High efficiency non-residential buildings: concepts, implementations and experiences from the UK

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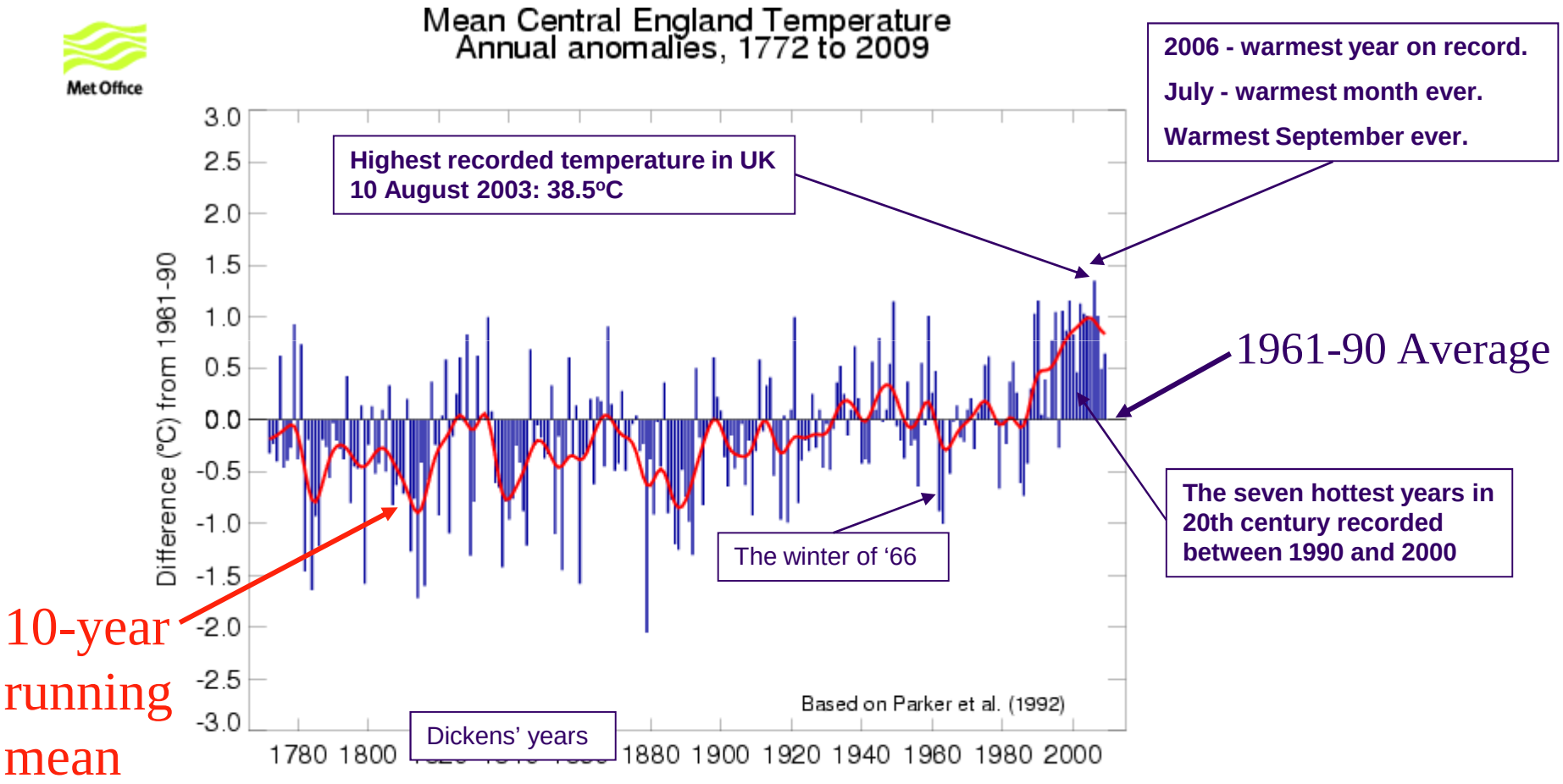
Structure of talk

- Global warming
- UK energy and CO_2 policy
- Advanced natural ventilation
  - ANV in a temperature climate
  - ANV hybrid in a severe climate
  - Resilience of ANV to UK climate change
- Conclusions

Central England Temperature since 1659: Evidence of Global warming?



The worlds longest available instrumental temperature record

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Impact of Global Warming: Ice Caps

North West passage open for first time since records began

BBC, Friday, 14 September 2007, 21:19 GMT 22.19 UK

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Impact of Global Warming: 2003 Heat Wave

- Hottest in France for 50 years.
- Heat wave lasted two weeks
  - UK: 2,045 additional deaths
  - France: 14,802 additional deaths
  - Germany: 7,000 additional deaths
  - Europe: 35,000 additional deaths
- The old especially, and the very young suffer.

In France 91% of victims were over 65.

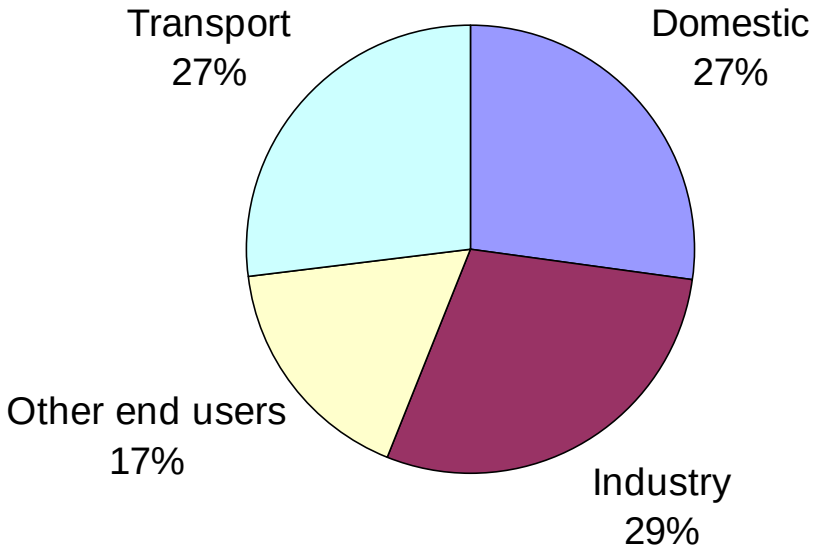
UK Targets to Curtail Global Warming

- Kyoto target - CO_2 levels to 12.5% below 1990 level by 2008 – 2012 (met).
- Aspire to reduce UK CO_2 to 20% below 1990 level by 2010 (not be met).

- 2008 Climate Change Act – cut UK CO_2 by 80% of 1990 level by 2050.
- Generate 10% of UK energy from renewables by 2010 (not met).

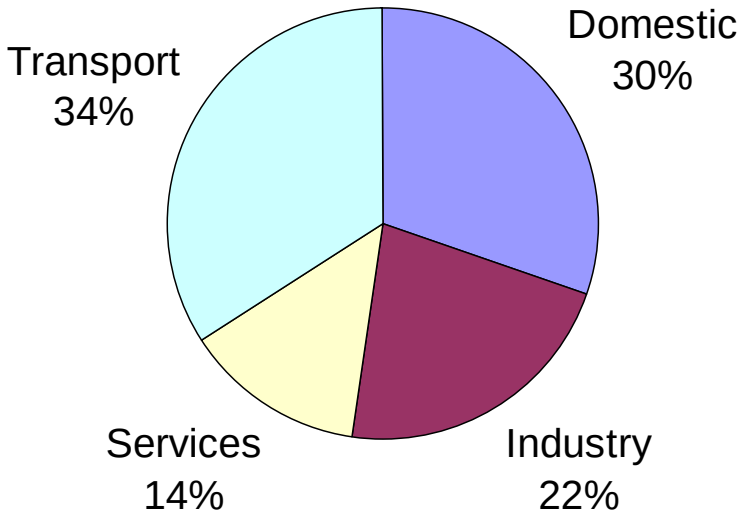
UK Energy & CO_2 emissions

Energy, 2001



Source: DTI 2002

CO_2 emissions, 2001



Source: DEFRA 2002

Commercial and public buildings 15% of UK emissions.

