Design and Delivery of Robust Hospital Environments in a Changing Climate (DeDeRHECC)

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De²RHECC
Design and Delivery of Robust Hospital Environments in a Changing Climate

Aim:

the design and delivery of credible, economical and safe strategies to adapt the buildings in which acute healthcare is delivered, and increase their Resilience to summertime overheating whilst meeting challenging energy reduction targets

Temperature thresholds – Department of Health GUIDANCE

Application	Ventilation	AC/hr	Pressure (Pascals)	Supply filter	Noise (NR)	Temp (°C)	Comments (for further information see Chapter 6)
General ward	S/N	6	–	G4	30	**18–28**	
Communal ward toilet	E	6	–ve	–	40	–	
Single room	S/E/N	6	0 or –ve	G4	30	**18–28**	
Single room WC	E	3	–ve	–	40	–	
Clean utility	S	6	+ve	G4	40	**18–28**	
Dirty utility	E	6	–ve	–	40	–	
Ward isolation room	–	–	–	–	–	–	See Health Building Note 04-01 (Supplement 1)
Infectious diseases isolation room	E	10	–5	G4	30	**18–28**	Extract filtration may be required
Neutropeanic patient ward	S	10	+10	H12	30	**18–28**	
Critical care areas	S	10	+10	F7	30	*18–25*	Isolation room may be –ve pressure

Notes: **18–22**°C indicates the range over which the temperature may float.
18–22°C indicates the range over which the temperature should be capable of being controlled.
S = suppy
E = extract
N = natural ventilation
a – European guidelines on good manufacturing practice published by the Medicines and Healthcare products Regulatory Agency (MHRA)

Health Technical Memorandum 03-01

A brief aside on comfort criteria.

Current standards and criteria ie guaranteed <28°C are problematic and paralyse effective design response, very noticeable in PFI teams (we are involved in two).

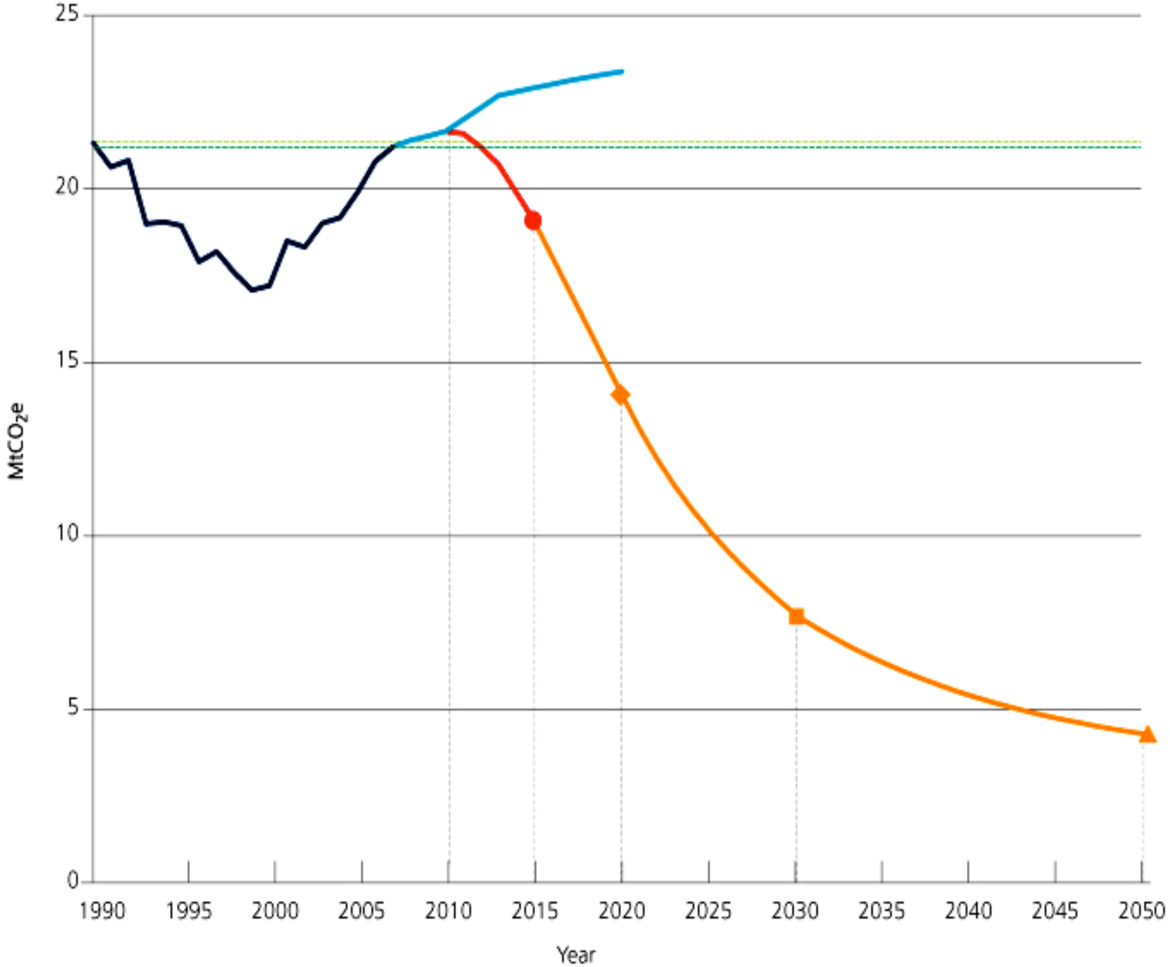
The much researched concept of **Adaptive Comfort** suggests the occupants' recent pre-history of the thermal environment conditions their responses, i.e. people adapt to a changing environment as it changes.

Our team has written about this in *Building and Environment*

In a warming climate, the dilemma is that risk-averse organisations may seek to implement air conditioning to maintain these thresholds…

But there is a problem with doing this…

NHS England Carbon Footprint, 1/3rd from buildings, we are not getting there. Could one ever with Business as Usual models?

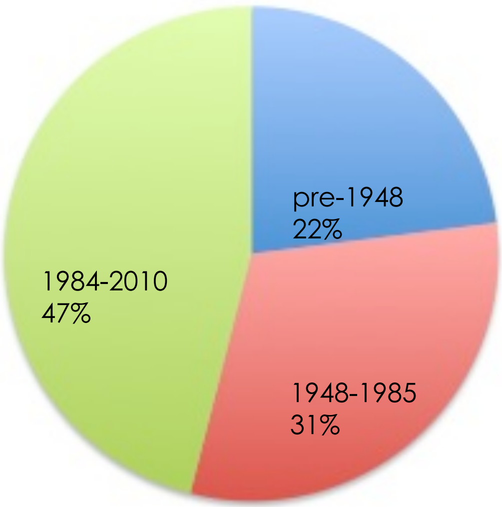


We're particularly interested in refurbishment…

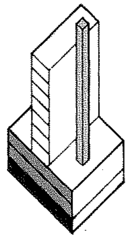
A clip from our project film: Sonia Roschnik, NHS Sustainable Development Unit

The NHS Acute Hospital building stock

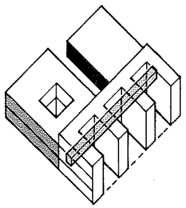
14,040 sites (2008), 330 acute hospitals in England. They vary but 5-6 basic types emerge.



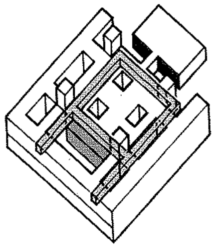
Age profile by site, nationally



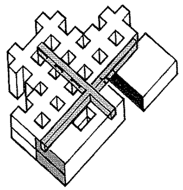
'Matchbox on a muffin'
Classic 1960s NHS hospital building form
Early examples include Princess Margaret, Swindon, 1958. c. 50 in England. Idea that facilities likely to change located in muffin, wards in the slab (sometimes offices).
DeDeRHECC *case studies: Maternity building, Bradford Royal Infirmary; Ward tower, Addenbrooke's, Cambridge.*



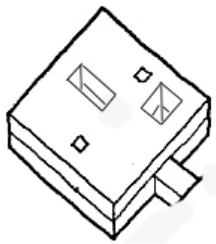
'Nightingale pavilions'
Predominant model from 1860s to 1930s
Design for daylight, natural ventilation.
DeDeRHECC case study: Bradford Royal Infirmary (1927-)



'Best Buy'/closed court
Developed late 1960s: minimum space without compromising clinical effectiveness
DeDeRHECC case study: Rosie Maternity as variant



'Nucleus'/open court
Developed late 1970s from 'Harness', a standardised set of templates. More than 100 Nucleus units built
DeDeRHECC case study: Glenfield, Leicester (1984)



Deep plan
Facilitated from 1960s by mechanical ventilation systems and acceptable solutions for artificial lighting. Many recent PFI examples
DeDeRHECC case study: St Albans City Hospital, Gloucester Wing (1988)

The mode of attack: c.110 spaces in different building types across four sites

**a Hobo is a small data logger in this context*

Hospital	Number of spaces	Number of loggers	Description
Addenbrookes: Maternity (Rosie) and Tower C&D level 6 and 8	32	48 Hobos and 3 Co_2 sensors	Waiting area, treatment , examination & consulting, Ultrasound, Single bed, Multi bed, nurses station, delivery, breast clinic, office, staff rest room etc
Bradford : Ward 8, 9, 29 & 30 and Maternity block	36	60 Hobos, 8 Tiny Tags and 3 Co2 sensors	Open ward (Nightingale), single bed, multi bed, twin bed, Nurses station, ultrasound, examination & consulting, waiting area etc
Glenfield: Ward 18,19, 27 & 32 and main waiting area	19	36 Hobos and 3 Co2 sensors	Waiting area, single bed, multi bed, nurses station, open ward (CCU &CDU) etc
St. Albans: Gloucester wing, Runcie, Sach Moynahan	24	38 Hobos and 2 Co2 sensors	Waiting area, examination &consulting, ultrasound, breast clinic single bed, multi bed, nurses station, staff rest room, office etc

