Comparison of Overheating Assessment Methods for a Naturally Ventilated Healthcare Premise in London

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ARUP

The project

- Mental health hospital composed of 4 buildings
- BREEAM Excellent to be achieved
- Natural ventilation is the main strategy for bedrooms and common spaces, where external openings are available
- The architects want advice on ventilation strategy and openings size in different areas for each building

HTM 03-01: Specialised ventilation for healthcare premises

Comfort cooling

2.14 Cooling is very expensive in terms of energy costs and should be provided only where necessary to maintain a comfortable environment for staff and patient, or to ensure satisfactory operation of equipment. The imaging department in particular may require cooling to offset the equipment load.

2.15 Calculations and thermal modelling should be undertaken to ensure that, during the summertime, internal temperatures in patient areas do not exceed 28°C (dry bulb) for more than 50 hours per year.

2.16 Certain non-patient areas may also require cooling (for example laboratories and other areas that are subject to high heat gains from equipment).

2.17 Where deep planning of other continuously occupied spaces (for example offices) is unavoidable, there will also be occasions when acceptable levels of comfort can only be maintained by cooling.

2.18 Refrigeration plant should be of sufficient capacity to offset heat gains and maintain areas at a temperature that does not exceed the external design shade temperatures by more than about 3 K, taking into account the level of design risk for the application.

HTM 03-01 (2007), pg.9

- "Overheating" is not specifically mentioned
- Internal temperature can exceed 28°C for maximum 50 hours in a year in spaces with **comfort cooling**

HTM 03-01: Specialised ventilation for healthcare premises

Natural ventilation

2.4 Natural ventilation is usually created by the effects of wind pressure. It will also occur if there is a temperature difference between the inside and the outside of a building. The "thermo-convective" effect frequently predominates when the wind speed is low, and will be enhanced if there is a difference in height between inlet and outlet openings.

2.5 Ventilation induced by wind pressures can induce high air-change rates through a building, provided air is allowed to move freely within the space from the windward to the leeward side. However, in most healthcare applications, internal subdivisions will restrict or prevent this effect.

2.6 It is almost impossible to maintain consistent flow rates and ensure that minimum ventilation rates will be achieved at all times. However, this variability is normally acceptable in such areas as office accommodation, staff areas, library/seminar rooms and dining rooms, where opening windows (of a design that facilitates natural ventilation) should be provided.

Note

If natural ventilation is "single-sided", it will usually only be effective for a three-metre depth within the space. Beyond that it will need to be supplemented by mixed-mode or forced ventilation.

2.7 Current guidance restricts the opening of windows for safety reasons; also, as many designs are top-hung, their ability to permit natural ventilation is limited. It may therefore be necessary to provide dedicated ventilation openings in the fabric of the building to allow a sufficient natural flow of air into and out of the space.

2.8 In all cases, excessive heat gain, indoor air-quality requirements or external noise may limit or preclude the use of natural ventilation.

2.9 Detailed guidance on natural ventilation can be found in CIBSE's (2005) Applications Manual AM10 – 'Natural ventilation in non-domestic buildings'.

HTM 03-01 (2007), pg.8

HTM 03-01: Specialised ventilation for healthcare premises

- For **naturally ventilated** spaces, no precise indication is given
- CIBSE AM10 does not refer to overheating assessment methods

BREEAM UK 2014 for non-domestic buildings

Hea 04 Thermal comfort

One credit - Thermal modelling

1. Thermal modelling has been carried out using software in accordance with CIBSE AM11[1] Building Energy and Environmental Modelling.
2. The software used to carry out the simulation at the detailed design stage provides full dynamic thermal analysis. For smaller and more basic building designs with less complex heating or cooling systems, an alternative less complex means of analysis may be appropriate (such methodologies must still be in accordance with CIBSE AM11).
3. The modelling demonstrates that:
    a. For air conditioned buildings, summer and winter operative temperature ranges in occupied spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design[2], Table 1.5; or other appropriate industry standard (where this sets a higher or more appropriate requirement/level for the building type).
    b. For naturally ventilated/free running buildings:
        i. Winter operative temperature ranges in occupied spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design, Table 1.5; or other appropriate industry standard (where this sets a higher or more appropriate requirement/level for the building type).
        ii. The building is designed to limit the risk of overheating, in accordance with the adaptive comfort methodology outlined in CIBSE TM52: The limits of thermal comfort: avoiding overheating in European buildings[3].

Naturally ventilated areas should follow CIBSE TM52 for overheating assessment

CIBSE TM52 – Control of overheating

According to CIBSE:

"the 'adaptive' approach to thermal comfort shows that the temperature at which the majority of people are comfortable 'tracks' the mean indoor temperature because of the ***correlation between indoor and outdoor temperature*** *in free-running buildings. This means that comfort temperature also varies with outdoor temperature in buildings in free-running mod*e" (CIBSE TM52, 2013).

A new method is proposed, taking into account the variability of outdoor and indoor temperatures.
Three criteria are given:

1. Hours of exceedance ≤ 3% occupied hours
2. Daily weighted exceedance ≤ 6 in any single day
3. Upper limit temperature ≤ 4°C

If a room or a building fails 2/3 criteria, it is classed as overheating.

CIBSE TM52 – Control of overheating

Criterion 1: HOURS OF EXCEEDANCE (He)

The number of hours (He) during which ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3% of occupied hours.

Where:

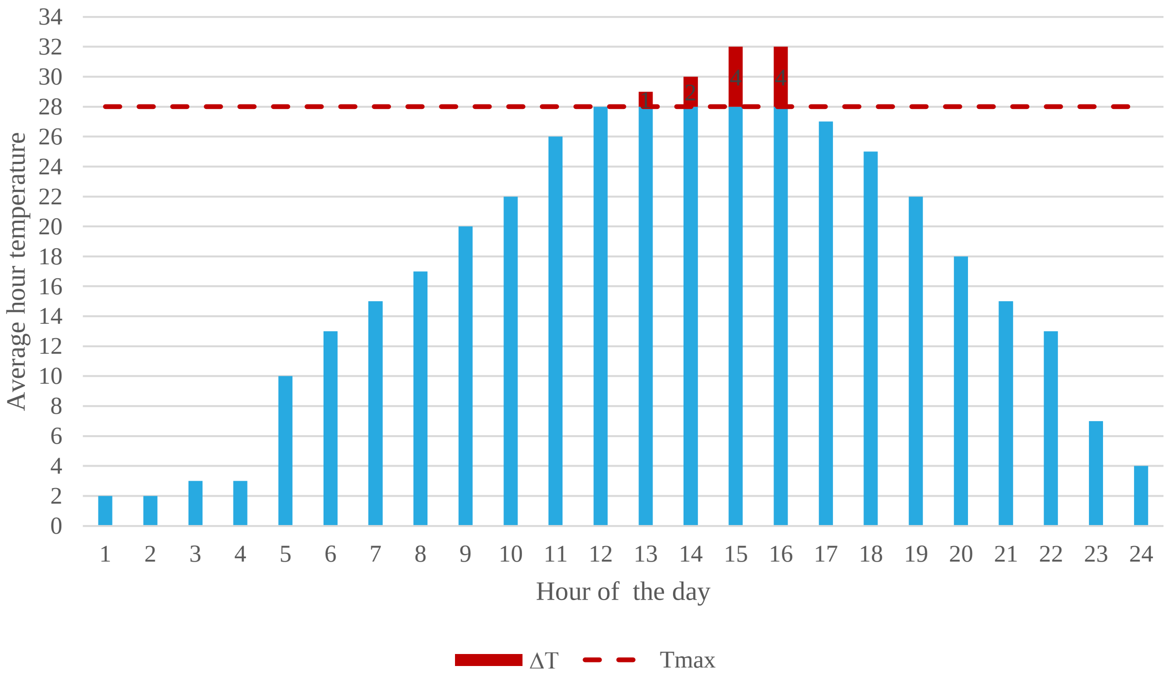
- ΔT = Top – Tmax
- Top: operative temperature (mean of air temperature and radiant temperature)
- Tmax = 0.33 Trm + 21.8 for new buildings in Category II (BS EN 15251:2007)
- Trm: exponentially weighted running mean of the daily mean outdoor air temperature

CIBSE TM52 – Control of overheating

Criterion 1: HOURS OF EXCEEDANCE (He)

The number of hours (He) during which ΔT is greater than or equal to one degree (K) during the period May to September inclusive shall not be more than 3% of occupied hours.

Example:



For day 1, $H_{e,1} = 4$

$H_e = \sum H_{e,i}$
from May to September

CIBSE TM52 – Control of overheating

Criterion 2: DAILY WEIGHTED EXCEEDANCE (We)

To allow for the severity of overheating the weighted exceedance (We) shall be less than or equal to 6 in any one day where:

$$We = \Sigma\,(he,i \times WFi) = (he,0 \times 0) + (he,1 \times 1) + (\ \dots\ ) + (he,n \times n)$$

Where:

- WF = 0 if $\Delta T \leq 0$, otherwise WF = ΔT
- he,i: number of hours when WF = i

CIBSE TM52 – Control of overheating

Criterion 2: DAILY WEIGHTED EXCEEDANCE (We)

To allow for the severity of overheating the weighted exceedance (We) shall be less than or equal to 6 in any one day where:

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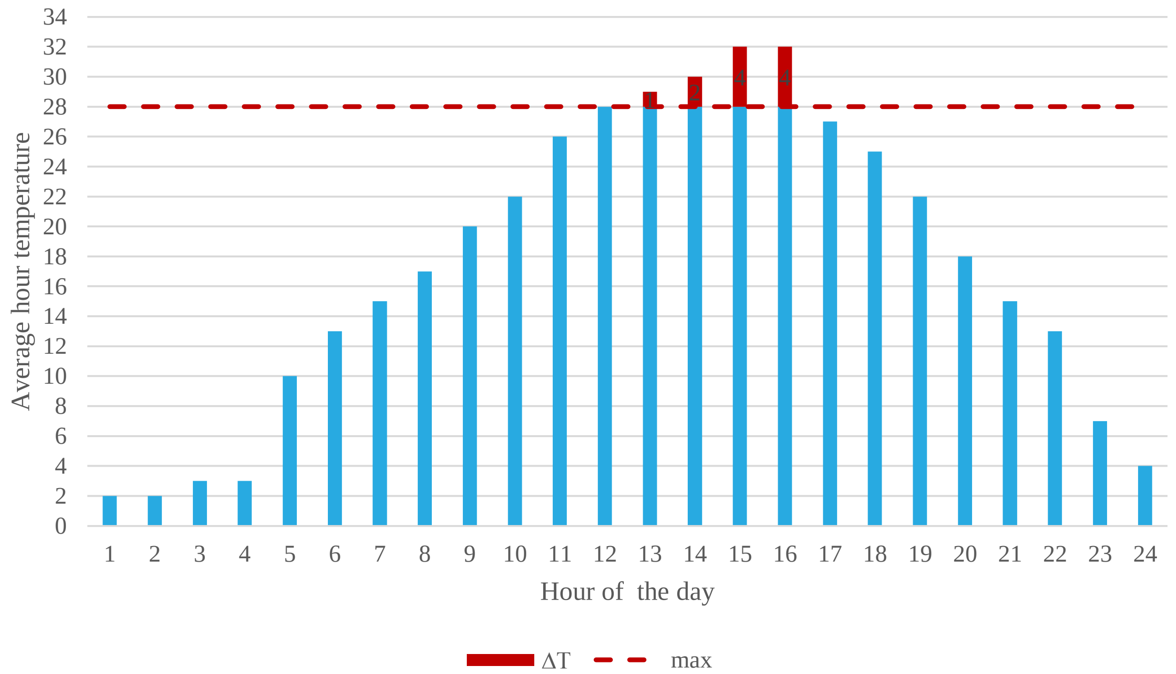
Example:



For 1 day:

$H_{e,0}$= 20

$H_{e,1}$= 1

$H_{e,2}$= 1

$H_{e,4}$= 2

W_e= 20x0+1x1+1x2+2x4=11

CIBSE TM52 – Control of overheating

Criterion 3: UPPER LIMIT TEMPERATURE (Tupp)

To set an absolute value for the indoor operative temperature the value of ΔT shall not exceed 4 K.

