation
Internal heat household

Persons: 3.8 P | Living area: 134 m²

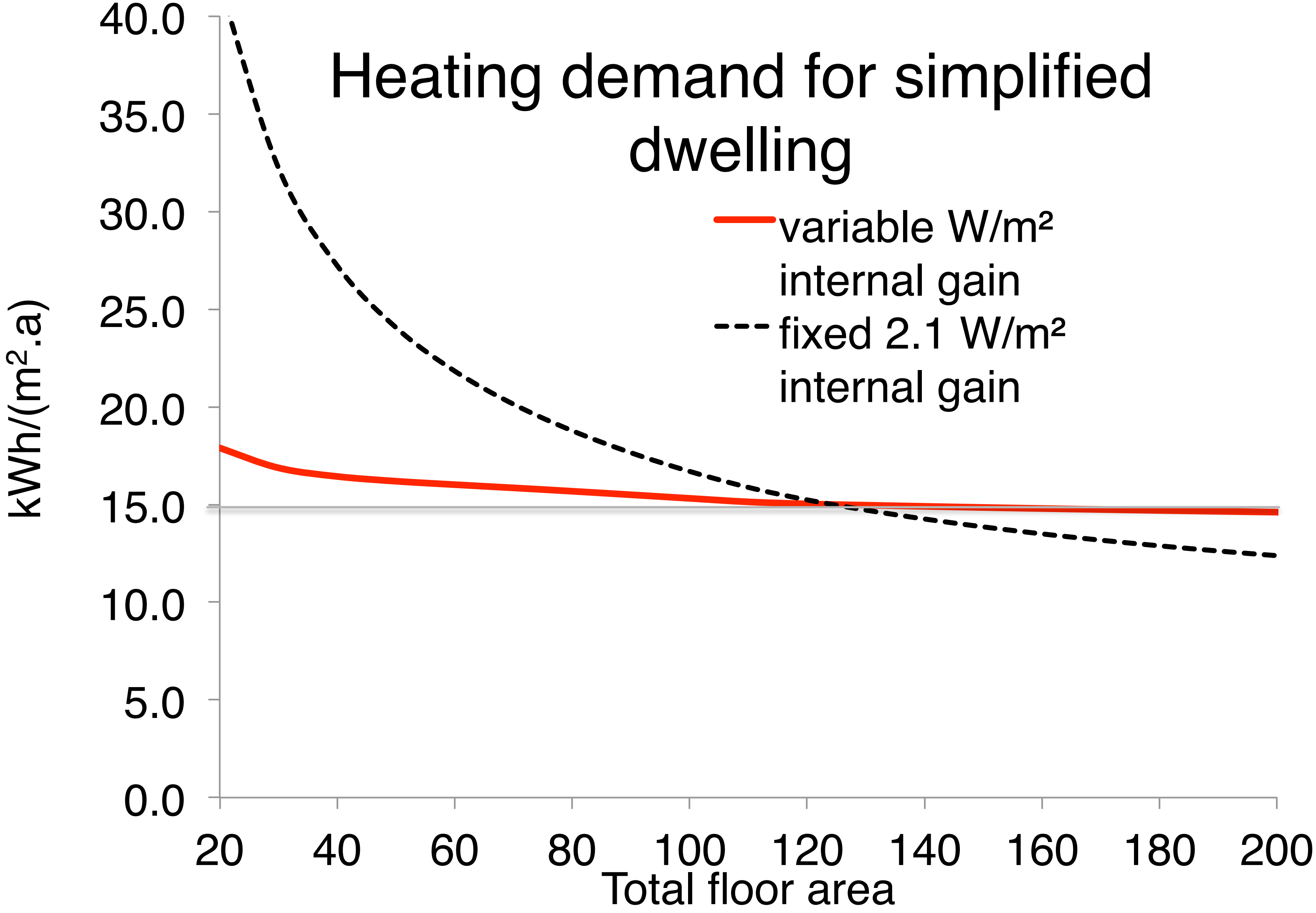
Heating demand: 16 kWh/(m²a) | Heating period: 228 d/a