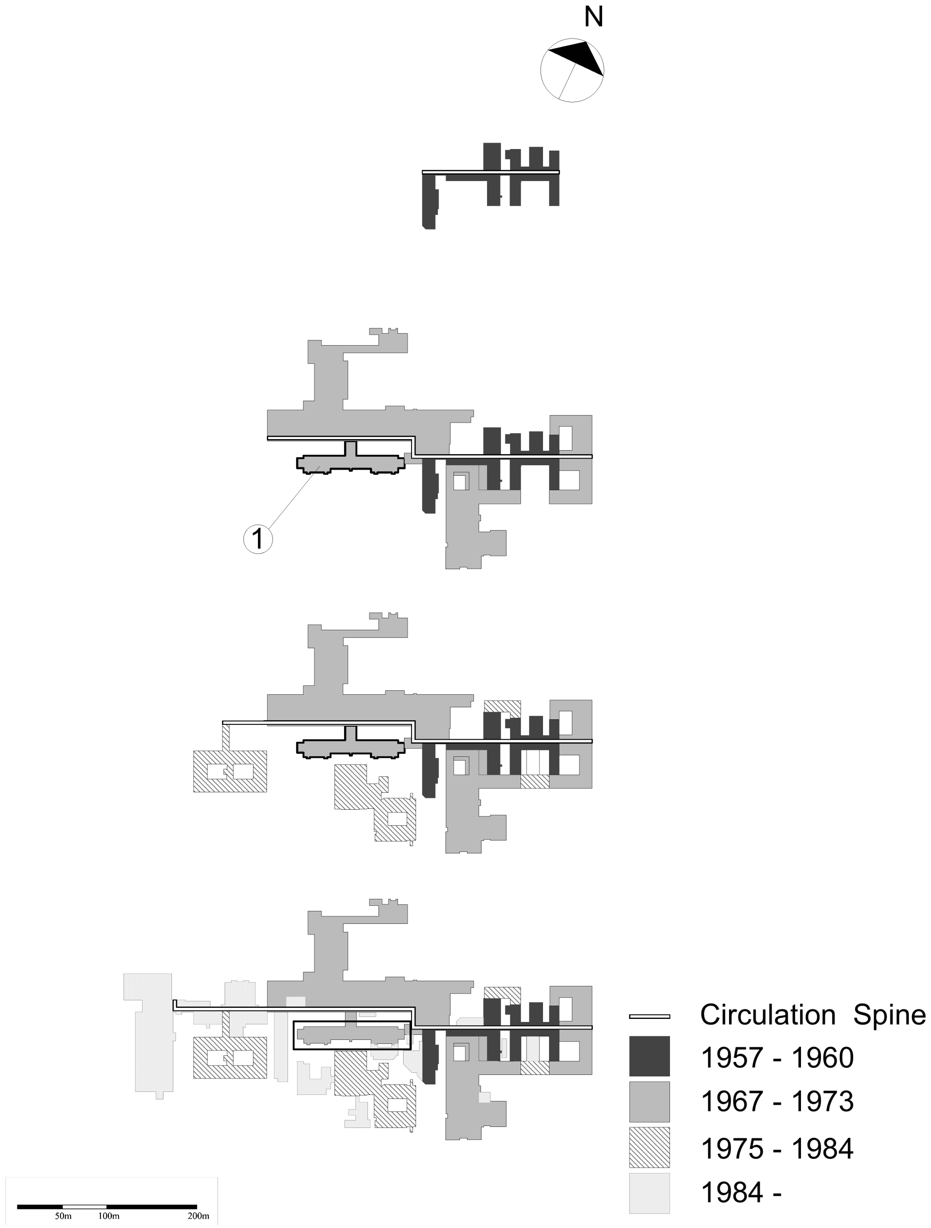
Monitoring June 2010 to September 2012: three summers and two winters

The methodology:

1. Monitor internal temperatures in typical spaces (June 2010 to present)
2. Build a model of the space and calibrate against the recorded data
3. Predict performance of current building to 2080
4. Devise refurbishment options
5. Predict performance of options to 2080
6. Cost and assess options for infection control

An example case study:

Addenbrooke's Hospital, Cambridge

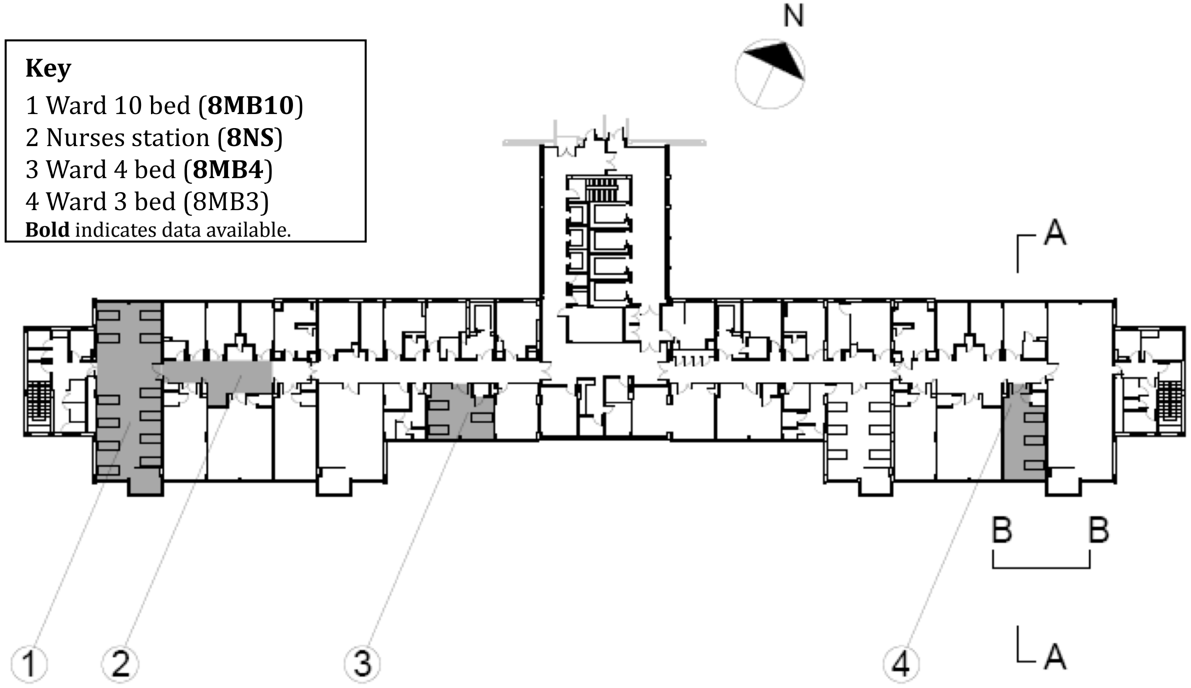


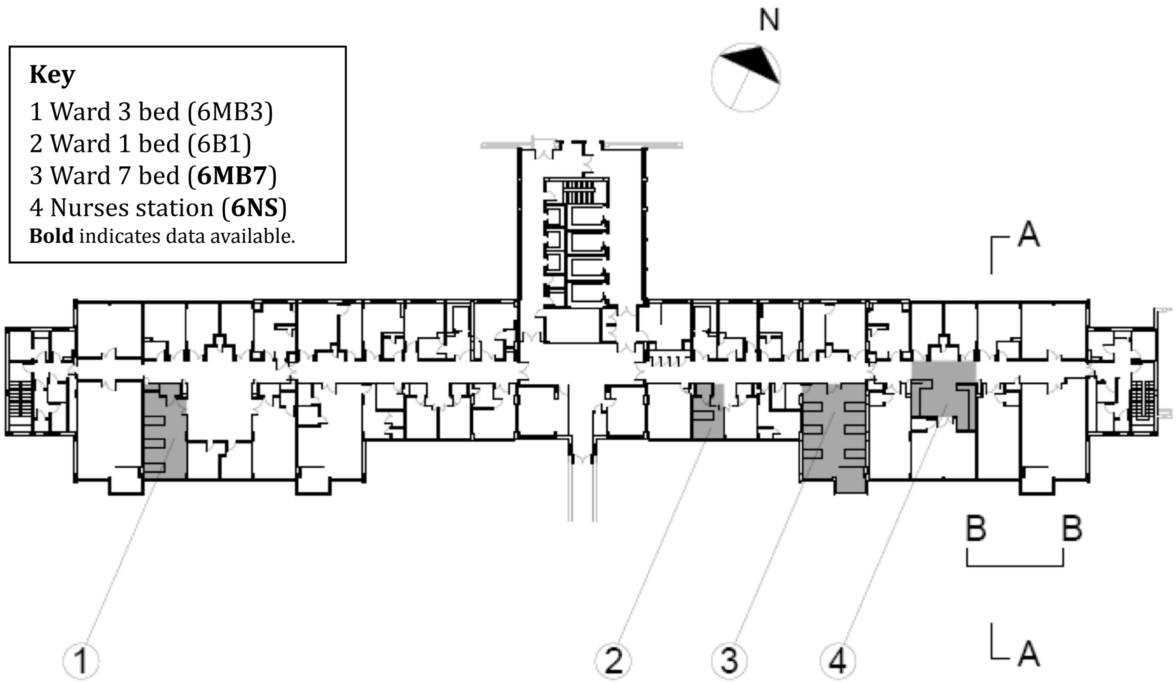
1950s Masterplan sets up
E/W spine.

First ward block perpendicular
to the spine

Subsequent phase places
main ward block (10sts)
(highlighted **1**)
parallel with the spine,
oriented south for views.

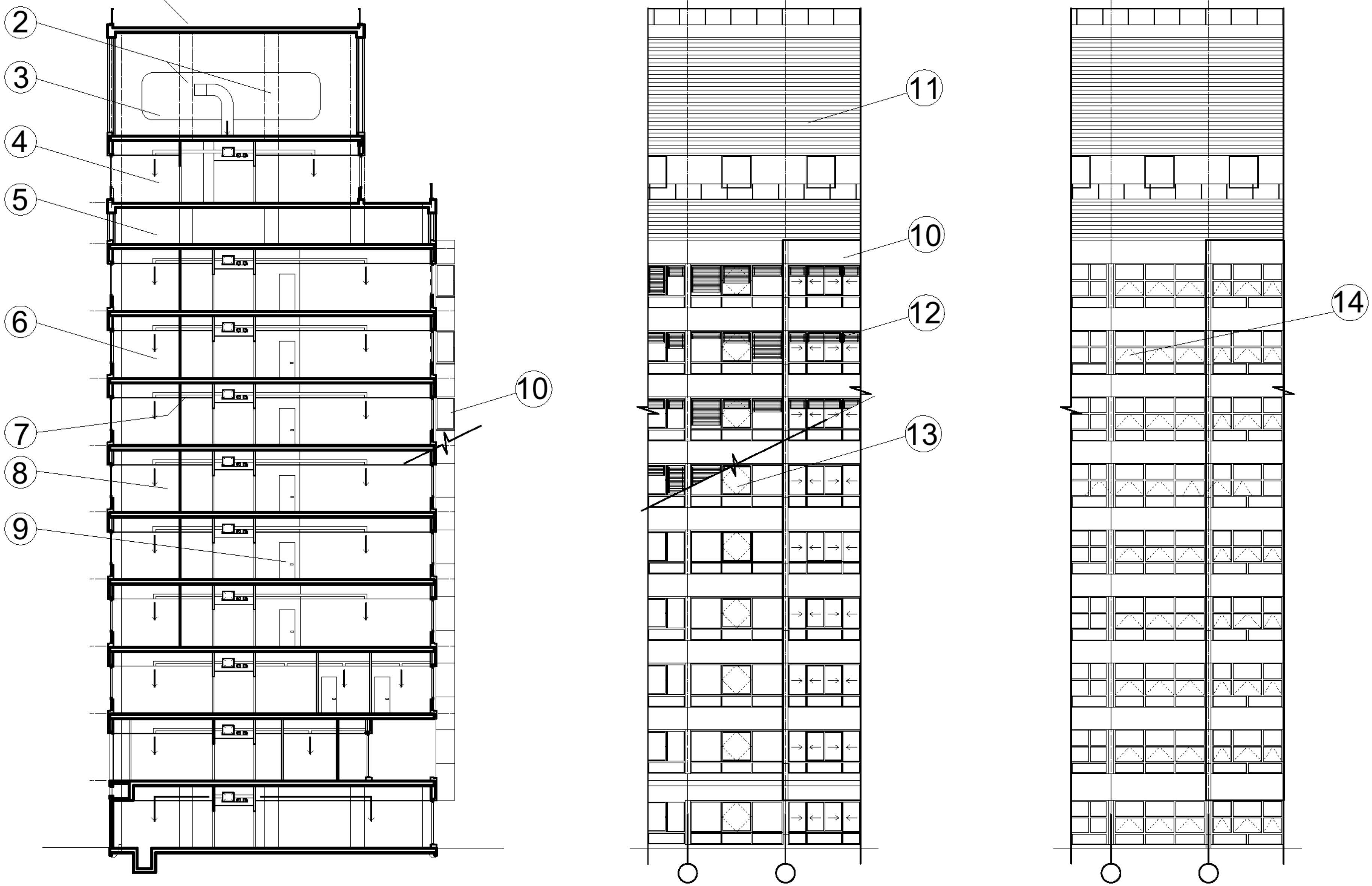
A ten-storey block coupled
to a slab to the north

