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

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Department of Architecture, University of Cambridge
Department of Civil Engineering, Loughborough University
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UNIVERSITY OF CAMBRIDGE

Loughborough University

The Open University

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EPSRC
Engineering and Physical Sciences Research Council

DH Department of Health

Aim:

the design and delivery of credible, economical and safe strategies to adapt the prodigious NHS Retained Estate (14000+ sites) **and increase its Resilience whilst meeting challenging energy reduction targets**

Objectives:

- Define the **meaning of resilience** in a healthcare context
- **Identify and catalogue** frequently-occurring building types within the NHS
- **Establish the resilience** of representative case-study buildings on partner Trusts' sites
- **Develop & model detailed refurbishment strategies** for these buildings
- **Examine complexitie**s and possible barriers to adaptive refurbishment
- Examine whole-site system implications of change**; develop tools to manage change**
- Deliver **catalogue of viable refurbishment strategies**

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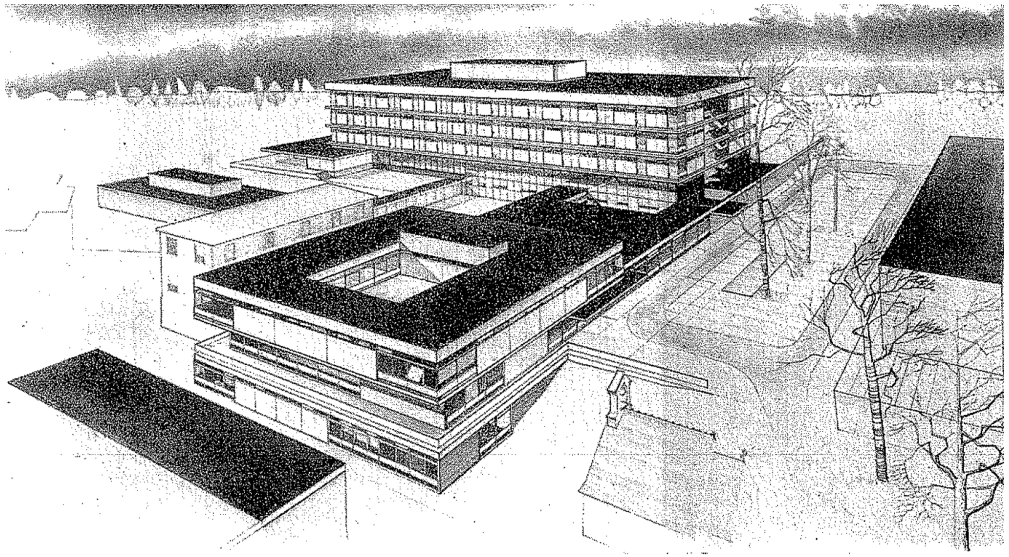
Design and Delivery of Robust Hospital Environments in a Changing Climate

Jan Filochowski,
Chief Executive, West Hertfordshire Hospitals NHS Trust



St Albans City Hospital: original published design

NHS energy saving targets

15% saving in energy 2000-2010. 35-55 GJ/100m^3 for all new capital development and 55-65 GJ/100m^3 for refurbishment

But there are temperature thresholds:

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

Dry bulb vs dry resultant temperature

Where do the thresholds come from?

	Building / room type[1]	Operative temperature range (DRT) / °C	
		Winter	Summer
Gown and blanket	Bedhead / wards 0.9 met 1.2 clo	22 – 24	23 – 25
Gown only	Consultancy / treatment 1.4 met 0.45 clo	22 – 24	23 – 25
Lightly dressed, no sleeves	Nurses station 1.4 met 0.65 clo	19 – 22	21 – 23
V. active in pinstripe suit or blazer and bow tie	Operating theatres 1.8 met 0.8 clo	17 – 19	17 – 19

CIBSE Guide A

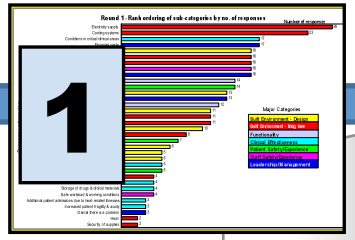
In a warming climate, custom and practice would suggest the installation of energy intensive mechanical cooling.

Can buildings be refurbished to improve current energy performance and to make them more resilient to changes in the future?

How can the 'stuff' of architecture be used to generate safe and comfortable internal environments?

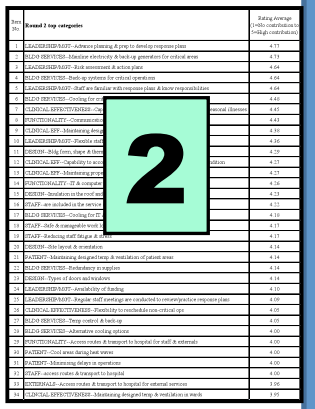
Defining Resilience Delphi Survey Process

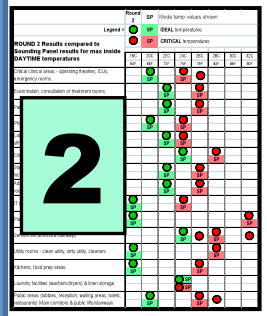
ROUND 1
Responses collected & grouped into
34 response areas &
7 major categories



Expanded into 67 statements for rating In Round 2

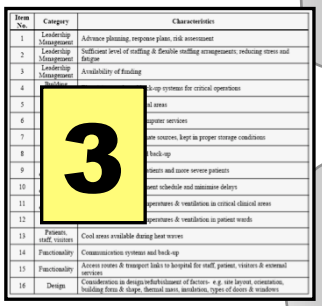
ROUND 2
Identified top issues = 34
Identified temperature ranges for ideal & critical conditions