Where:

- $\Delta T = T_{op} - T_{max}$

Overheating assessment methods

- HTM 03-01 – Healthcare premises

  for comfort cooled rooms: Top > 28ºC for max 50 hours in a year

- CIBSE TM52 – Control of overheating

  for naturally ventilated rooms: 3 Comfort criteria (overheating if 2/3 failures)

  1. Hours of exceedance ≤ 3% occupied hours
  2. Daily weighted exceedance ≤ 6 in any single day
  3. Upper limit temperature ≤ 4°C

Weather Files

CIBSE Guide requires to assess overheating under all three new Design Summer Year weather files, which are three warm years selected from a 30 year baseline 1984 – 2013:

- DSY1: Moderately warm summer (1989)
- DSY2: Short, intense warm spell (2003)
- DSY3: Long, less intense warm spell (1976)

	DSY1	**DSY2**	**DSY3**
Average year temperature	12.0	11.9	11.3
Average summer temperature	17.5	17.4	17.5
Peak temperature	33.6	**37.3**	34.0
N. hours over 28	63	98	**164**

Highest peak

Longest warm spell

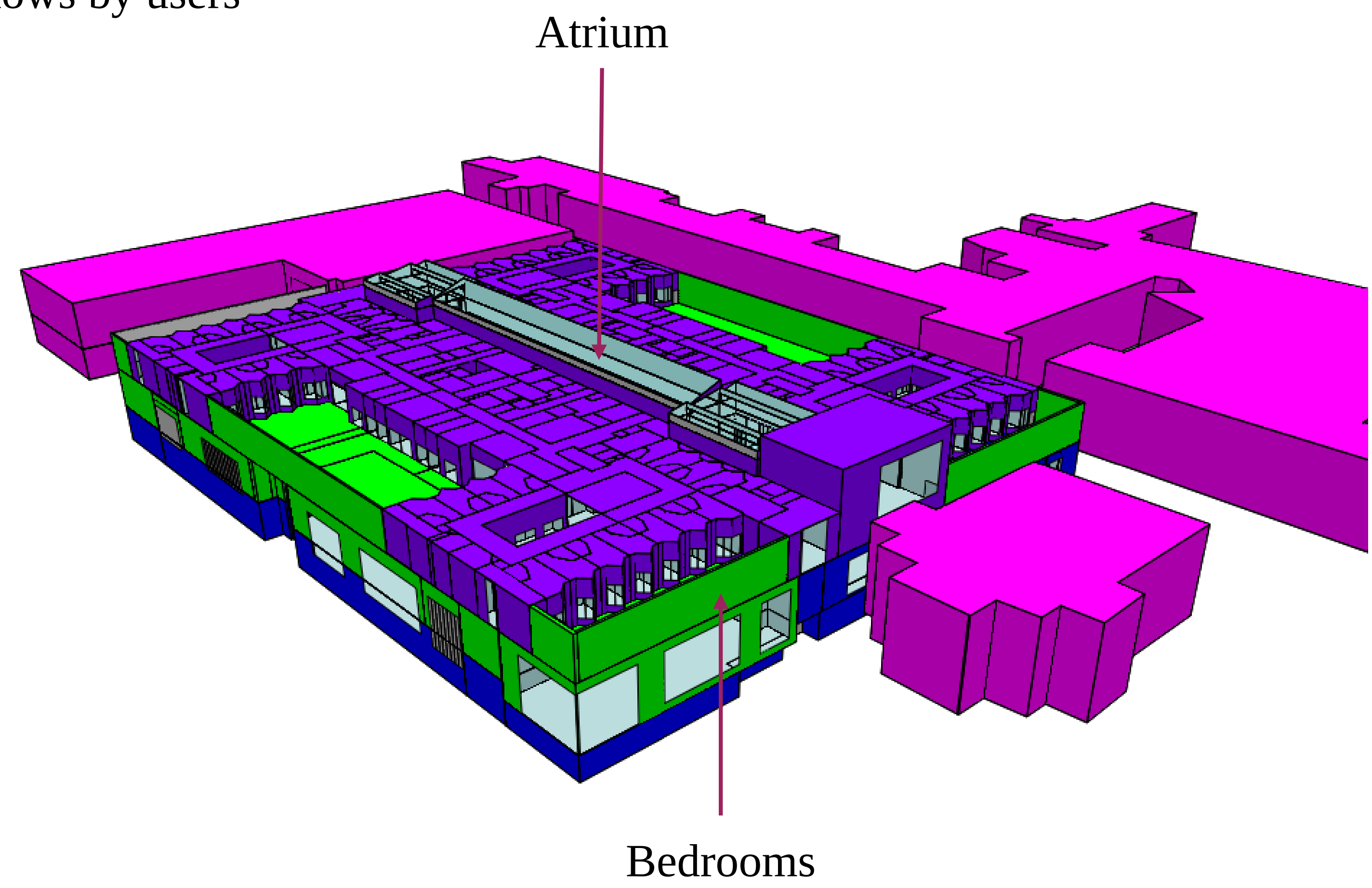
Example 1

Overheating assessment of naturally ventilated bedrooms

IES Model

The model was set in Apache in terms of internal gains, constructions and systems

Then, ventilation profiles have been defined in Macroflo, to represent typical operation of windows by users



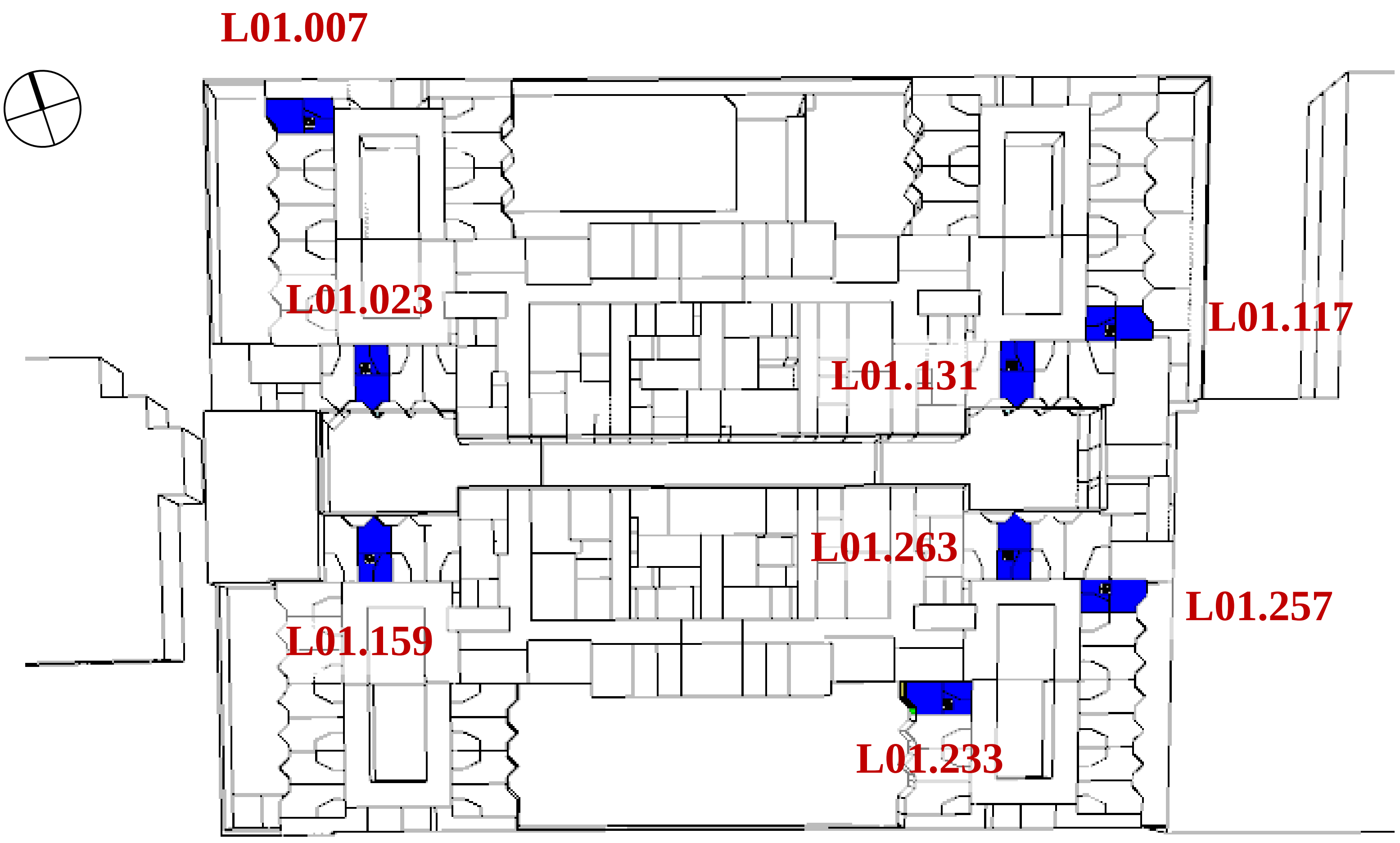
Main Inputs

- Air permeability: 0.15 ACH
- Occupancy: 1 person 24/7 – 100W/person
- Lighting gain: 8 W/m^2
- Equipment gains: 0 W/m^2
- g-value = 0.3
- Constructions:

Element	U-value (W/(m^2.K))	Cm (kJ/(m^2.K))	G-value
Wall	0.22	162.5	-
Roof	0.16	98.8	-
Ground floor	0.18	176.4	-
Internal ceiling	1.2	95	-
Windows	1.5	-	0.3

