UNIVERSITY OF WESTMINSTER

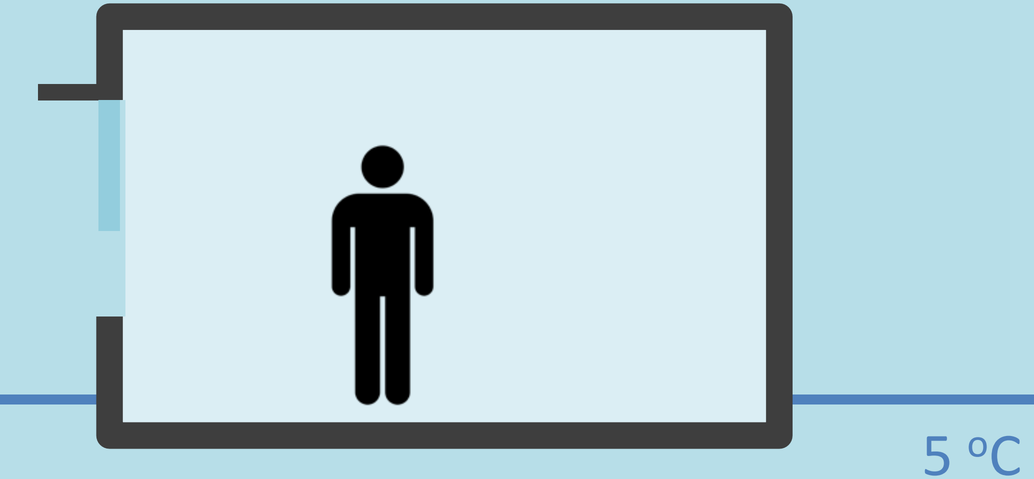
Energy Index and the Calculation of Heating Demand

Rosa Schiano-Phan, Zhenzhou Weng, Juan Vallejo, Sao Paulo 23rd Jan 2017

Energy Index and the Calculation of Heating Demand

- Space heating demand
- Indoor heat balance and heating
- A (simple) way of heating demand estimation
- Energy Index

Space heating demand



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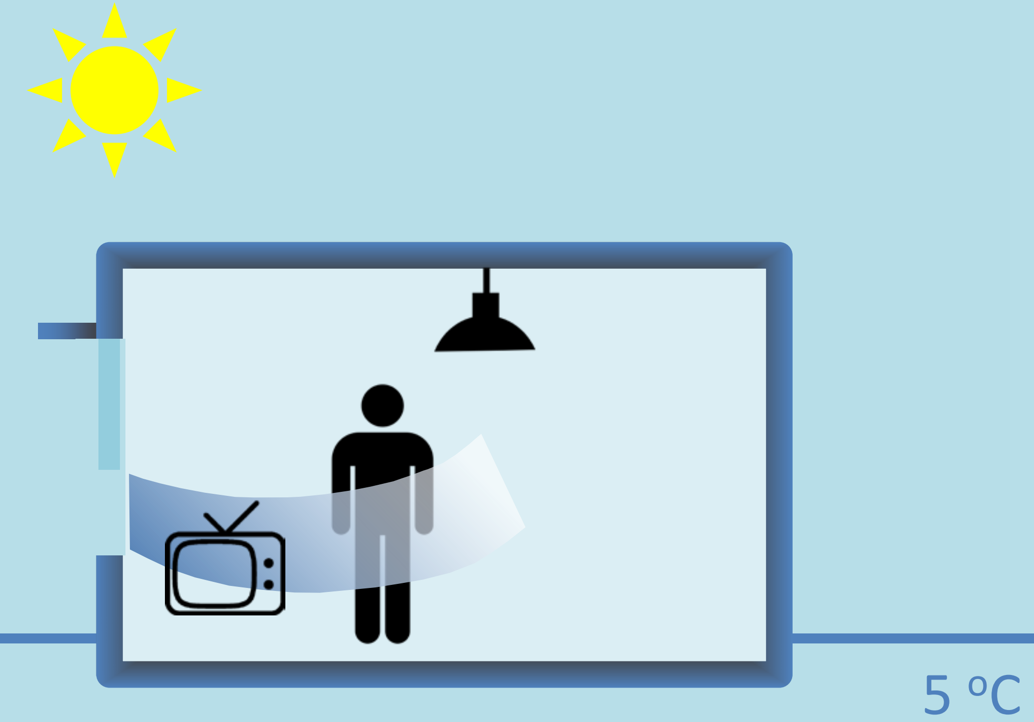

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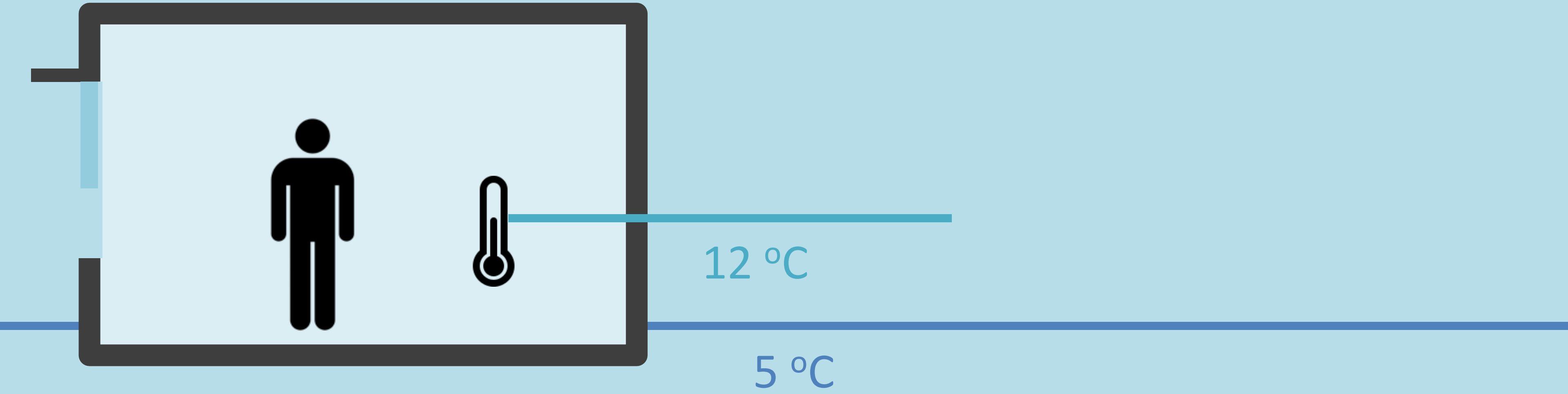

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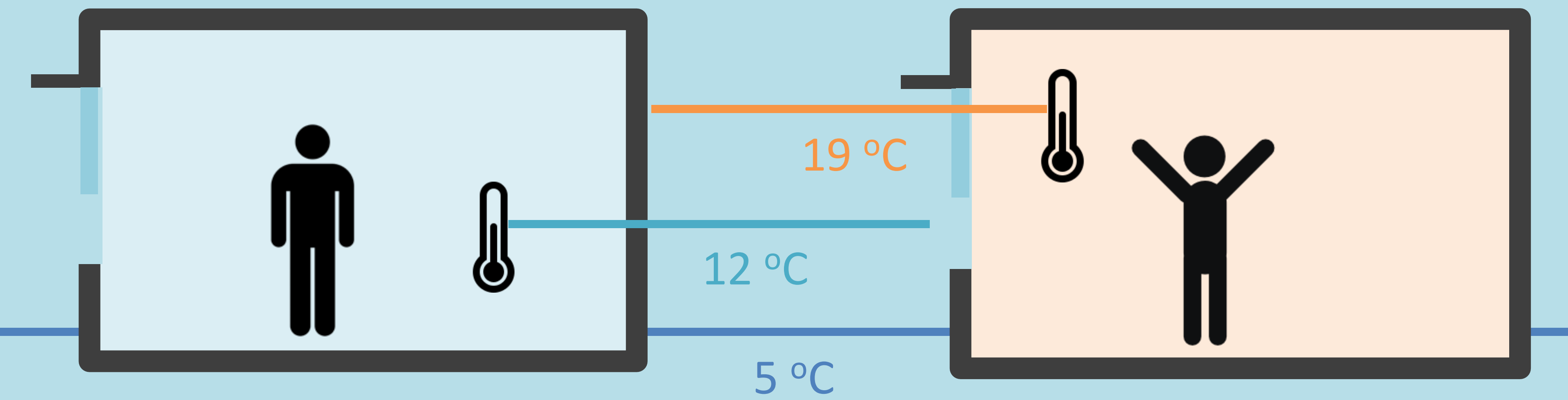

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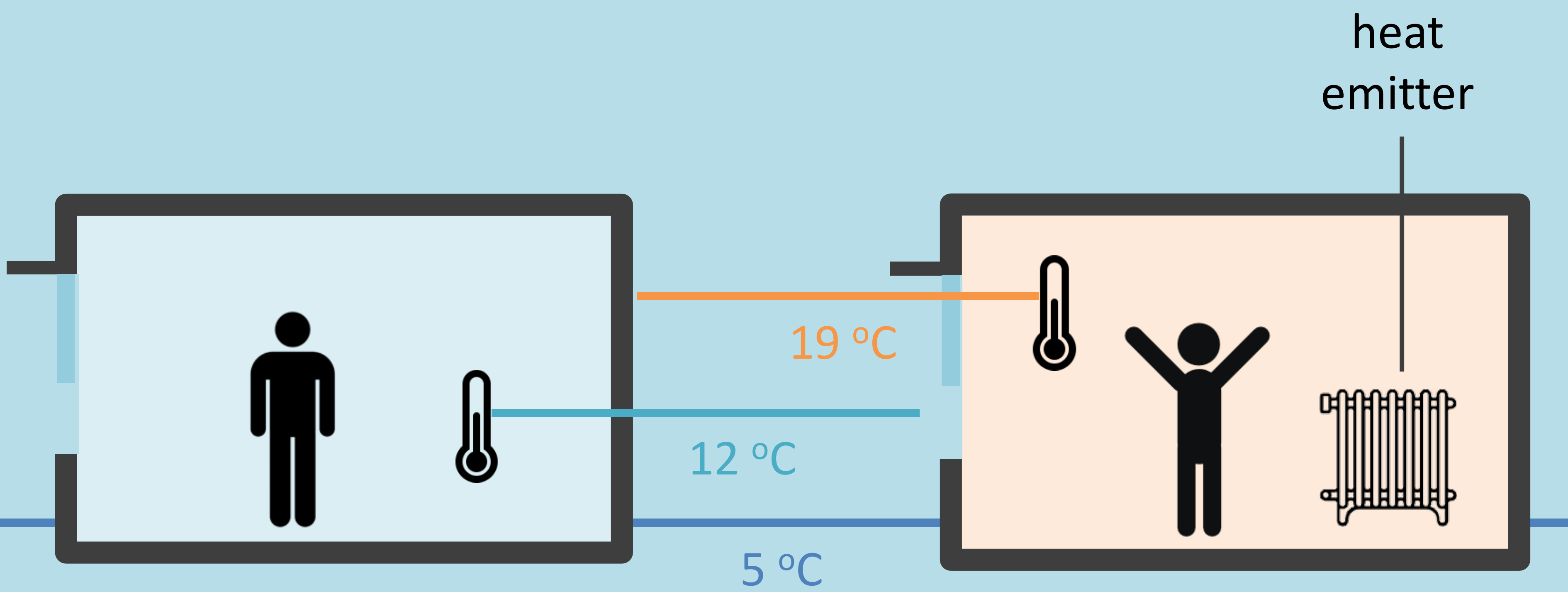