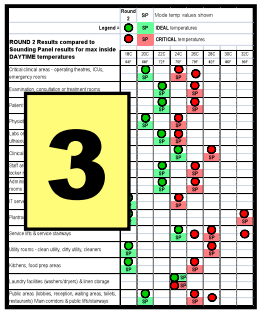




Clustered into
16 topics for rating
in Round 3

ROUND 3
Identified top priorities
Evaluated temp. ranges





Preliminary Results
6 top priorities
R2 & R3 modal temp. values are the same

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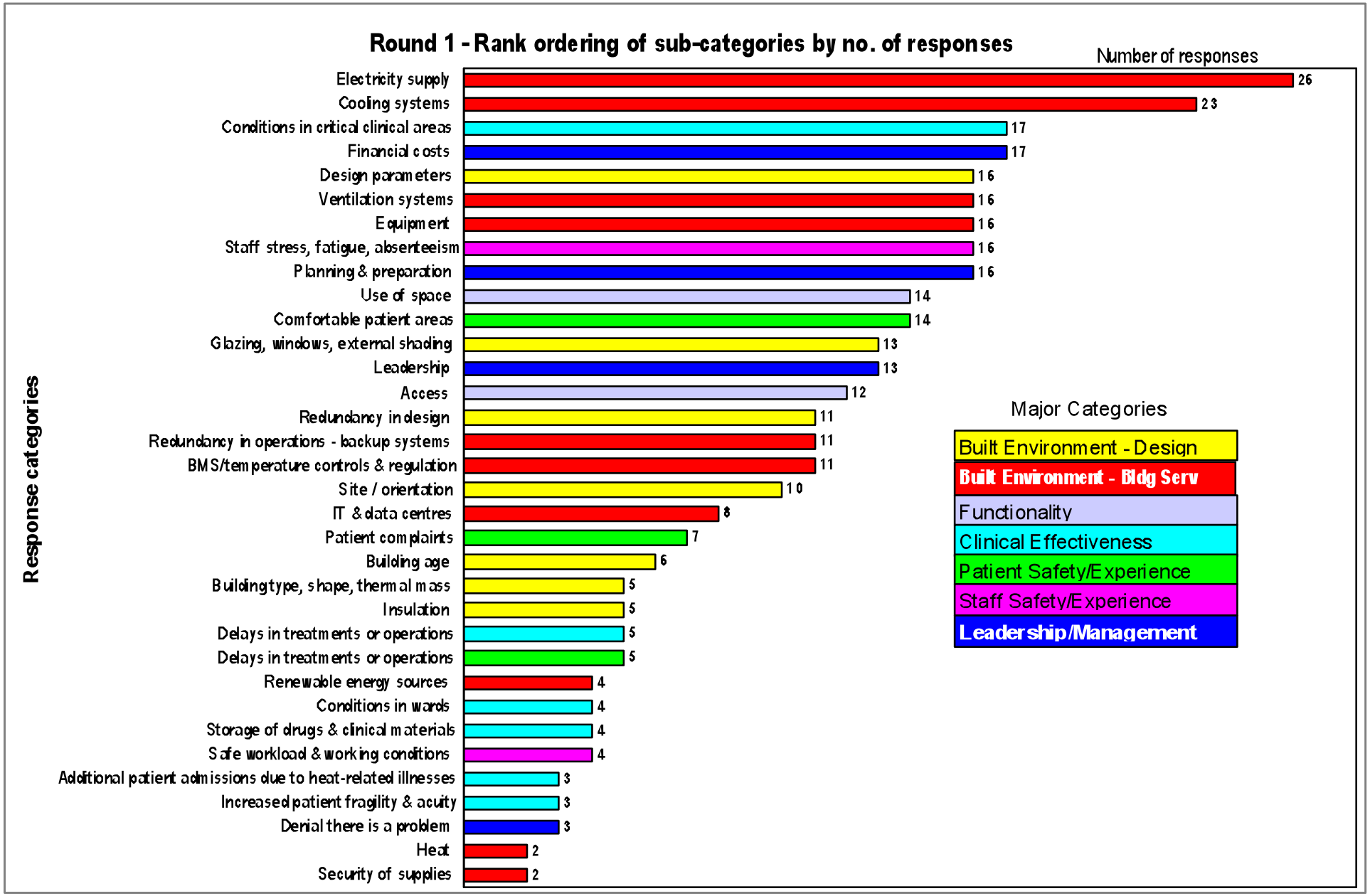
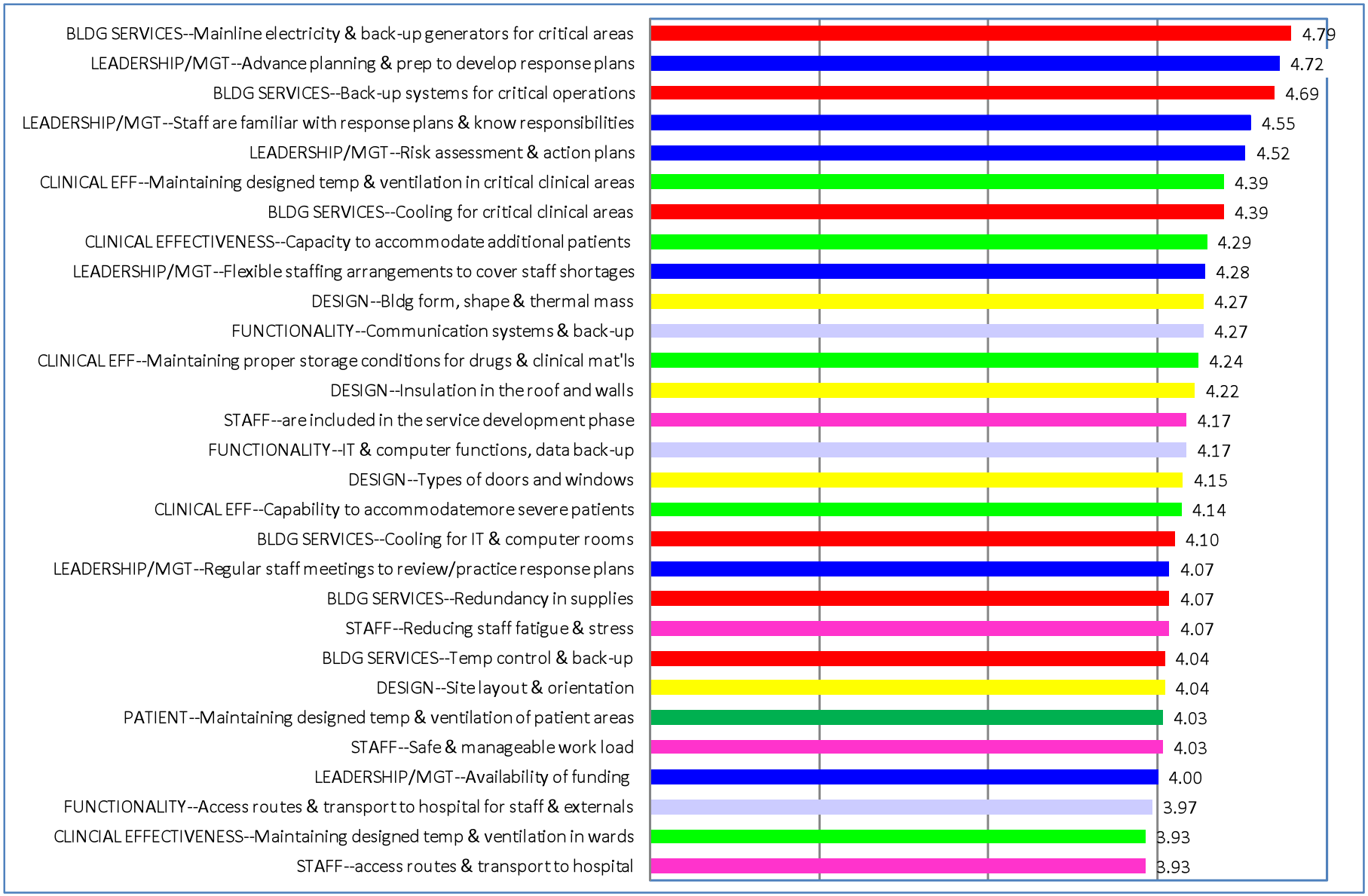

Round 1 - Rank ordering of sub-categories by no. of responses
Number of responses
Response categories
Electricity supply 26
Cooling systems 23
Conditions in critical clinical areas 17
Financial costs 17
Design parameters 16
Ventilation systems 16
Equipment 16
Staff stress, fatigue, absenteeism 16
Planning & preparation 16
Use of space 14
Comfortable patient areas 14
Glazing, windows, external shading 13
Leadership 13
Access 12
Redundancy in design 11
Redundancy in operations - backup systems 11
BMS/temperature controls & regulation 11
Site / orientation 10
IT & data centres 8
Patient complaints 7
Building age 6
Building type, shape, thermal mass 5
Insulation 5
Delays in treatments or operations 5
Delays in treatments or operations 5
Renewable energy sources 4
Conditions in wards 4
Storage of drugs & clinical materials 4
Safe workload & working conditions 4
Additional patient admissions due to heat-related illnesses 3
Increased patient fragility & acuity 3
Denial there is a problem 3
Heat 2
Security of supplies 2
Major Categories
Built Environment - Design
Built Environment - Bldg Serv
Functionality
Clinical Effectiveness
Patient Safety/Experience
Staff Safety/Experience
Leadership/Management

Round 2 results – design factors in yellow



Round 3 Results - Temperature Ranges

= Ideal = Acceptable = Critical

Hospital spaces in a general acute hospital	18C 64F	19C 66F	20C 68F	21C 70F	22C 72F	23C 73F	24C 75F	25C 77F	26C 79F	27C 81F	28C 82F	29C 84F	30C 86F	31C 88F	32C 90F
Critical clinical areas with controlled environment conditions (e.g. operating theatres, delivery rooms, isolation units, etc.)															
Daytime range															
Night time range															
Critical care units (e.g. ICUs, emergency rooms, etc.)															
Daytime range															
Night time range															
Patient wards - General medical															
Daytime range															
Night time range															
Patient wards - Geriatric or paediatric															
Daytime range															
Night time range															
Staff areas - nurses station, offices, on-call rooms, locker rooms															
Daytime range															
Night time range															
IT server rooms & data centres															
Daytime range															
Night time range															
Public areas (lobbies, reception, waiting areas, toilets, restaurants) Main corridors & public lifts/stairways															
Daytime range															
Night time range															

Broader range of temperatures than current guidance, but actually lower maximum

Actual now is often 24C-26C in case study buildings

Although evidence exists of the detrimental effects of heatwaves on the health of the vulnerable, and of the effect of ambient temperature on sleep, there appears to be little physiological or medical evidence linking ambient temperature and health. *(George Hanna, Professor of Surgery, Imperial)*

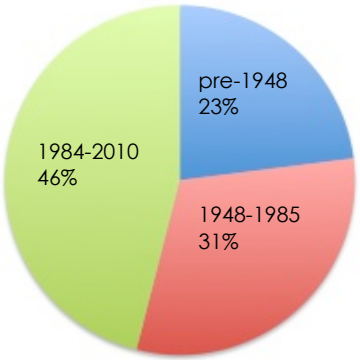
Two types of case study

1. ‘Monitoring’ case studies
   - representative buildings on the sites of our four Partner NHS Trusts
   - selection of representative spaces within those buildings
   - gather data of current performance
   - simulate future performance
   - design and test refurbishment strategies

2. ‘Process’ case studies
   - construct detailed design histories on the basis of interviews, archival analysis, including minutes, drawings, reports