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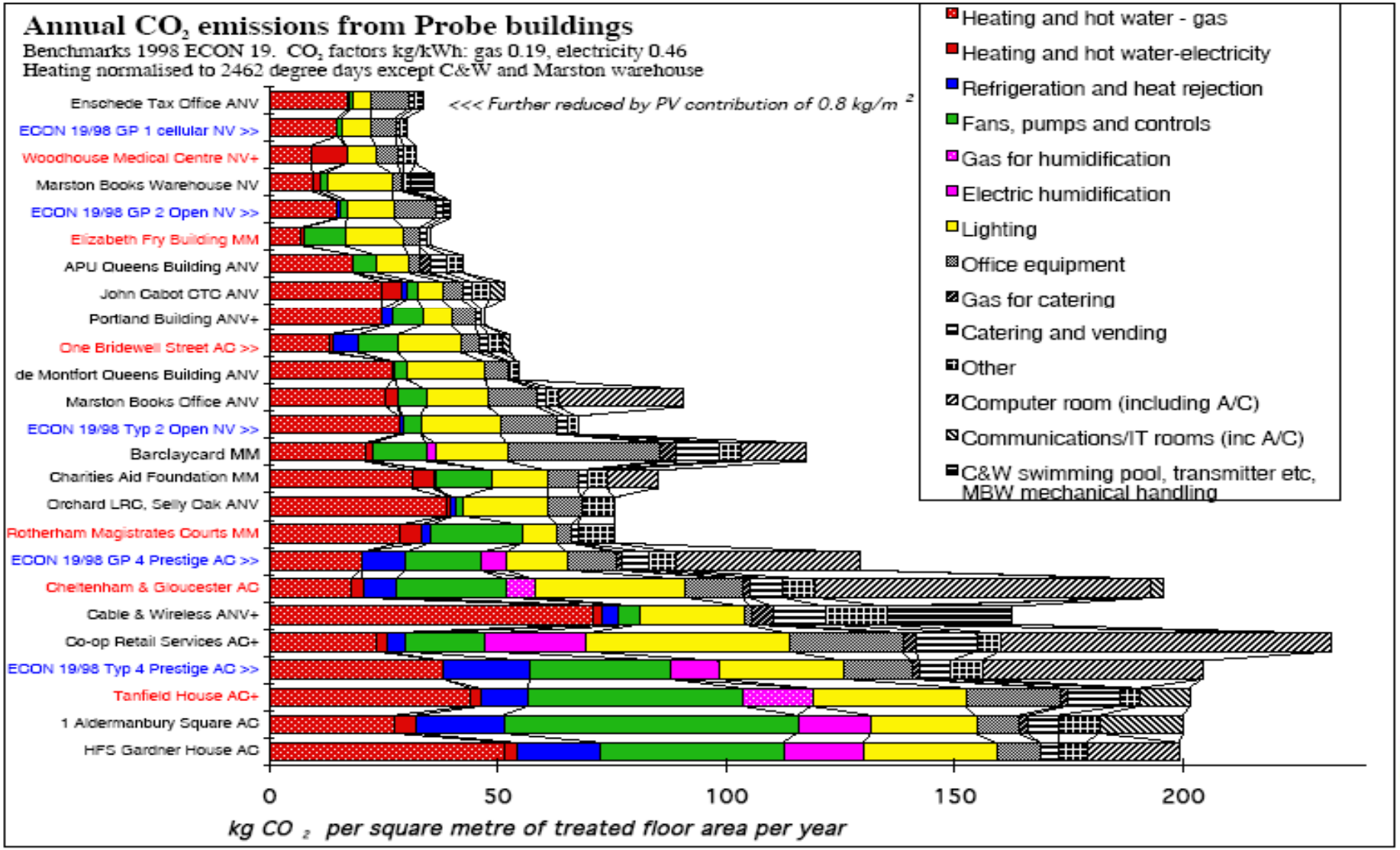
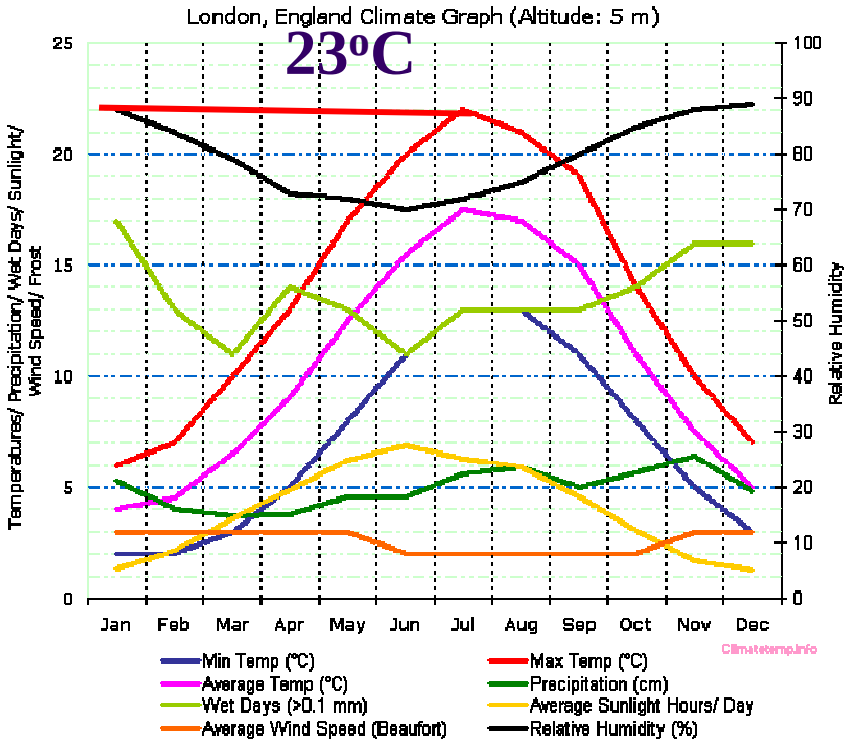
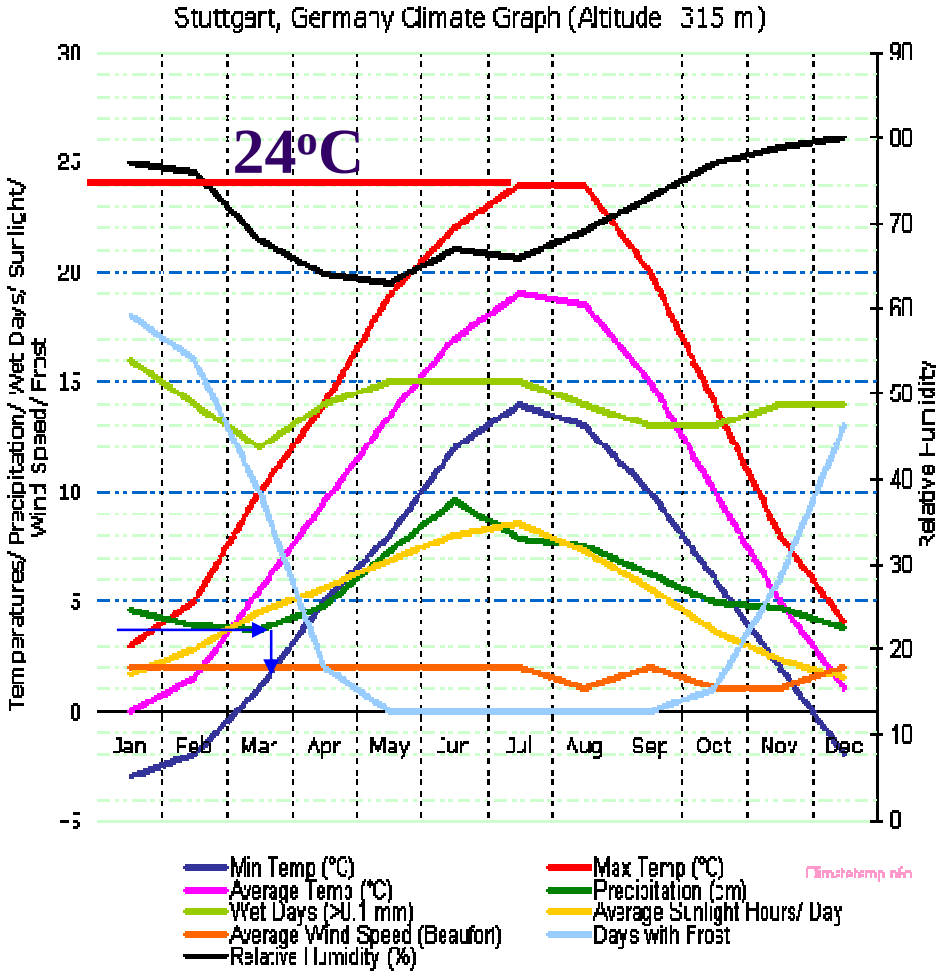
The CO_2 emissions from 20 buildings



Temperatures – London and Stuttgart





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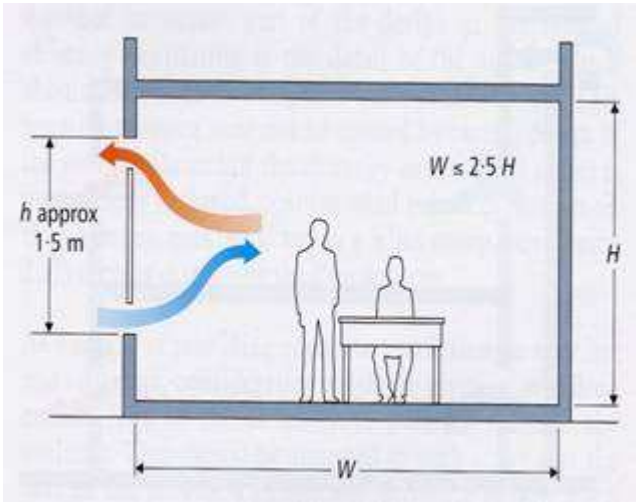
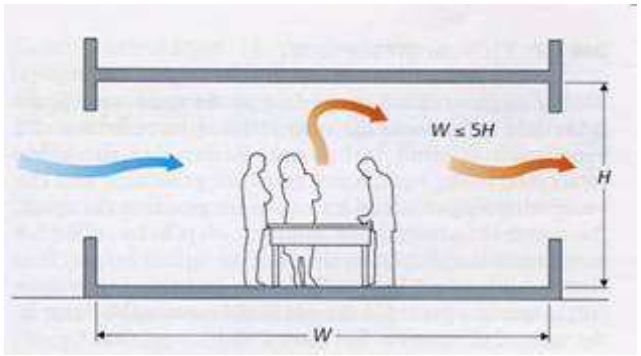
Simple natural ventilation (SNV)





Deep plan	No
Security / urban protection	Poor
Occupant control	Yes
Draught control	Poor
Ventilation assistance	No
Mechanical cooling	No
Energy recovery	No

Source: CIBSE Guide AM10

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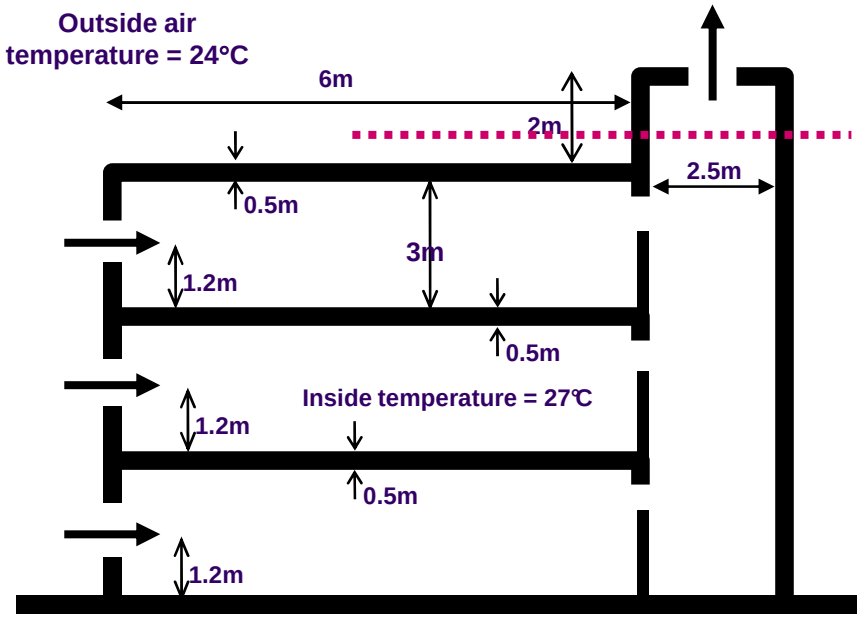
Stack driven flow

$$\Delta p_s = \rho_o g h T_o \left(\frac{1}{T_{\text{ext}}} - \frac{1}{T_{\text{int}}} \right)$$

$$Q = C_d A \sqrt{\frac{2\Delta P}{\rho}}$$

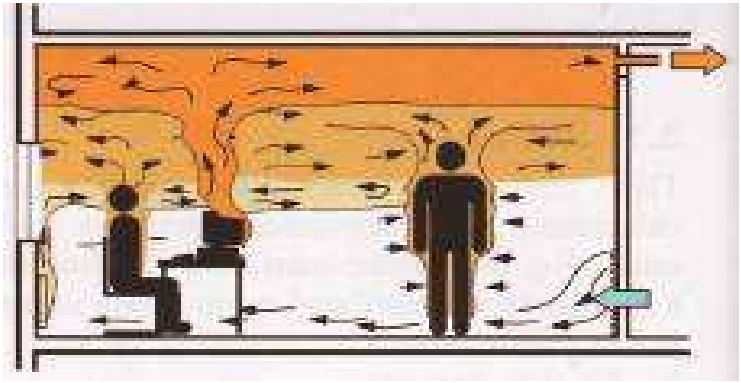
$$Q = C_d A \sqrt{2 g h T_o \left(\frac{1}{T_{\text{ext}}} - \frac{1}{T_{\text{int}}} \right)}$$

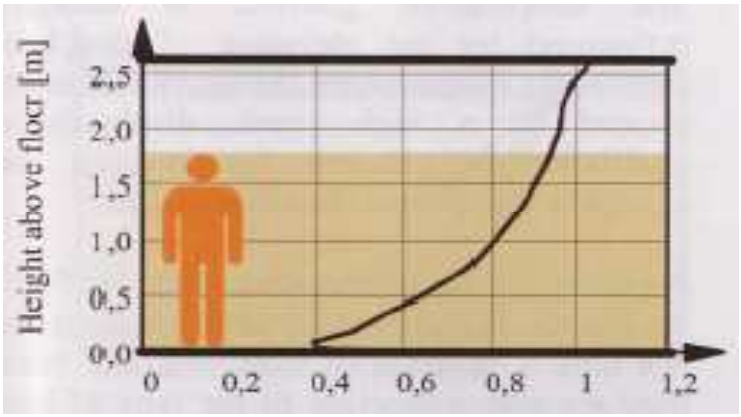


Set NPL mid-way between upper-most opening and outlet

Opening	Distance from NPL (m)	Required flow rate (m^3/s)	Stack pressure (Pa)	C_dA (m^2)	C_d (-)	A (m^2)
1	9.15	0.448	1.077	0.334	0.61	0.548
2	5.65	0.448	0.665	0.426	0.61	0.698
3	2.15	0.448	0.253	0.690	0.61	1.131
outlet	2.15	1.344	0.253	2.069	0.61	3.393