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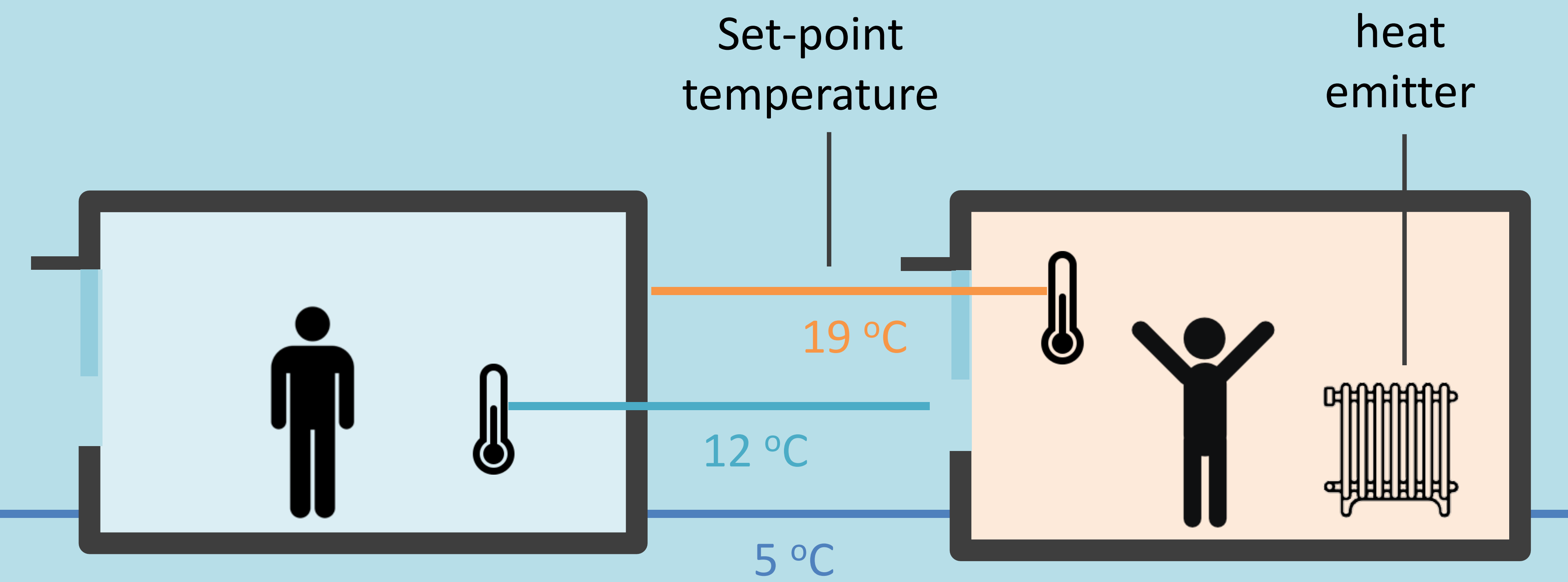

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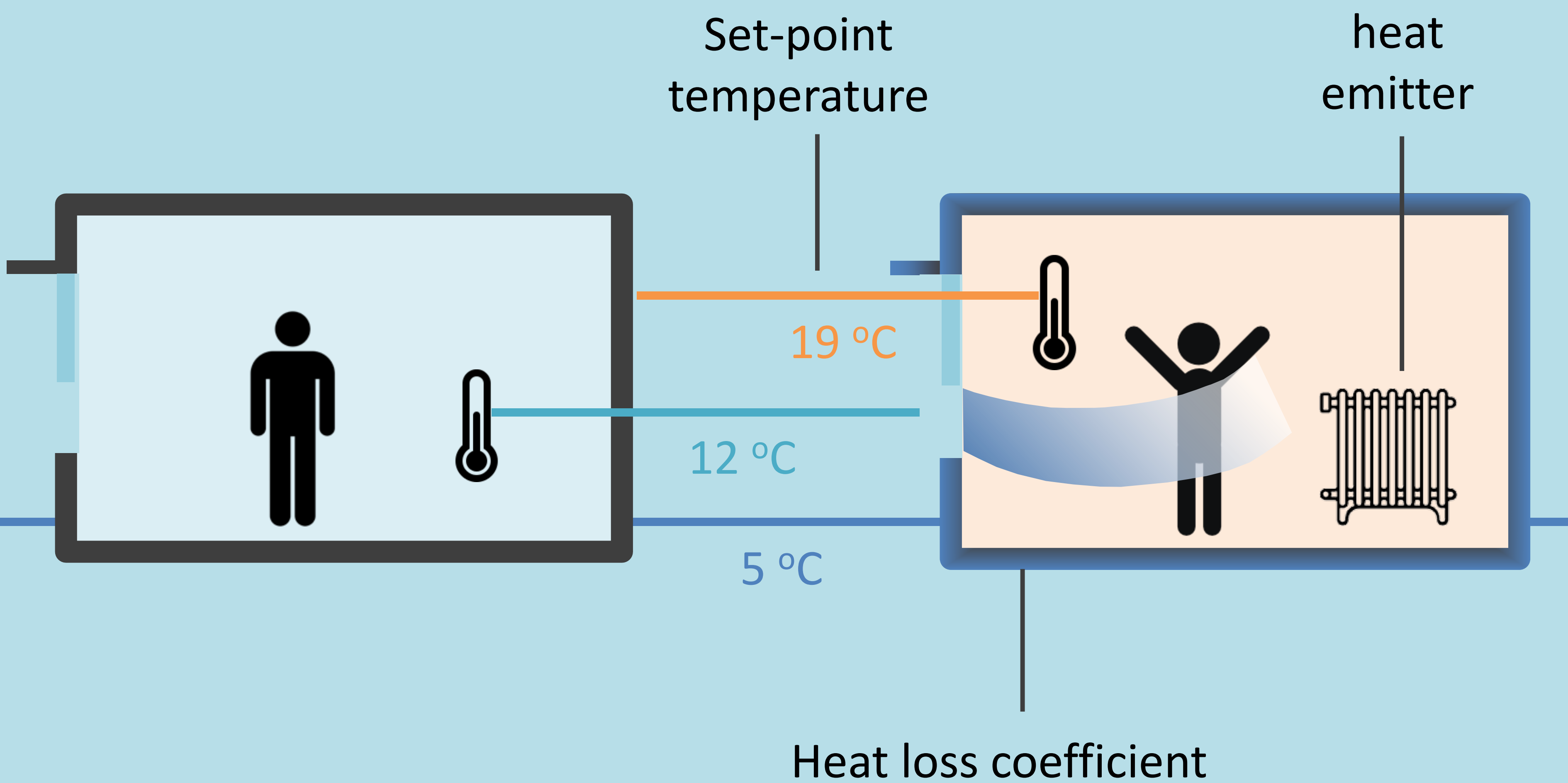