IES Model

A sample room for each orientation and typology was selected and assessed

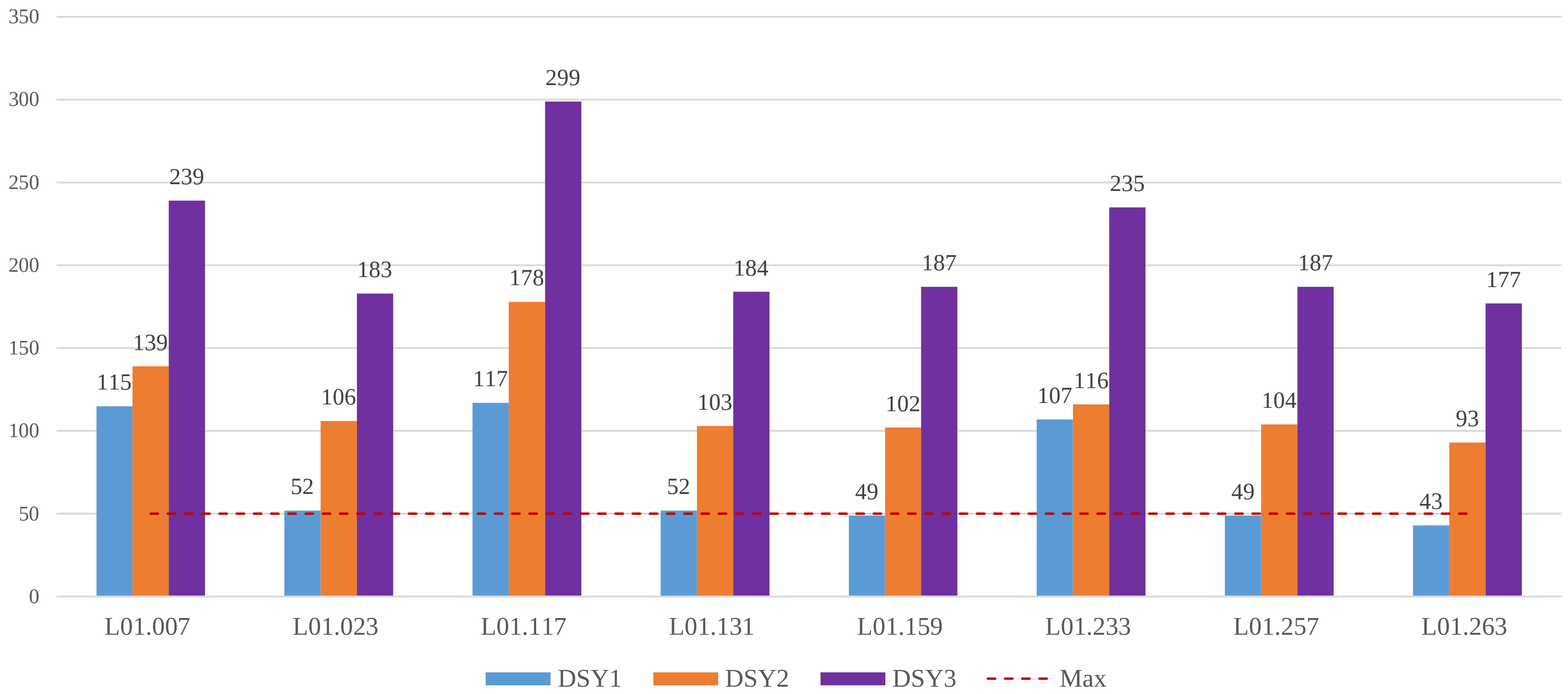


Options tested:

1. Only windows opening
2. Toilet extracts extracting 6ACH for the whole volume of toilet and bedroom
3. Windcatchers

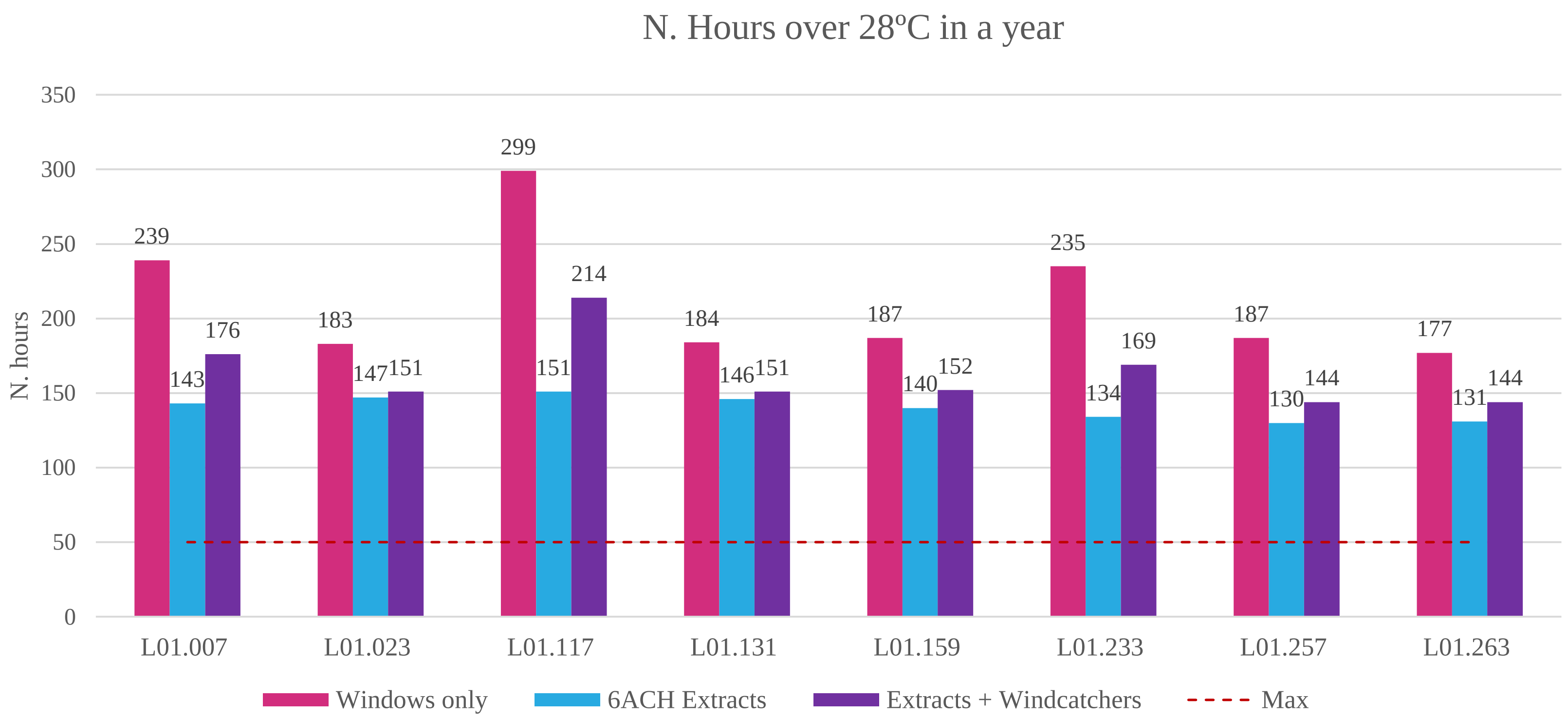
Results: HTM 03-01

Initial design (Windows only)



DSY3 was the most overheating → This was used for the comparison between strategies