Evaluating the NHS Estate

14000+ sites

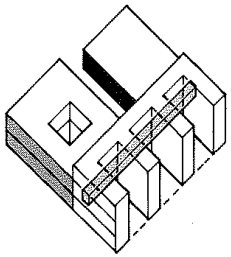


Age profile by site, nationally

263 general acute hospitals

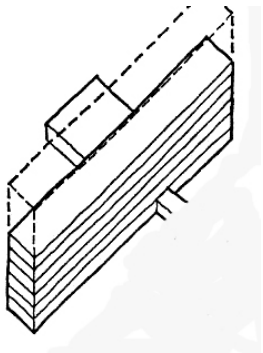
116 specialist hospitals

(DH, 2010)



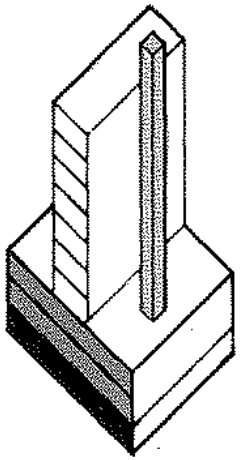
'Nightingale pavilions'
Predominant model from 1860s to 1930s
Design for daylight, natural ventilation

DeDeRHECC case study: Bradford Royal Infirmary (1927-)



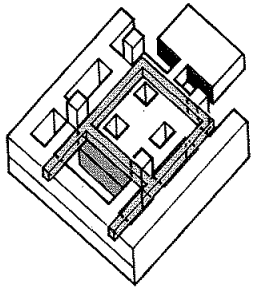
Linear slab
Emerges from 1930s, aided by lifts

DeDeRHECC case study: Kensington Building Leicester Royal Infirmary (1967)



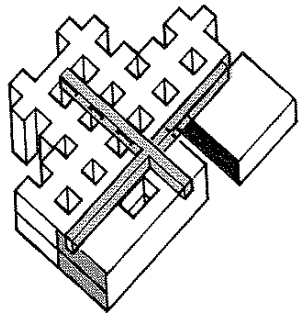
'Matchbox on a muffin'
Classic 1960s NHS hospital building form

DeDeRHECC case studies: Maternity building, Bradford Royal Infirmary; Ward tower, Addenbrooke's, Cambridge



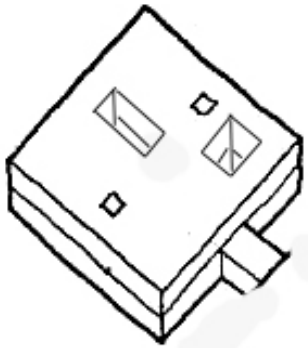
'Best Buy'/closed court
Developed late 1960s:

DeDeRHECC case study: Rosie Maternity as variant



'Nucleus'/open court
Developed late 1970s from 'Harness'. 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*

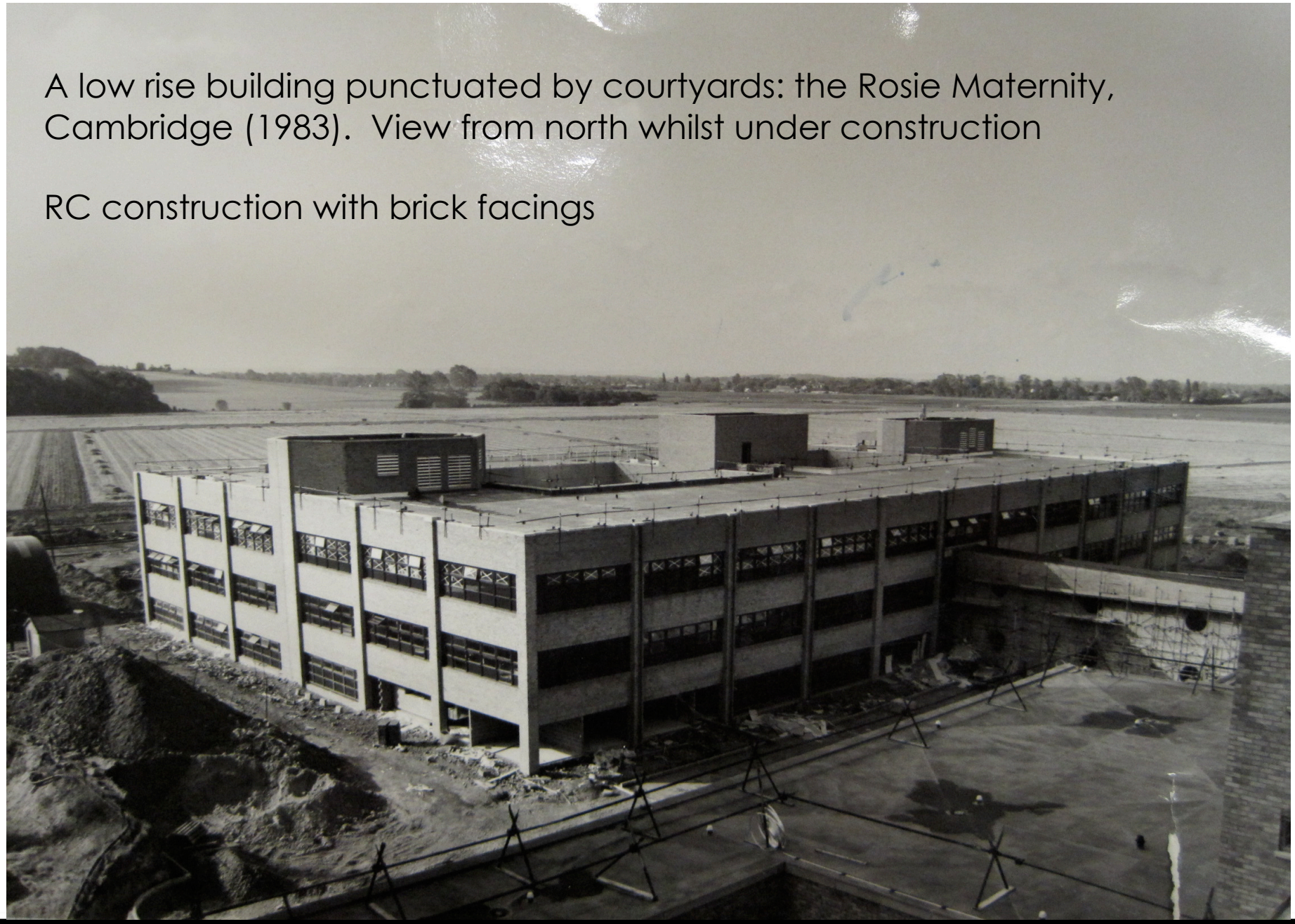
Hospital	Number of spaces	Number of loggers	Description
Addenbrookes: Maternity (Rosie) and Tower C&D level 6 and 8	32	48 Hobos and 3 Co_2 sensors	Waiting area, treatment , examination & consulting, Ultrasound, Single bed, Multi bed, nurses station, delivery, breast clinic, office, staff rest room etc
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 2011: two summers and one winter

A sample of the results…

A low rise building punctuated by courtyards: the Rosie Maternity, Cambridge (1983). View from north whilst under construction