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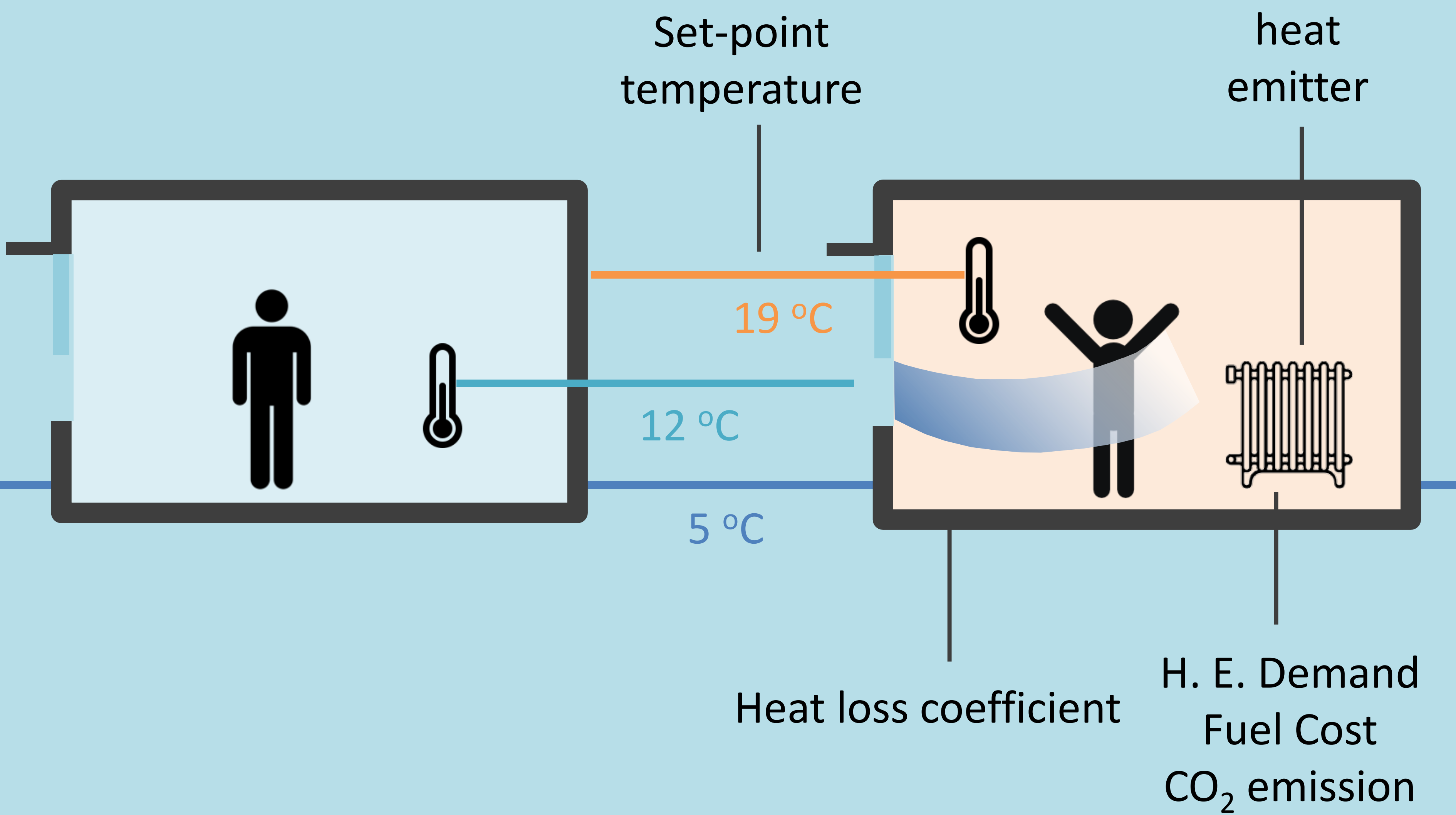
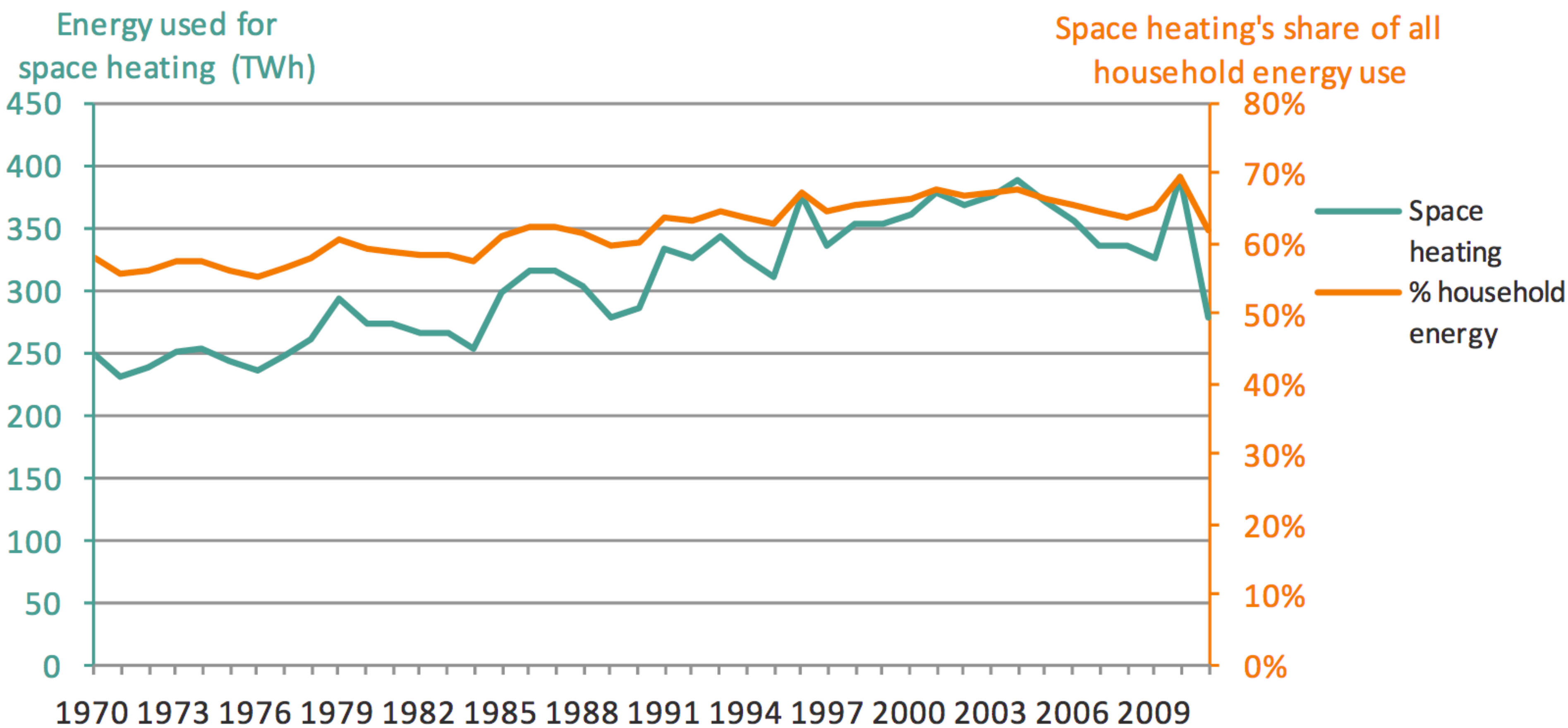


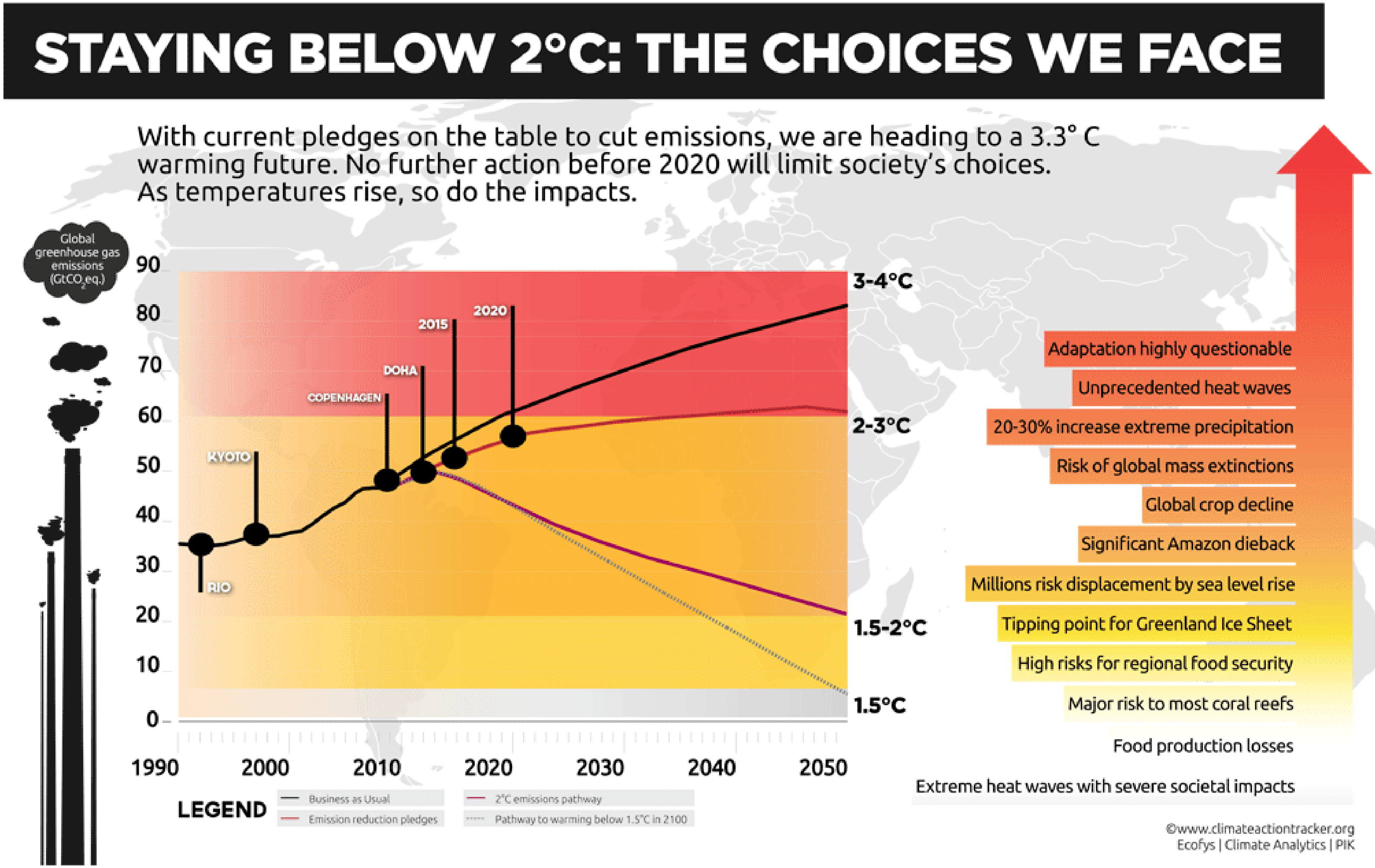
Space heating demand

Space heating accounts for 58% - 62% of household energy use in UK



UK. CAR, Eclipse. United Kingdom Housing Energy Fact File. By Jason Palmer and Ian Cooper. N.p.: n.p., 2013. Web. 09 July 2015.

Space heating demand



http://www.climatechangenews.com/2013/05/10/is-it-time-to-abandon-the-2-degree-warming-target/

Space heating demand

Reducing heating demand for the occupants

Cut running costs (i.e. heating bills)

Source: https://www.flickr.com/photos/59937401@N07/5856793551/player/2efa2e32af

Smaller mechanical systems, cutting installation and maintenance costs

Source: http://www.homesweethomefund.com/lower-the-cost-of-your-hvac-system/

The building relies less on mechanical systems to maintain comfort, therefore less risky

Source: http://humor-world.blogspot.co.uk/2008/09/feeling-cold.html

Indoor heat balance and heating

(Active) heating is provided to maintain the indoor heat balance at a desired temperature (set-point temperature)

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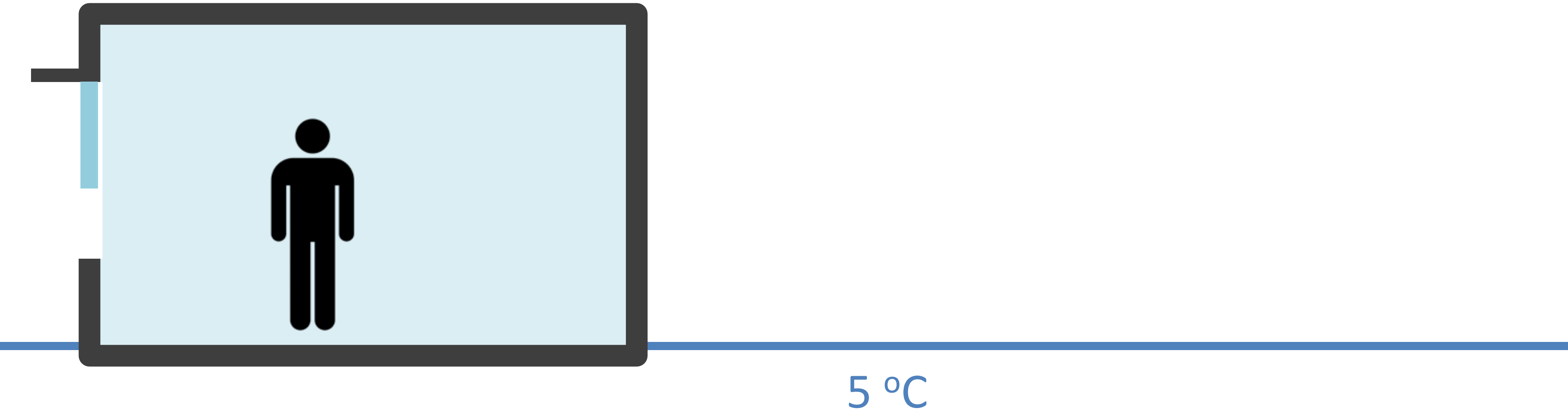