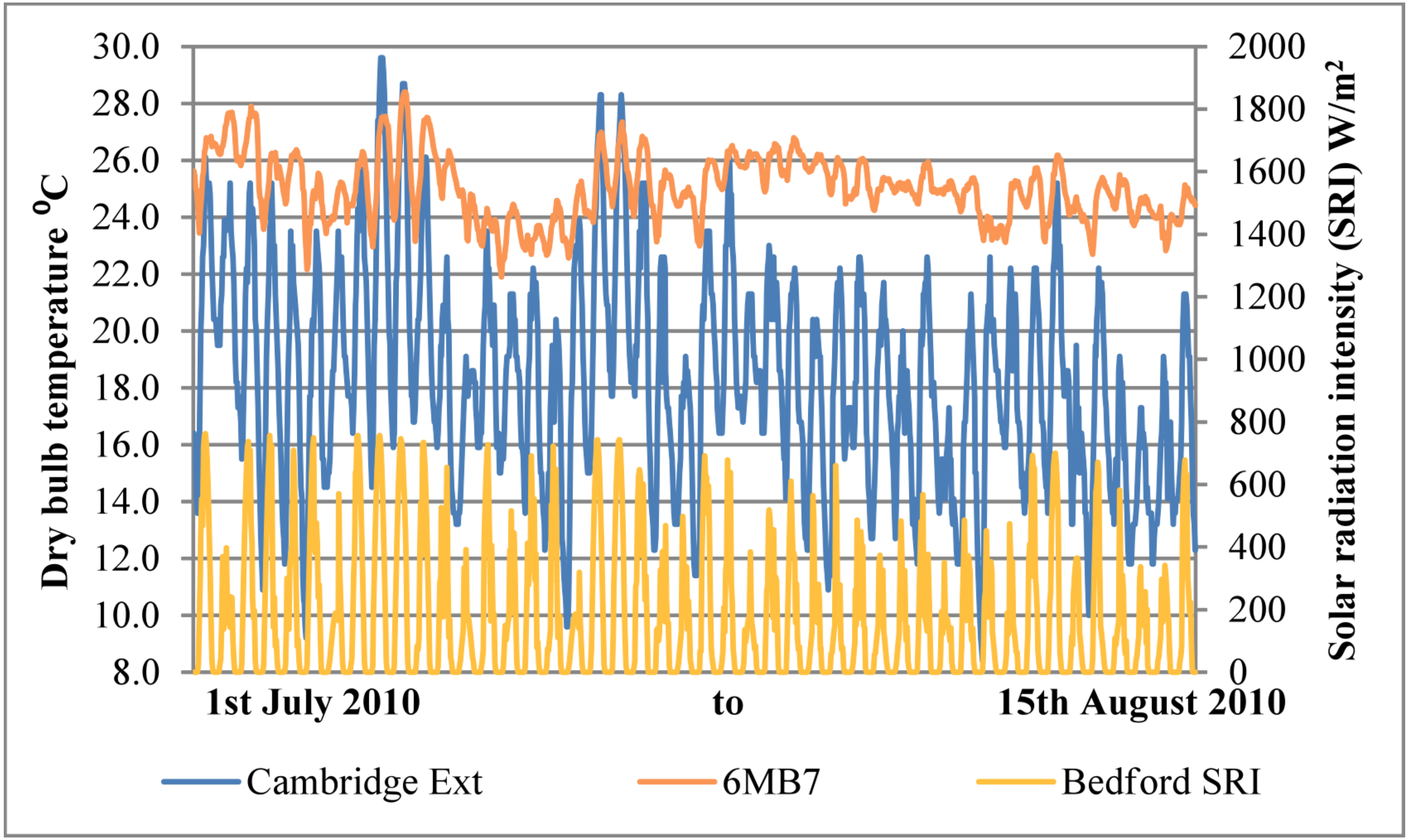




Internal layout essentially the same on each floor: central corridor with rooms off ('Nuffield layout')

Original strategy focussed on winter warmth with mechanical ventilation and Frenger radiant ceilings
Shading devices of original scheme omitted ('Tygan' blinds, horticultural cloth). Centre pivot windows and glazed dayspaces replaced 1990s with thermally broken aluminium frames (U ~ 1.9 Wm^2 K). Reports of heat 1975.





Temperatures in one multibed ward against exterior temperature and local solar radiation intensity
Temperatures between 21.2°C and 28.5°C.

By way of context there were just 4 hours in Cambridge in 2010 when the ambient temperature exceeded 28°C

Many hours above 25°C (value above which thermal dissatisfaction for healthy people); 28°C is upper limit in HTM03-01. No more than 6 hours above 28°C in any ward. High night-time temperatures.

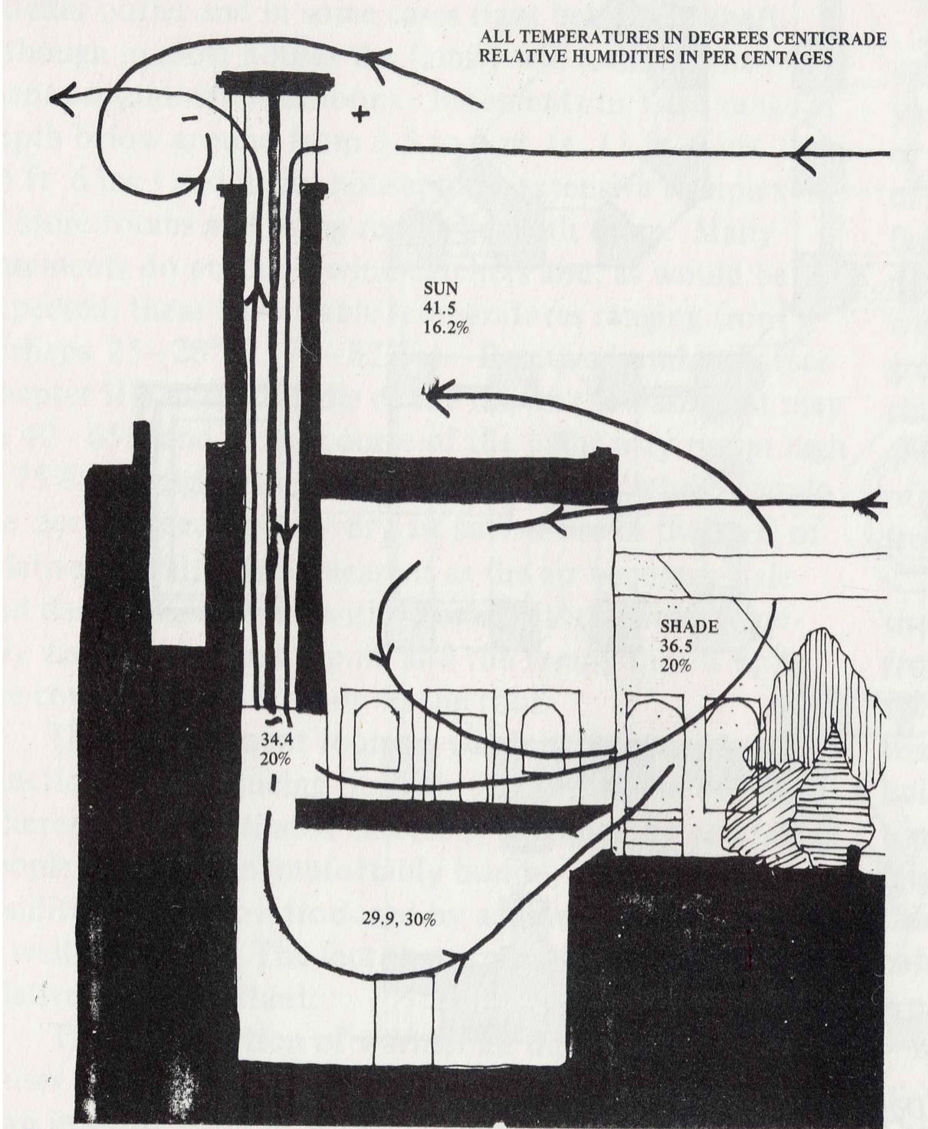
Level	Space	Max Maximum temperature °C (24 hours)	Min Minimum temperature °C (24 hours)	Mean (day) Mean daytime temperature °C (7:00 to 20:00)	Mean (night) Mean night time temperature °C (21:00 to 6:00)	Maximum diurnal range (K)	Hours over 25°C (24 hours)	Hours over 28°C (24 hours)	Hours over 24°C (21:00 to 6:00)	Hours over 26°C (21:00 to 6:00)
6	Multi-bed 6MB7	28.4	21.9	25.3	24.6	4.6	535 (48.5%)	6 (0.5%)	328 (71.3%)	43 (9.3%)
	Nurse station 6NS	29.3	24.4	27.1	26.4	3.6	1098 (99.5%)	110 (10%)	*460 (100%)*	*339 (73.7%)*
8	Multi-bed 8MB10	28.5	21.4	25.0	24.6	6.4	493 (44.7%)	3 (0.2%)	338 (73.5%)	38 (8.3%)
	Multi-bed 8MB4	28.1	21.2	25.3	24.7	6.6	581 (52.6%)	1 (0.1%)	350 (76.1%)	17 (3.7%)
	Nurse station 8NS	29.1	23.9	26.1	25.9	3.3	990 (89.7%)	15 (1.4%)	*459 (99.8%)*	*205 (44.6%)*