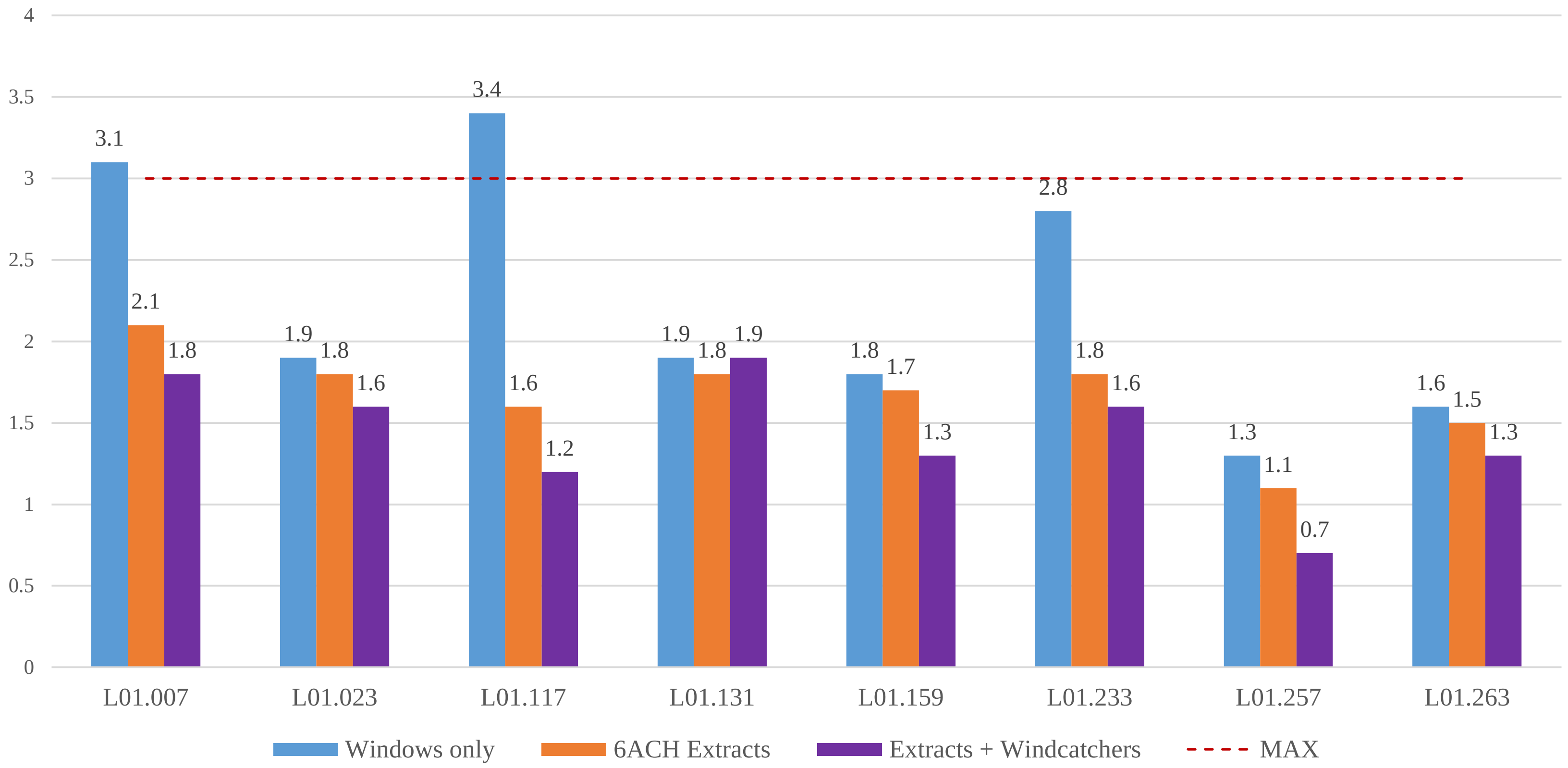
Results: HTM 03-01



None of the options comply with HTM 03-01 requirements

Results: CIBSE TM52

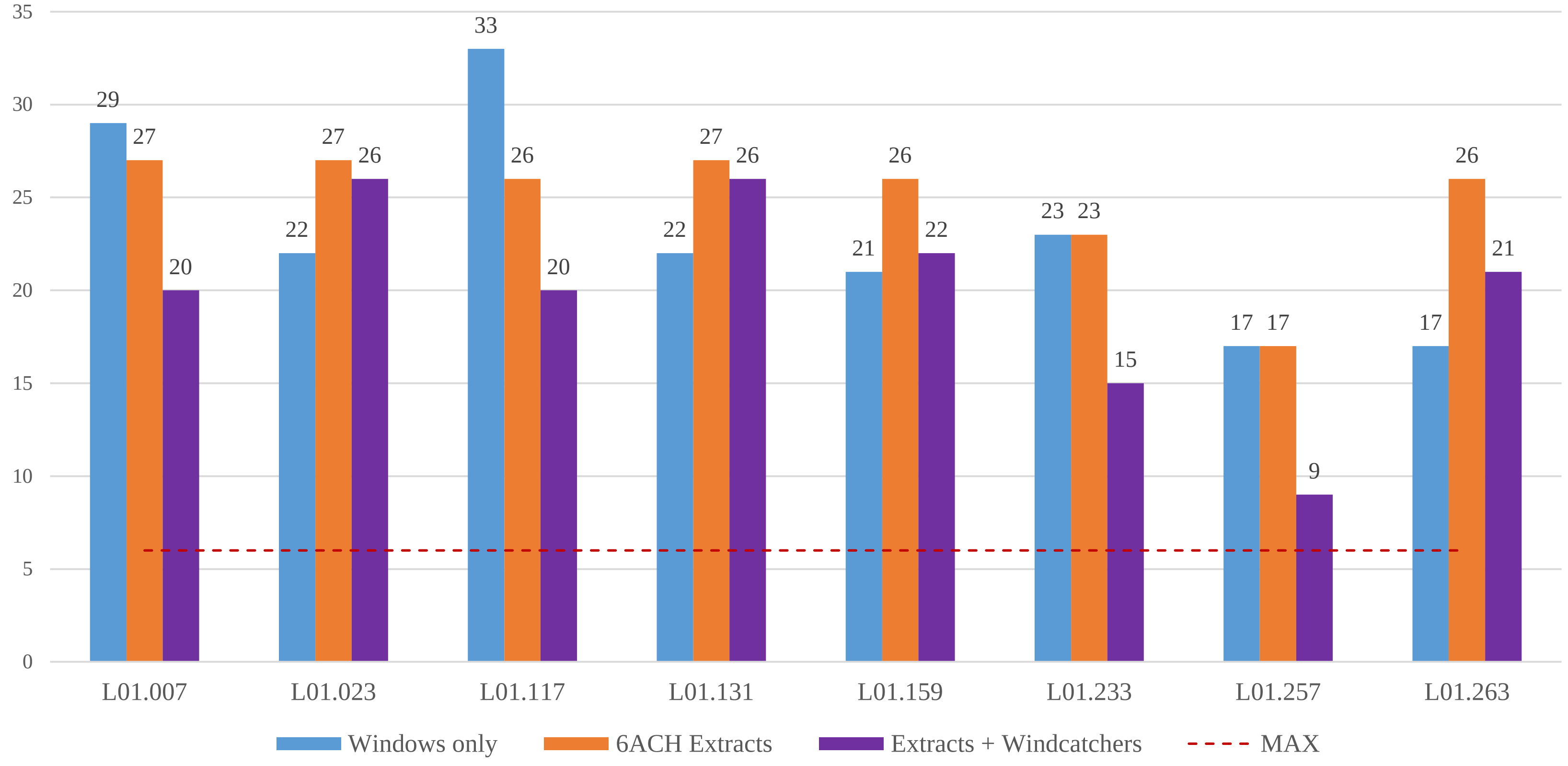
CRITERION 1: Hours of exceedance ≤ 3% occupied hours



6ACH Extracts and Windcatchers pass the criterion

Results: CIBSE TM52

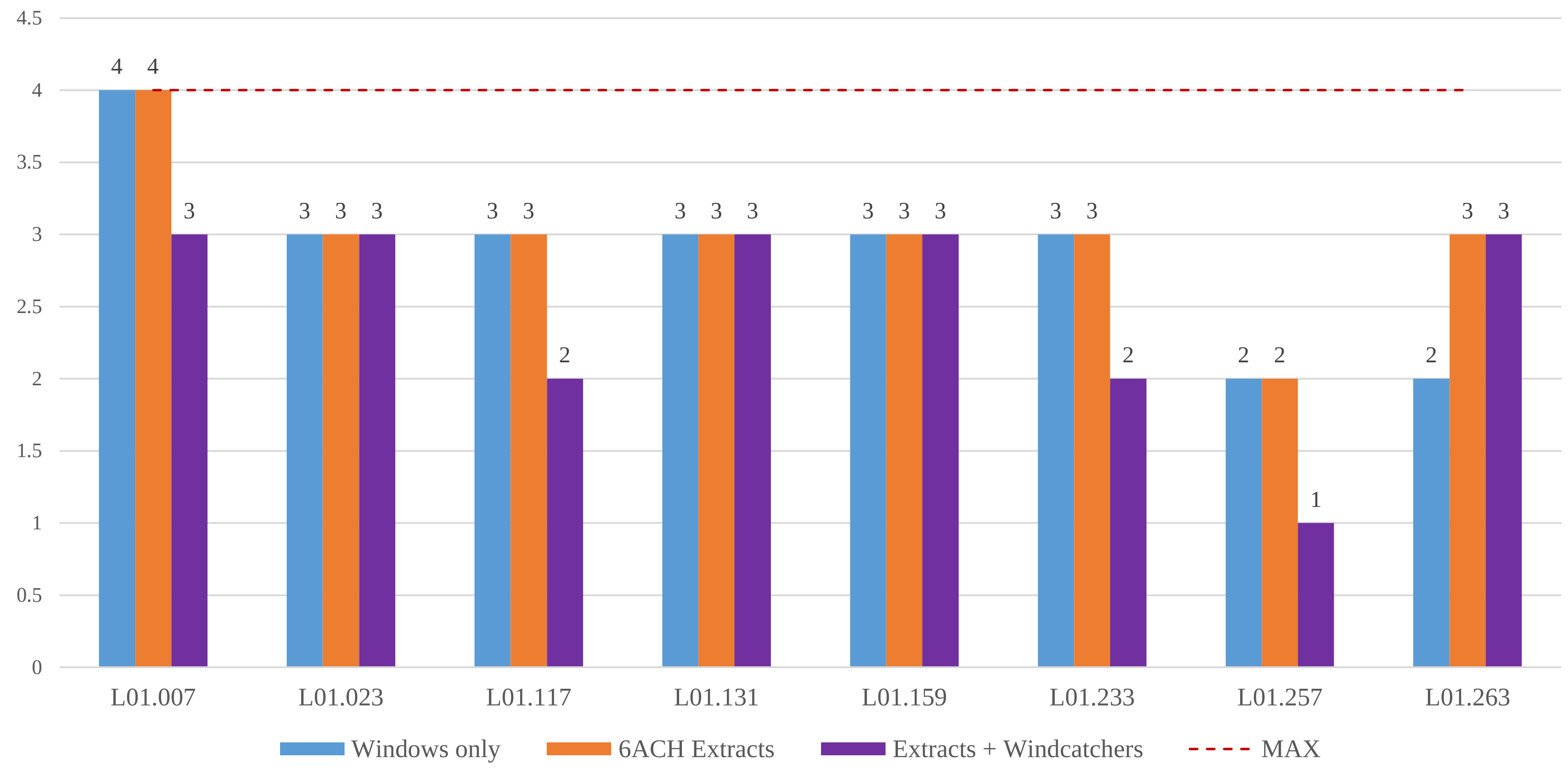
CRITERION 2: Daily weighted exceedance ≤ 6 in any single day



None of the options pass the criterion

Results: CIBSE TM52

CRITERION 3: Upper limit temperature (ΔT ≤ 4°C)



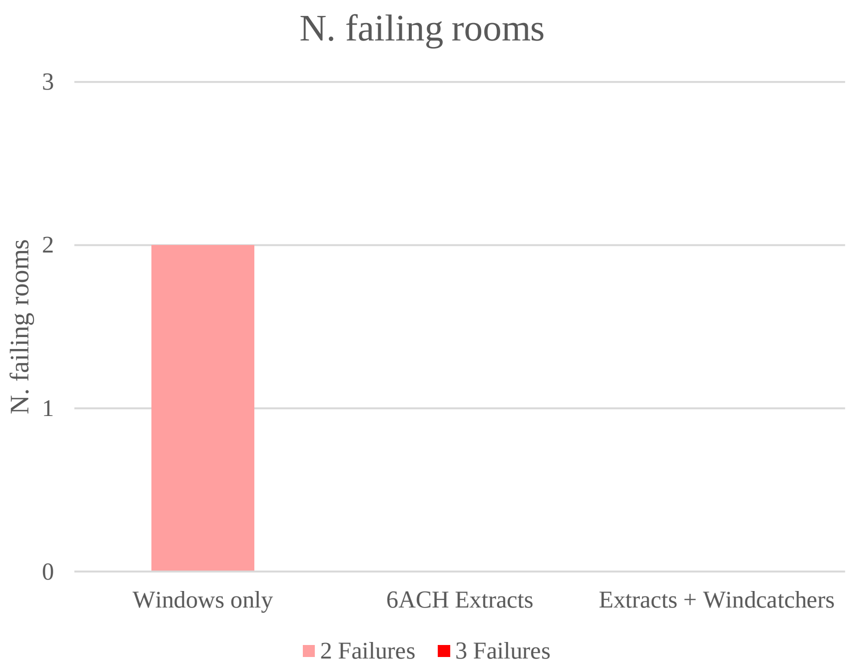
All options pass the criterion

Results: CIBSE TM52

Overall

N. Criteria failing for each room

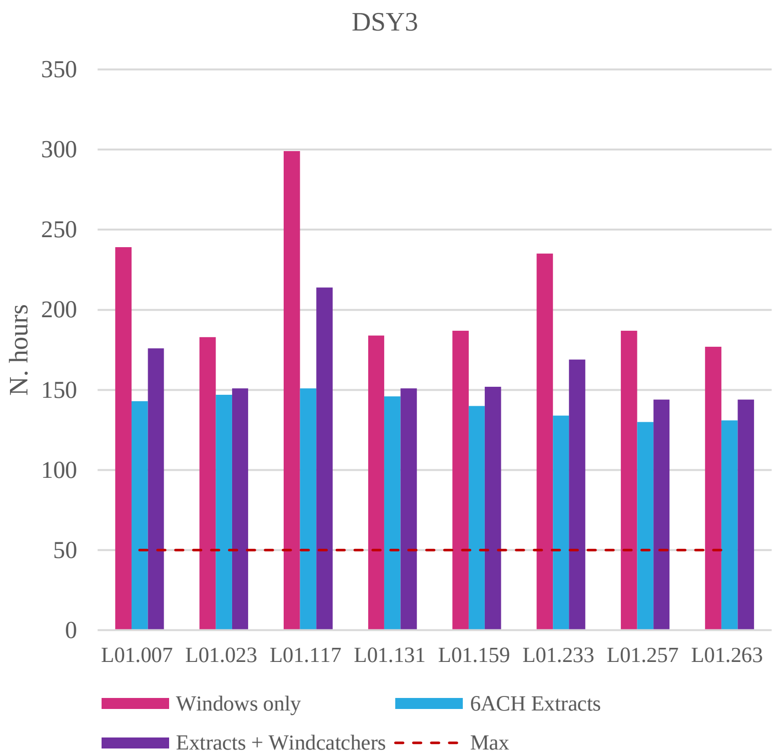
Room Number	Windows only	6ACH Extracts	Extracts + Windcatchers
L01.007	2	1	1
L01.023	1	1	1
L01.117	2	1	1
L01.131	1	1	1
L01.159	1	1	1
L01.233	1	1	1
L01.257	1	1	1
L01.263	1	1	1