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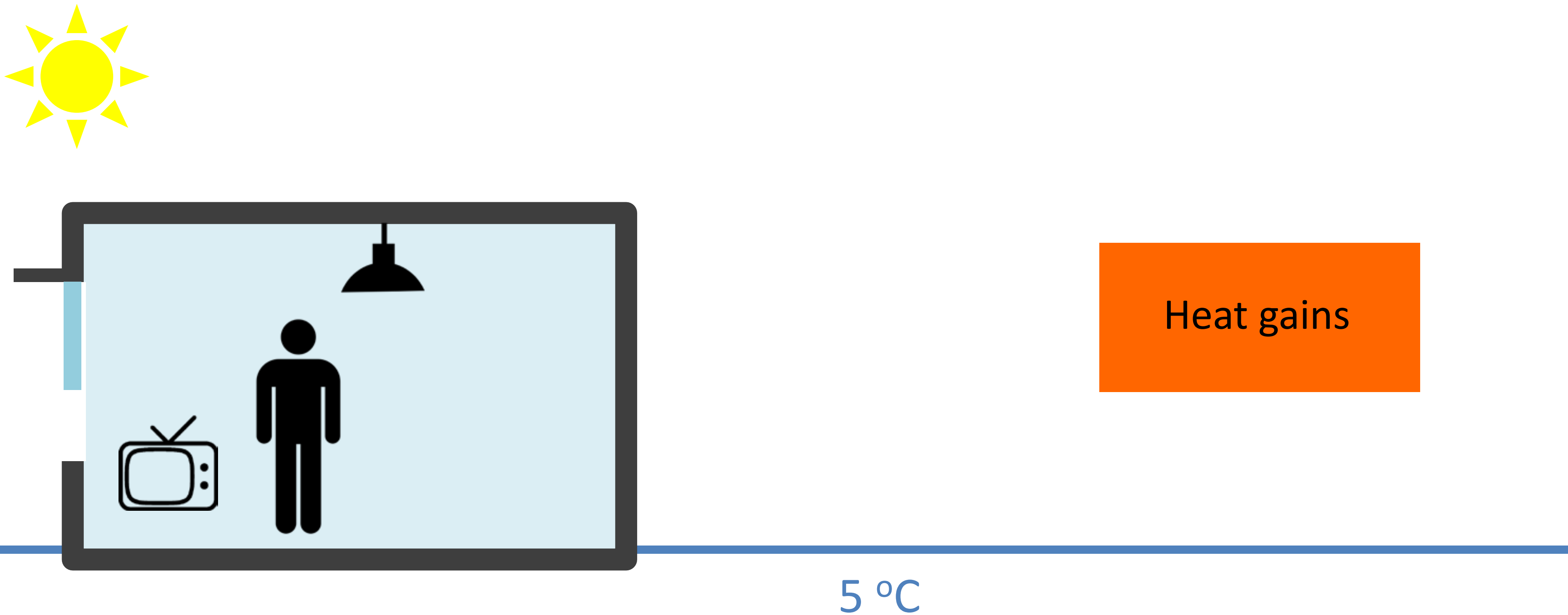

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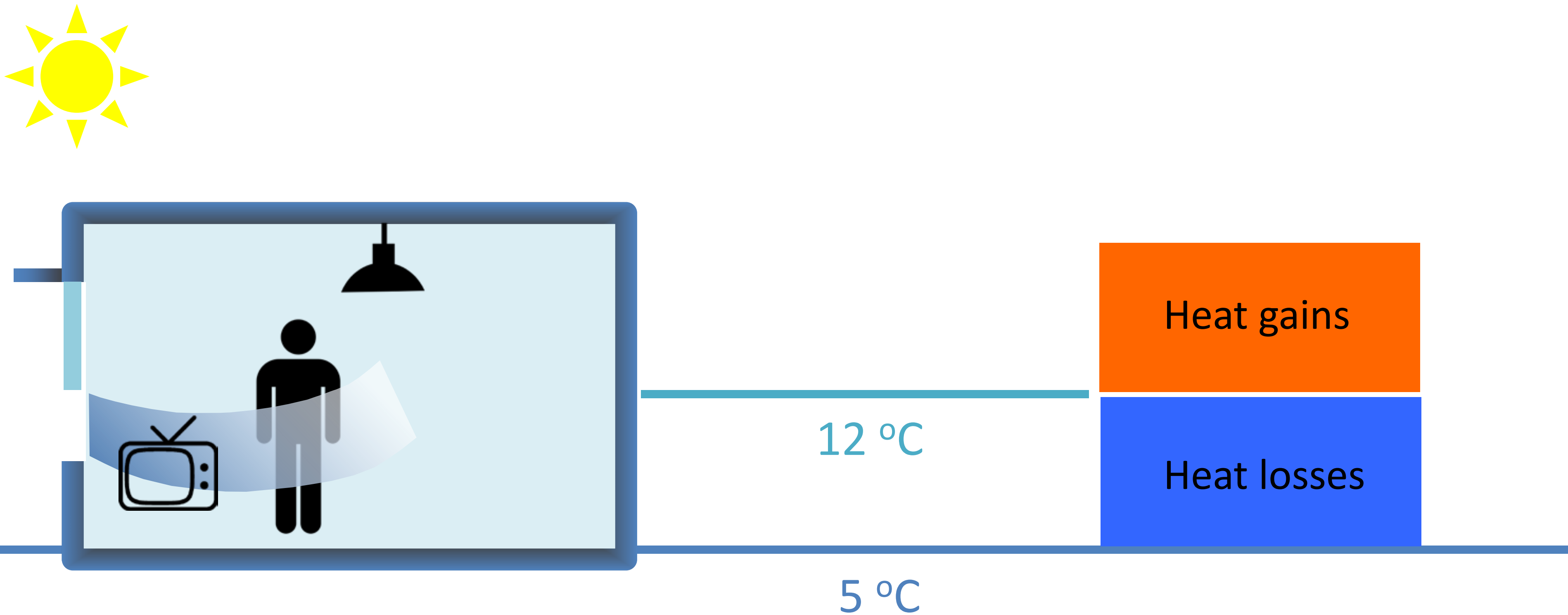

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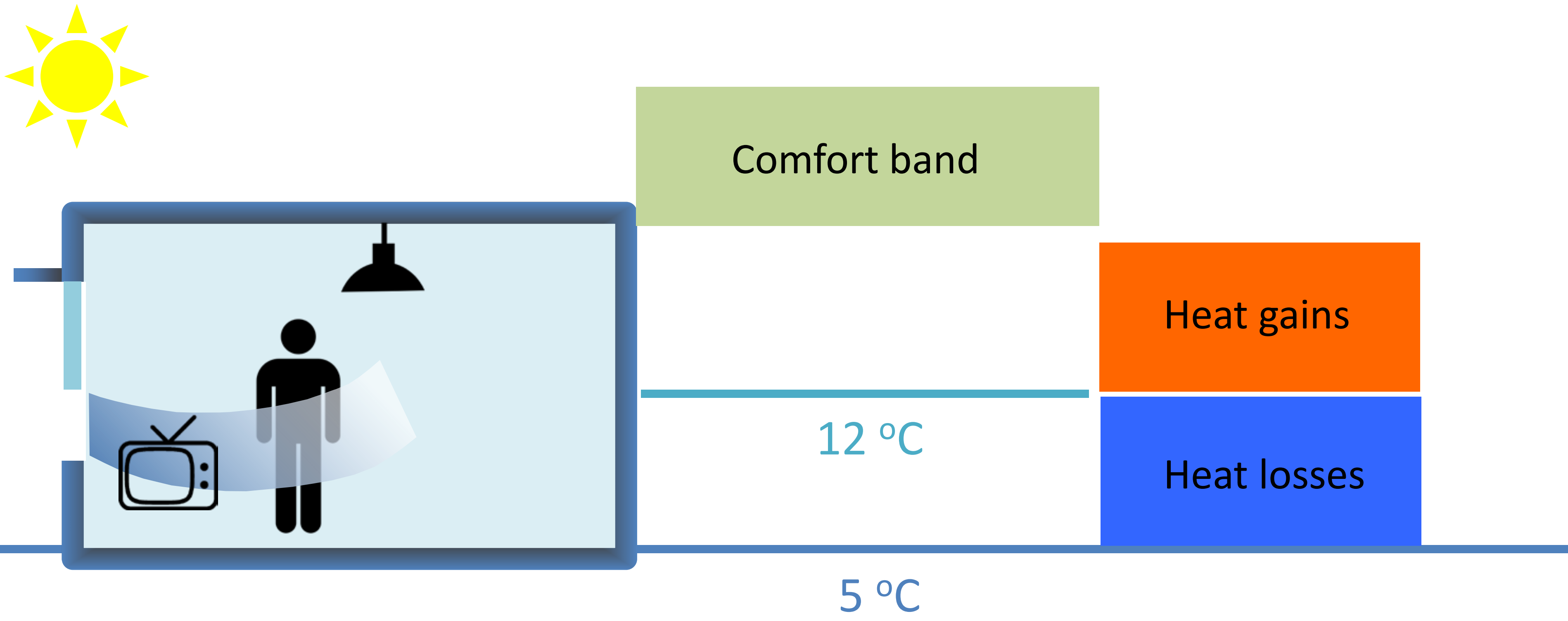