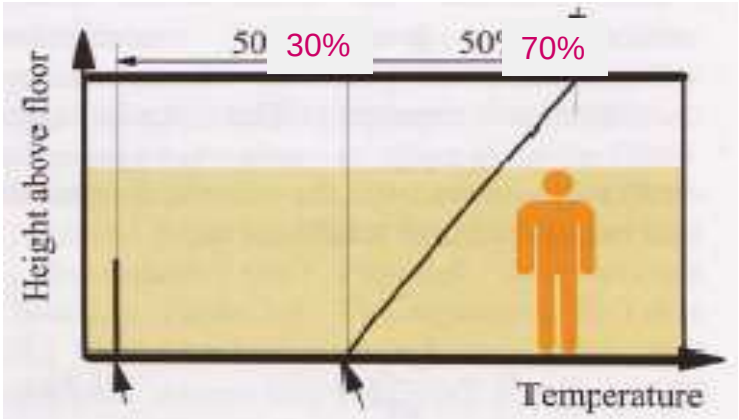
Displacement ventilation principles





T_a + 7 K

Extract air temperature



T_a (℃)

Supply air temperature

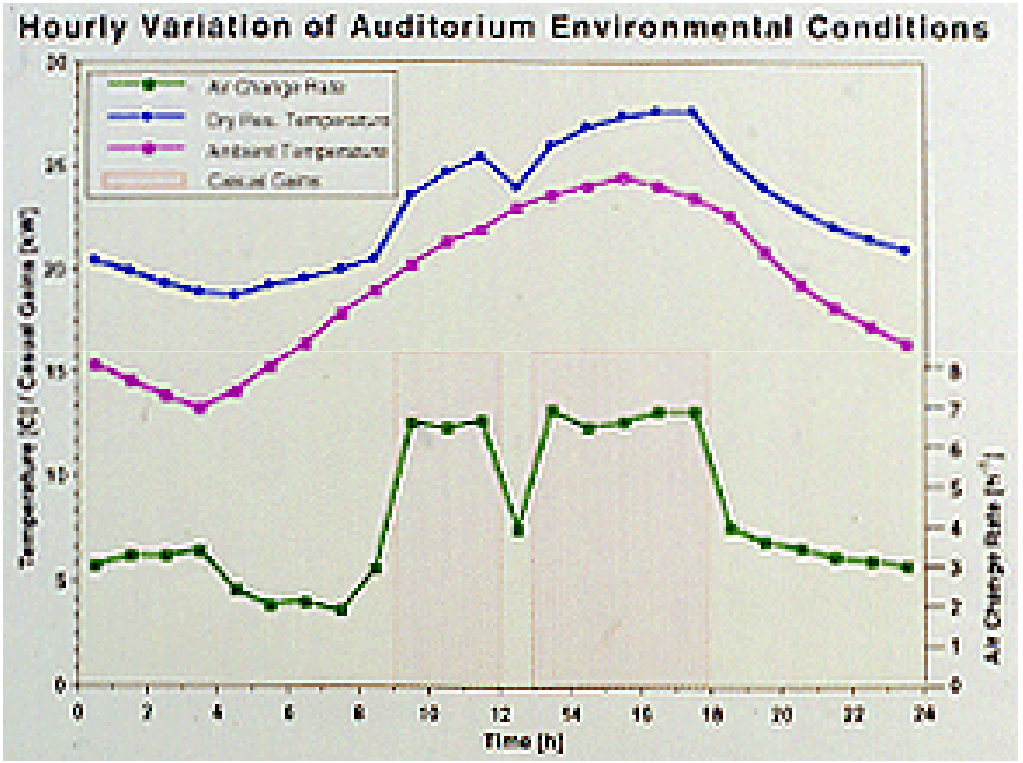
T_a + 2 K

Air temperature at floor

Source: REHVA, Displacement ventilation in non-industrial premises, in: H Skistad (Ed), Guidebook No 12, Federation of European Heating and Air-conditioning Associates, 2000, 95pp

CFD animation: stack-driven ventilation

The stack effect – the self-rectifying ventilation system



Queens Building – De Montfort U.

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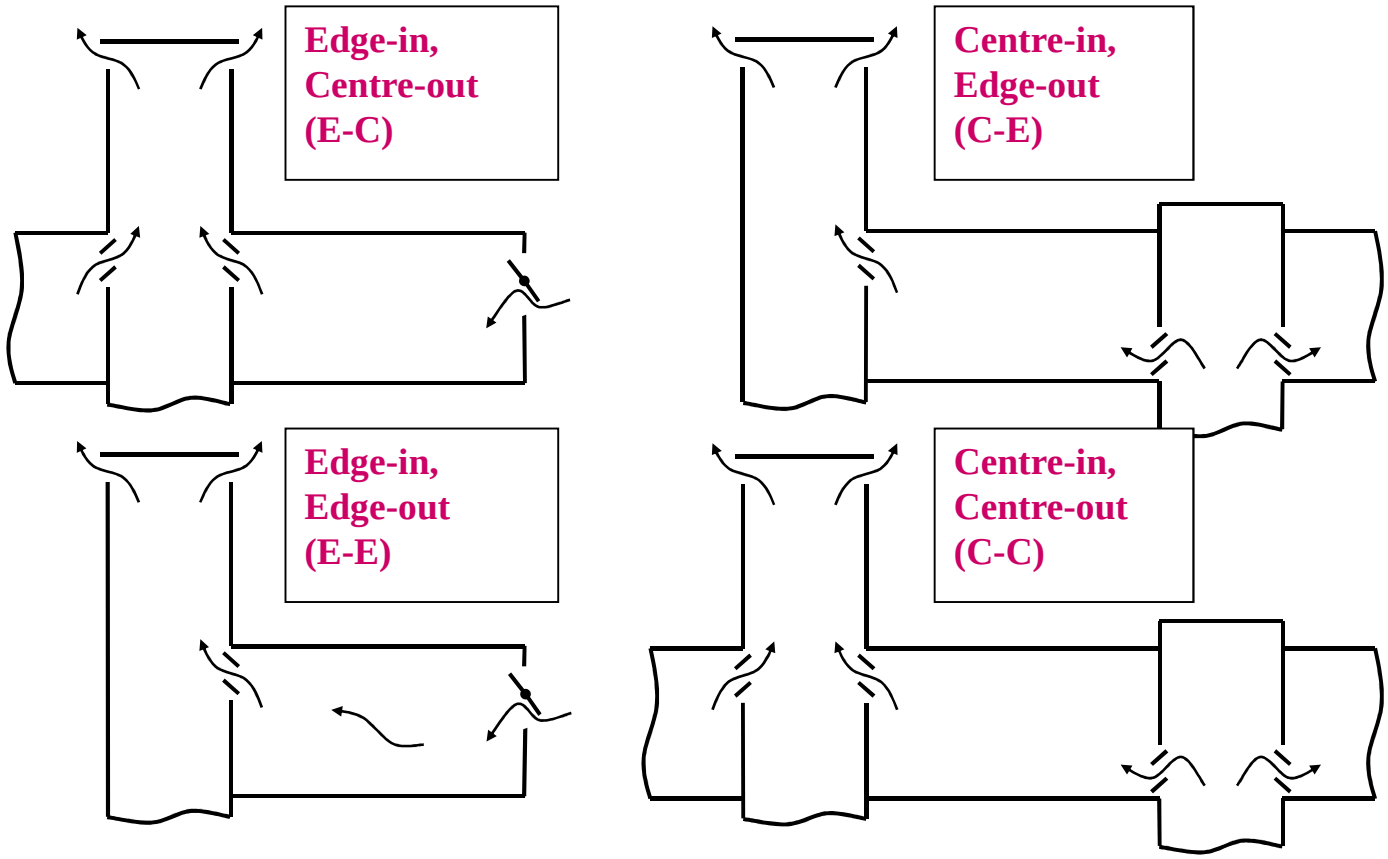
Different forms of stack ventilation



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The lightwells

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Stacks

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Frederick Lanchester Library: Coventry University

- Central UK location
- City centre site
- Strong architecture
- Advanced natural ventilation
- Night venting and exposed thermal mass
- Daylight
- CHP

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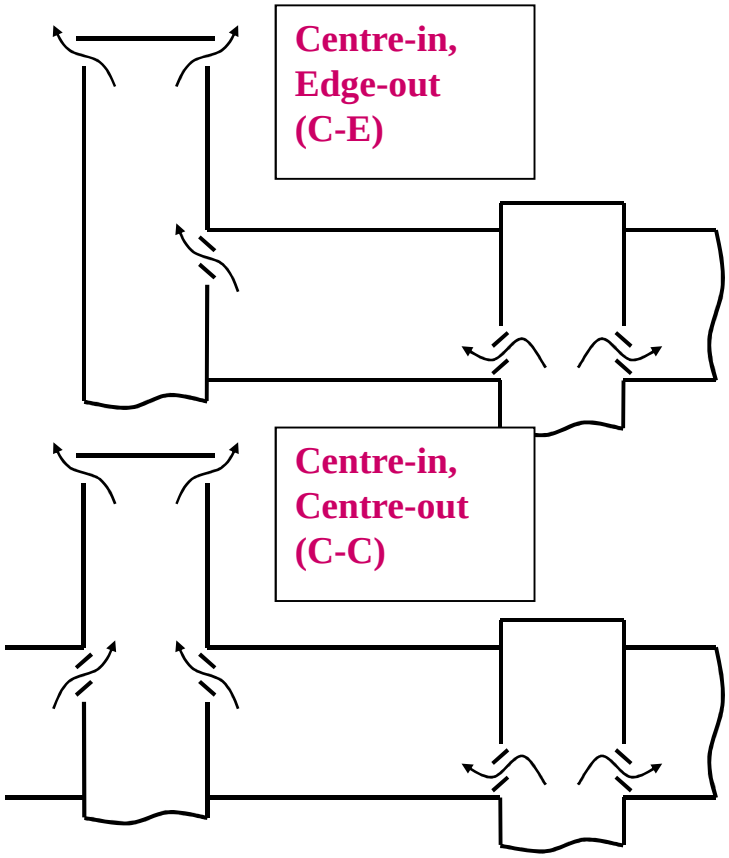
Centre-in edge-out stack ventilation

Deep plan	Yes
Security / urban protection	Good
Occupant control	No
Draught control	Good
Ventilation assistance	Yes
Mechanical cooling	Yes
Energy recovery	No *