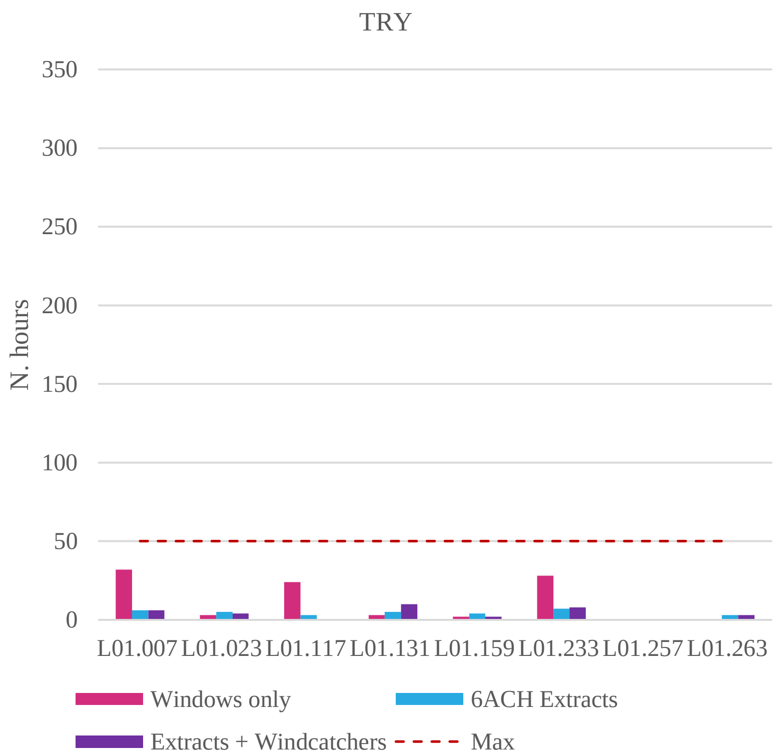


- The overheating assessment is passed by all rooms with extracts only and extracts + windcatchers (only 1/3 criteria failing)
- Windcatchers don't produce a relevant improvement on extracts only

Simulation with other weather files

HTM 03-01 results



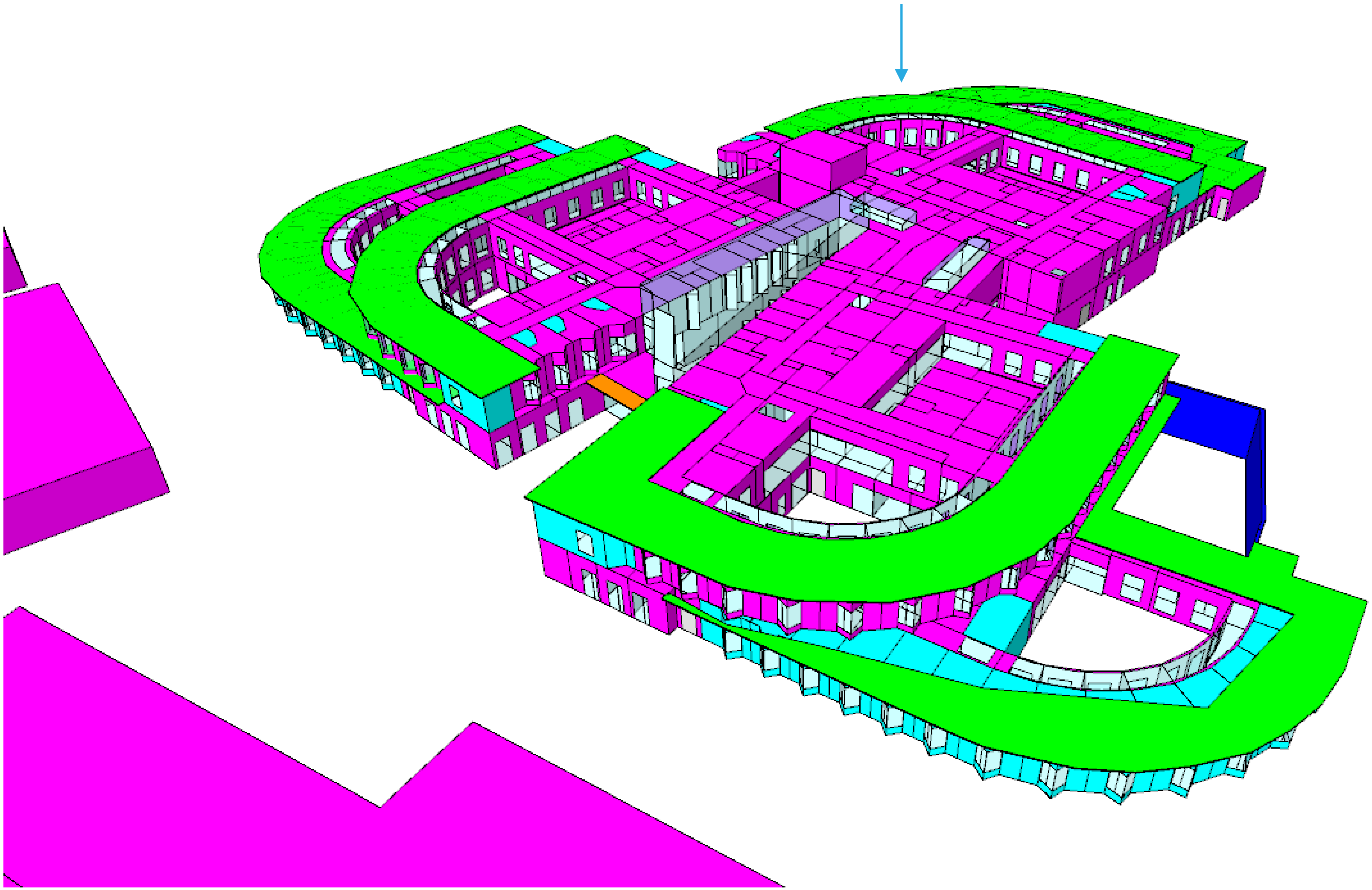


Assessing overheating under TRY underestimates the risk of overheating

Example 2

Design of openings for naturally ventilated corridors

IES Model



BREEAM Hea04 – Thermal Comfort

One credit - Thermal modelling

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   a. For air conditioned buildings, summer and winter operative temperature ranges in occupied spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design[2], Table 1.5; or other appropriate industry standard (where this sets a higher or more appropriate requirement/level for the building type).
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      i. Winter operative temperature ranges in occupied spaces are in accordance with the criteria set out in CIBSE Guide A Environmental design, Table 1.5; or other appropriate industry standard (where this sets a higher or more appropriate requirement/level for the building type).
      ii. The building is designed to limit the risk of overheating, in accordance with the adaptive comfort methodology outlined in CIBSE TM52: The limits of thermal comfort: avoiding overheating in European buildings[3].
4. For air conditioned buildings, the PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) indices based on the above modelling are reported via the BREEAM assessment scoring and reporting tool.

Corridors do not need to comply

BUT

The overheating assessment can be used to help the design

Occupied space

Refer to Hea 01 Visual comfort, however for the purpose of BREEAM issue Hea 04 the definition excludes the following;

1. Atria or concourses
2. Entrance halls or reception areas
3. Ancillary space e.g. circulation areas, storerooms and plant rooms.

Weather files

Because circulation areas are not occupied spaces, they do not require the standard overheating assessment

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The simulation has been run also under the Test Reference Year (TRY) to evaluate performance under average conditions

	DSY1	**DSY2**	**DSY3**	**TRY**
Average year temperature (°C)	12.0	11.9	11.3	11.4
Average summer temperature (°C)	17.5	17.4	17.5	16.4
Peak temperature (°C)	33.6	37.3	34.0	30.7
N. hours over 28 (-)	63	98	164	25

Initial design | CIBSE AM10

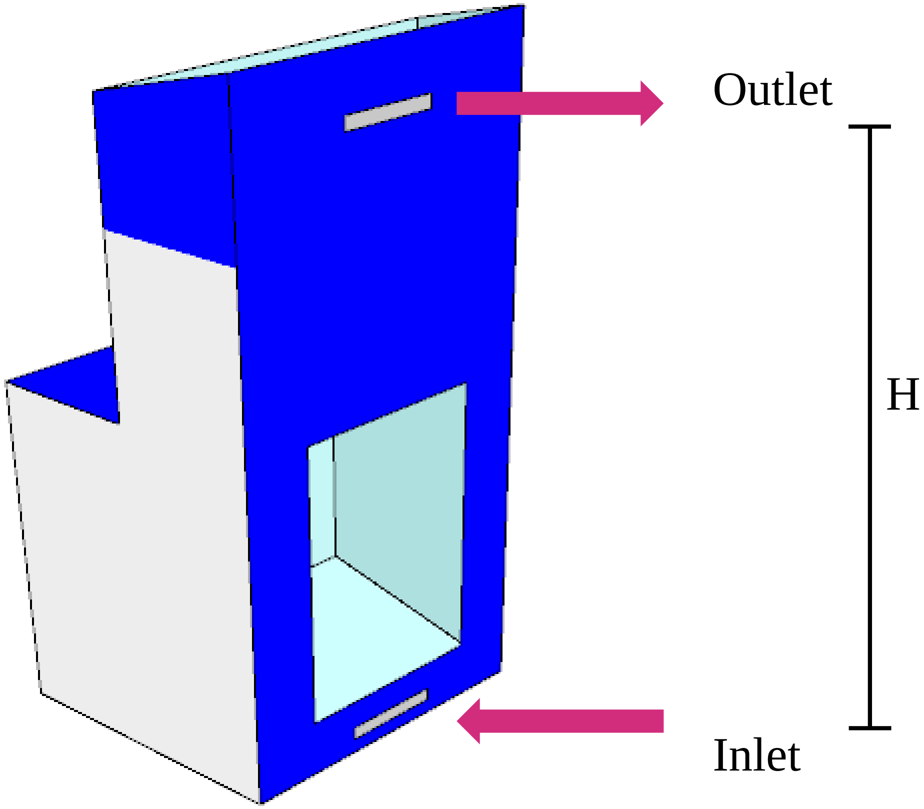
Required air flow: 2ACH (25l/s)

H = 4.20 m

Openable area = 30%
(anti-ligature)