RC construction with brick facings

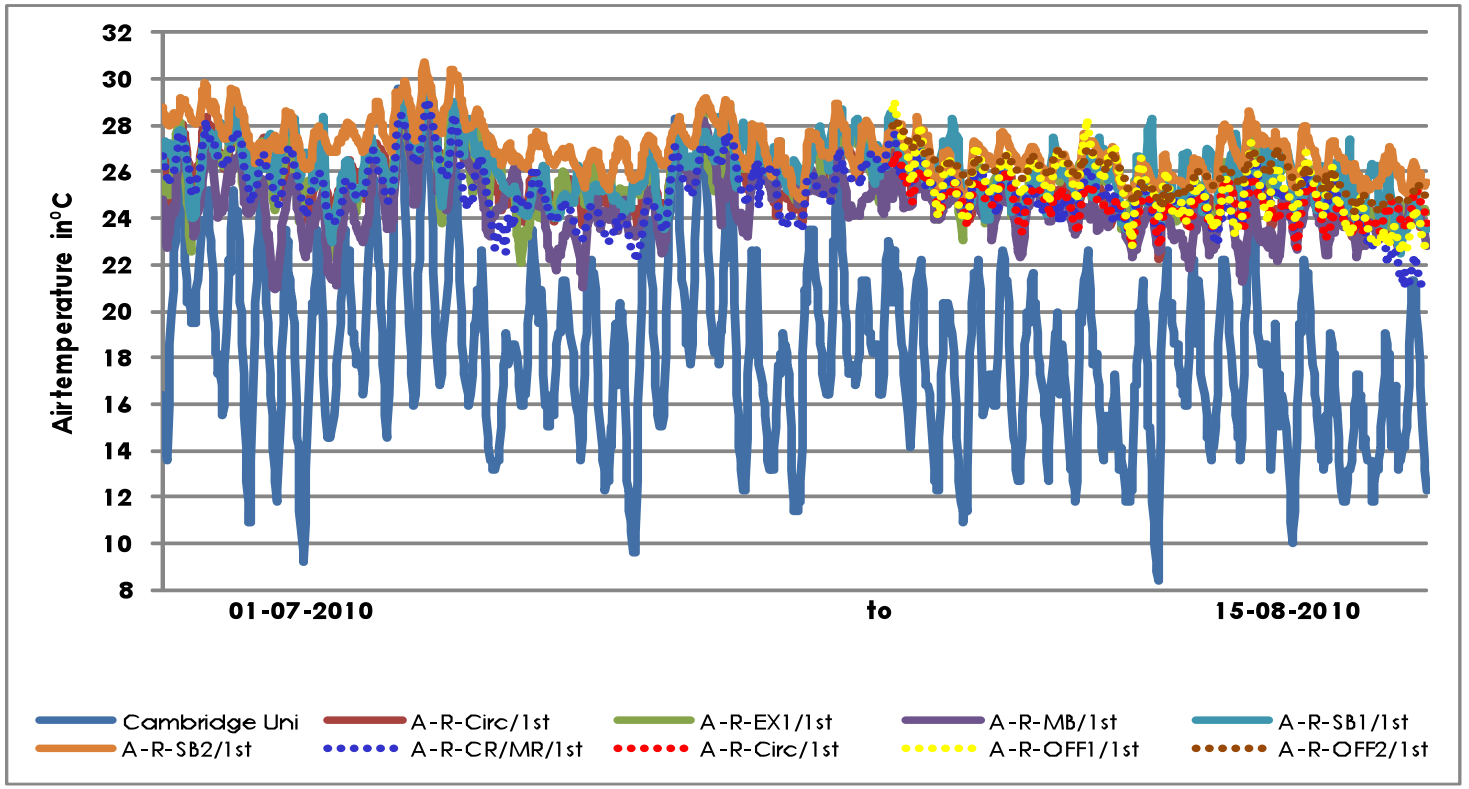


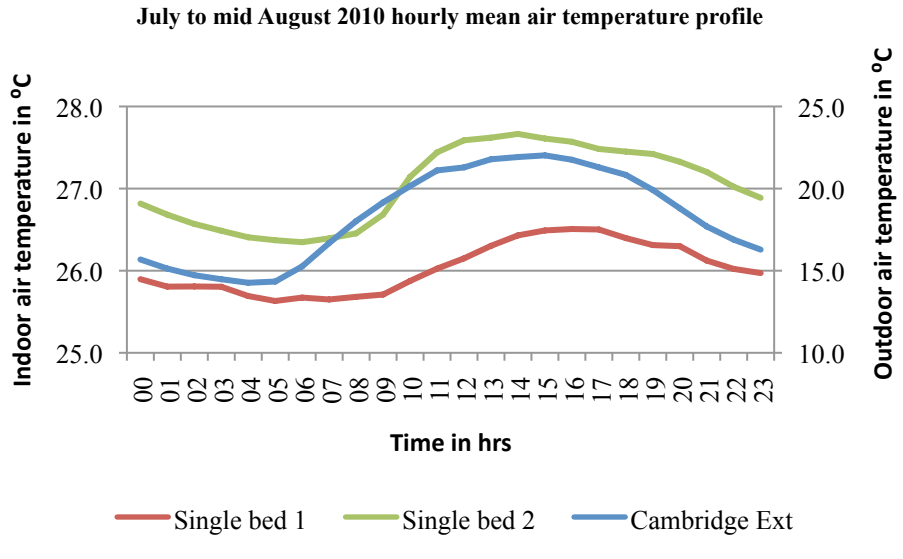
July to Mid August 2010 hourly mean air temperature profile- Single bed rooms in Rosie Maternity Hospital

Supply air heated to 26C.

Year round set point is 24.5C. Heating ceases only after the external temperature rises above 20C.

No feedback of actual room temperatures, which are influenced by other factors – occupants, equipment etc





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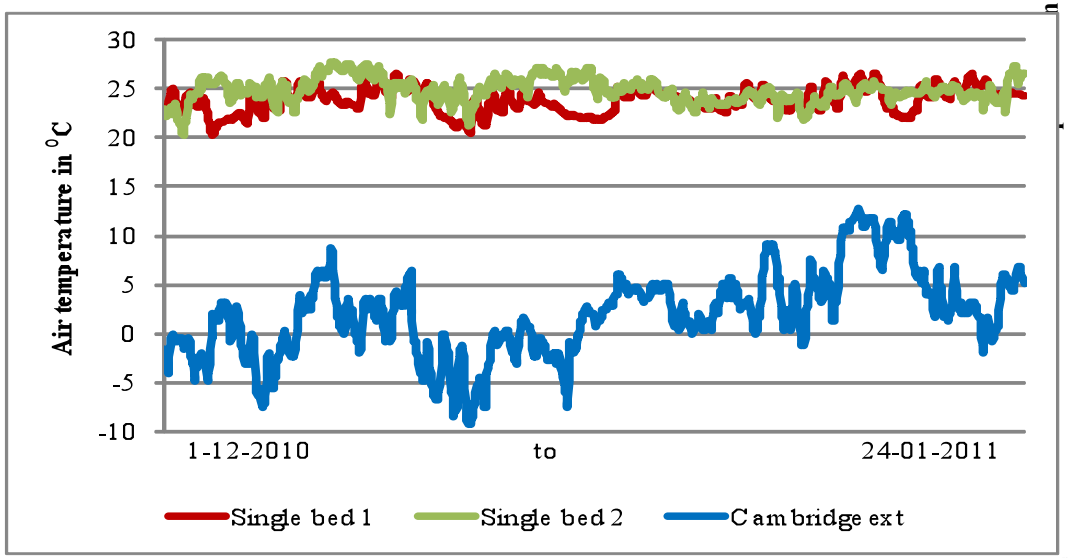
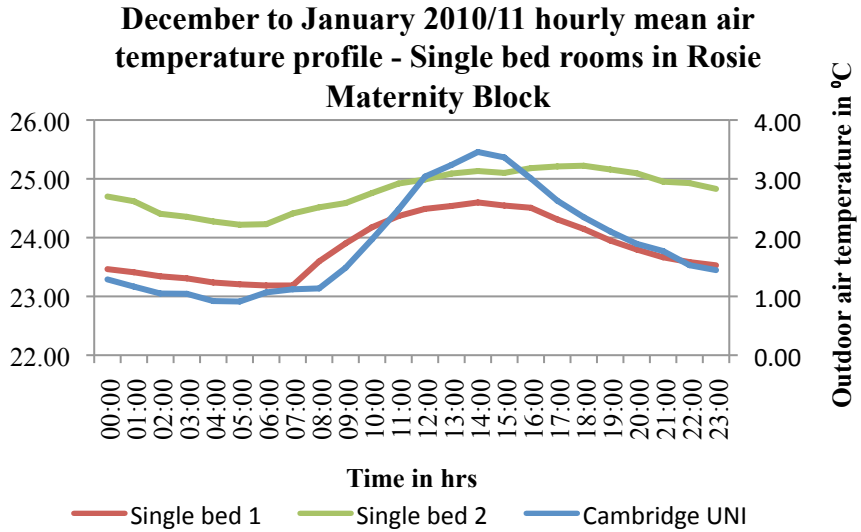
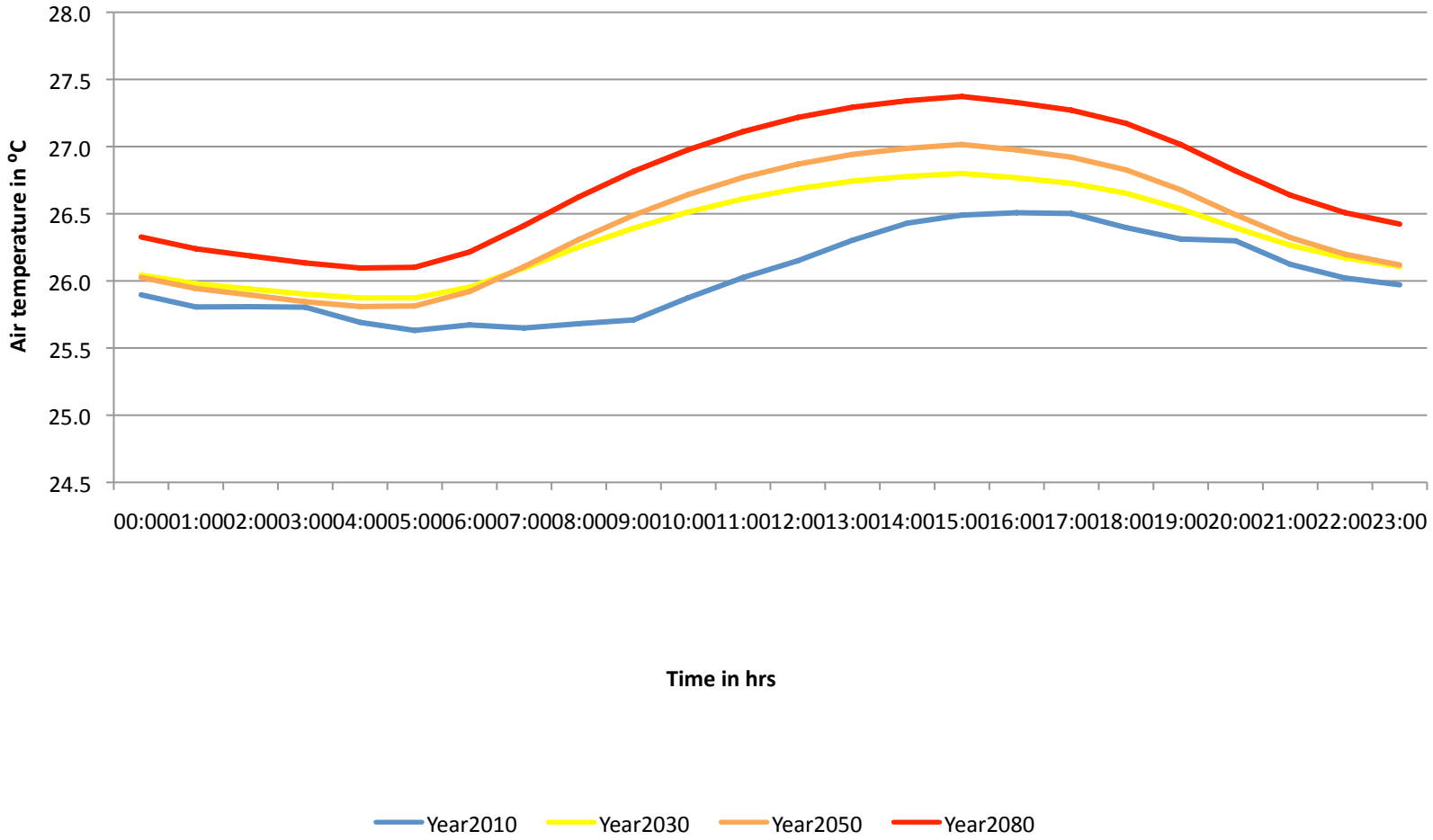