* Possible in mixed-mode variant, eg Judson



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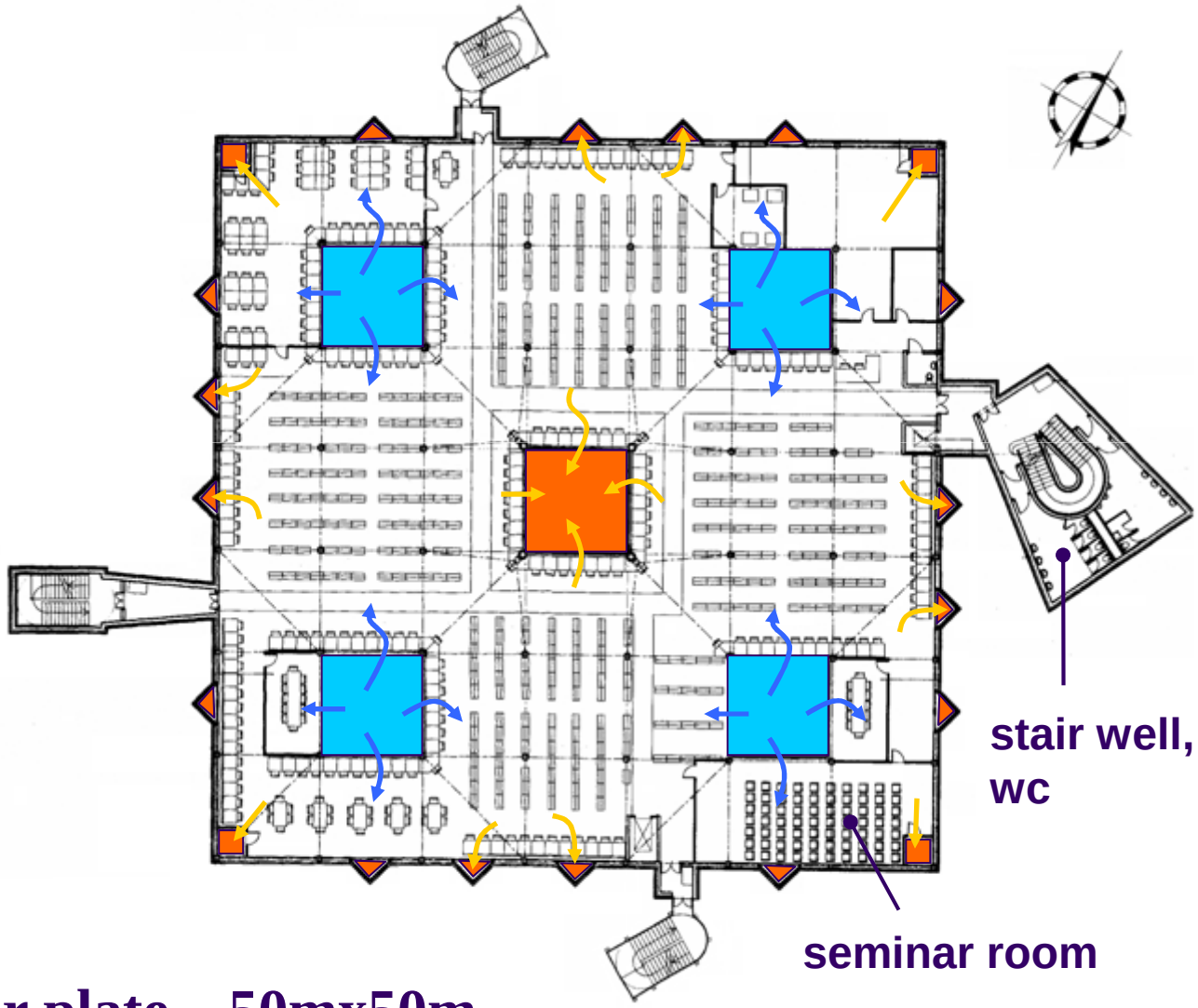
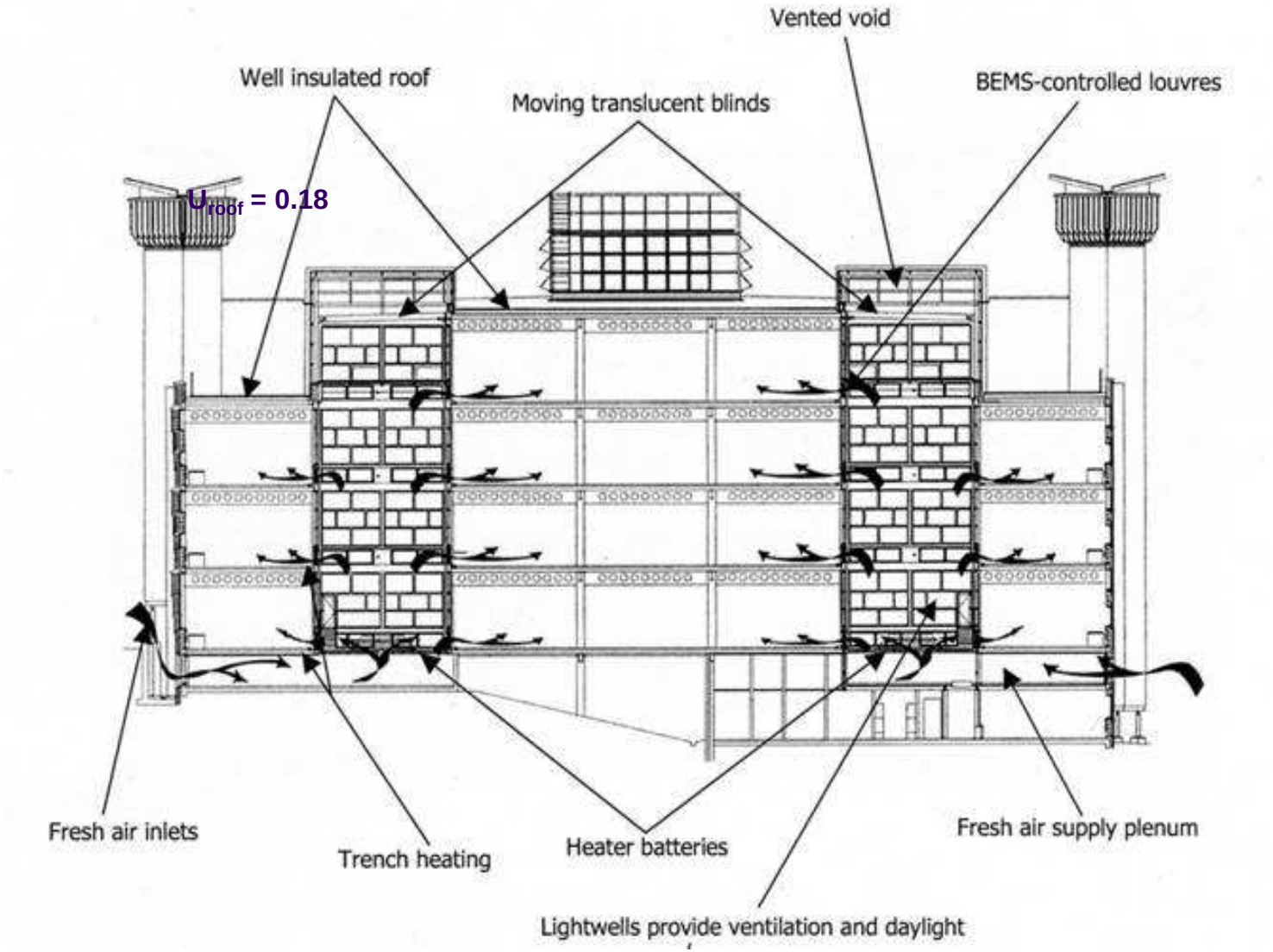
Typical Floor Layout

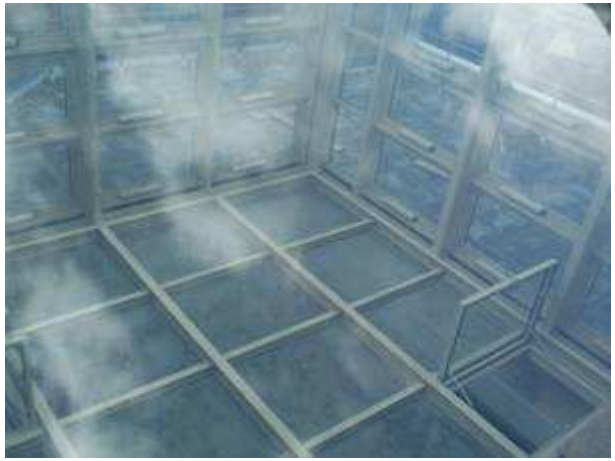


Floor plate – 50mx50m

Environmental Control: Air Supply



Coventry: Air Supply



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Tried and tested energy saving techniques

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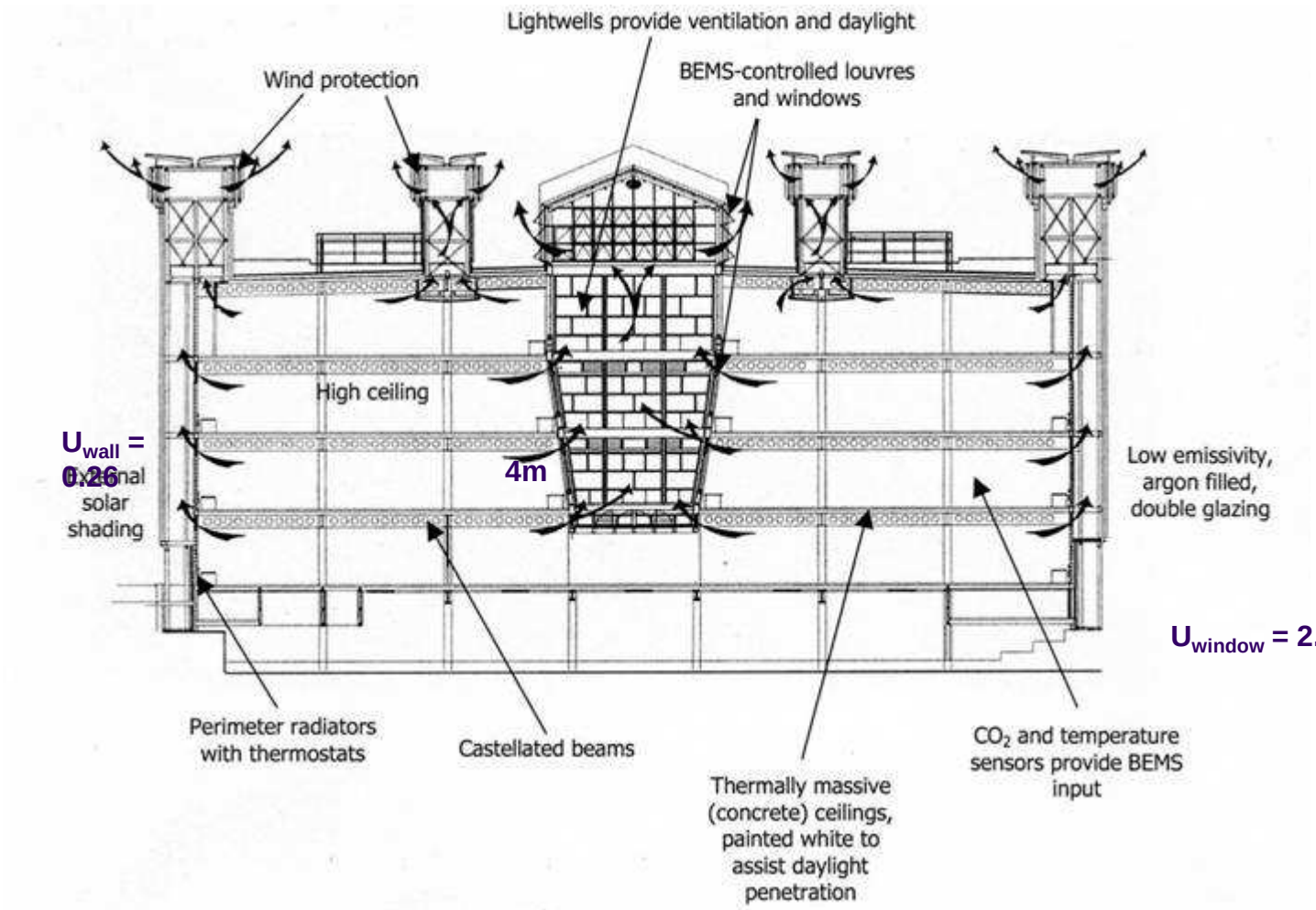
Environmental Control: Air Exhaust