Current estimated energy (light and space heating: 101 GJ/100m^3

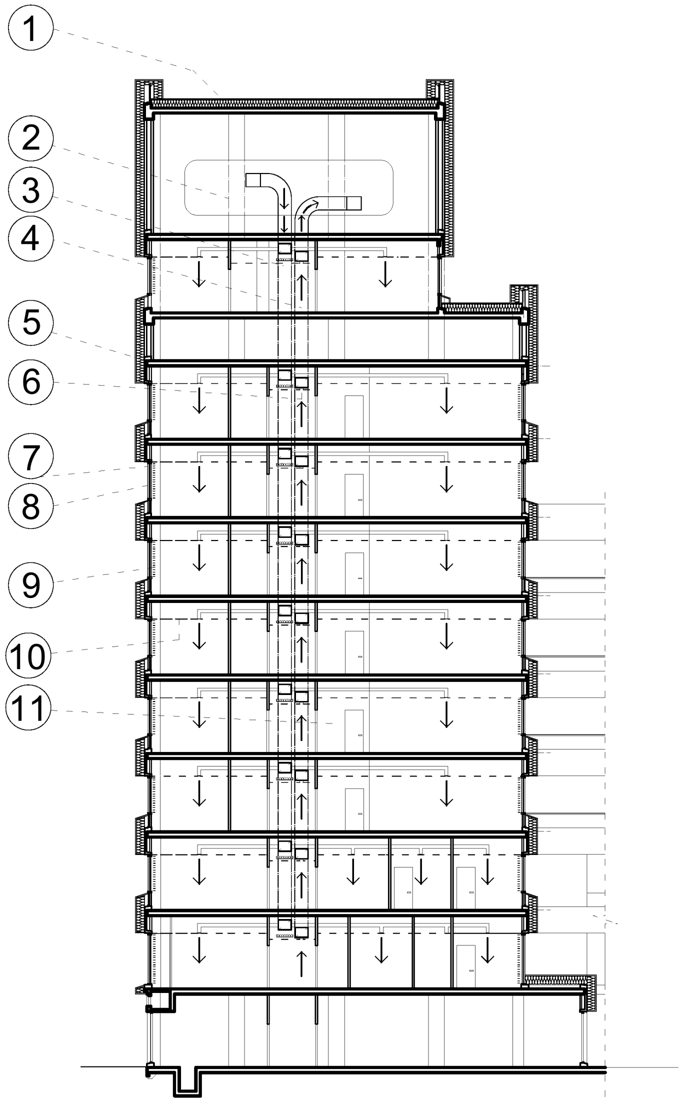
Can refurbishment improve the building now, and make it more resilient in the future?

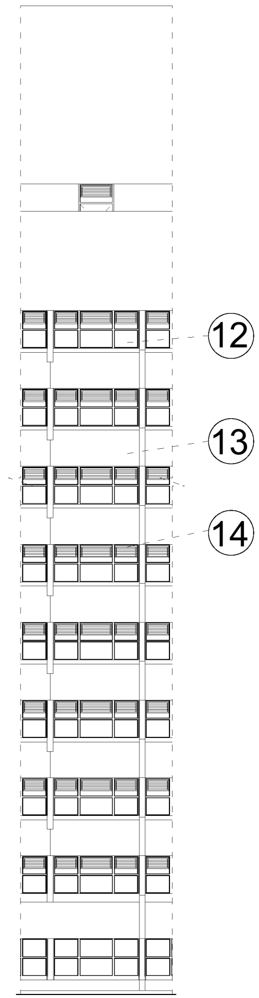
Can it do this without increasing energy use?

Historically, architecture itself is configured to moderate the internal environment.



74. Section to show the performance of a wind-catcher in a Yazdi house.





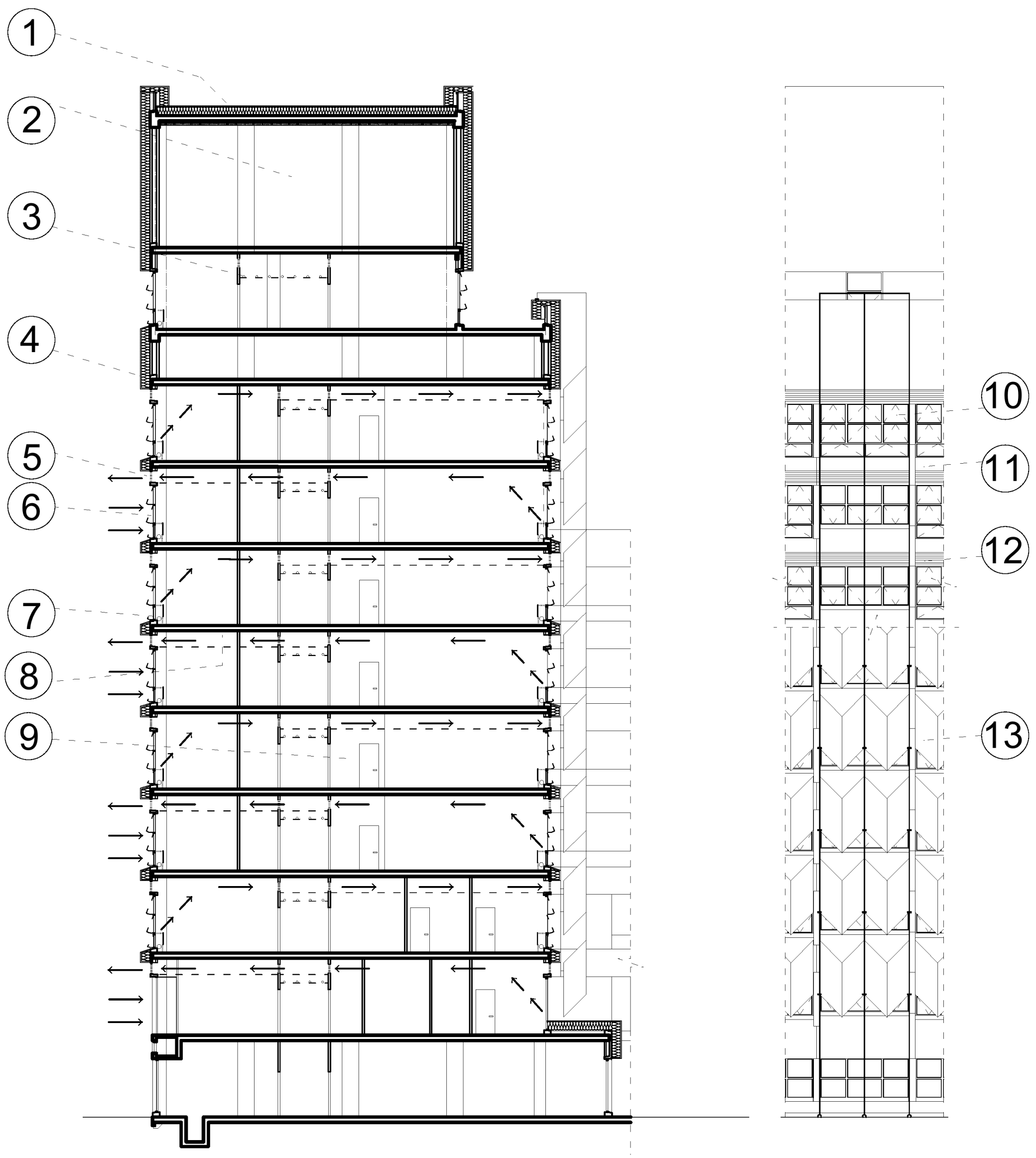
Refurbishment Option 1 SMVHC, ie Sealed, Mechanical Ventilation delivering heating and cooling with full heat recovery, with window blinds to control solar gain with triple glazing.

Annual predicted energy demands
59 GJ/100m^3

Annual predicted emissions
137 kg CO_2/m^2

Total hours above 28°C:	**Total hours above Cat I limit**
Typical year:	
2005 – 0	n/a
2030 – 0	
2050 – 0	
2080 – 0	
Extreme year	
2005 – 13	n/a
2030 – 14	
2050 – 59	
2080 – 145	

Cost per sq.m. = £1056.88



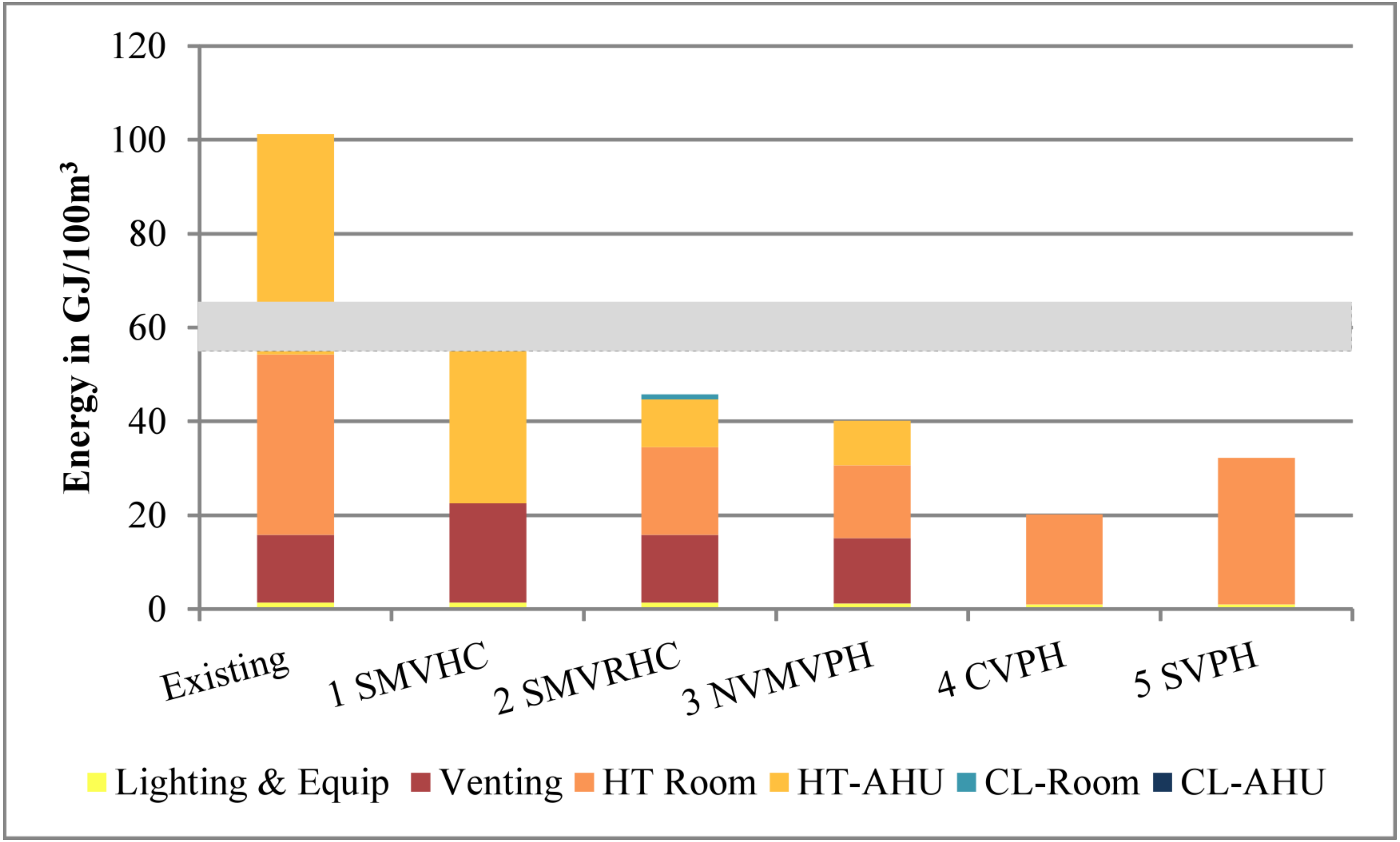
Refurbishment Option 4: CVPH
Natural Cross Ventilation using transfer ducts at high level, perimeter BMS operated dampers, ie no mech.vent., exposed ceilings between, sunshading and Perimeter Heating.