Air temperature in °C
30
25
20
15
10
5
0
-5
-10
1-12-2010
to
24-01-2011
Single bed 1
Single bed 2
Cambridge ext

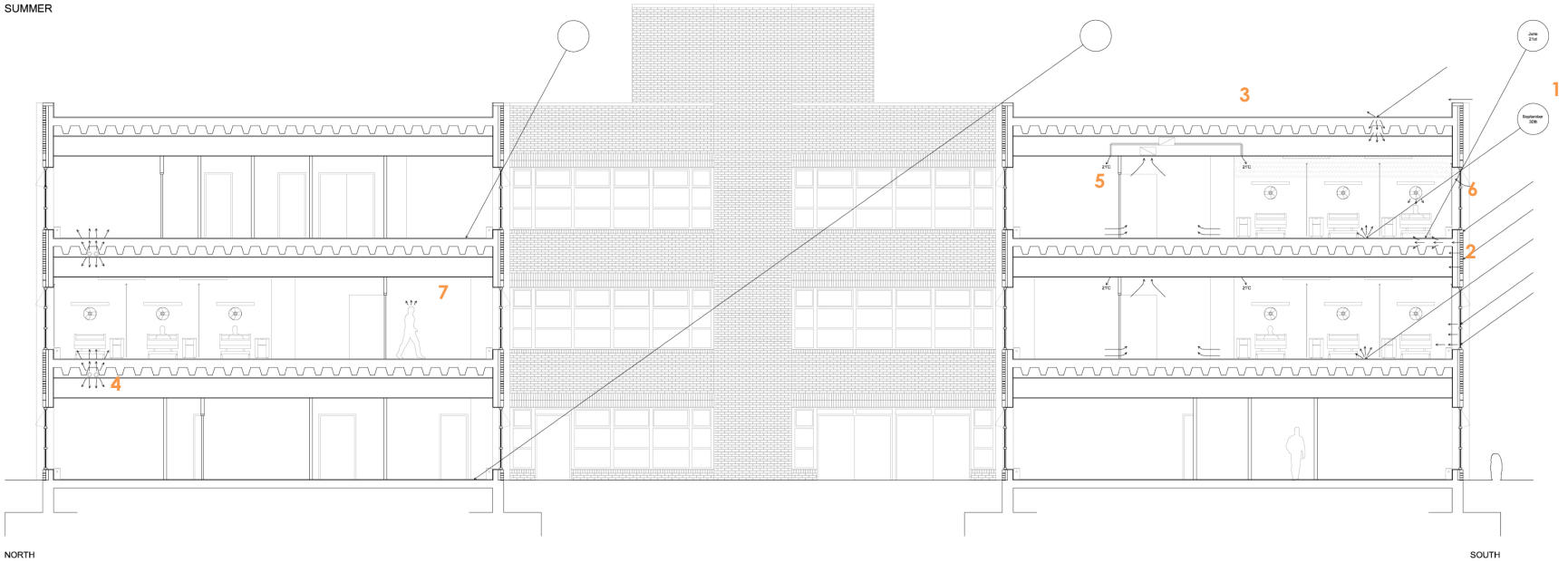

December to January 2010/11 hourly mean air temperature profile - Single bed rooms in Rosie Maternity Block
26.00
25.00
24.00
23.00
22.00
4.00
3.00
2.00
1.00
0.00
Outdoor air temperature in °C
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time in hrs
Single bed 1
Single bed 2
Cambridge UNI


Office 2
Office 1
Single bed 2
N
Single bed 1
Counselling & Meeting
Multi bed
Circulation
Examination

2010 and predicted
July to mid August hourly mean air temperature profiles –
Single bed room-1 in Rosie Maternity Block (North facing)