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Coventry: Air Exhaust

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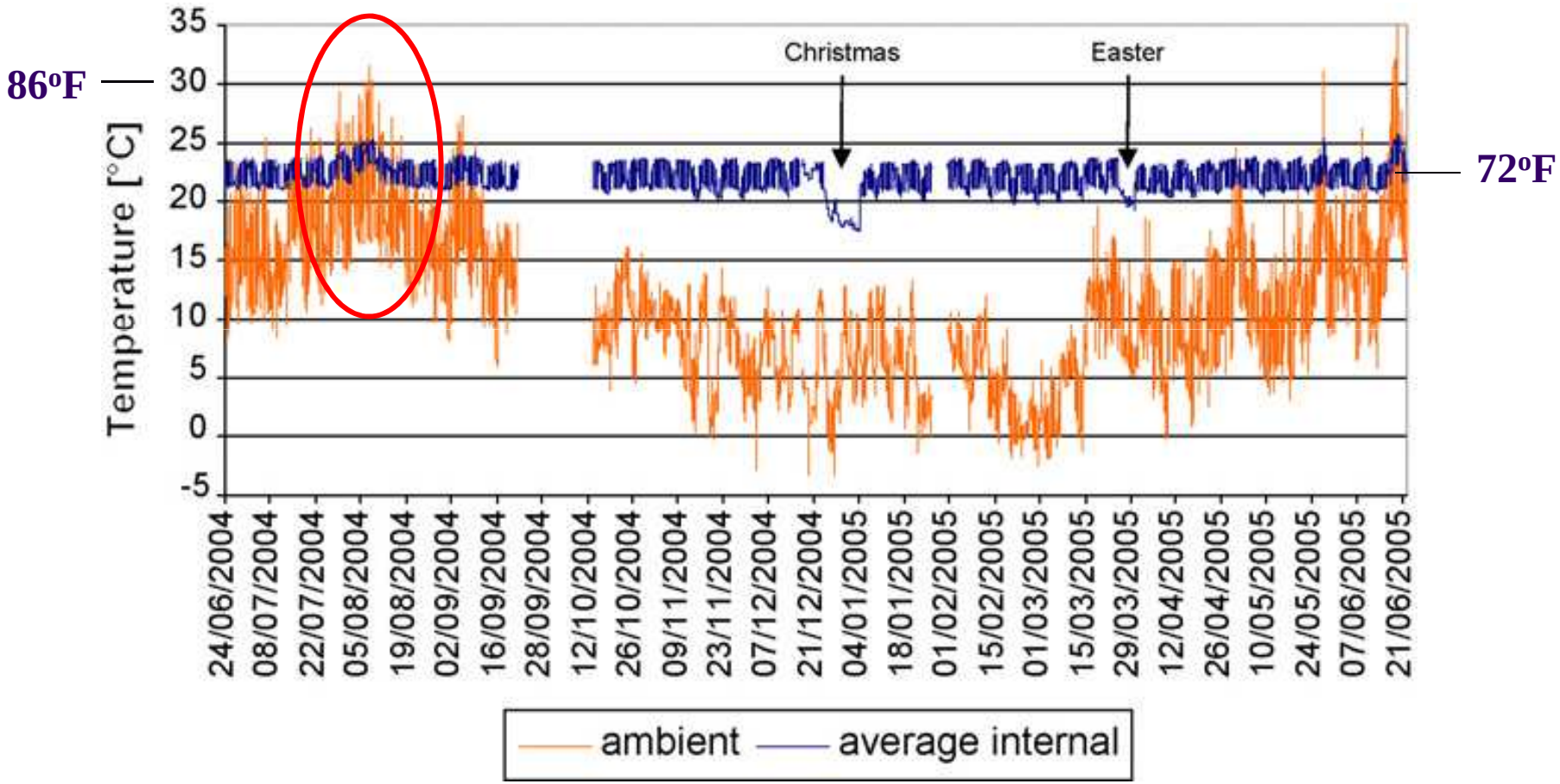
UK design guidance : overheating criterion for free running buildings (CIBSE Guide A)

- Need to analyse risk of overheating and minimise length and severity of discomfort
- **Limit expected occurrence of operative temperatures over 28℃ [82℉] to 1% of annual occupied period[1]**
- Overheating criteria to be assessed using the CIBSE design summer year (DSY)

1 Criterion for offices, schools and dwelling areas

Internal and external temperatures during the monitoring period (June 2004–June 2005).



Source: Krausse B, Cook M & Lomas K (2007) Environmental performance of a naturally ventilated city centre library, Energy and Buildings

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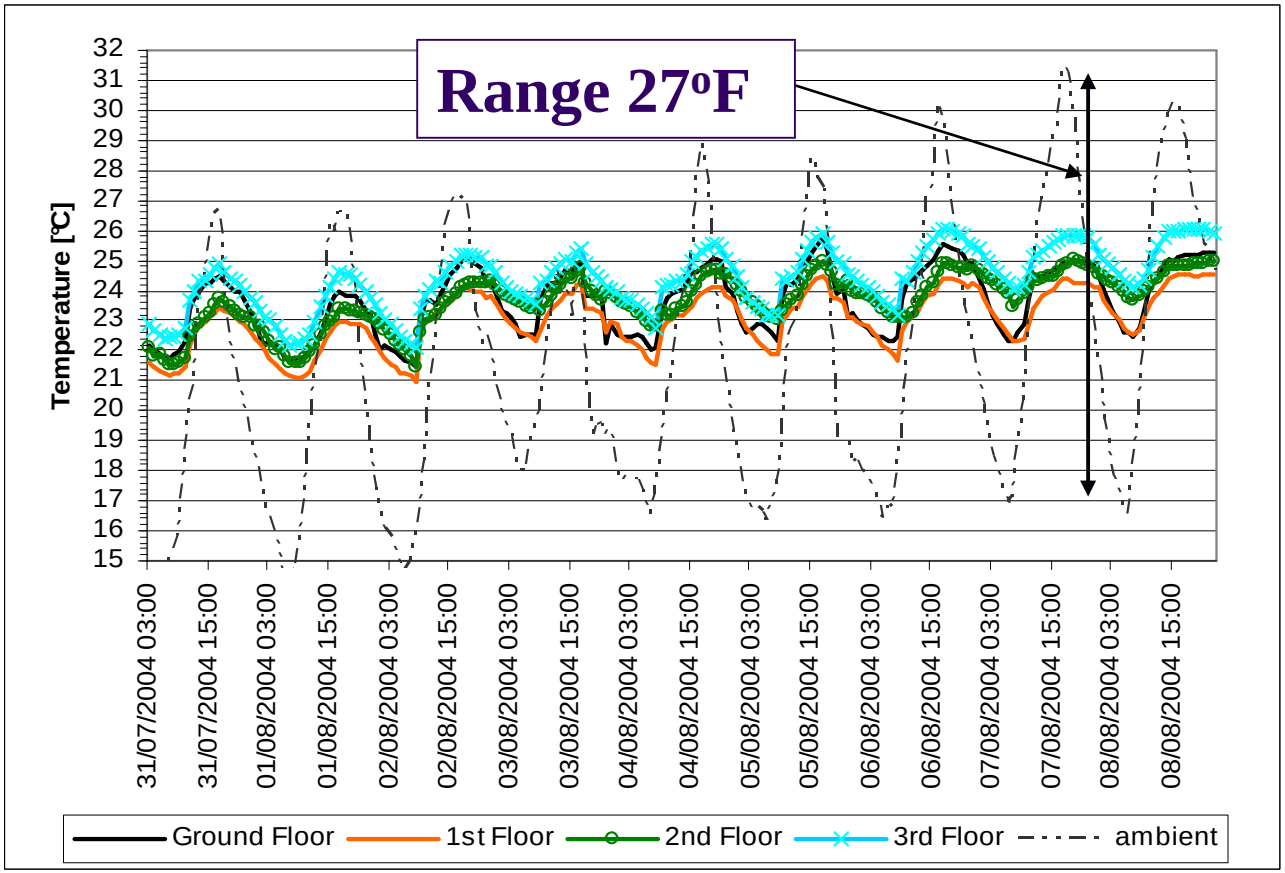
Average floor temperatures during a hot spell



Throughout the entire year there were no occurrences of internal temperatures in excess of 28ºC.

Source: Krausse B, Cook M & Lomas K (2007) Environmental performance of a naturally ventilated city centre library, Energy and Buildings

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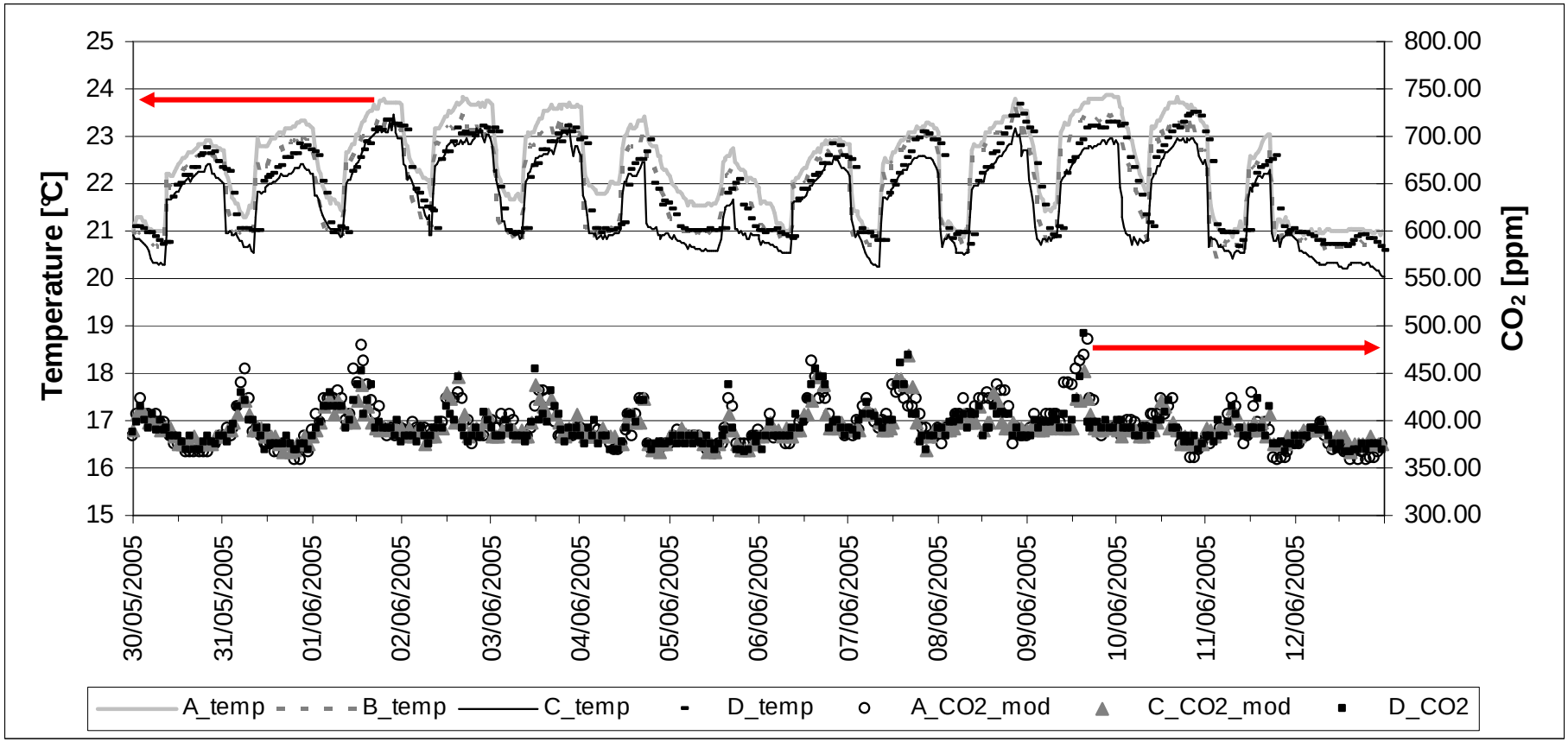
Temperatures and CO_2 levels on the second floor: 30 May – 12 June 2005