Louver Area = 0.08 m^2

Eqv Opening Area = 0.025m^2



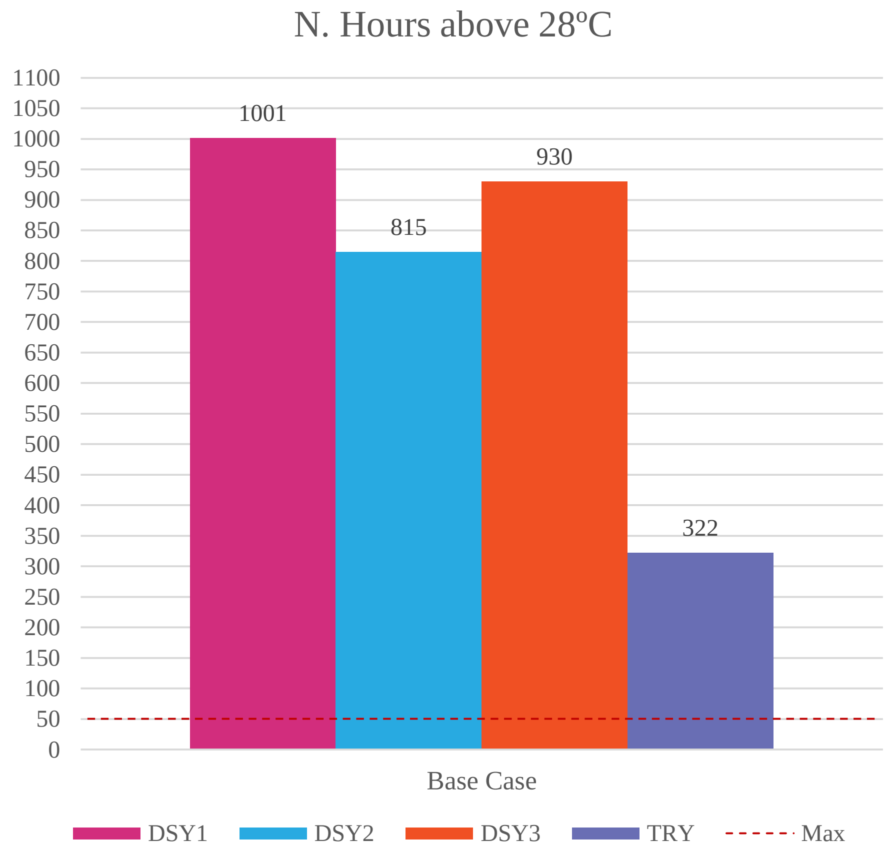
Main Inputs

- Air permeability: 0.15 ACH
- Occupied for very short periods of time (≈0)
- Lighting gain: 8 W/m^2
- Equipment gains: 0 W/m^2
- Constructions:

Element	U-value (W/(m^2.K))	Cm (kJ/(m^2.K))	G-value
Wall	0.22	162.5	-
Roof	0.16	98.8	-
Ground floor	0.18	176.4	-
Internal ceiling	1.2	95	-
Windows	1.5	-	0.3
Louvers	1.1	-	-

Results: HTM 03-01

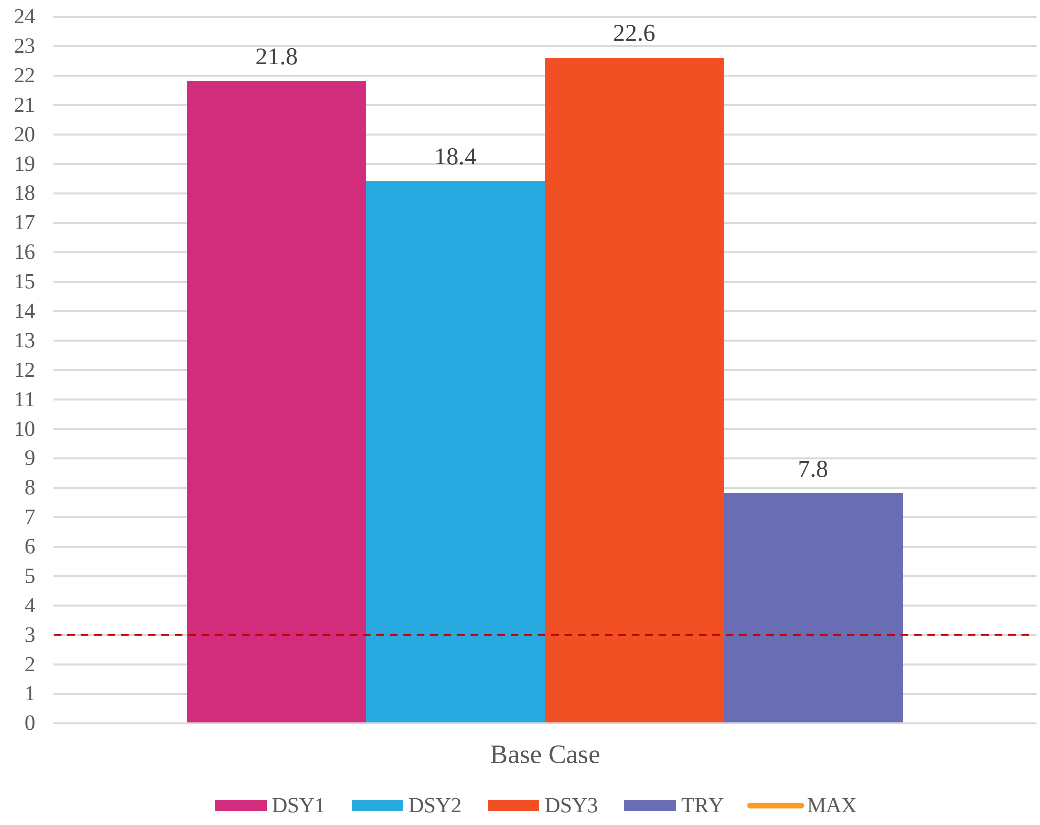
Max 50 hours above 28°C



The design does not comply with HTM 03-01 requirements under any weather files

Results: CIBSE TM52

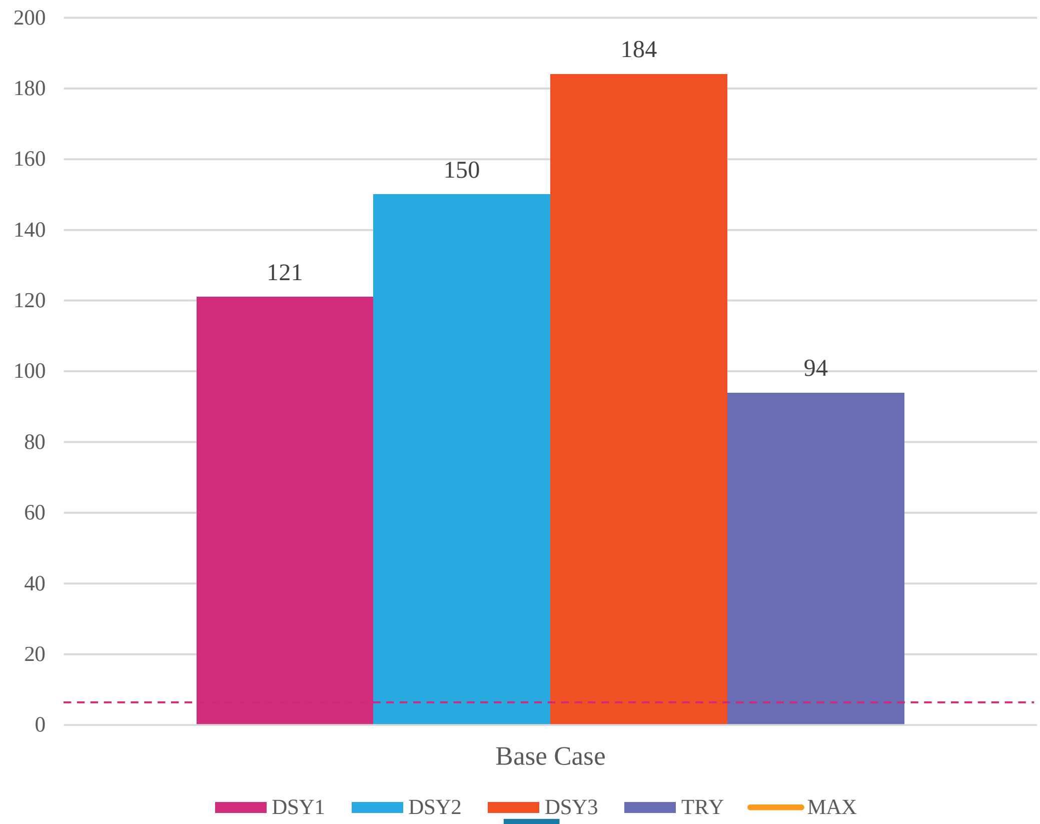
CRITERION 1: Hours of exceedance ≤ 3% occupied hours



The design fails the criterion under all weather files

Results: CIBSE TM52

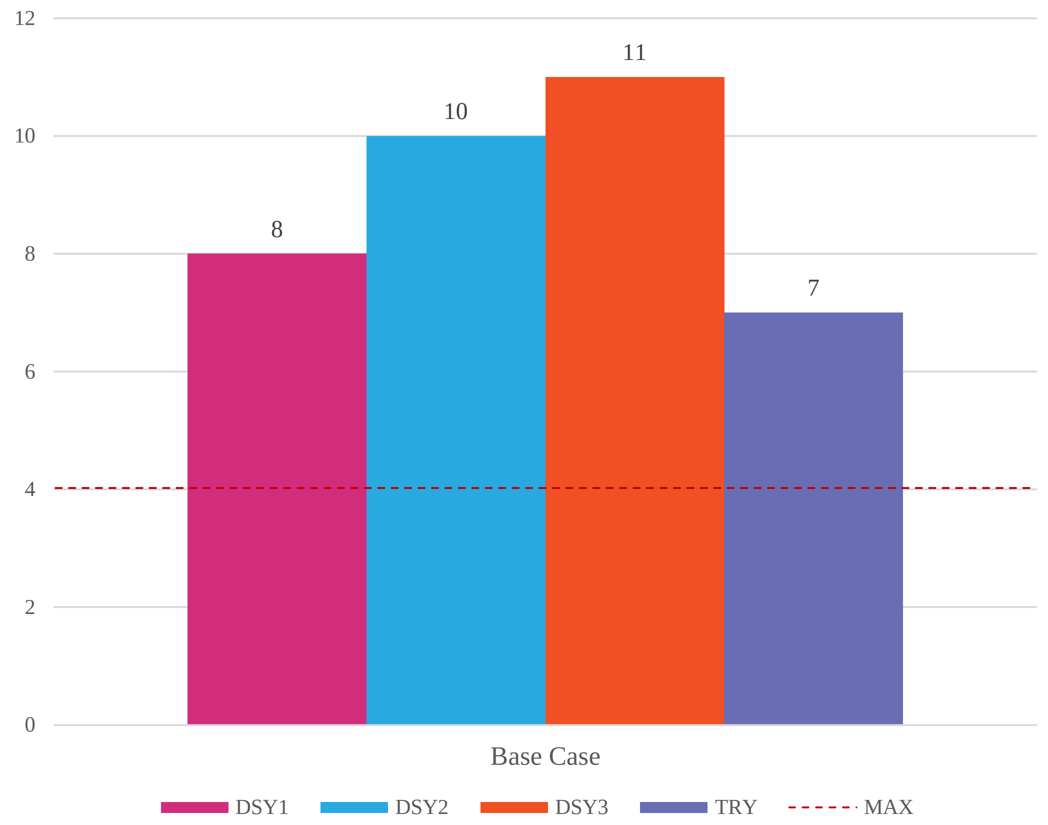
CRITERION 2: Daily weighted exceedance ≤ 6 in any single day



The design fails the criterion under all weather files

Results: CIBSE TM52

CRITERION 3: Upper limit temperature ($\Delta T \leq 4°C$)