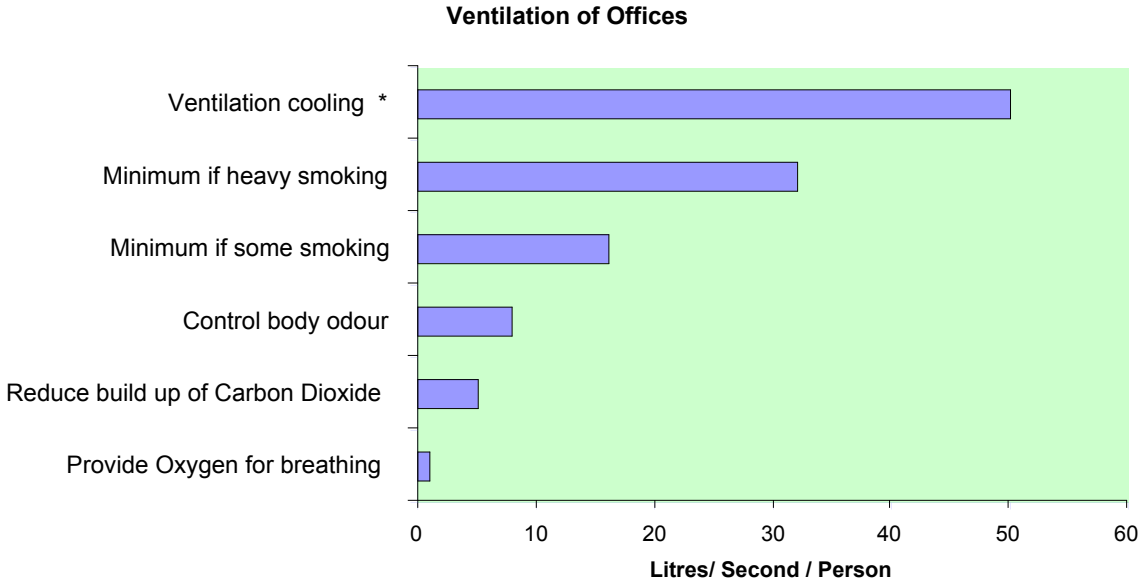


Next: diagnosing the problems



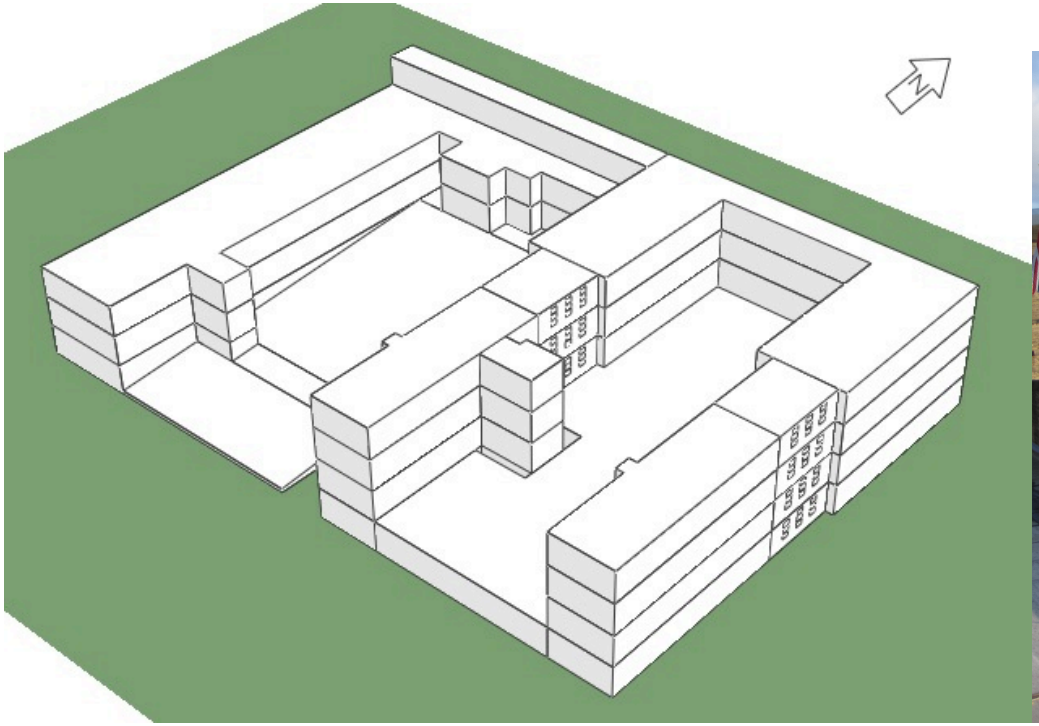
Rosie Maternity Hospital, Cambridge **Reinforced concrete frame, built 1983** *(architects: Yorke Rosenberg Mardall)*

1. *Main elevation oriented south for views but fully exposed to solar gains through overheating seasons*
2. *Glazed opaque elements of external façade become, in effect, heating elements. Steam and hot water pipes in lightweight cavities contribute heat all year*
3. *Direct solar gains through llightly insulated roof*
4. *Gains at first floor level on north side from pipes embedded in the slab; these spaces the most uncomfortable*
5. *Supply air heated to 26C. Year round set point is 24.5C. Heating ceases only after the external temperature rises above 20C. No feedback of actual room temperatures, which are influenced by other factors – occupants, equipment etc*
6. *Windows often open, even in winter, as a consequence of 5.*
7. *Casual gains from occupants and equipment. Loughborough commencing monitoring.*



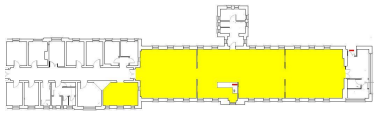
Supply air heated to 26C. Year round set point is 24.5C. Heating ceases only after the external temperature rises above 20C. No feedback of actual room temperatures, which are influenced by other factors – occupants, equipment etc

Air change rates…



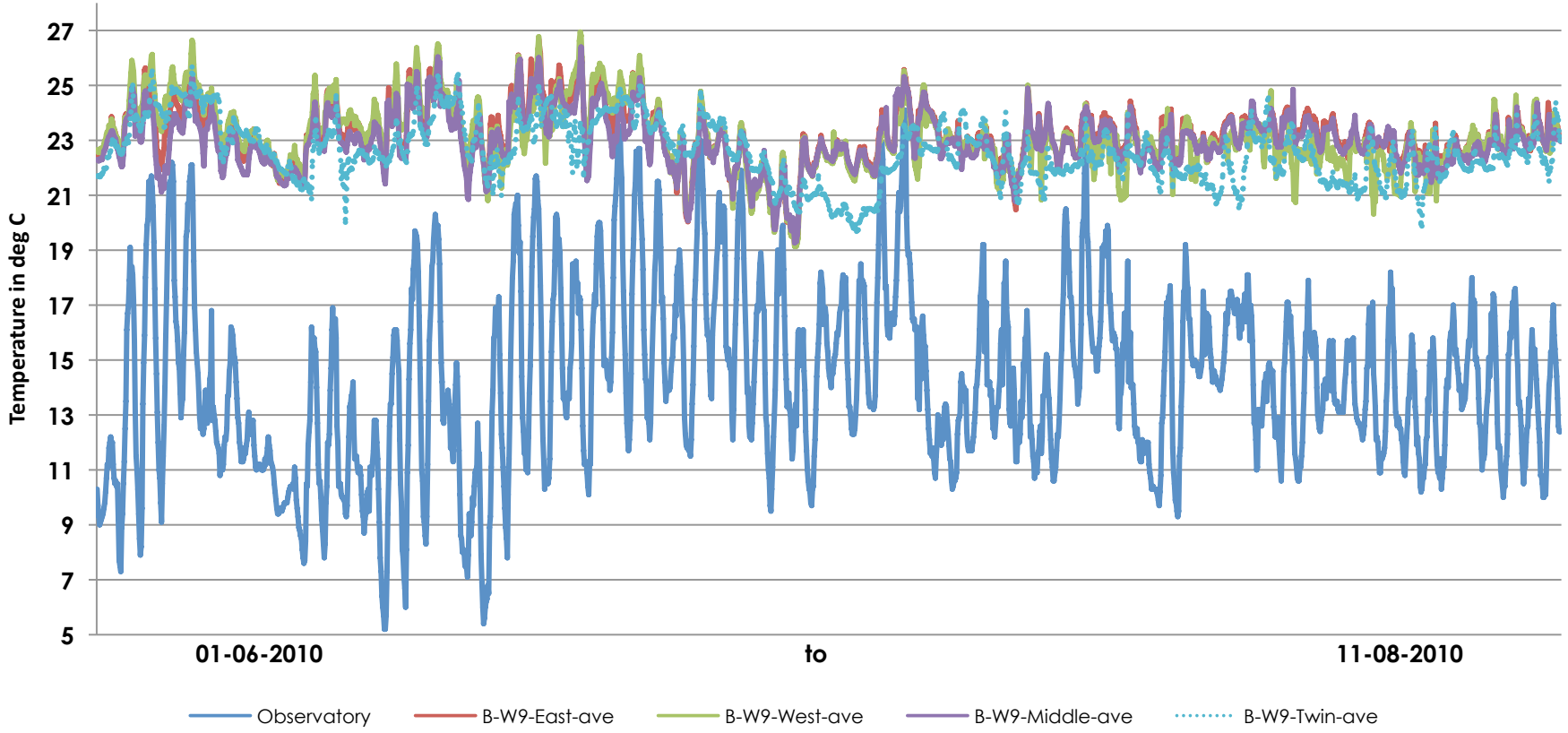
Bradford Royal Infirmary

'Nightingale' wards, built from 1927. Traditional construction, stone skin with brick inner layer