Annual predicted energy demands
20 GJ/100m^3

Annual predicted emissions
44 kg CO_2/m^2

Total hours above 28°C:	**Total hours above Cat I limit**
Typical year:	
2005 – 0	0
2030 – 3	22
2050 – 18	24
2080 – 96	123
Extreme year	
2005 – 8	22
2030 – 199	187
2050 – 582	478
2080 – 1060	861

Cost per sq.m. = £1069.89



Predicted energy demands for existing ward
and each refurbishment options: Cambridge 2010.

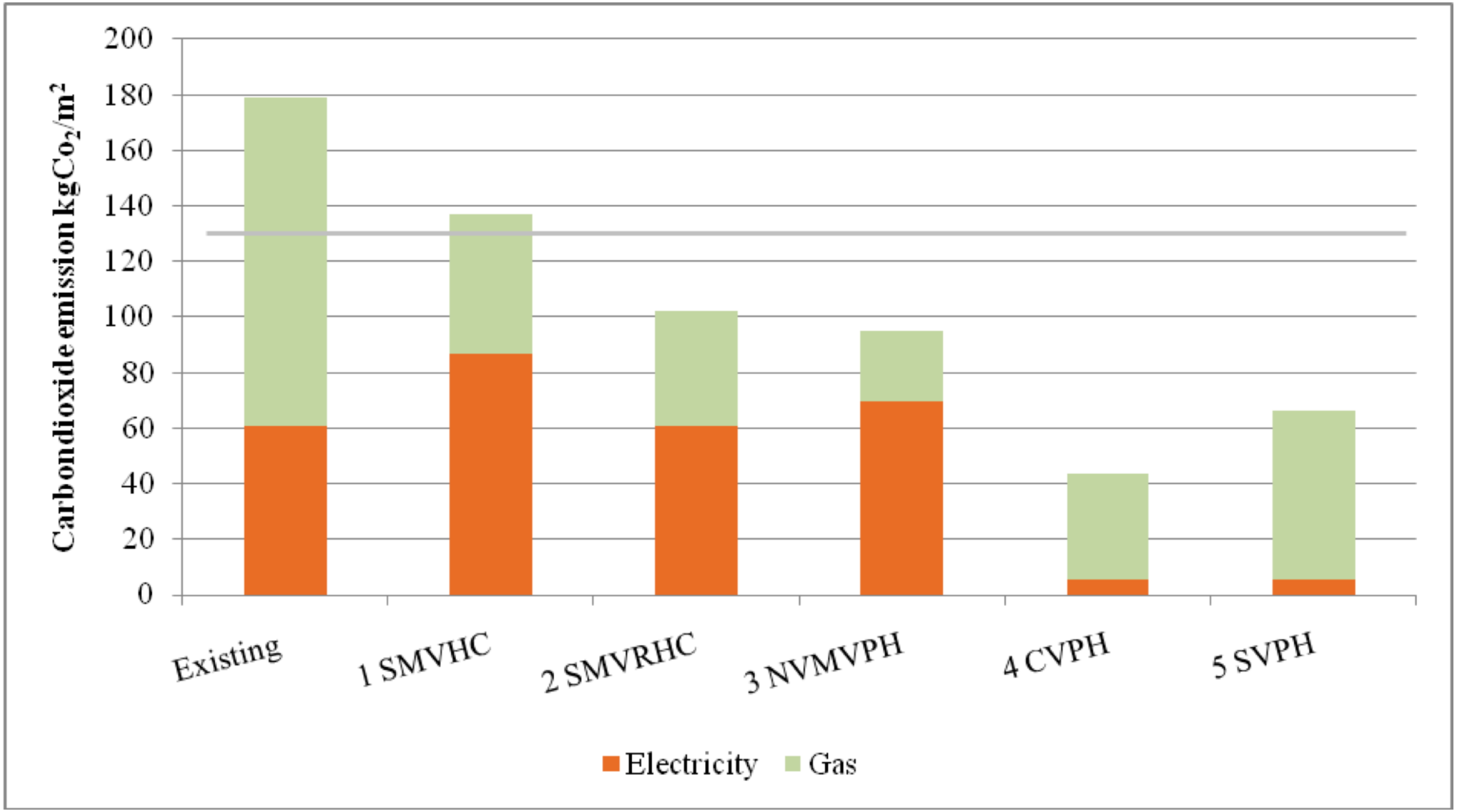
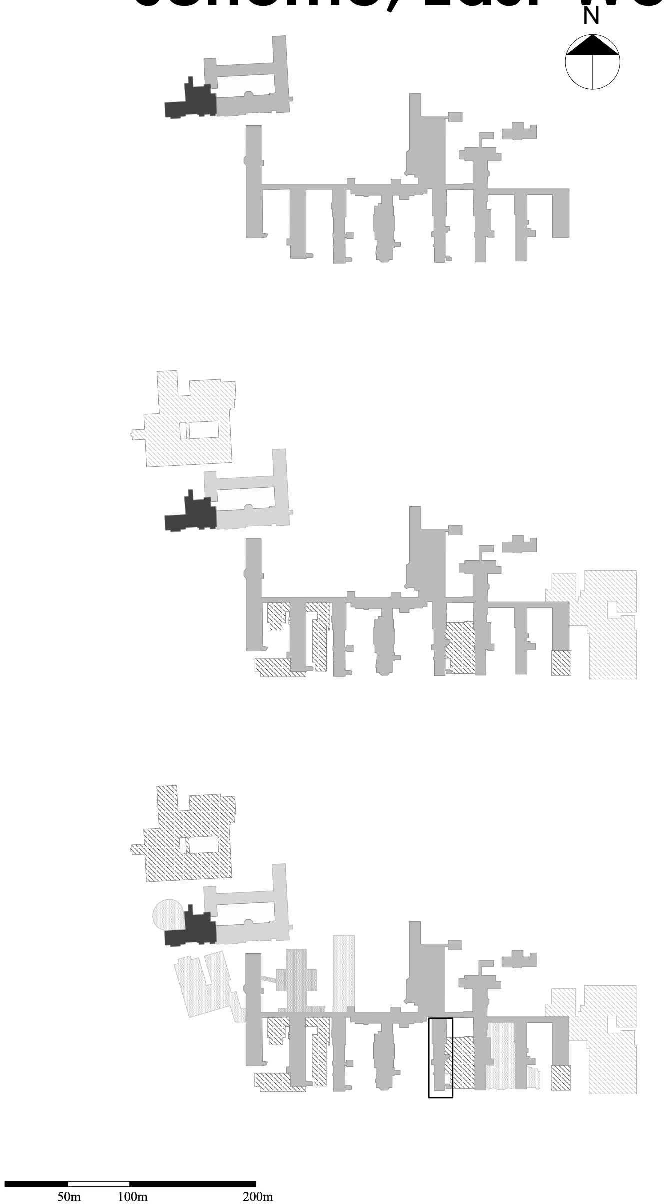


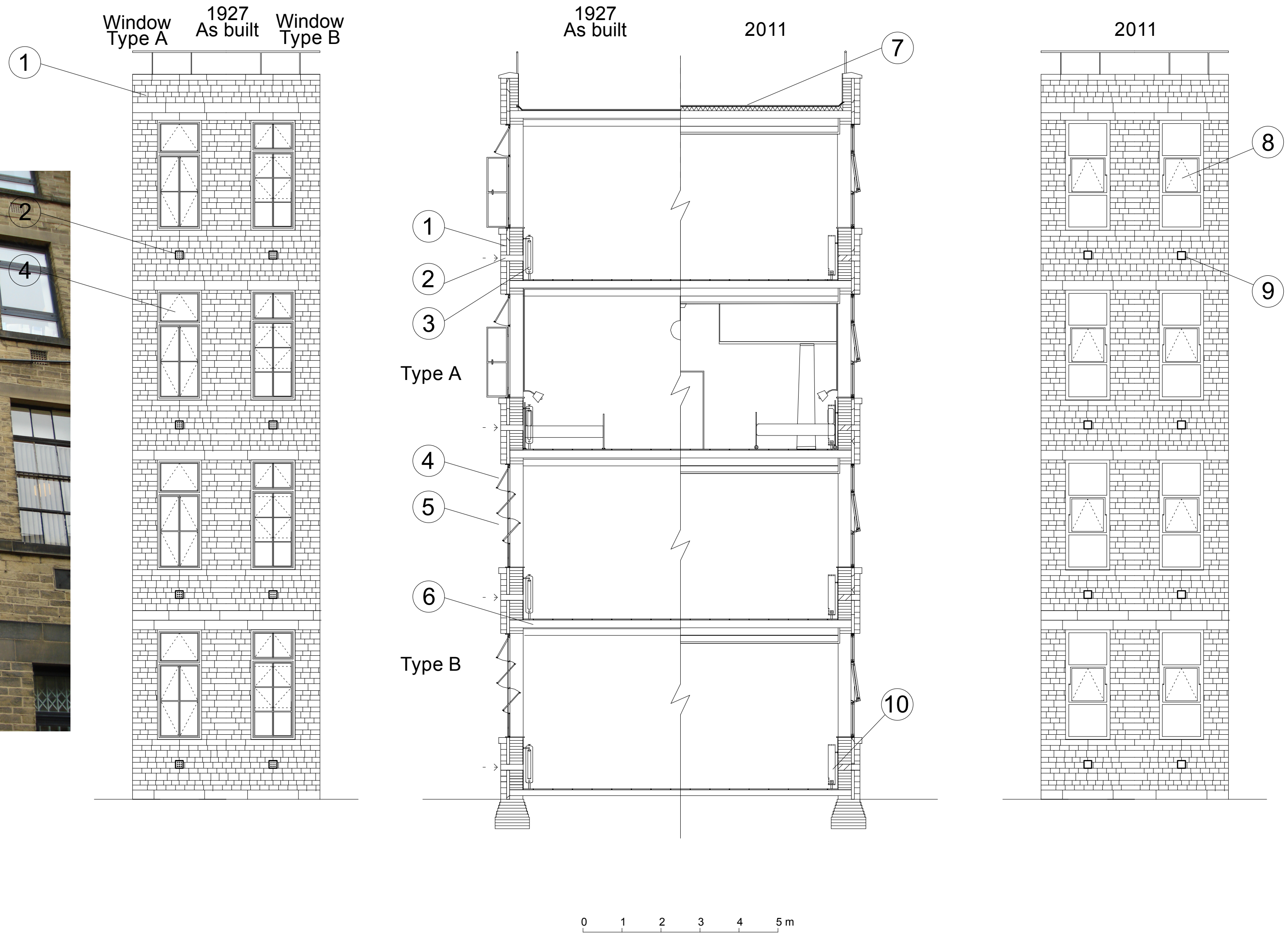
Fig 14 Predicted CO_2 emissions for
Existing Building and Refurbishment
Options: Cambridge 2010.