Column nr.	1	2	3		4	5		6	7	8	9	10
Application	Existing (1/0), or number of people	Within the thermal envelope (1/0)	Norm consumption		Utilization factor	Frequency		Useful energy (kWh/a)	Included in electricity balance?	Availability	Used during time period (kh/a)	Internal heat source Winter (W)
Dishwashing	1	1	1.1	kWh/Use	1.00	65	/(P*a)	274		0.30	8.76	9
Clothes washing	1	1	1.1	kWh/Use	1.00	57	/(P*a)	240		0.30	8.76	8
Clothes drying with:	1	1	3.5	kWh/Use	0.88	57	/(P*a)	668		0.70	8.76	53
Condensation dryer		1	0.0					0		0.80		
Energy consumed by evaporation	0	1	-3.1	kWh/Use	0.60	57	/(P*a)	0	* (1- 0) *	0.00	8.76	0
Refrigerating	1	1	0.8	kWh/d	1.00	365	d/a	285		1.00	8.76	33
Freezing	1	1	0.9	kWh/d	1.00	365	d/a	321		1.00	8.76	37
or combination	0	1	1.0	kWh/d	1.00	365	d/a	0		1.00	8.76	0
Cooking	1	1	0.3	kWh/Use	1.00	500	/(P*a)	479		0.50	8.76	27
Lighting	1	1	60.0	W	1.00	2.9	kh/(P*a)	666		1.00	8.76	76
Consumer electronics	1	1	80.0	W	1.00	0.55	kh/(P*a)	168		1.00	8.76	19
Household appliances/Other	1	1	50.0	kWh	1.00	1.0	/(P*a)	191		1.00	8.76	22
Auxiliary appliances (cf. aux Electricity sheet)												0
Other applications (cf. Electricity sheet)	0	0.0						0		0	8.76	0
Persons	4	1	80.0	W/P	1.00	8.76	kh/a	2683		0.55	8.76	168
Cold water	4	1	-4.7	W/P	1.00	8.76	kh/a					-18
DHW - circulation	1	1	91.7	W	1.00	8.76	kh/a	803		1.00	8.76	92
DHW - individual pipes	1	1	0.6	W	1.00	8.76	kh/a	5		1.00	8.76	1
DHW - storage	0	0	0.0	W	1.00	8.76	kh/a	0		1.00	8.76	0
Evaporation	4	1	-25.0	W/P	1.00	8.76	kh/a	-838		1.00	8.76	-96
Total											W	339
Specific demand											W/m²	2.53
Heat available from internal sources									227.5 d/a		kWh/(m²a)	13.8