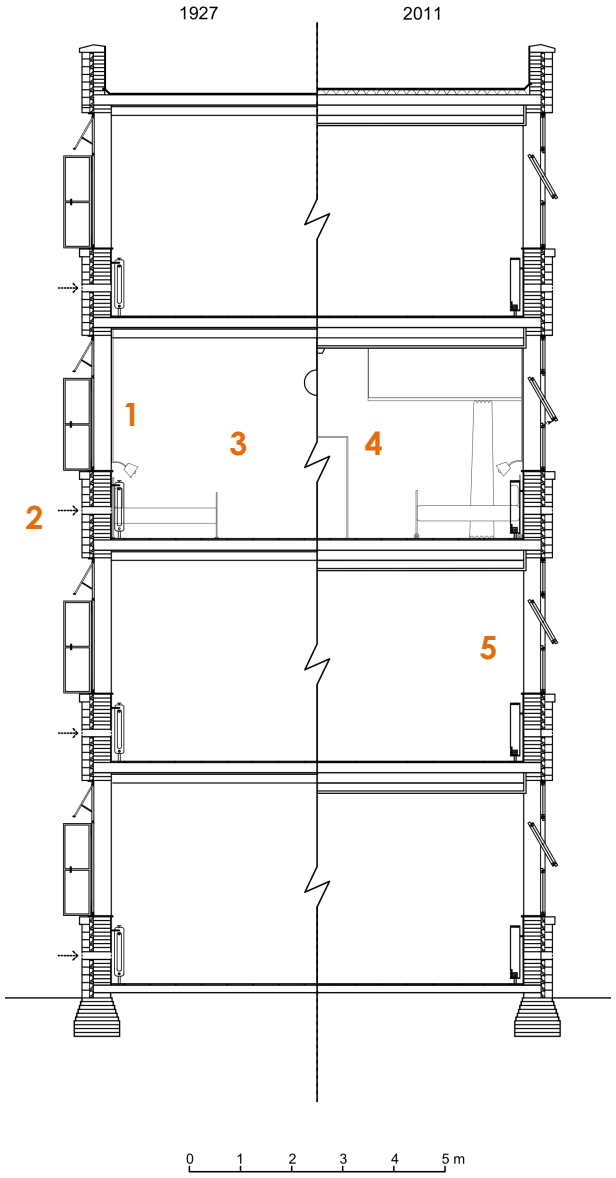


Hourly temperature trends in ward-9 of Bradford NHS

Set point 23.5C

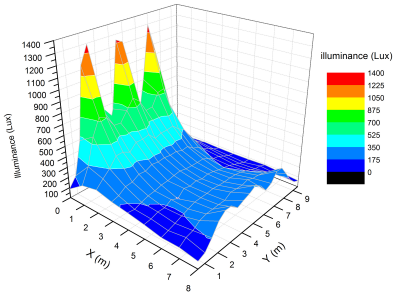


	Observatory	B-W9-East-ave	B-W9-West-ave	B-W9-Middle-ave	B-W9-Twin (off)ave
Min	5.2	19.2	19.1	19.3	19.7
Ave	14.2	23.2	23.1	23.0	22.6
Max	24.1	26.7	26.9	26.4	25.7

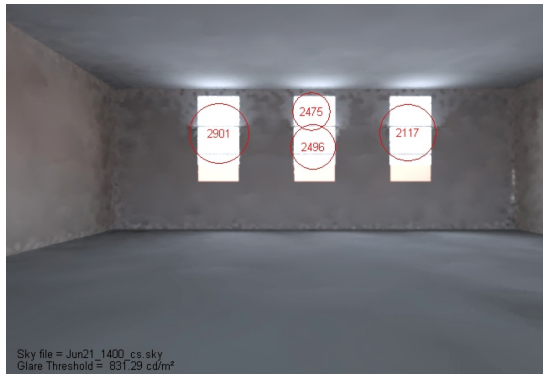


Bradford Royal Infirmary, 'Nightingale' wards
Traditional construction with stone facings, built from 1927
(architect: Eric Morley)

1. *1927: Natural ventilation from Crittall windows*
2. *1927: Ventilation via grilles, ducted into ward behind radiators*
3. *1927: Ward a single open space, no partitions*
4. *2011: Ward divided into sections by transverse partitions. Suspended ceiling. Beds in curtained bays.*
5. *2011: Double glazed windows, restricted opening for safety, air duct below blocked*



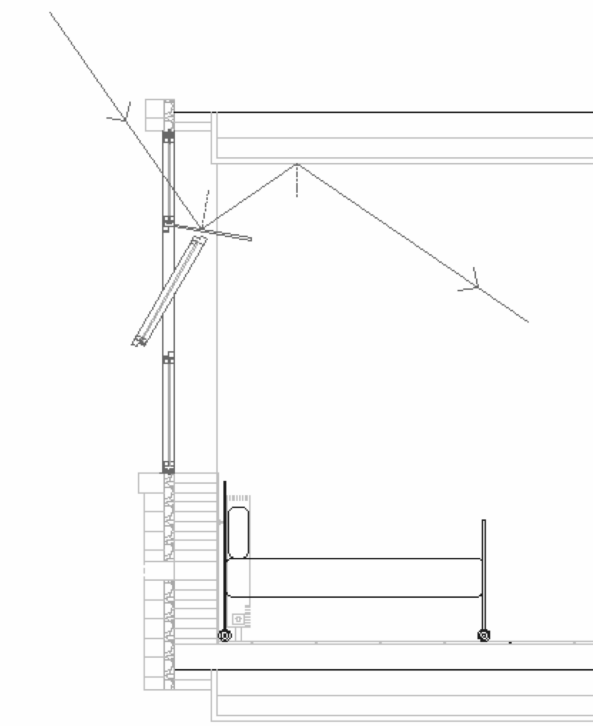
Daylight analysis, as built, clear sky.