The design fails the criterion under all weather files

Results: CIBSE TM52

3/3 criteria failed

↓

The space does overheat

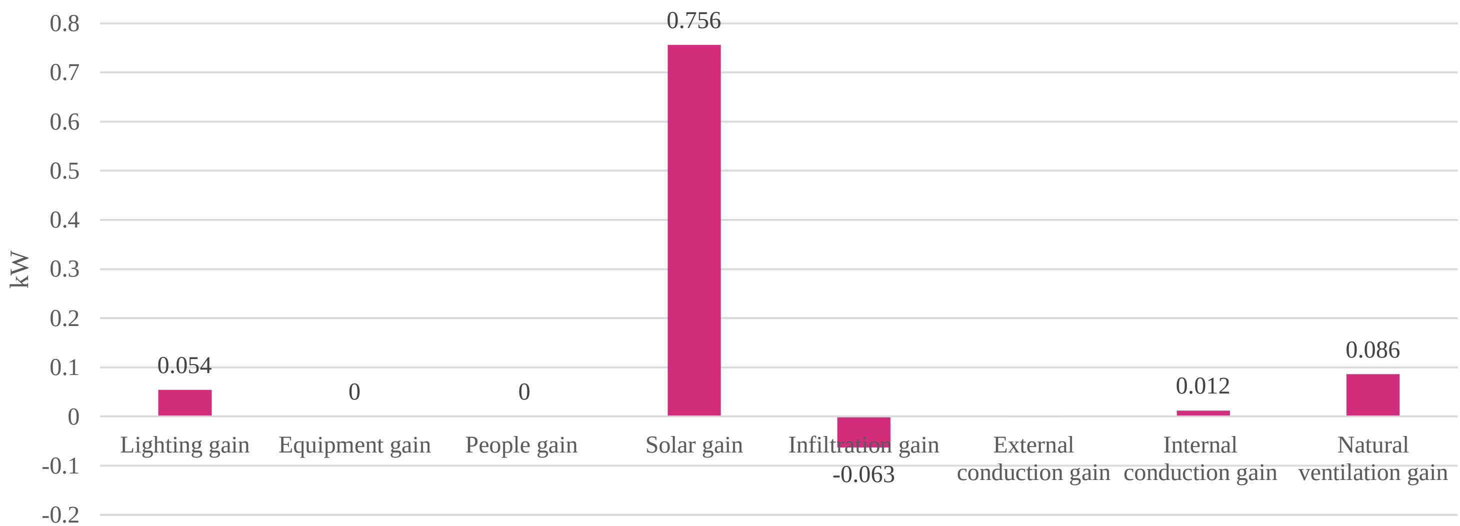
↓

The design need to be revised

Results: Peak cooling loads

DSY3 | Assuming cooling set-point 23°C

Lighting gain (kW)	Equipment gain (kW)	People gain (kW)	Solar gain (kW)	Infiltration gain (kW)	External conduction gain (kW)	Internal conduction gain (kW)	Natural ventilation gain (kW)
0.054	0	0	0.818	0.02	-0.018	-0.001	0.183



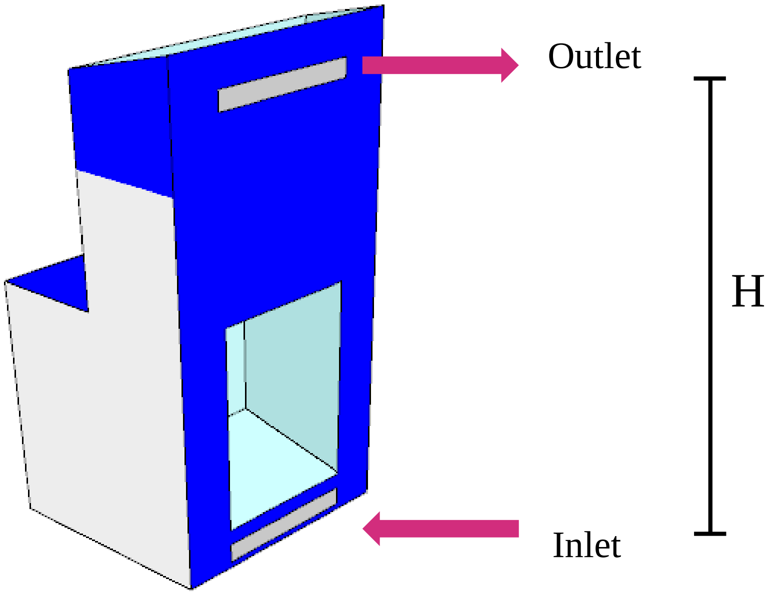
Solar gains are the most relevant

Modifications to initial design:

1. Increased vents

Louver Area = 0.30 m^2

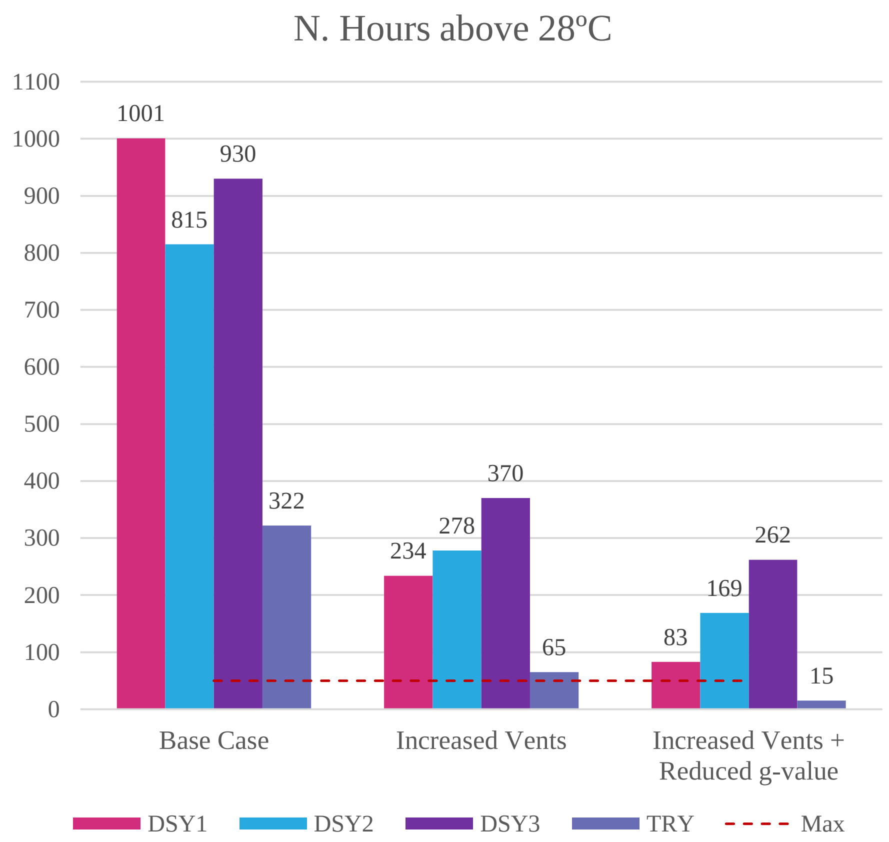
Eqv Opening Area = 0.09m^2
(3.5 times the initial value)



2. Increased vents + Reduced g-value

Rooflight G-value = 0.15 (half of initial value)

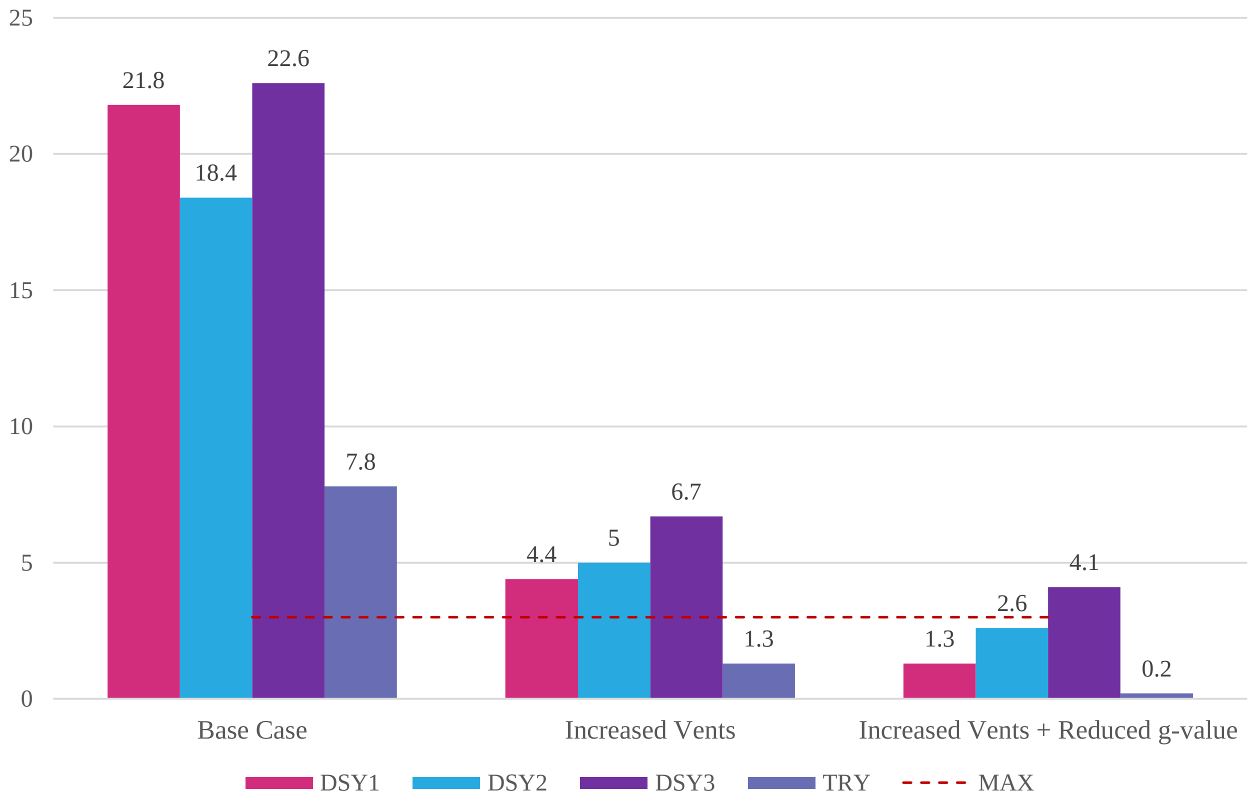
Results: HTM 03-01



The third option passes under TRY (average conditions)