IHG with BRE occupancy to obtain curve fit



Annual Heat demand
Using IHG = $71TFA^{-0.73}$



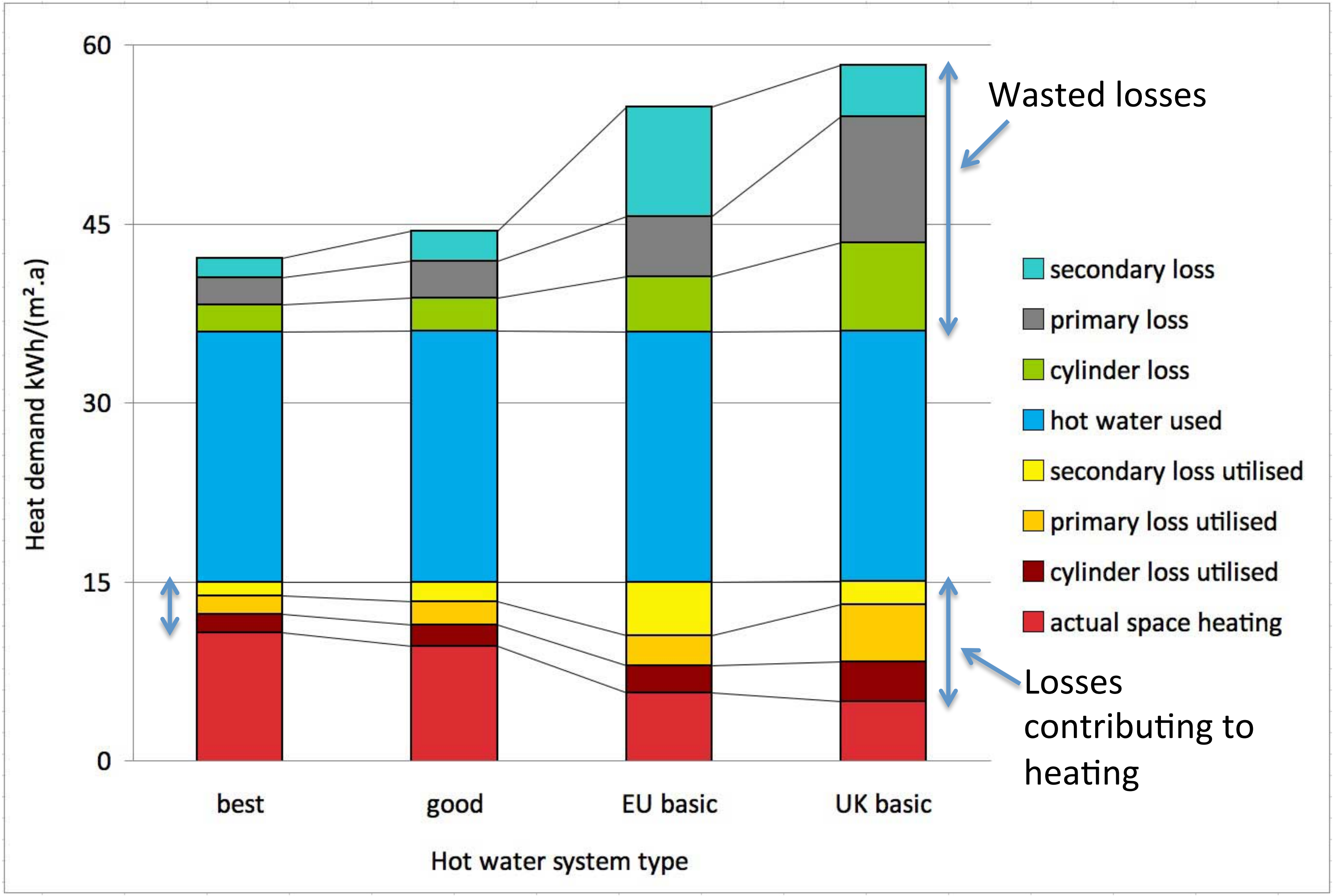
“All models are wrong, some are useful”
George Box

IHG assumptions will never be correct over the life of building but an improved heuristic* model will better reflect reality for smaller and larger buildings.

The downsides of overestimating IHGs for small buildings are less than for underestimating.

*Rule of thumb/trial and error

'The importance of hot water system design in the passivhaus' Clarke & Grant Dresden 2010



Assume state of the art DHW

Dwelling will probably have either:

1. Hot water distribution from central system:

   Say 15m x 15mm pipe with 25mm insulation
   = 45W ignoring conduction to outlets etc.

Or:

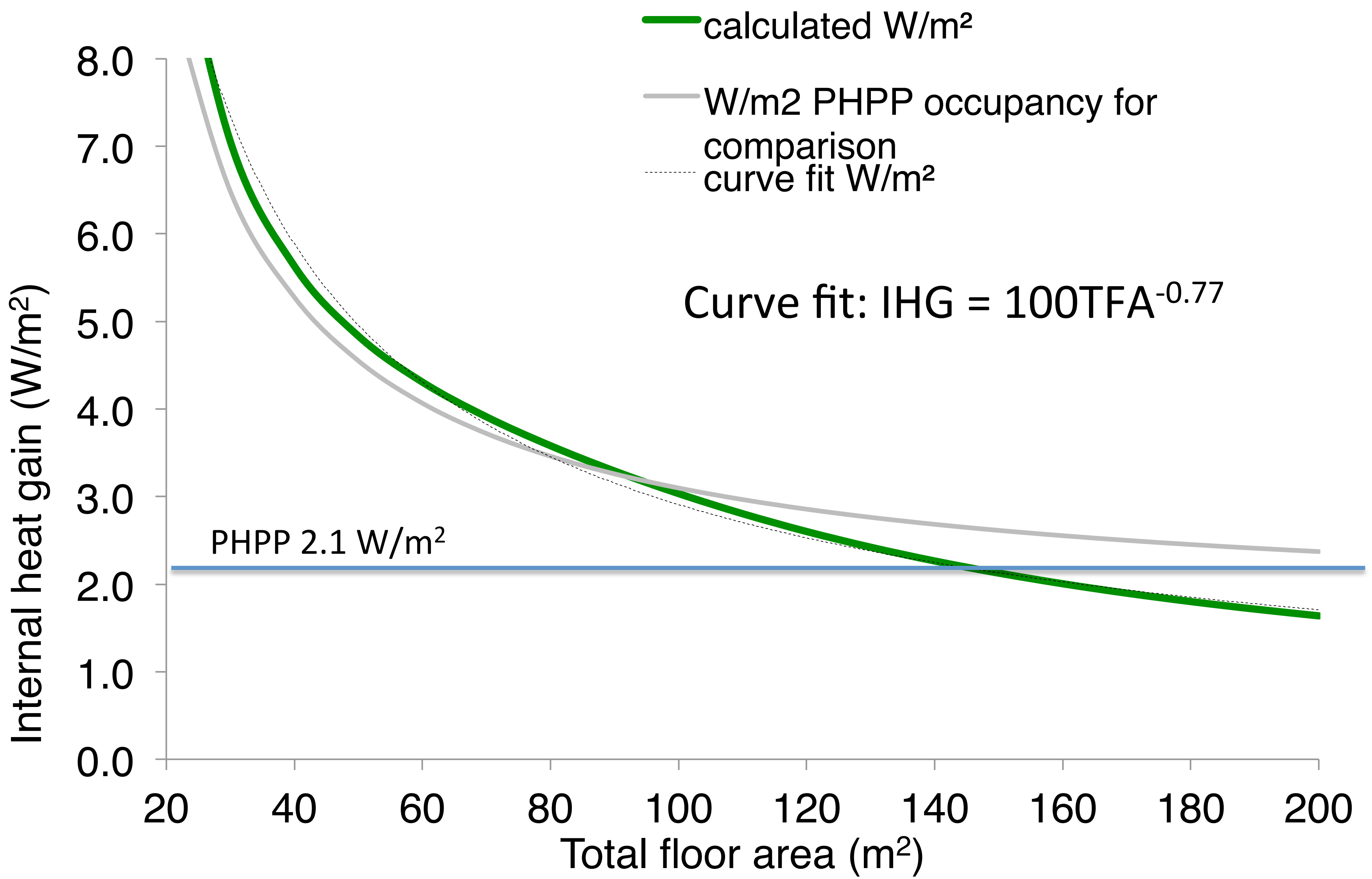
2. Storage:

   3W/K PHPP default = 120W
   2W/K minimum in PHPP = 80W

Plus distribution losses and actual DHW use heating space

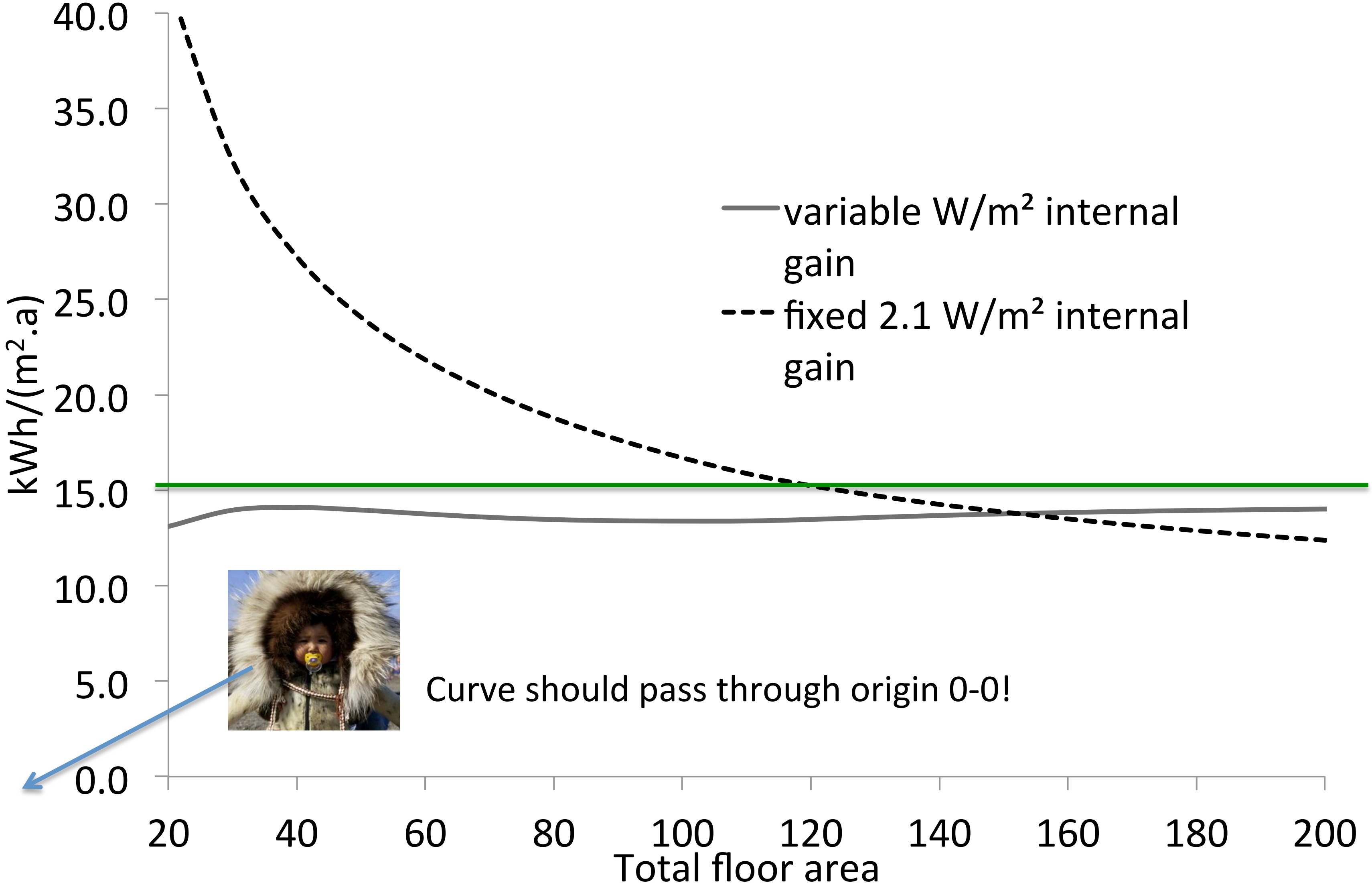
Can we agree **40W**/dwelling is a low estimate?