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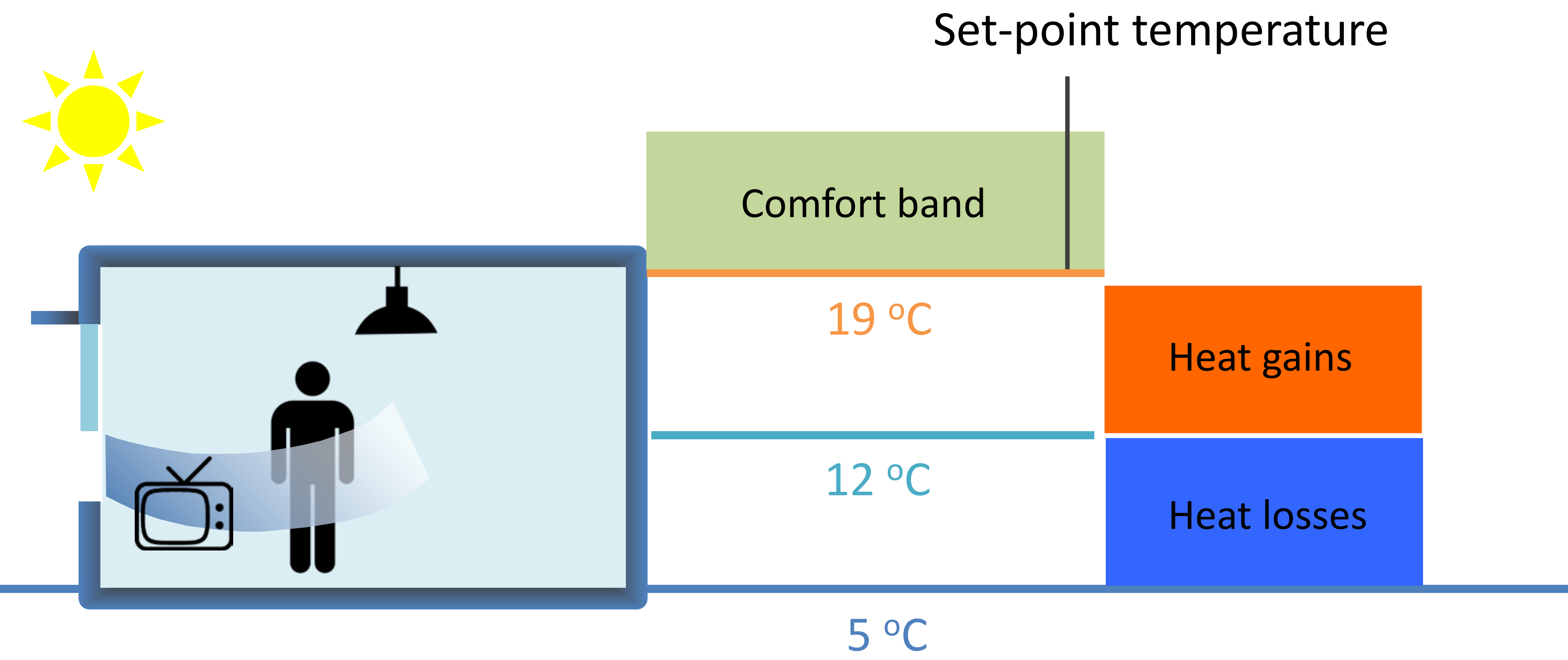

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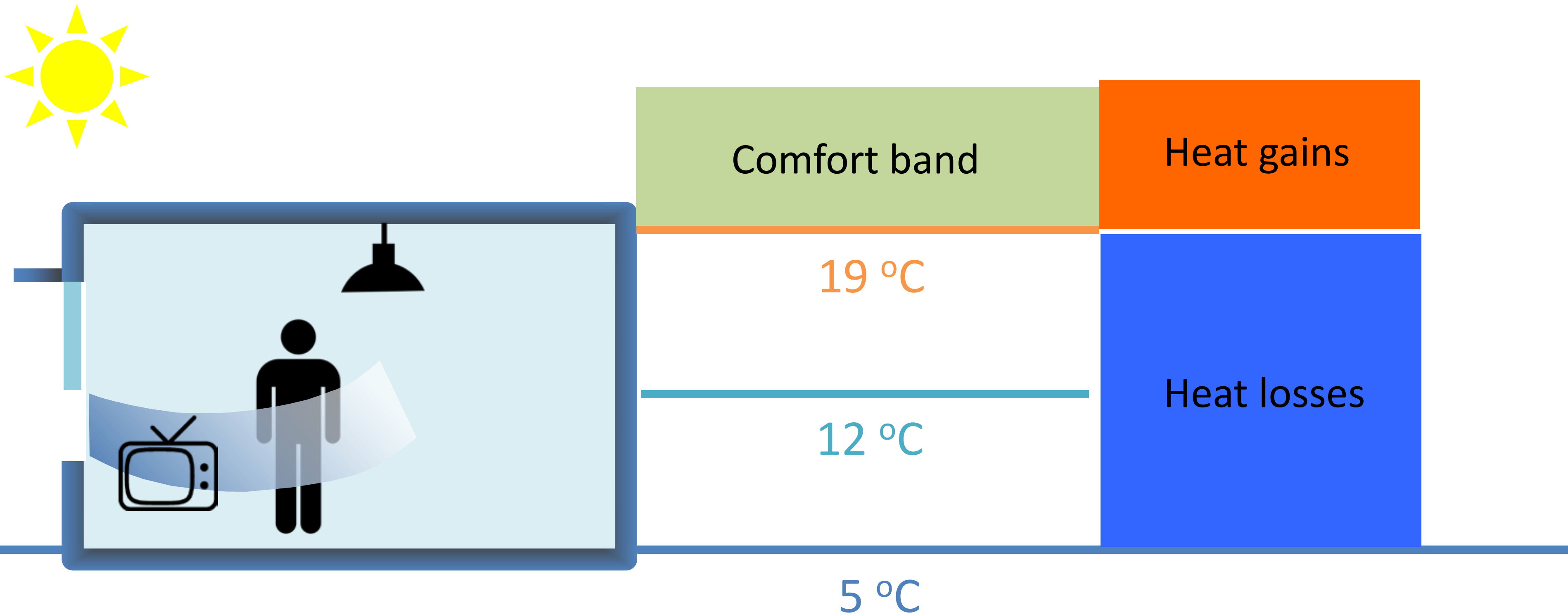

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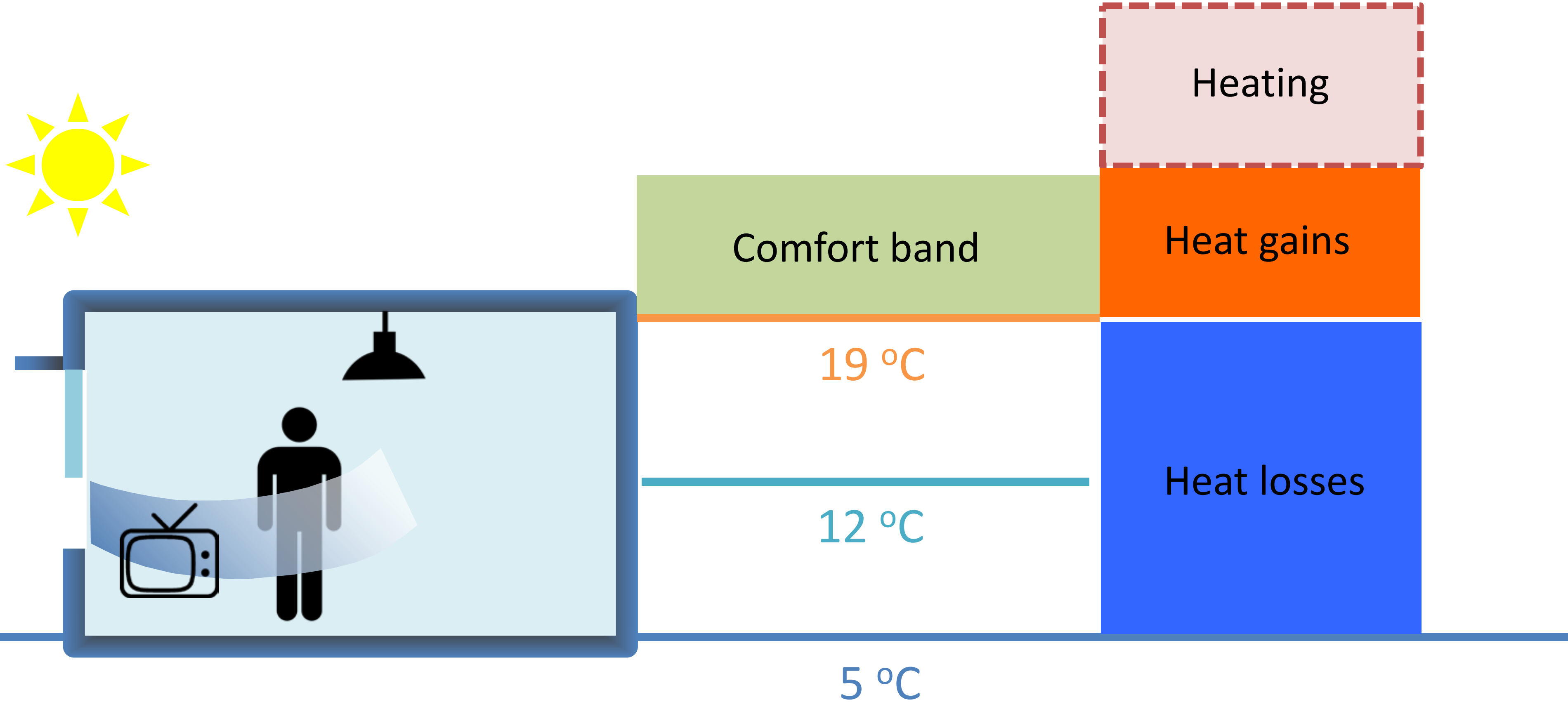
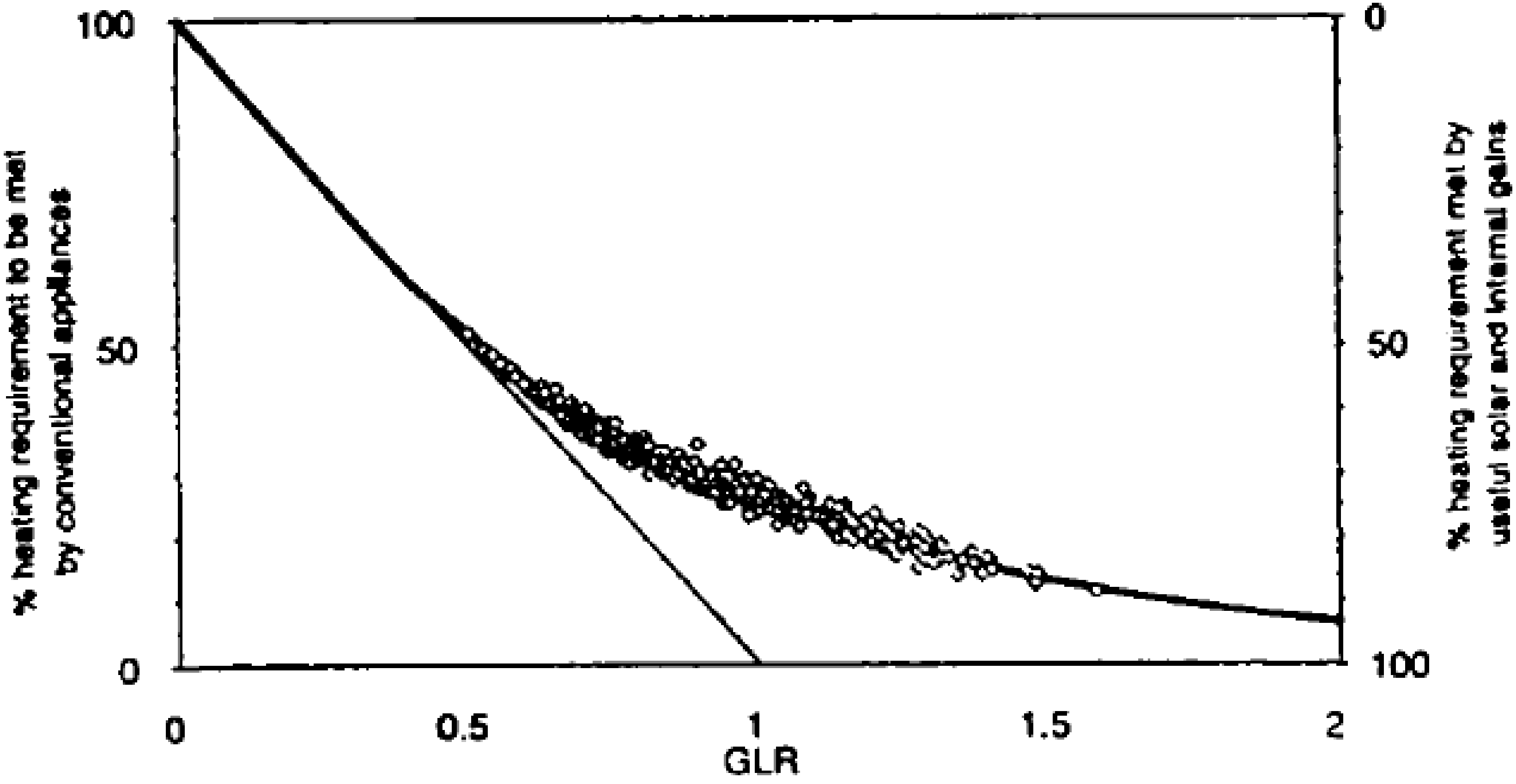