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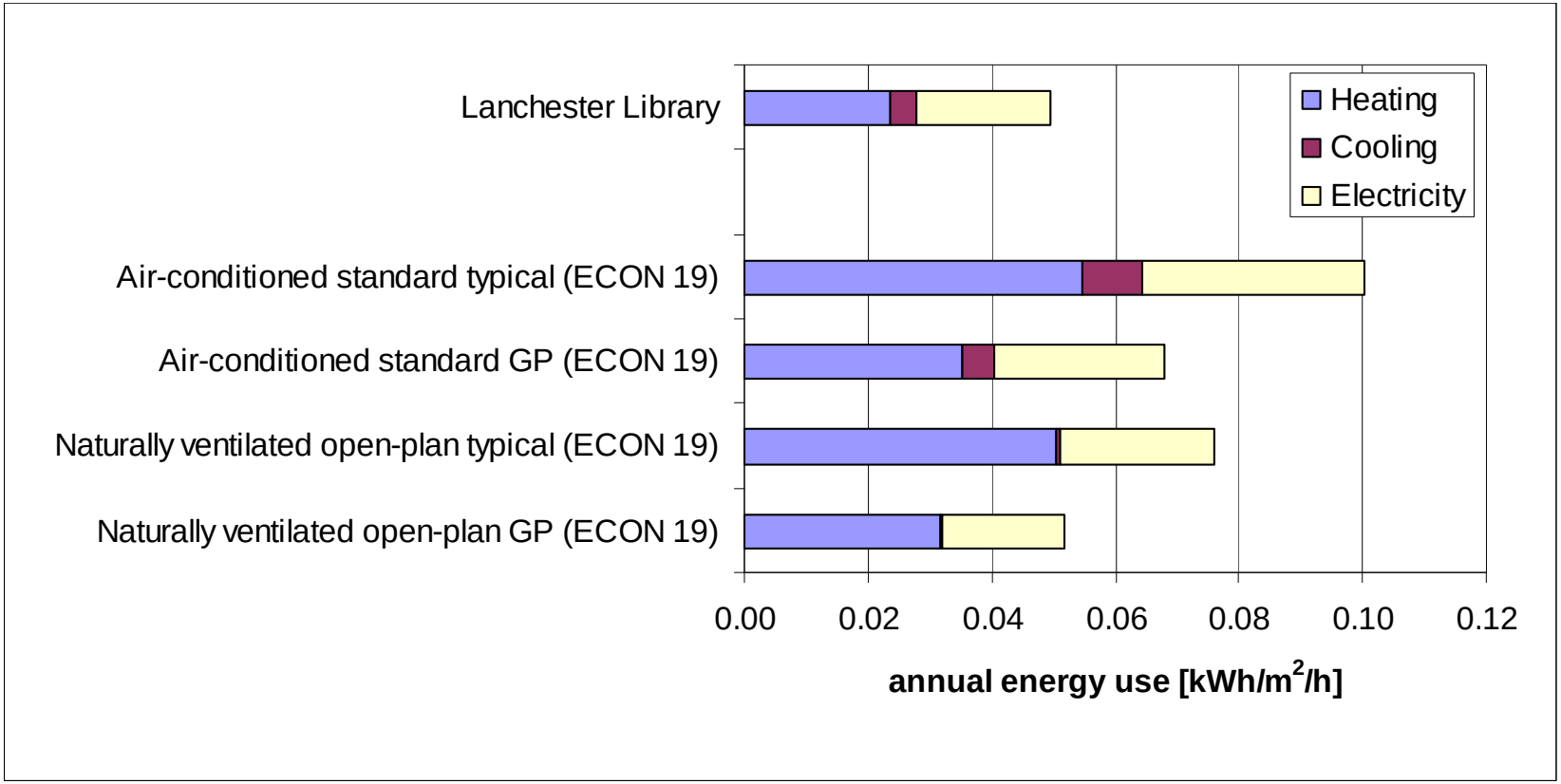
Comparison of measured annual energy consumption in 2004 with benchmark values



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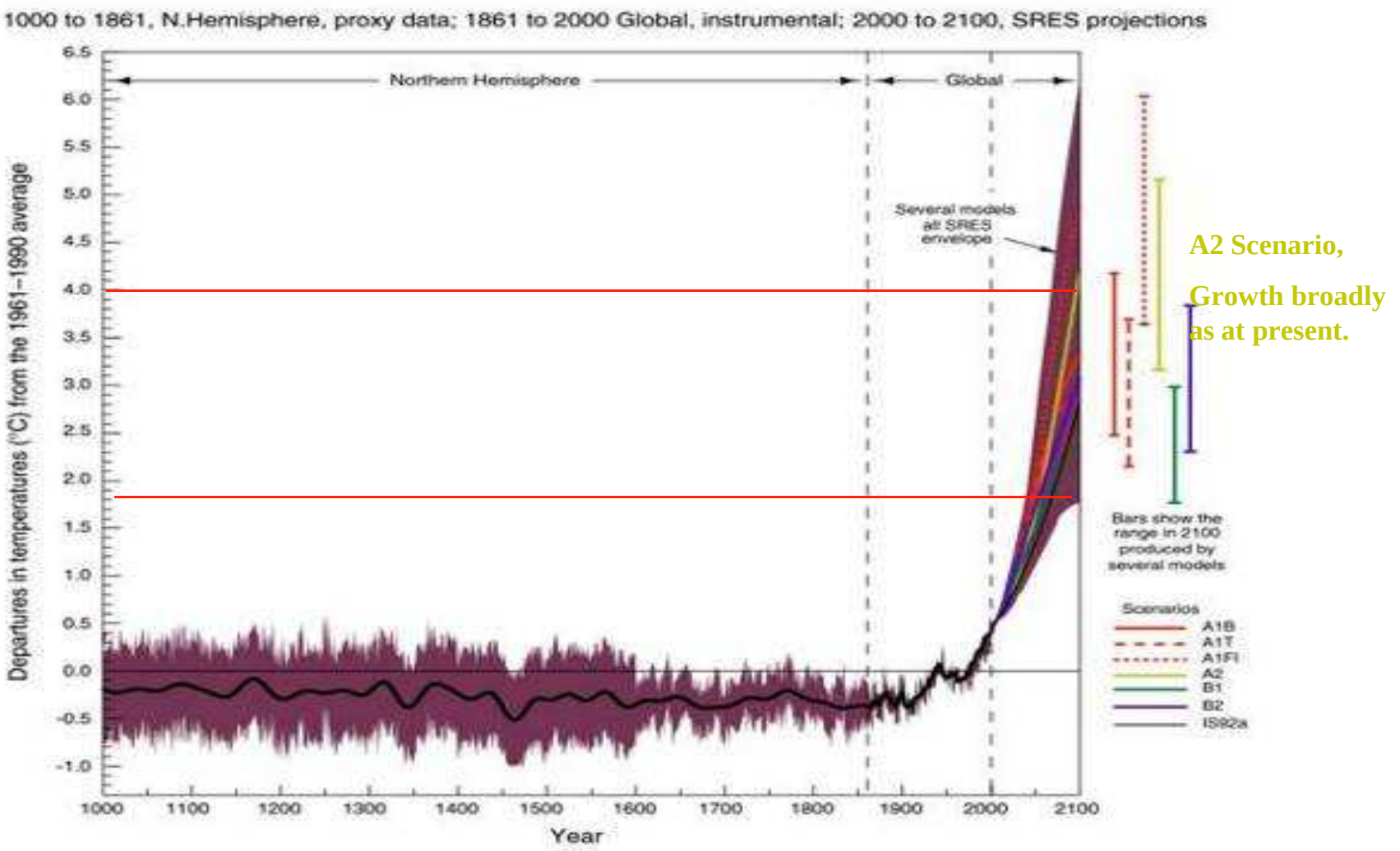
How resilient is ANV to projected future climate of the UK

- How will a warmer climate influence the energy demand of ANV buildings?
- Will ANV buildings maintain thermal comfort in the UK climate of the future?

If not -

- What will the internal temperatures be in ANV buildings at various UK locations?
- Does ANV perform better than SNV in a warmer climate?
- In which areas of the country might ANV fail to meet thermal comfort criteria?
- At what date in the future will thermal comfort criteria be exceeded?

Past and projected global surface temperatures



A2 Scenario,

Growth broadly as at present.