IHG including 40W/dwelling DHW losses

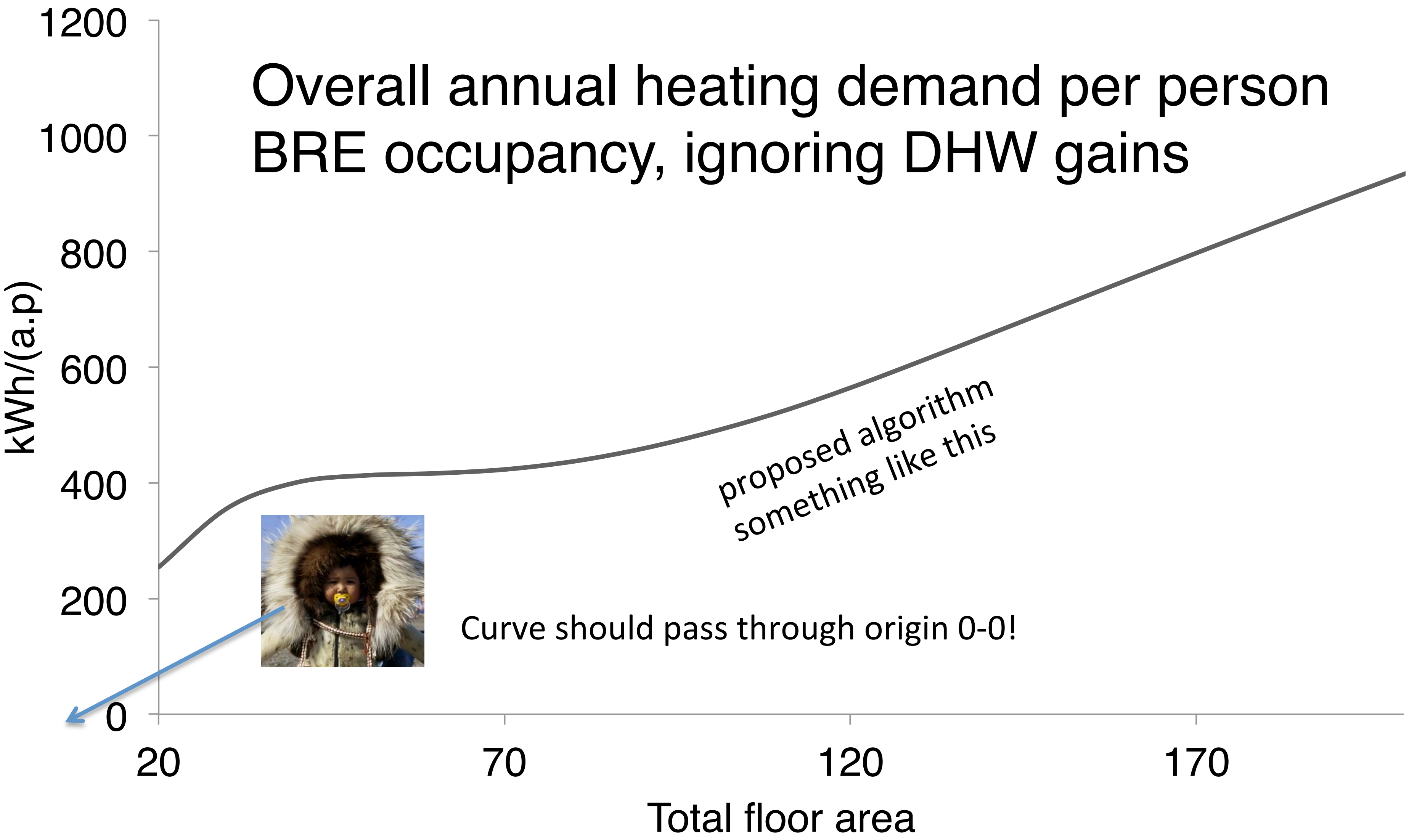


Adding 40W/dwelling DHW gains

IHG = 100TFA$^{-0.77}$



Small buildings do need less heat/p



Conclusions

- kWh/(m^2.a) metric validated, (usually criticised as favouring larger dwellings).
- Small homes work better than large ones.
- No relaxation is needed for small dwellings.
- Implications for summer overheating calculations.
- More realistic occupancy assumptions have implications for primary energy calculations.