A (simple) way of heating demand estimation

Based on measurements and simulations of a large sample of residential buildings in the UK

GLR = (internal + solar) / (fabric + ventilation + infiltration) over the year



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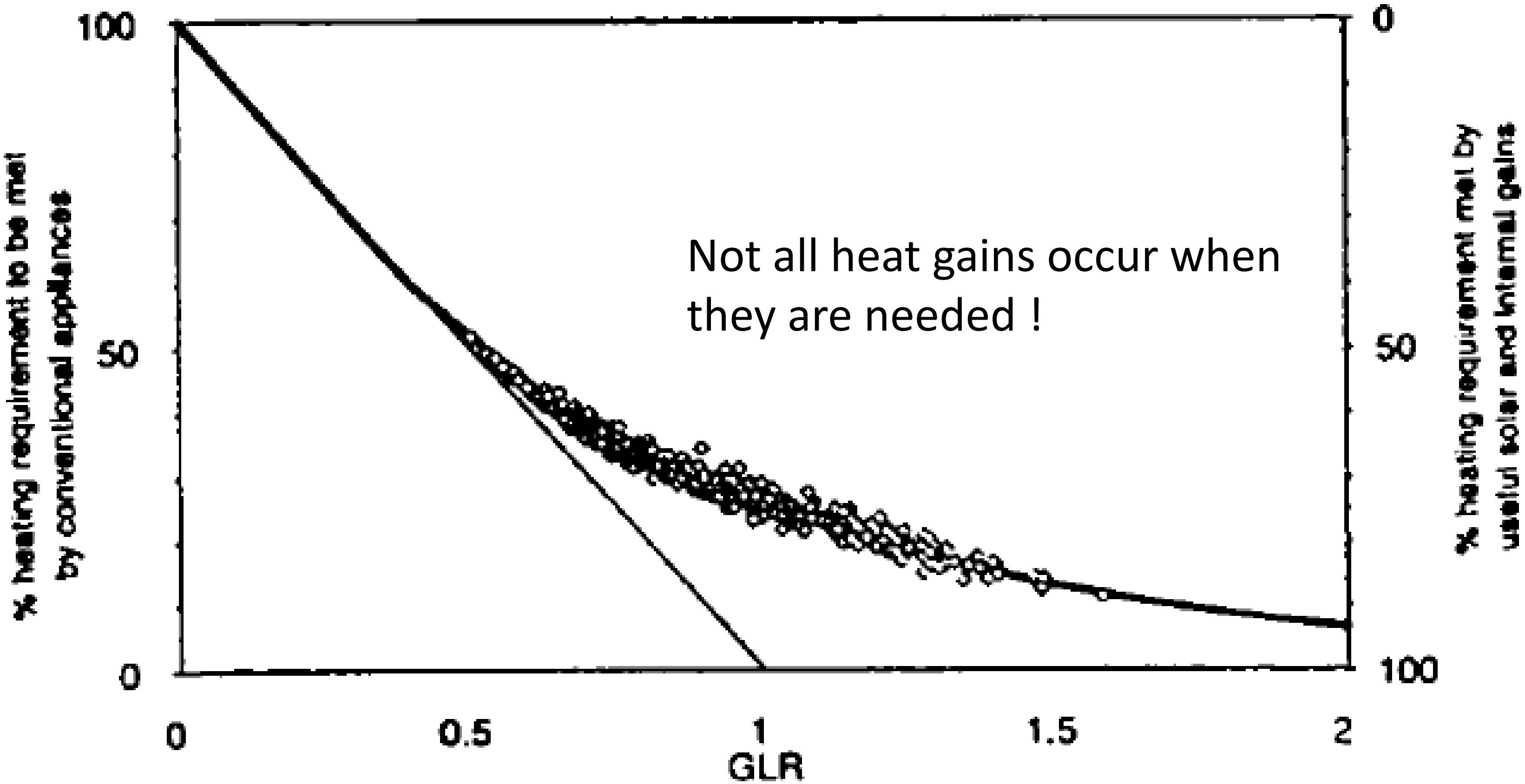
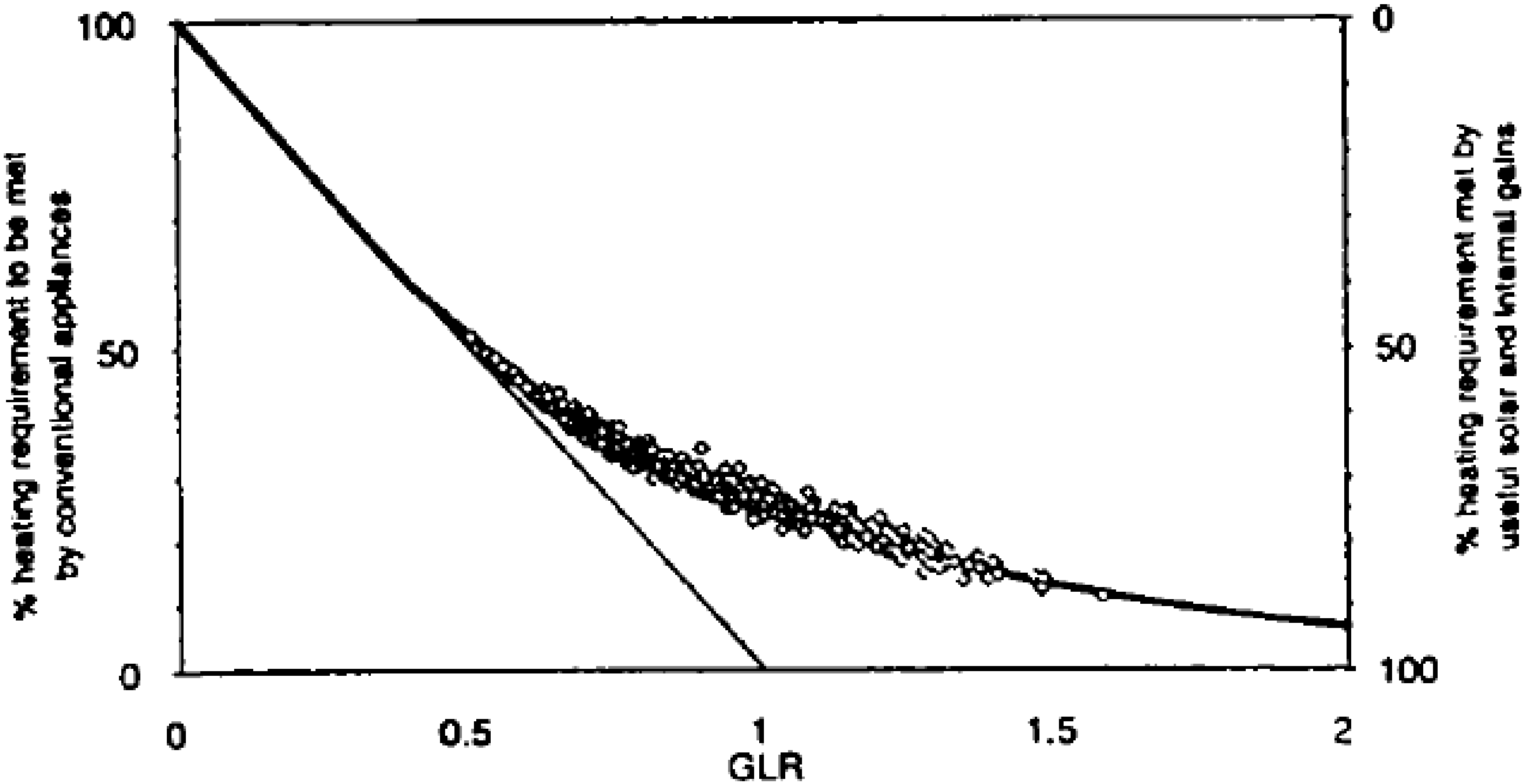


Not all heat gains occur when they are needed !