Source: Intergovernmental panel on climate change

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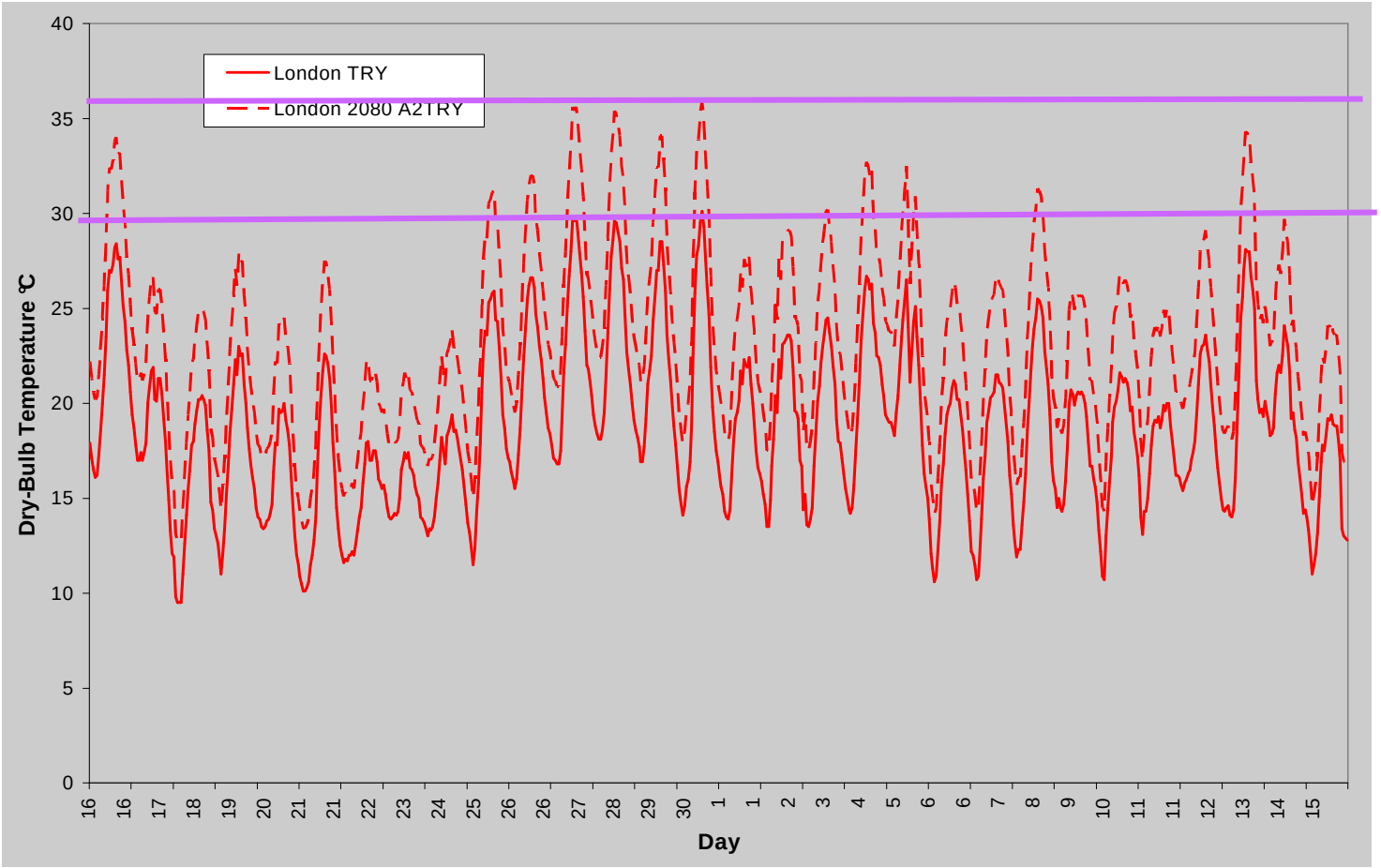
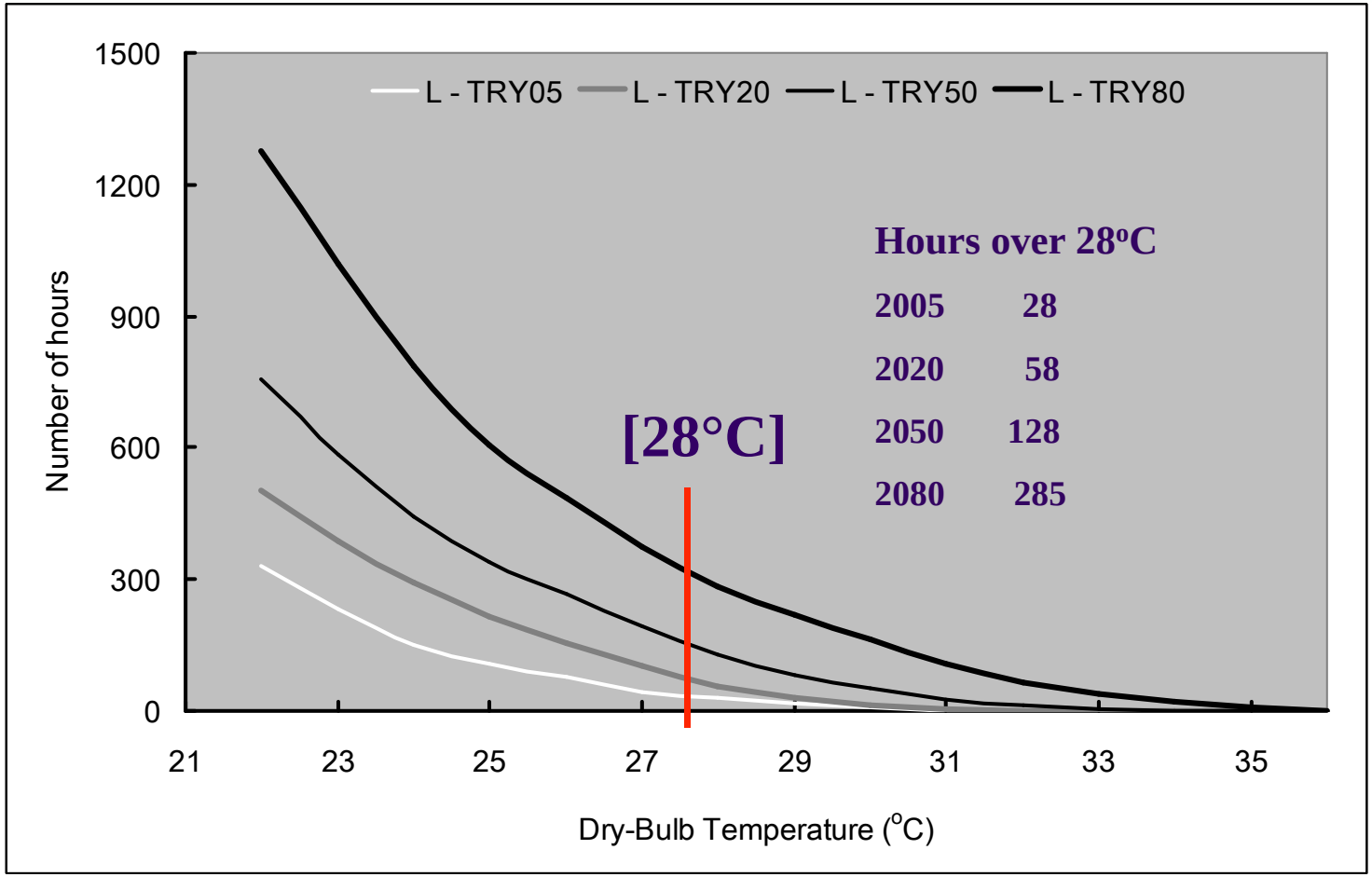
Typical temperatures in the London and Projected Temperatures for 2080 (A2 scenario)



37ºC

30ºC

Occurrence of warm temperatures: London 2005, 2020, 2050, 2080.



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London temperatures in 2080

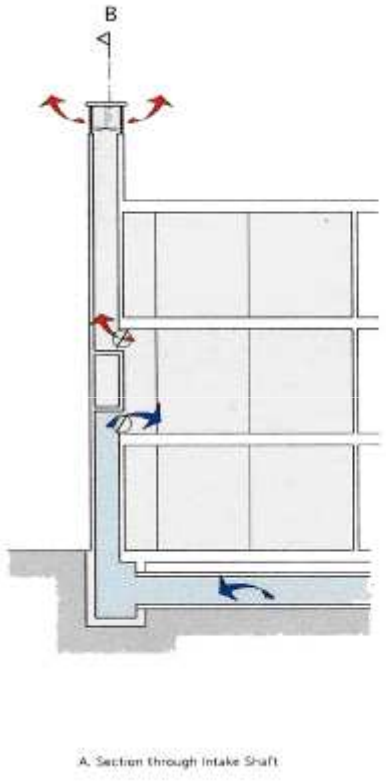
In 2080 London could be as warm as the following places are today:

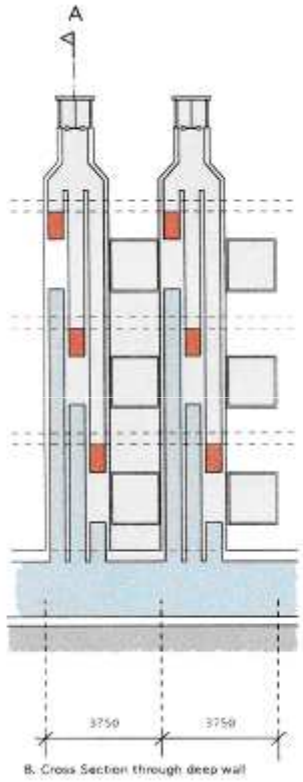
- Tanger
- Toulouse
- Tenerife and
- Thessaloniki

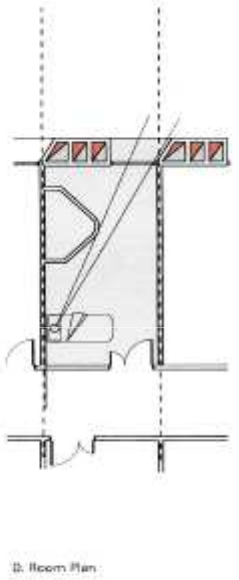
but

- there will be more frequent and more intense heat waves.

Hospital ward with ANV: section, elevation and plan







Stack - tunnel to inlet: 3m

Stack - outlet to exhaust: 9.5m

Window: 1.4m x 1.6m

7.2m x 3.6m x 3.6m high

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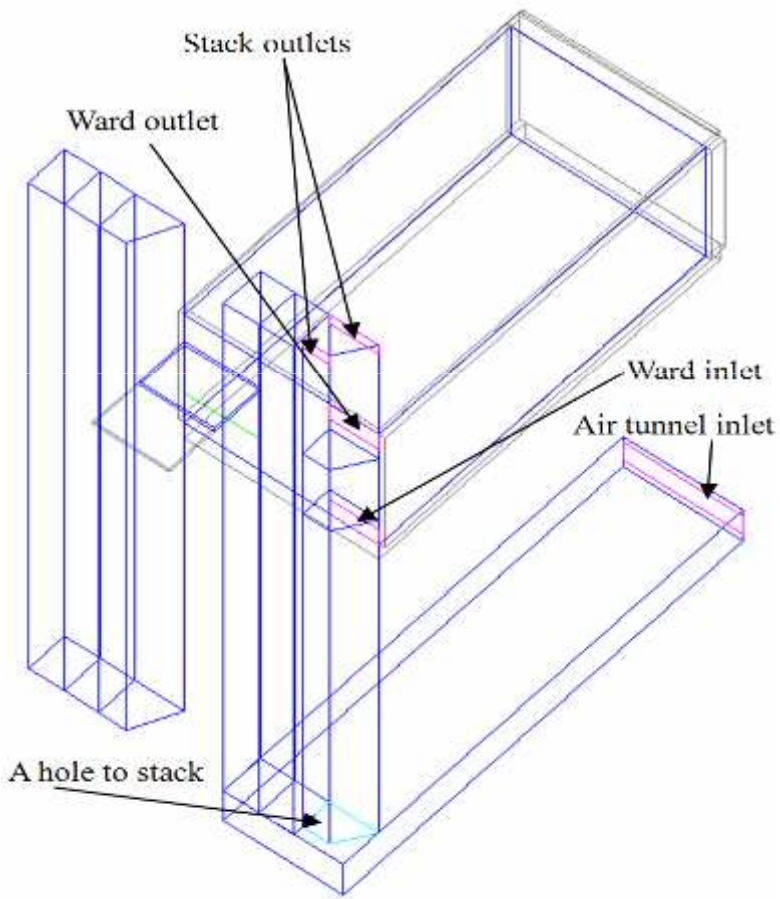
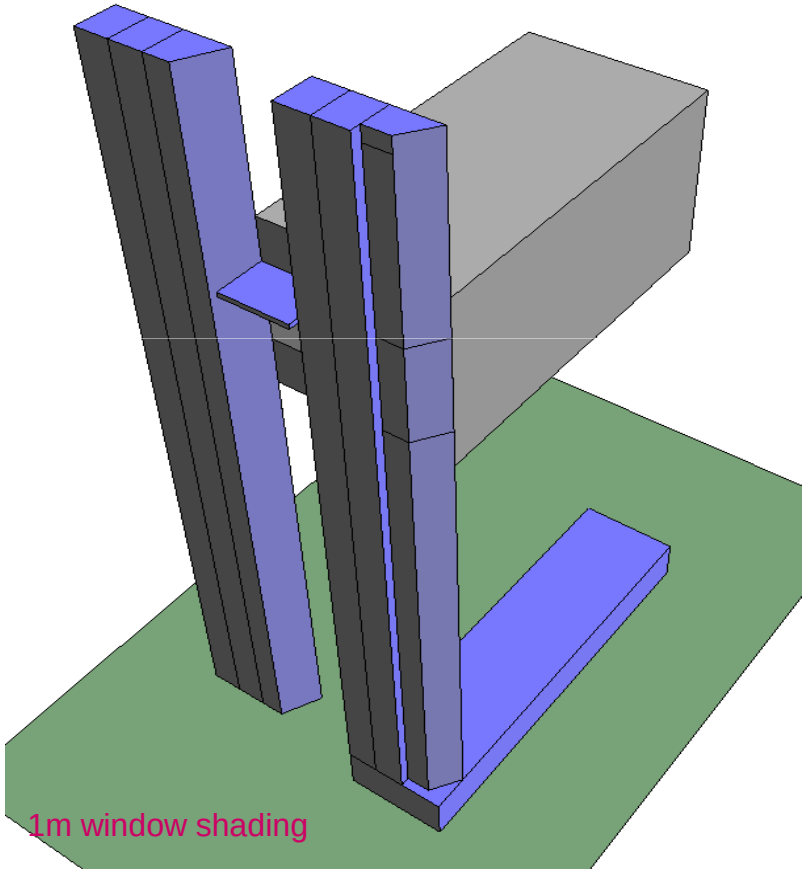
The ANV geometry studied