Schools (in brief)

Δ Metabolic Heat Gains Only

School	**Children**	**TFA m^2**	**m^2/child**
Bushbury Hill (UK)	240	1707	7.1
Oakmeadow (UK)	450	2205	4.9
Montgomery (UK)	446	2367	5.3
Swillington (UK)	240	1344	5.6
Wilkinson (UK)	459	2500	5.4
LH Hannover (D)	300	3507	11.7
Gronau (D)	336	2953	8.8
Reidberg (D)	500	5540	11.1

Average for UK examples 5.7 m^2/child
Average for German examples 10.5 m^2/child

Difference +**1.32W/m^2** → **+ 5-6 kWh/(m^2.a) of useful heating**
Against 15kWh/(m^2.a) target

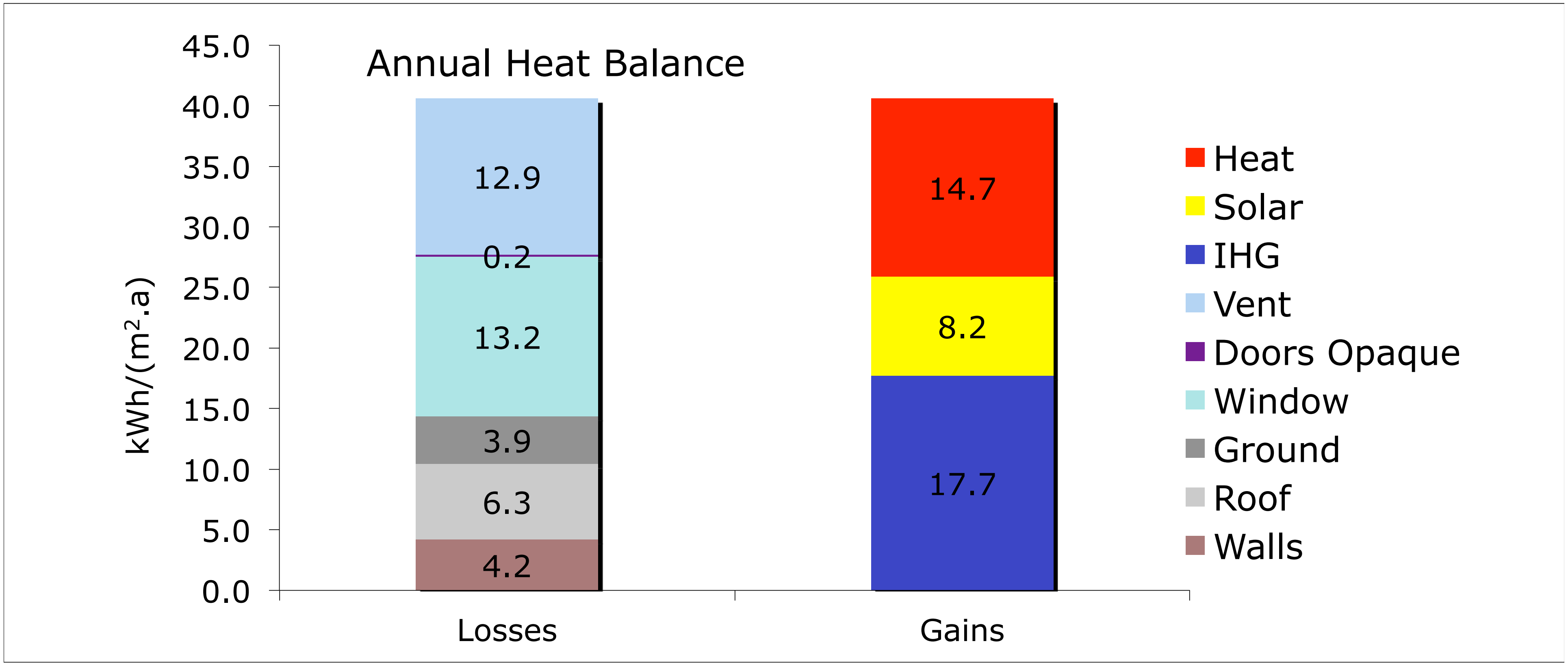
Less reliance on solar gain

3.8W/m² v 2.8W/m² IHG

Means we designed a different building

50% v 60% g glass

No additional south glazing just to meet 15kWh/(m².a)



Schools Conclusions

- Design is very sensitive to IHG assumptions.
- Too low an IHG assumption favours passive solar design with associated high cost and increased overheating risk.
- Custom IHG calculations could lead to game playing but occupancy density and time should be factored in.

- More detailed analysis could not be fitted into this paper.