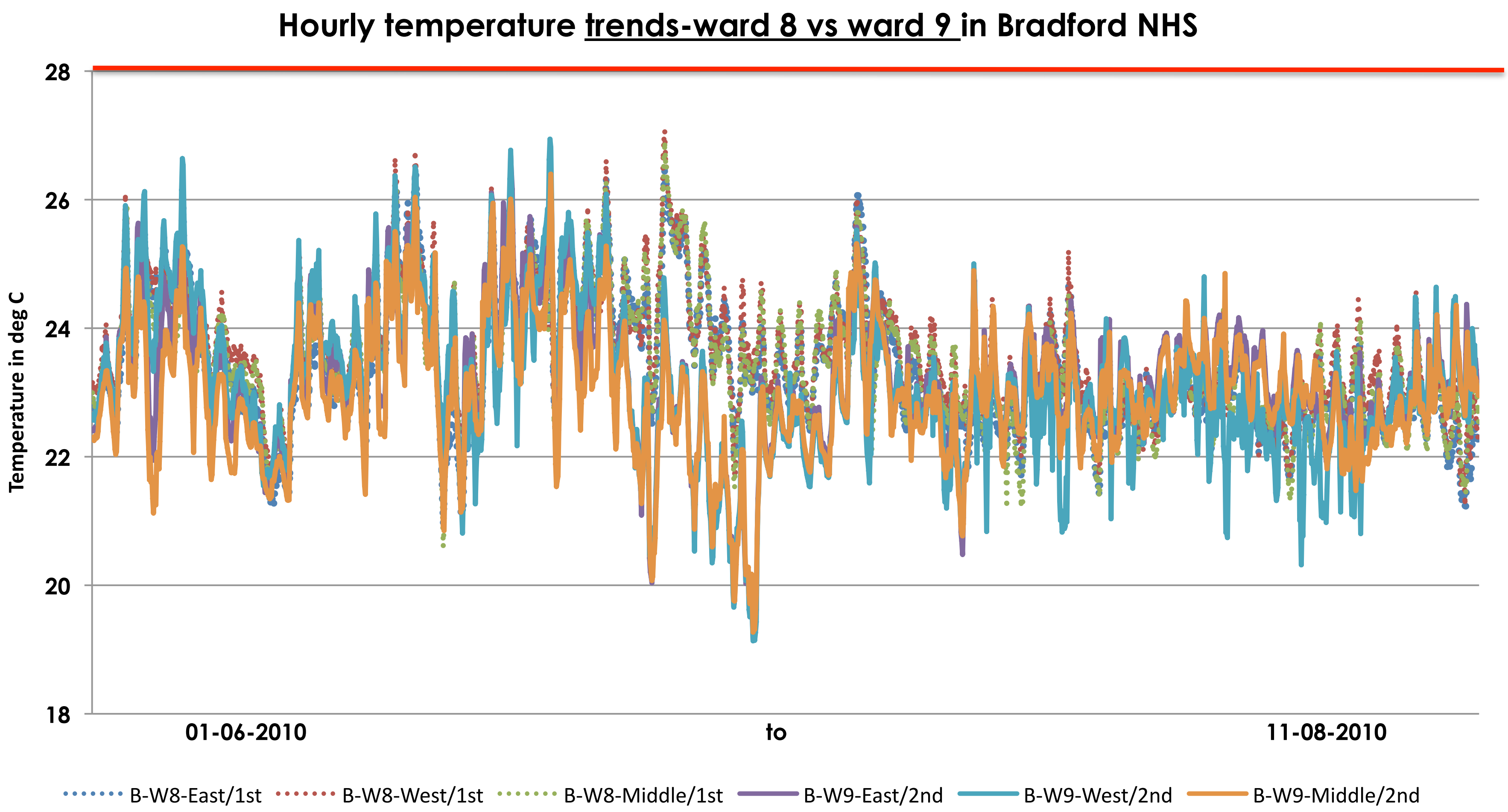
A 1920's Nightingale ward block in Bradford, Many of these remain in use but there is a general assumption that they should be taken out of service. However they are pretty resilient.

Bradford Royal Infirmary, a classic Nightingale scheme, East-West facing ward blocks



Heavy masonry construction, high ceilings, large opening areas for effective cross ventilation





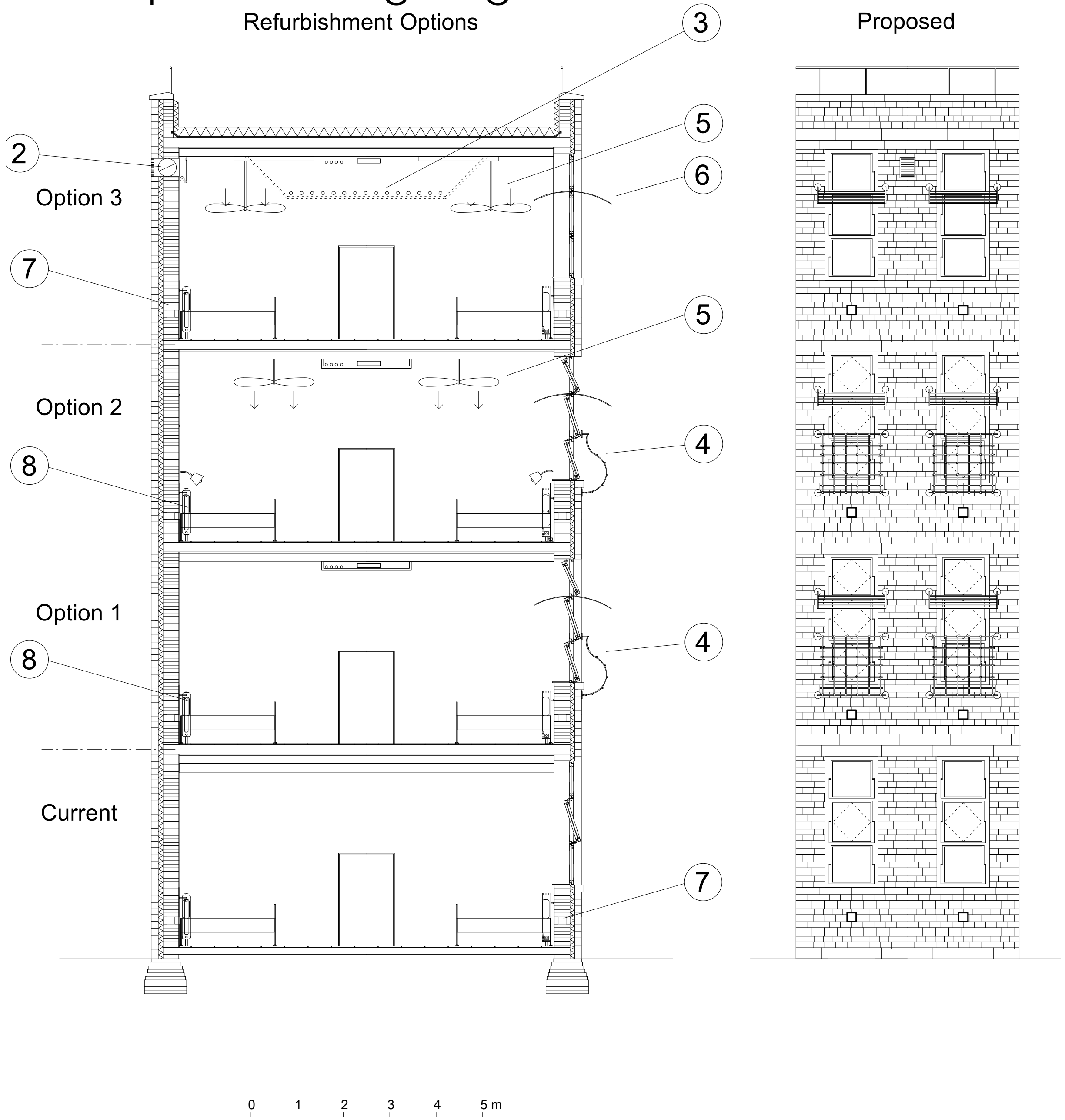
Temperatures are stable in normal conditions

Simple refurbishment options for Nightingale Wards

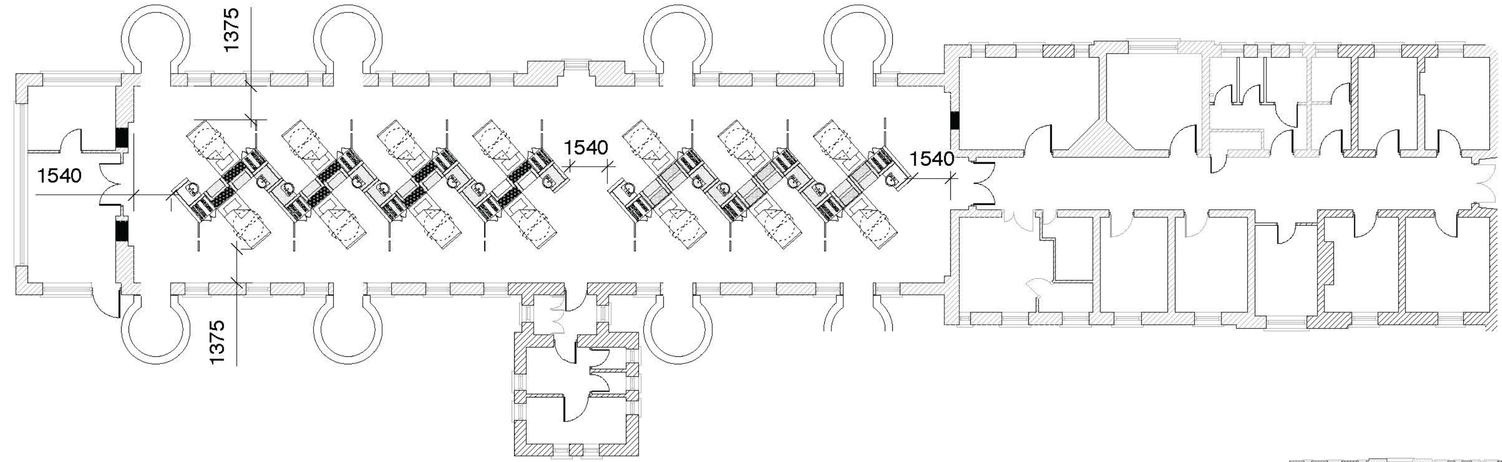
Option 3:
- Insulate walls and roof as above
- Windows fixed
-Inlet above windows for ventilation
- Ceiling lowered with radiant panels for heating and cooling