A (simple) way of heating demand estimation

For quick comparison of annual heating demand of different designs, and suggesting where to improve based on analysis of the heat balance



Energy Index

Originally developed by Simos Yannas in the UK solar energy R&D program for a housing design guide in 1994

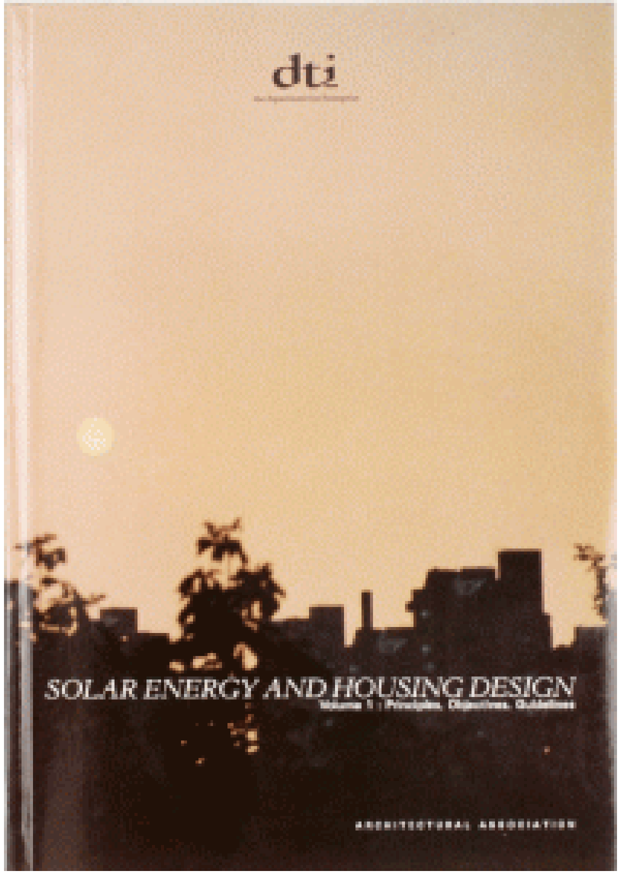
Has built-in data of annual average outdoor air temperature and solar radiation for 11 locations across the UK

Two indices based on measurements and simulations of a large sample of residential buildings in the UK are used to improve the accuracy of estimation

The complete calculation steps of EI have been assembled in an Excel spreadsheet by us.

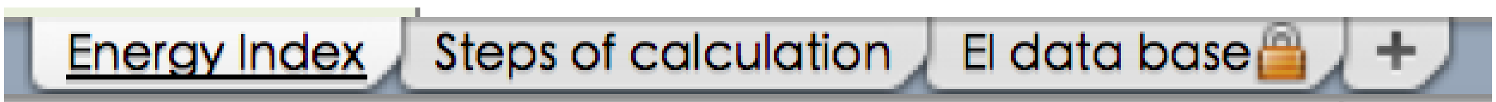
Energy Index

Method contained in the Book: Solar Energy and Housing Design, S. Yannas, 1994



Energy Index

The spreadsheet has three worksheets:



All inputs are here

Shows you each step of the calculation

Built-in data

Energy Index

Title of the section

Name of the input

the input value

SITE INFORMATION

Dwelling type	Small house
Location	London
Latitude	51° 28'
Annual mean temp [° C]	11.98

You only need to give inputs to the cells with white background

Energy Index

Not influencing the calculation but help you check the inputs

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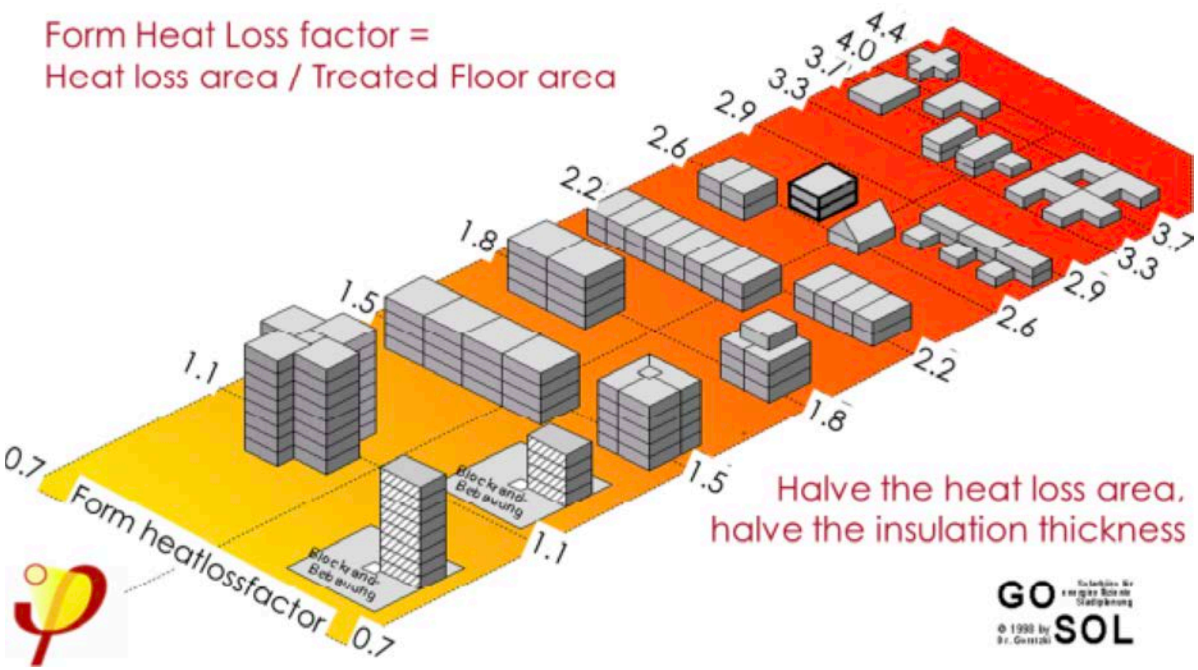

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SITE INFORMATION

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Select a location from the list. The latitude, annual mean (outdoor air) temperature, and all the solar radiation data of that location will be applied in the calculation automatically

Energy Index

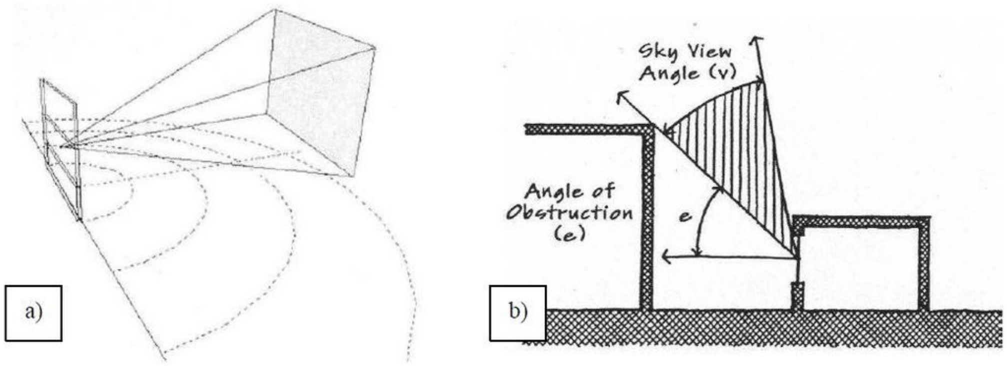


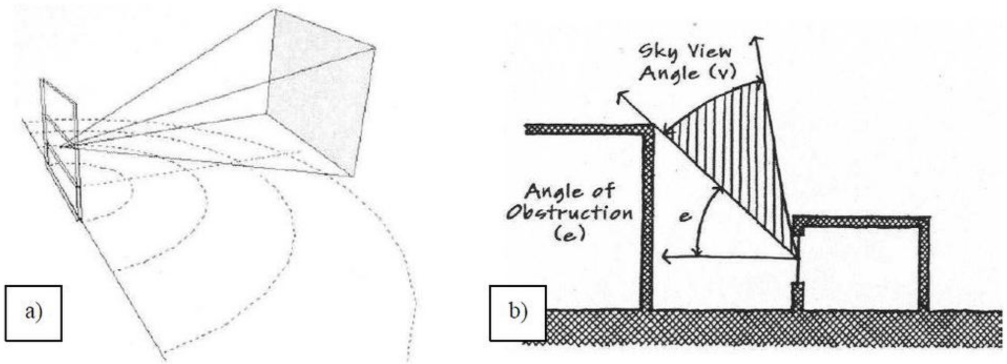
Figure 1: a) Sky Solid Angle (Capeluto, 2003),
b) Sky View Angle (v) and Angle of Obstruction (e) (Brown, G. Z., 2001)

Take an average when multiple obstructions present, the obstruction angle is applied to all orientations for solar gain calculation

SPACE LAYOUT

Obstruction angle in degrees (integer)	10
Floor-to-ceiling height [m]	2.83
Ventilation rate [ac/h]	0.75
Space volume [m^3]	113.2
Overall window-to-floor ratio [%]	69.0%

Energy Index



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Total ventilation rate including infiltration, and fresh air ventilation

Energy Index

Floor (total) includes all floor areas, either internal, or external (ground, exposed). For multi-story building, add all floor areas together.