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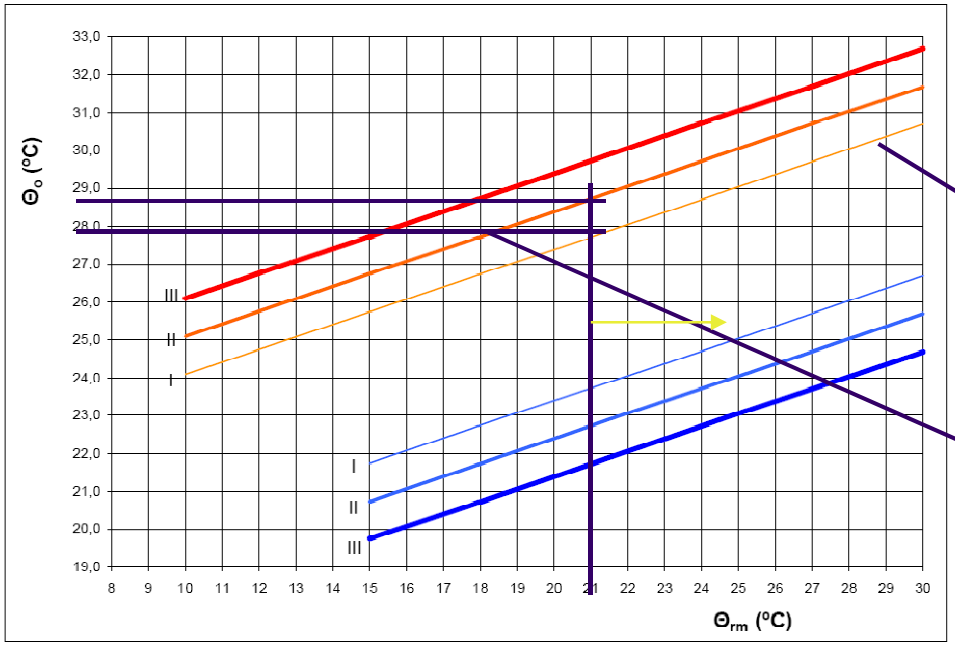
Comfort perception in future climates - European Standard EN15215



High level of expectation for spaces occupied by very sensitive and fragile persons special requirements like handicapped, sick, very young children and elderly persons.

Normal level of expectation used for new buildings and renovations.

- **Only apply when spaces regulated by occupants**
- **Spaces must have operable windows opening to outdoors**
- **No mechanical cooling in the space**
- **Weather data to use not stated**
- **Limiting hours-over not stated.**

Θ_{rm} = Outdoor Running mean temperature °C.

Θ_n = Operative temperature °C.

$$\Theta_{rm} = (1- \alpha).\{ \Theta_{ed\ -1} + \alpha.\ \Theta_{ed\ -2} + \alpha^2\ \Theta_{ed\ -3} \ldots\ldots\}$$

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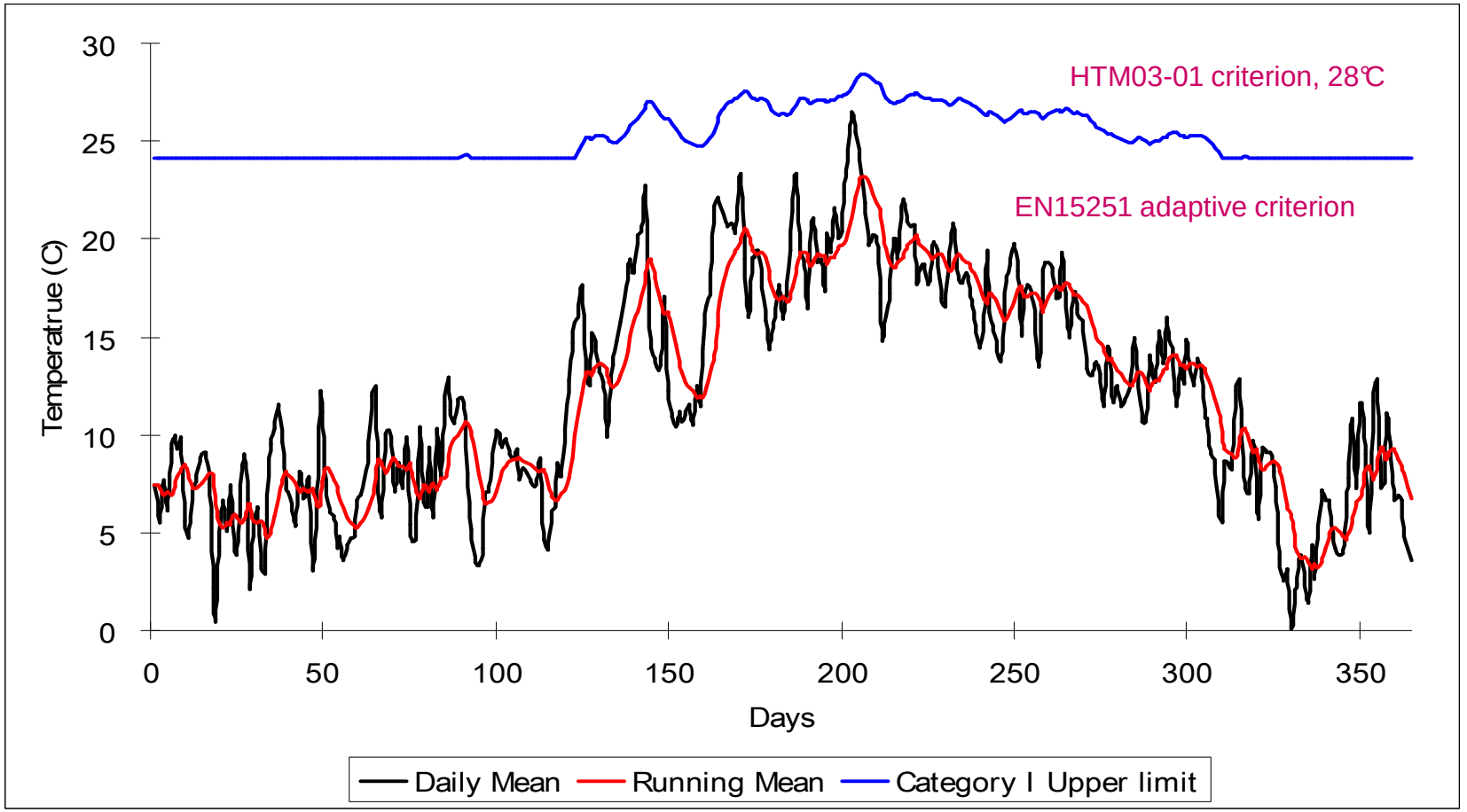
The EN15251 adaptive criteria: current London DSY data



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“Life expectancy” of naturally ventilated wards in a warming UK climate.

Vent Type	Therm Mass	Win area m^2	Vent as % FA	Or	Glazng	Heat Gains W/m^2 day/night	2005	2020	2050	2080
SNV	LW	5.2	4.8	N	Low-e	21/4				
					S.C.	21/4				
SNV	LW	2.6	2.4	S	Low-e	21/4				
					S.C	21/4				
ANV	LW	2.24	1.0	S	Low-e	21/4				
ANV	HW	2.24	1.0	S	Low-e	21/4				
						31/14				
						41/24				
						51/34				
ANV	HW	2.24	1.6	S	Low-e	21/4				
						31/14				
						41/24				
						51/34				

Predicted energy use and CO_2 emissions: ANV and mechanically ventilated (MV) ward

Case and Year	Space Conditioning	Parameters	[1]	[2]	[3]	[4]	[5]	[6]	[7]
			Demanded MWh	Delivered			Emissions		
				MWh	GJ	GJ/100m^3	Tonnes Carbon	kgC/m^3 C	kgCO_2/m^2
1a 2005	ANV Winter 40-50l/s ventilation	Heating	3.46	5.77	20.78	19.38	0.291	11.23	41.18
		Ventilation	0.03	0.03	0.11	0.12	0.005	0.18	0.66
		Light and Appl.	1.99	1.99	7.16	7.68	0.279	10.78	39.52
		Total				**27.18**			**81.36**
2b 2005	MV, 6ach^{-1} Heat exch. 70% efficient.	Heating	3.24	5.40	19.46	18.16	0.272	10.49	38.46
		Ventilation	2.72	2.72	9.79	10.49	0.409	15.79	57.90
		Light and Appl.	1.99	1.99	7.16	7.68	0.279	10.78	39.52
		Total				**36.33**			**135.88**
1a 2080	ANV Winter 40-50l/s ventilation	Heating	2.14	3.58	12.86	13.88	0.193	7.48	27.31
		Ventilation	0.03	0.03	0.11	0.12	0.005	0.18	0.66
		Light and Appl.	1.99	1.99	7.16	7.68	0.279	10.78	39.52
		Total				**21.68**			**67.49**

Both meet new build 35-55W/100m^3 target and refurb. target of 55 - 65W/100m^3.
MV is very sensitive to heat recovery efficiency.

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Conclusions – natural ventilation

- Simple natural ventilation, even with solar control glazing, is unlikely to prevent overheating in the London area even in today's climate.
- ANV can, at present, prevent overheating in all UK locations except London area[1].
- The 'life expectancy' of naturally ventilated buildings depends on location, internal heat gains, ventilation areas, and thermal mass – in this order.
- ANV offers much greater resilience to climate change than simple natural ventilation.
- ANV can reduce the CO_2 emissions by 50% compared to mechanically ventilation.
- ANV has potential in many area of Europe.

[1] Unless heat gains are very low.

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