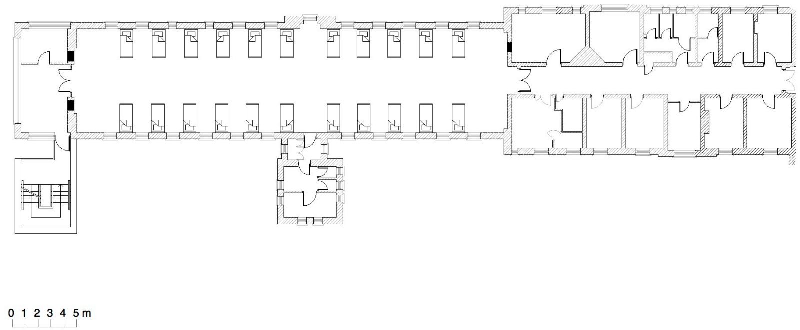
Option 2:
- As option 1 but with slow rotating fan above beds also low-level opening behind radiator for ventilation re-opened

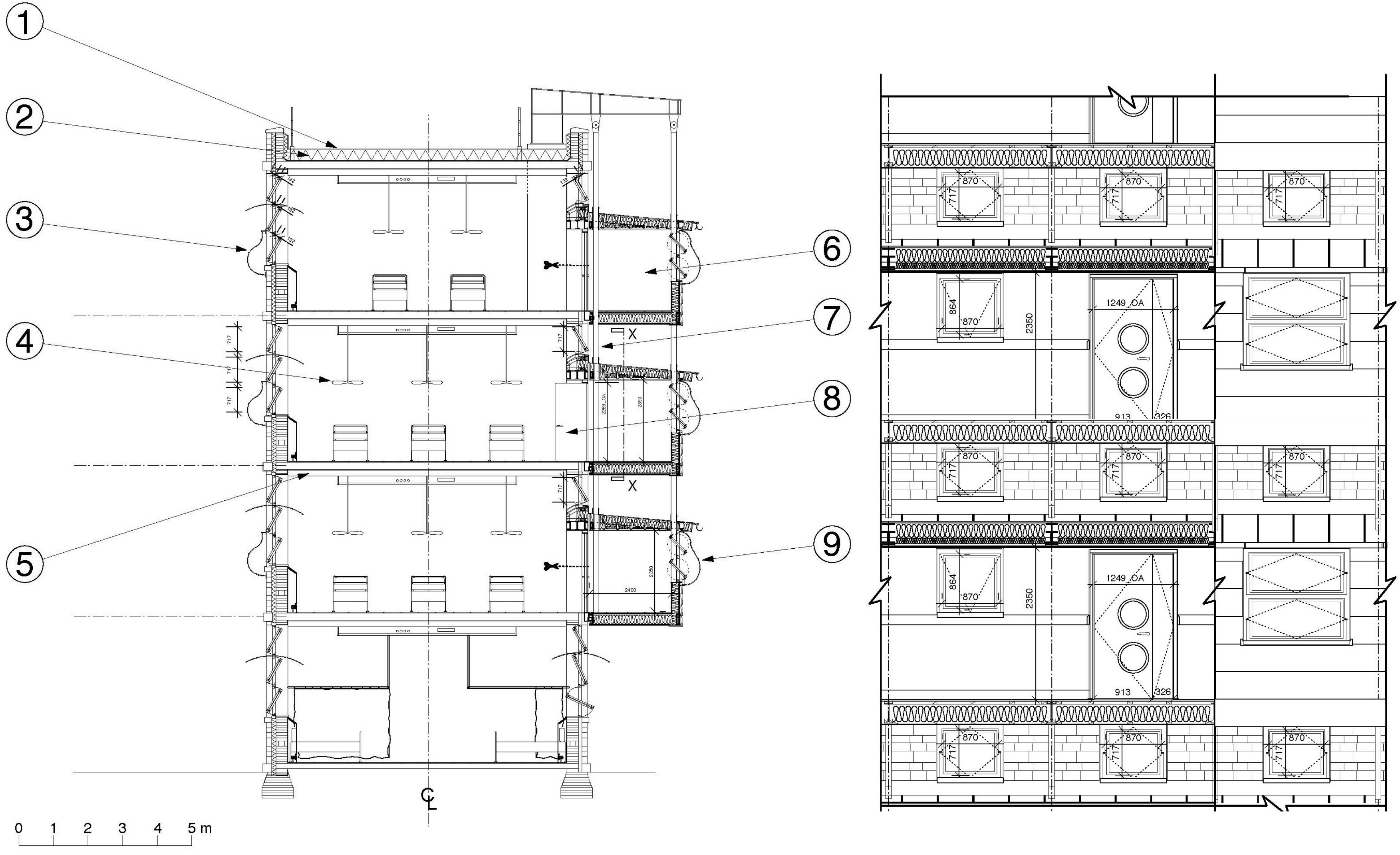
Option 1:
- Insulate walls (125mm)
- All windows openable but safety guards
- Perimeter heating
- 300mm roof insulation



Retaining the resilient characteristics of the ward, esp. its open volume, but reconfiguring beds around a zig zag central spine to offer greater privacy and dignity, wash basins and wardrobes, bathroom pods added to perimeter.

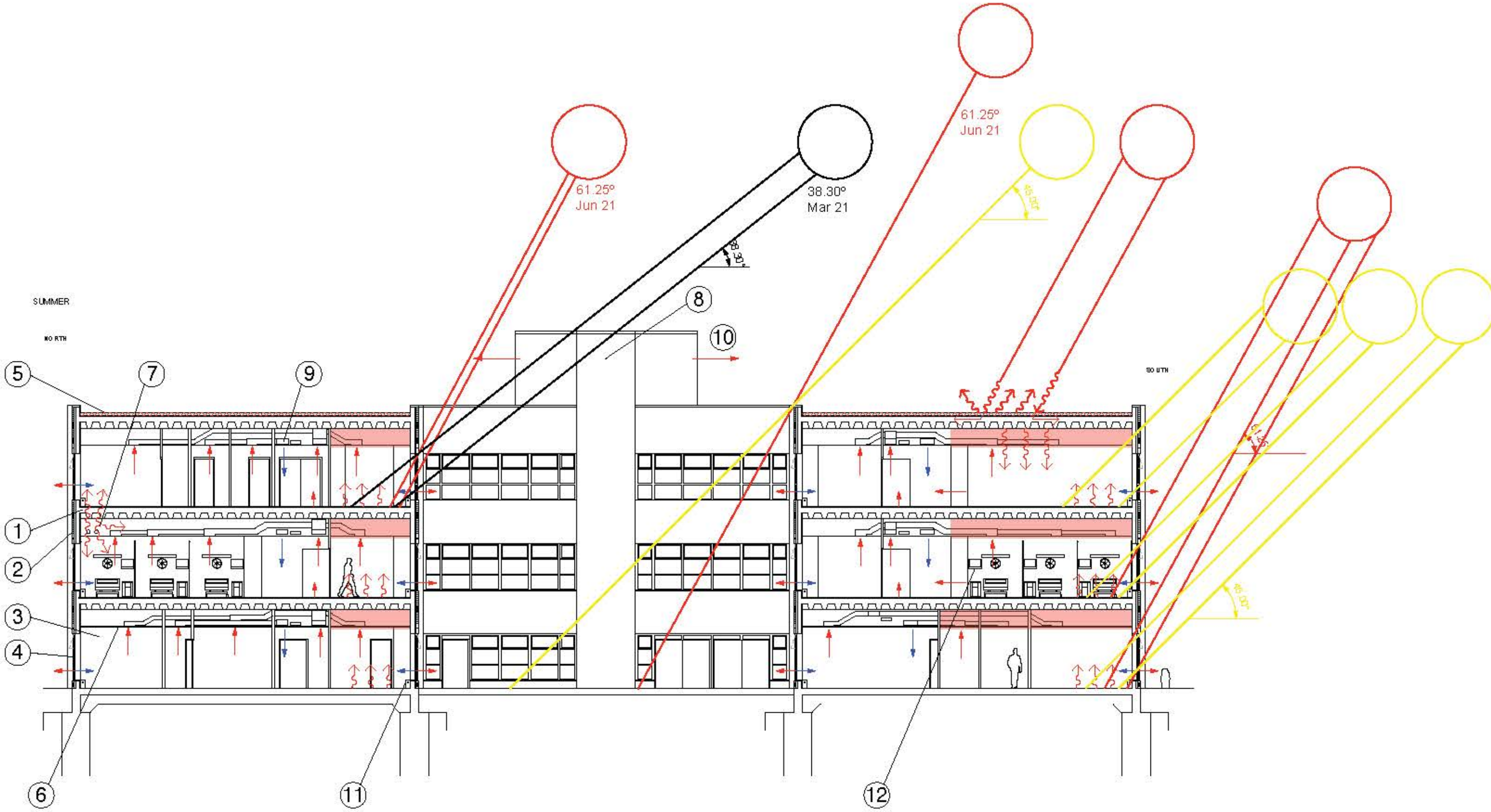


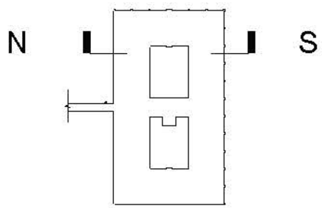




This reconfiguration preserves cross ventilation and is largely external to the ward

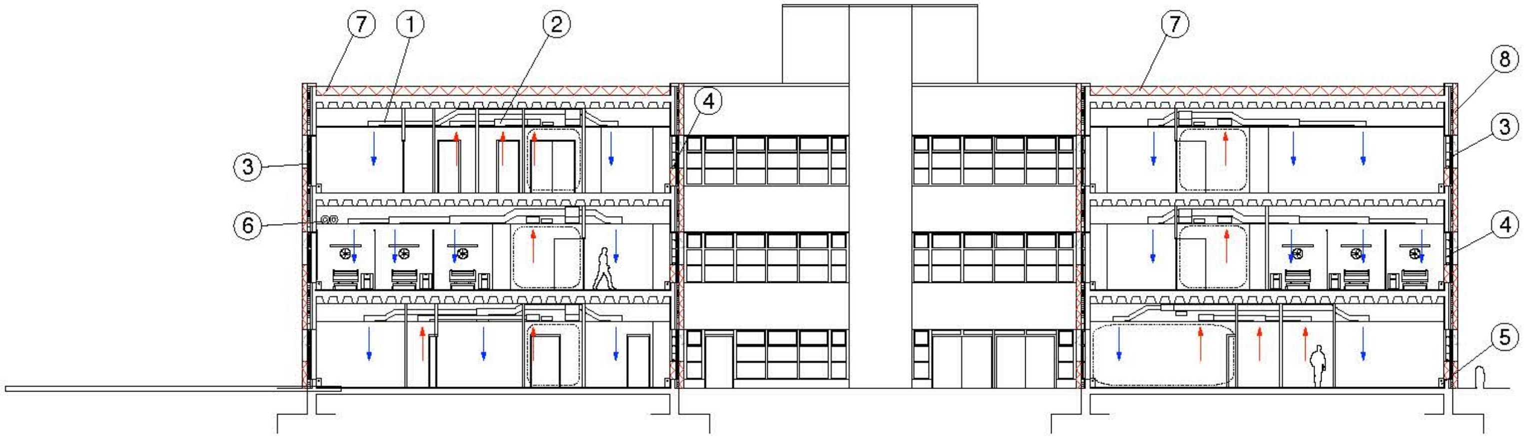
Another common type, the medium rise double-loaded corridor building arranged around courtyards, the 1980 YRM designed Rosie Maternity building at Addenbrookes.