BUILDING ELEMENTS

Opaque	Area [m^2]	U-value [W/m^2K]
Floor (total)	40	
Exposed floor	38.2	0.48
Wall (gross)	56.7	0.16
Roof	20	1.2
Other	10	1.3
Mean U-value [W/m^2K]		1.12

Energy Index

Area and U-value of each of the element (if multiple rooms present, sum the areas of their floors, walls and roofs)

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Note that the gross area of the wall is needed. You don't need to exclude the window area, which will be done automatically after you specify the windows

Energy Index

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Mean U-value of all the exposed building elements, giving a summary of the overall insulation level of the opaque building fabrics

Energy Index

Divided into five orientations, and it will apply the built-in solar radiation data to calculate the solar gains through the windows on each of the orientations

Transparent	Area [m^2]	% Frame	Net (glazing) area [m^2]	Window-to-floor ratio [%]	Glazing type	U-value [W/m^2K]	Floor reflectance (0.2 - 0.8)	Net solar gain [kWh]
N	12	20	9.6	30	DG	2.9	0.2	1690
NE/NW		20	0.0	0	DG		0	0
E/W		20	0.0	0	DG			0
SE/SW		20	0.0	0	DG			0
S	15.6	20	12.5	39	DG	2.9	0.6	4222
Total	27.6							5912

Energy Index

Divided into five orientations, and it will apply the built-in solar radiation data to calculate the solar gains through the windows on each of the orientations

Area of the windows and their U-values together determine the amount of heat losses through the windows

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Auxiliary heating fraction (AHF)

Energy Index

Annual total internal gains of the whole building = daily total internal gains [kWh/day] x 365 days

60W PC X used for 3 hours per day X 365 days
= 60 X 3 X 365 / 1000 = 65.7 kWh

INTERNAL CONDITIONS

Internal gains [kWh]	3639
Additional internal gains [kWh]	
Fuel type (Gas, Oil, Electricity, Coal)	Gas
Mean indoor temperature [° C]	21

Energy Index

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Heating set-point temperature

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Select a type of fuel to obtain the cost and carbon emission

Heating set-point temperature

Energy Index

HLC

STEP 1: HEAT LOSS COEFFICIENT

Building element			Area [m^2]		U-value (average) [W/m^2K]		A × U [W/K]
Roof			20.0	×	1.20	=	24.00
Windows			27.6	×	2.90	=	80.04
Walls (net)			29.1	×	0.16	=	4.66
Ground floor			38.2	×	0.48	=	18.34
Other			10.0	×	1.30	=	13.00
			Volume of the space [m^3]		Ventilation rate [ac/h]		0.33×N×V [W/K]
Ventilation	0.33	×	113.20	×	0.75	=	28.02
Building heat loss coefficient [W/K]							168.05
Heat loss per m^2 floor area [W/Km^2]			168.05	÷	40		4.20

Energy Index

Check those values to see how much each building element and ventilation contributes to the total heat loss

HLC

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Building element			Area [m²]		U-value (average) [W/m²K]		A × U [W/K]
Roof			20. 0	×	1. 20	=	24. 00
Windows			27. 6	×	2. 90	=	80. 04
Walls (net)			29. 1	×	0. 16	=	4. 66
Ground floor			38. 2	×	0. 48	=	18. 34
Other			10. 0	×	1. 30	=	13. 00
			Volume of the space [m³]		Ventilation rate [ac/h]		0. 33×N×V [W/K]
Ventilation	0. 33	×	113. 20	×	0. 75	=	28. 02
Building heat loss coefficient [W/K]							168. 05
Heat loss per m² floor area [W/Km²]			168. 05	÷	40		4. 20

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Heat loss per m² floor area [W/Km²]			168.05	÷	40		4.20

HLC of the whole building and per unit floor area

Energy Index

Indoor-outdoor Temperature difference when heating is applied

STEP 2: GROSS ANNUAL HEAT LOSS								
	Mean indoor temperature [° C]							21
	Mean annual outdoor temperature [° C] (obtained from EI data base Table 13.2)							11.98
	Mean indoor-outdoor temperature difference [° C or K]							9.02
		Annual total hours/1000 [kh]		Mean in-out temp difference [K]		Building heat loss coefficient [W/K]		
	Annual heat loss [kWh]	8.76	×	9.02	×	168.05	=	13278

Energy Index

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Mean indoor temperature [° C]							21
Mean annual outdoor temperature [° C] (obtained from EI data base Table 13.2)							11.98
Mean indoor-outdoor temperature difference [° C or K]							9.02
	Annual total hours/1000 [kh]		Mean in-out temp difference [K]		Building heat loss coefficient [W/K]		
Annual heat loss [kWh]	8.76	×	9.02	×	168.05	=	13278

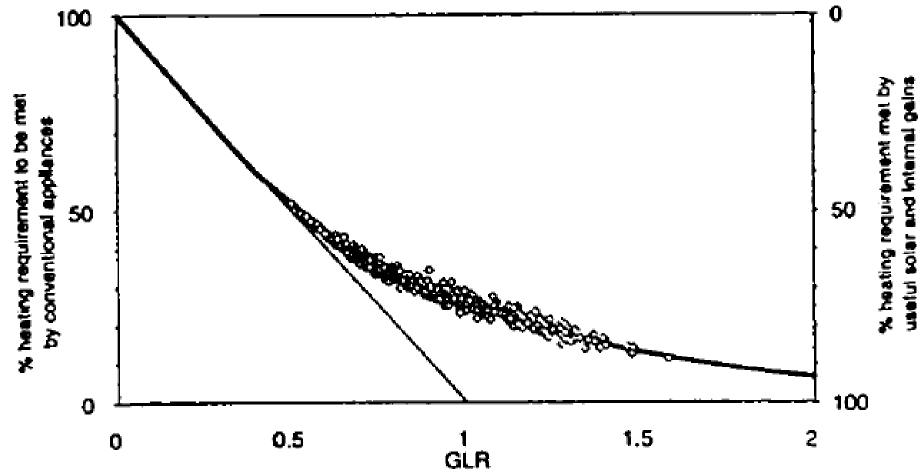
Total hours of a year = 8760 hours

Energy Index

STEP 3: SOLAR AND INTERNAL HEAT GAINS

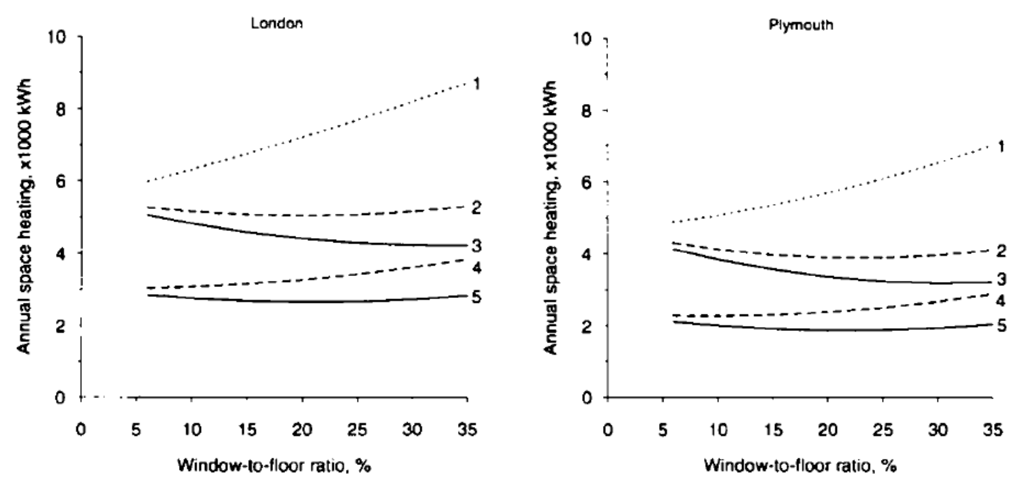
Window orientation	Correction factors		Transmitted radiation (Table 13.2)		Fraction unobstructed		Glass area [m2]		Fraction retained (Table 13.3)		Net solar gain [kWh]
N	0.98	×	209.79	×	0.982	×	9.6	×	0.872	=	1690
NE/NW	0.00	×	0.00	×	0	×	0	×	0	=	0
E/W	0.00	×	0.00	×	0	×	0	×	0	=	0
SE/SW	0.00	×	0.00	×	0	×	0	×	0	=	0
S	1.00	×	465.49	×	0.982	×	12.48	×	0.74	=	4222
Total annual solar gain [kWh]											5912
Internal gains [kWh]											3639
Total annual heat gains [kWh]											9551

Energy Index



							0.507					0.536
										0.514		
STEP 4: GLR AND AHF	Gains to loss ratio (GLR)						9551		÷	13278	=	0.72
	Auxiliary heating fraction (AHF)											0.536
	0.507	0.507	##	0.507	0.507	##	0.514	0.514	##	0.536	##	0.536

AHF is a function of GLR and window-to-floor-ratio



Energy Index

Continuous heating (at least 18 hours per day)

STEP 5: ANNUAL SPACE HEATING REQUIREMENT						
	Conituous heating					
	Total [kWh]	0.536	×	13278	=	7116
	per m2 floor area [kWh/m2]	7116	÷	40	=	177.9
	Total primary energy equivalent [kWh]					10775.9
	Intermitent heating					
	Total [kWh]	0.85	×	7116		6049
	per m2 floor area [kWh/m2]	6049	÷	40		151.2
	Total primary energy equivalent [kWh]					9159.5

Intermittent heating means heating off during part of the day (normally when the space is not occupied) and on in the rest of the time

Energy Index

Continuous heating (at least 18 hours per day)

AHF

Annual total heat loss

STEP 5: ANNUAL SPACE HEATING REQUIREMENT						
	Conituous heating					
	Total [kWh]	0.536	×	13278	=	7116
	per m2 floor area [kWh/m2]	7116	÷	40	=	177.9
	Total primary energy equivalent [kWh]					10775.9
	Intermitent heating					
	Total [kWh]	0.85	×	7116		6049
	per m2 floor area [kWh/m2]	6049	÷	40		151.2
	Total primary energy equivalent [kWh]					9159.5

Intermittent heating means heating off during part of the day (normally when the space is not occupied) and on in the rest of the time

Energy Index

Continuous heating (at least 18 hours per day)

AHF

Annual total heat loss

STEP 5: ANNUAL SPACE HEATING REQUIREMENT						
	Conituous heating					
	Total [kWh]	0.536	×	13278	=	7116
	per m2 floor area [kWh/m2]	7116	÷	40	=	177.9
	Total primary energy equivalent [kWh]					10775.9
	Intermitent heating					
	Total [kWh]	0.85	×	7116		6049
	per m2 floor area [kWh/m2]	6049	÷	40		151.2
	Total primary energy equivalent [kWh]					9159.5

Intermittent heating means heating off during part of the day (normally when the space is not occupied) and on in the rest of the time

The primary energy equivalent is calculated for the selected fuel type

Energy Index

STEP 6: FUEL COST AND CO_2 EMISSIONS					
	Conituous heating				
	Fuel cost [£]	0.020	× 7116	=	142
	CO2 emissions [kg]	0.271	× 7116	=	1932
	Intermitent heating				
	Fuel cost [£]	0.020	× 6049	=	121
	CO2 emissions [kg]	0.271	× 6049	=	1642

Energy Index

Calculate the excessive gains

STEP 7: OVERHEATING RISKS

Excess gains [kWh]

0.75	5912	+	0.75	× (	3639	+	7116	-	13278	)	=	2541

0.75	for N and S
0.84	for NE/NW/SE/SW
0.94	for E and W

A factor will be selected depending on the orientation where most of the windows are positioned

Maximum indoor air temperature

Peak temperature [°C] (from Fig. 13.3 and calculated excess gains)	28.3
Number of hours above 27 °C [h] (from Fig. 13.3 and calculated excess gains)	43

Assume 27ºC is the upper limit of the comfort band