Results: CIBSE TM52

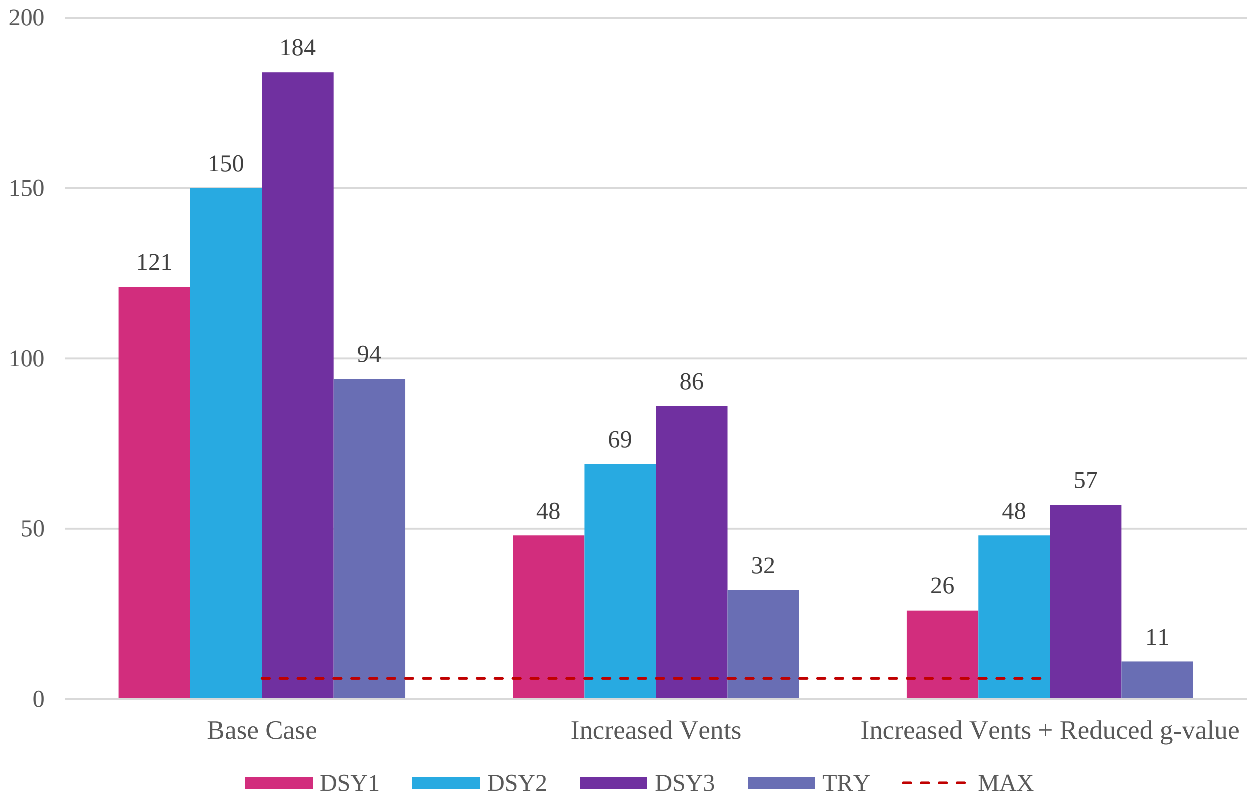
CRITERION 1: Hours of exceedance ≤ 3% occupied hours



Only DSY3 fails, the criterion is passed under other weather files

Results: CIBSE TM52

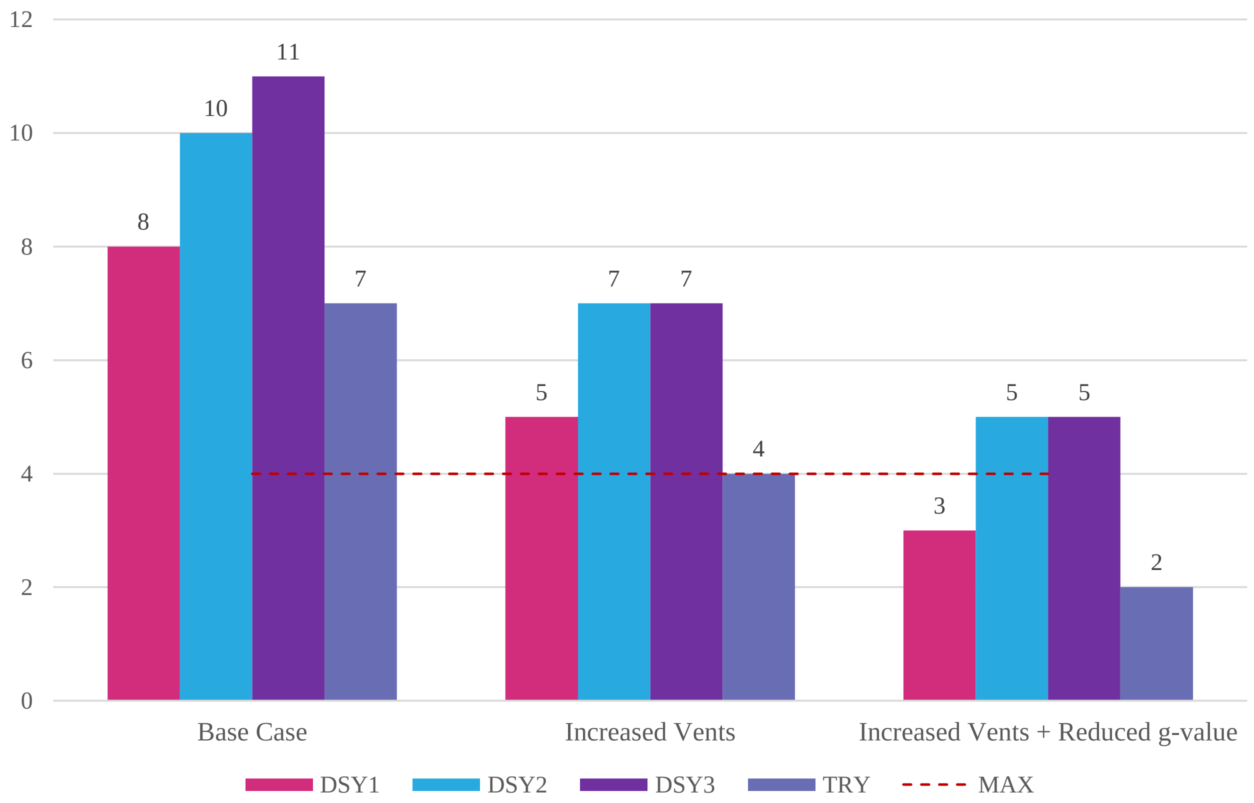
CRITERION 2: Daily weighted exceedance ≤ 6 in any single day



The criterion is failed under all weather files

Results: CIBSE TM52

CRITERION 3: Upper limit temperature ($\Delta T \leq 4°C$)



DSY1 and TRY pass the criterion, DSY2 and DSY3 fail the criterion

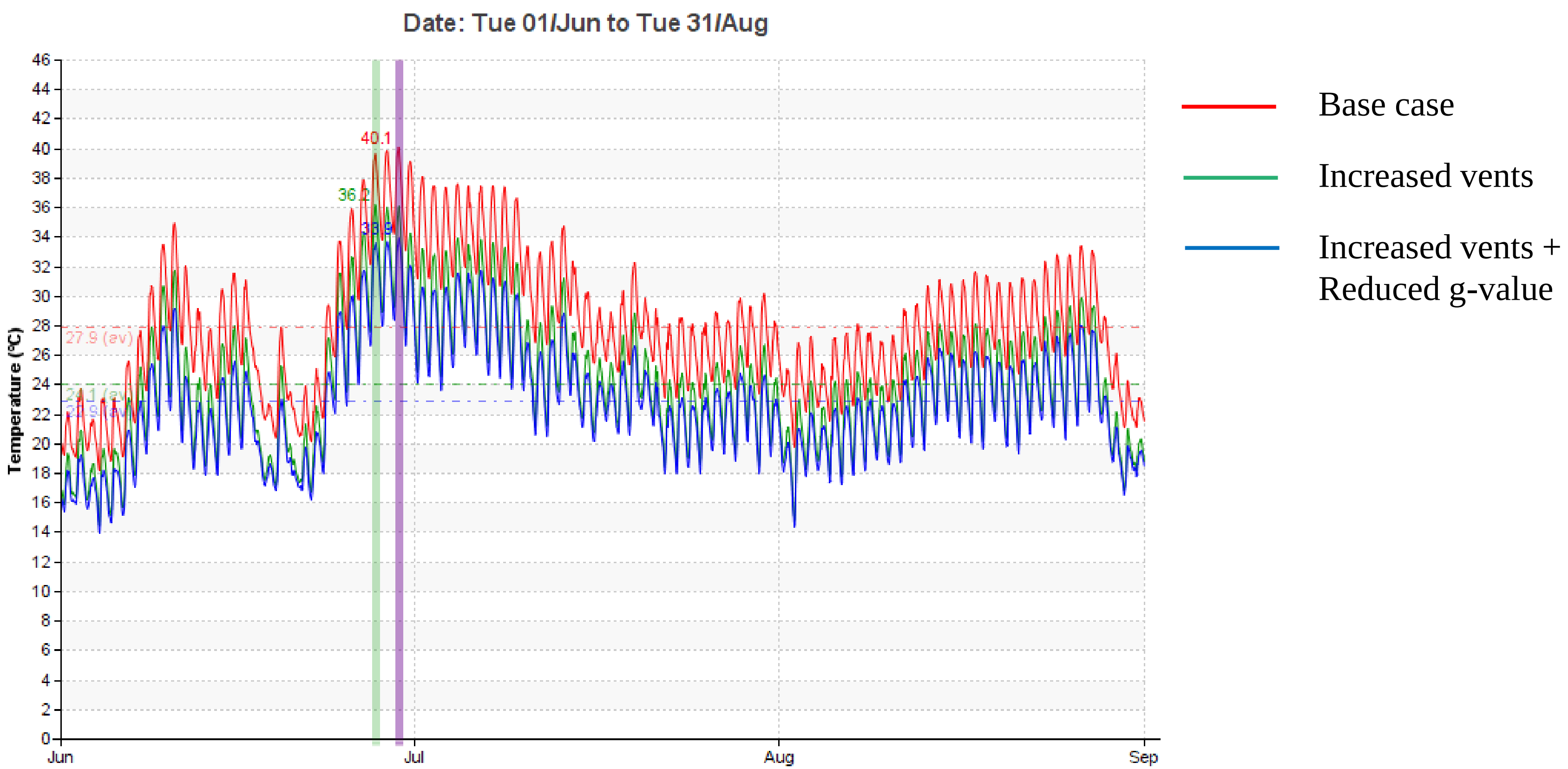
Results: CIBSE TM52

Strategy	DSY1	DSY2	DSY3	TRY
Base Case	3	3	3	3
Increased Vents	3	3	3	1
Increased Vents + Reduced g-value	1	2	3	1

The assessment is failed under DSY2 and DSY3
BUT
It is passed under DSY1 and TRY for the final strategy

The space does not pass the standard overheating assessment
BUT
It presents good results under average conditions

Results: Temperature in the hottest months (DSY3)



Solution	Average Temperature (°C)	Max Temperature (°C)	Reduction on Max Temp. (°C)
EXTERNAL CONDITIONS	17.7	30.7	-
Base case	27.9	40.1	-
Increased Vents	24.1	36.2	**-3.9**
Reduced g-value	22.9	33.9	**-6.2**

Results

	N. Hours above 28°C	TM52 Criterion 1	TM52 Criterion 2	TM52 Criterion 3
Increased vents	-69%	-77%	-58%	-37%
Increased vents + Reduced g-value	-81%	-90%	-76%	-60%

(Average reductions on base case for DSY3)

The overheating assessment method helped in improving the design