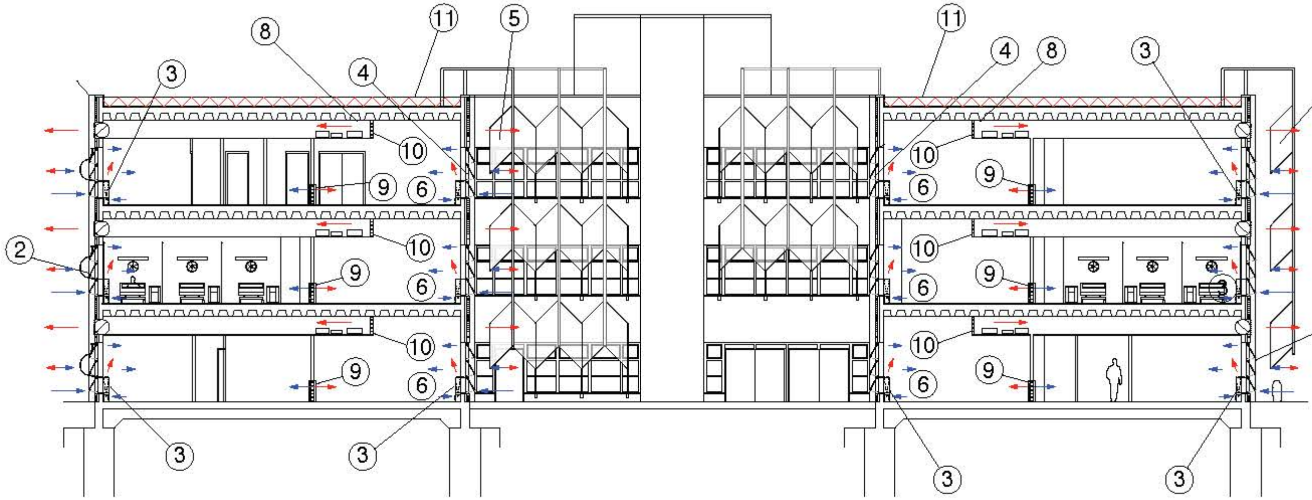


The Rosie is very glazed and wards face south to enjoy the countryside, wards overheat, not least the courtyard Facing rooms, internal unlagged HW pipes heat the interior all year, set points can heat the Rosie at night in hot spells.

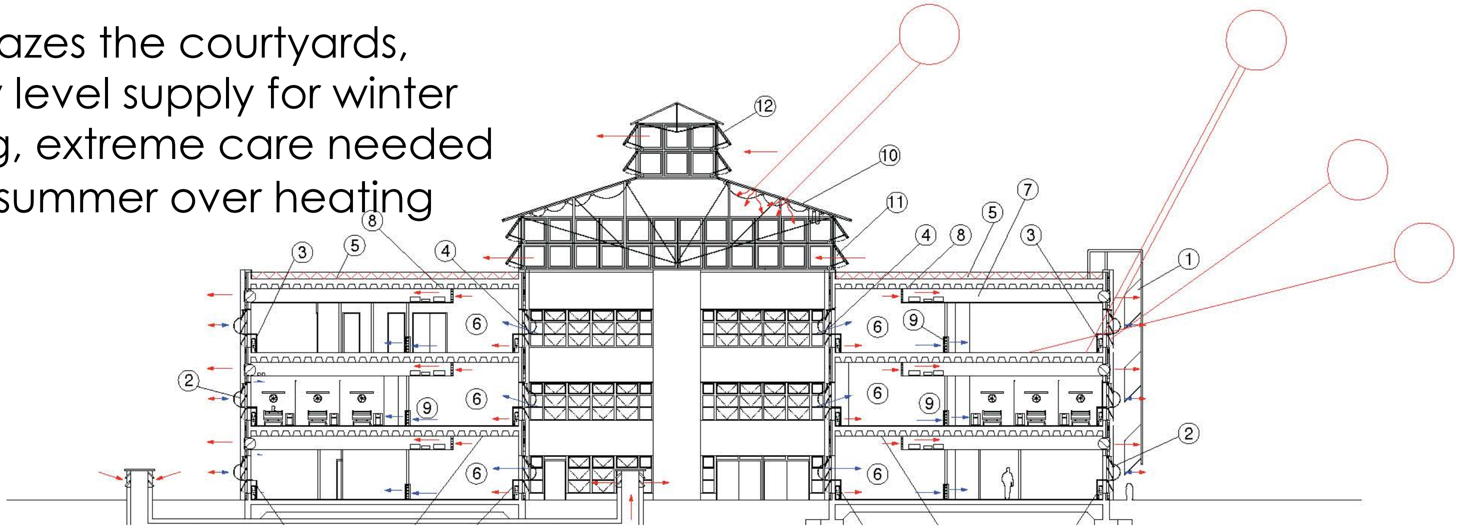
Option 1 seals, insulates and mechanically ventilates with heat recovery



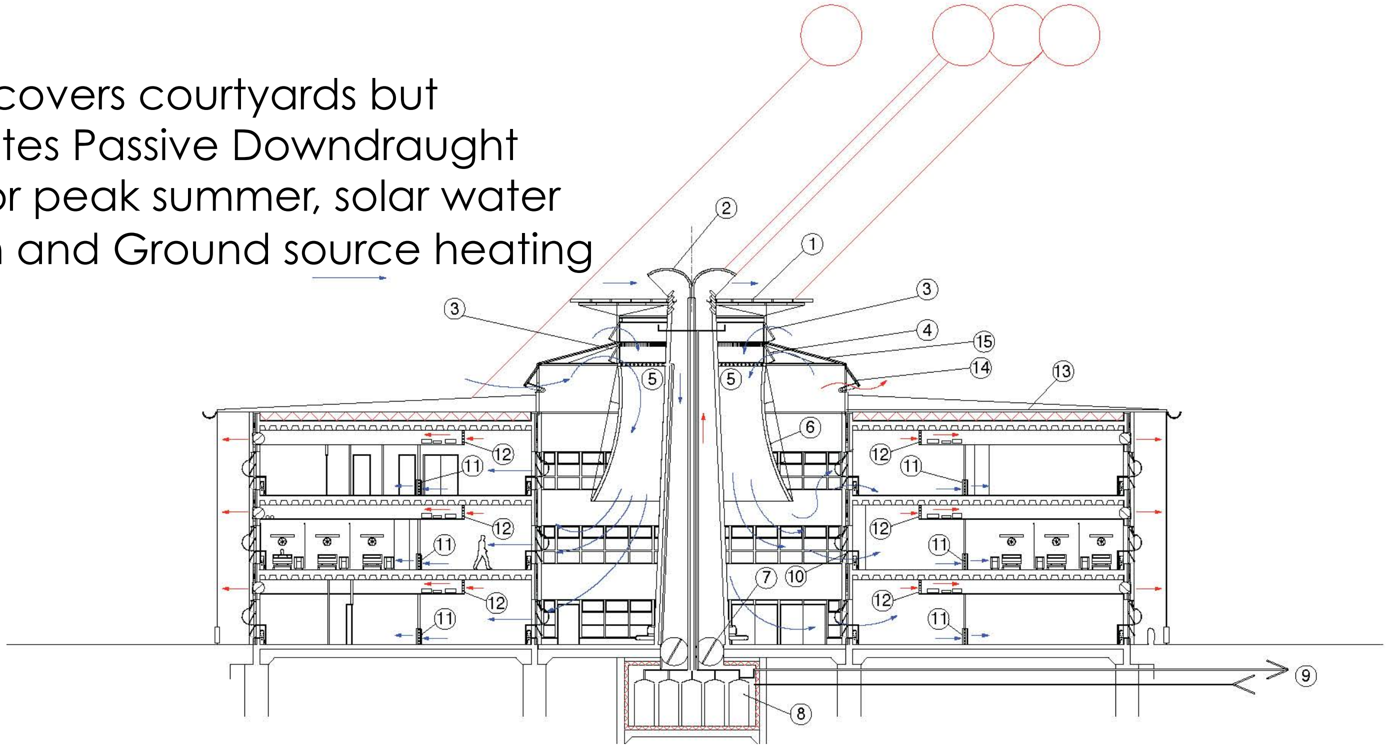
Option 2 opens up windows and airflow from the courtyards via transfer Ducts, perimeter heating and shading



Option 3 glazes the courtyards, Takes a low level supply for winter pre-heating, extreme care needed to prevent summer over heating



Option 4 covers courtyards but incorporates Passive Downdraught cooling for peak summer, solar water collection and Ground source heating for winter



A taste of the project film

Published:

Lomas K.J. & Ji Y. (2009), 'Resilience of naturally ventilated buildings to climate change: Advanced natural ventilation and hospital wards', *Energy & Buildings,* 41/6, 629-653

Short, C.A., and al-Maiyah, S. (2009), 'Design strategy for low-energy ventilation and cooling of hospitals', *Building Research and Information* 37(3), 264-292

Short, C.A., Cook, M., et al., 'Low energy refurbishment strategies for health buildings', *Journal of Building Performance Simulation*, 2010

Short, CA, Lomas KJ, Giridharan R, Fair A, 'Building resilience to overheating into UK hospitals within the constraint of the national carbon reduction target: adaptive strategies for 1960's buildings', *Building and Environment* 55 (2012), 73-95

Lomas KJ, Giridharan R, 'Thermal comfort standards, measured internal temperatures and resilience to climate change of free-running buildings: a case study of hospital wards', *Building and Environment* 55 (2012)

Eckert, C.M., Stacey, M.K., **Garthwaite, P.**, Wyatt, D., 'Change as little as possible: Creativity in design by modification', *Journal of Engineering Design*, special issue on engineering creativity

Short CA, Lomas KJ, Giridharan R, Fair A, 'Resilience of early twentieth-century "Nightingale" wards in a changing climate', *BSERT* 33/1 (2012), 81-103

-Conference papers include:

Masko ML, 'Designing for resilience: using a Delphi study to identify resillience issues for hospital designs in a changing climate', ICED 11, Denmark

Gilkeson, C., **Noakes, C**., et al., 'Simulating pathogen transport within a naturally ventilated hospital ward', International Conference on Computational Fluid Dynamics, Paris, June 2011

featured in *Health Estates Journal*, June 2010 (available online)

www.robusthospitals.org.uk for full publications list and abstracts