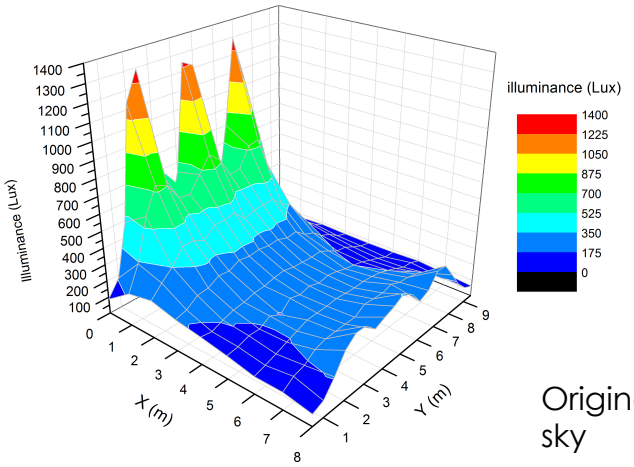


Glare analysis extract

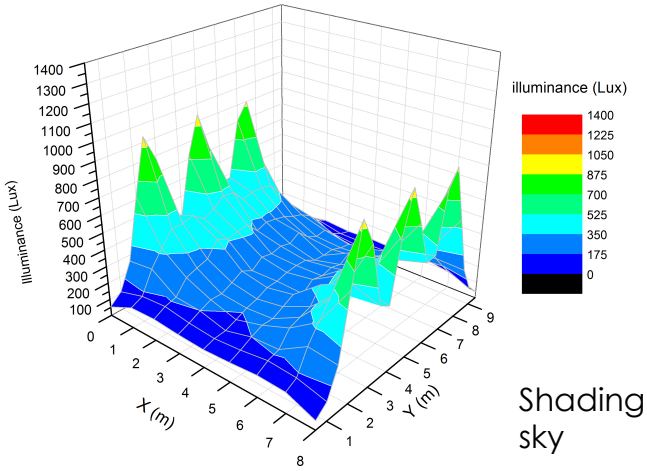
LIGHT SHELVES

Bradford Royal Infirmary
Nightingale ward

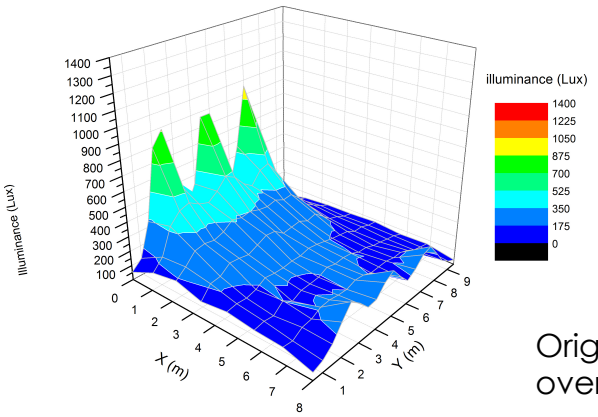




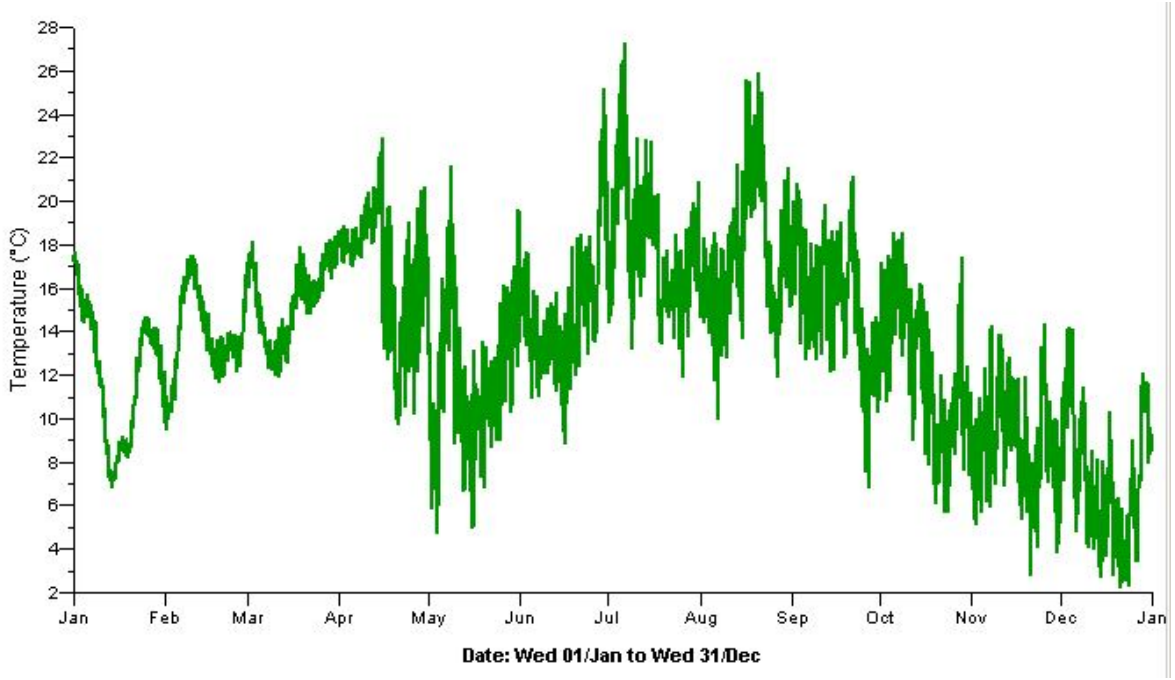
Original, clear sky



Shading, clear sky



Original, overcast sky

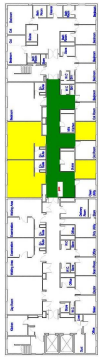


Model of current performance (IES)

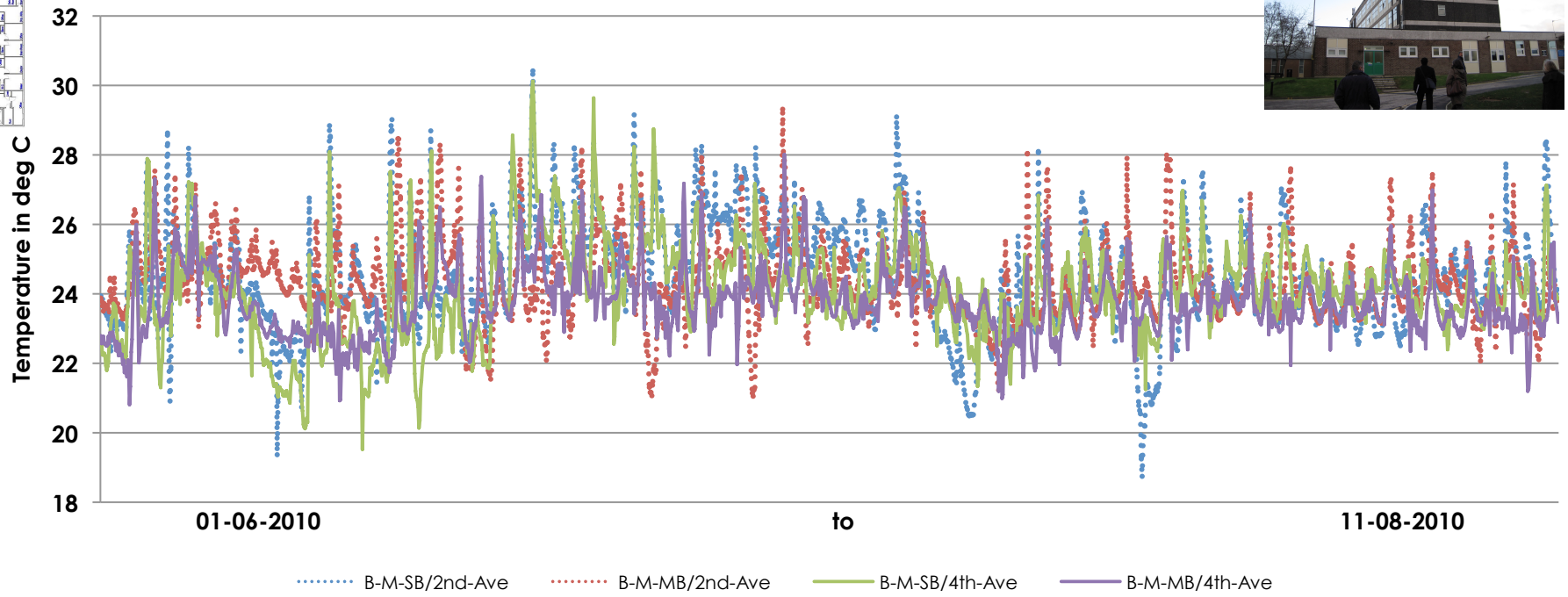
	Current	2020	2050	2080
Hours over 26°C	11	285	514	867
Hours over 28°C	0	91	231	285

Simulation using UKCIP medium scenario

Other builldings on the site fare less well, however…



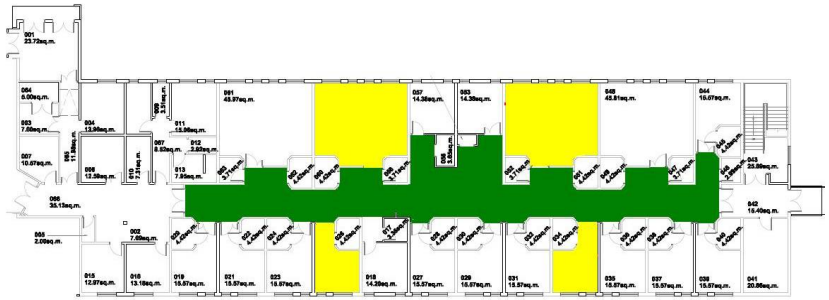
Hourly temperature trends in single and multi bed spaces of maternity block- Bradford NHS



	B-M-SB/2nd-Ave	B-M-MB/2nd-Ave	B-M-SB/4th-Ave	B-M-MB/4th-Ave
Mini	18.7	21.1	19.5	20.8
Ave	24.6	24.4	24.2	23.7
Max	30.4	29.3	30.1	28.0

- **Single bed in second floor is approx 295 hrs above 26°C**
- **Double bed in top floor is approx 40 hrs above 26°C**
- **Problematic set points.**

Hourly temperature trends-Bradford modular building



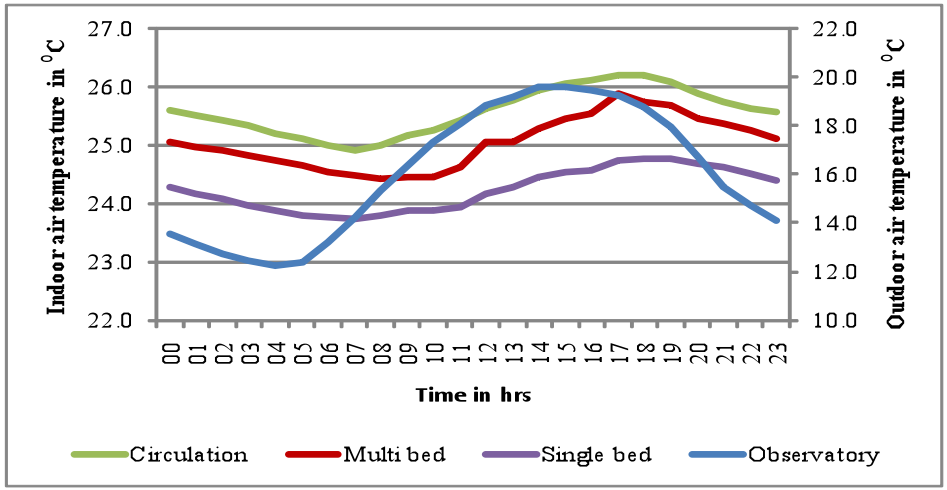
Modular building completed 2010
Advantages of modular building: timescale and cost certainty, minimise disruption

'Finger plan' analagous to Nightingale ward; layout similar to 1960s Maternity building

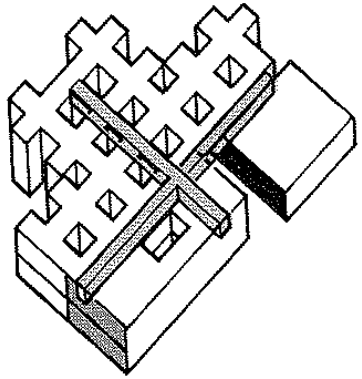
Heated ceiling panels. Natural ventilation to rooms via high and low level opening window. sMechanical ventilation to core corridor and extract from en-suite areas including heat recovery.
Heating set point 23C

This exercise also underway in other buildings, including:

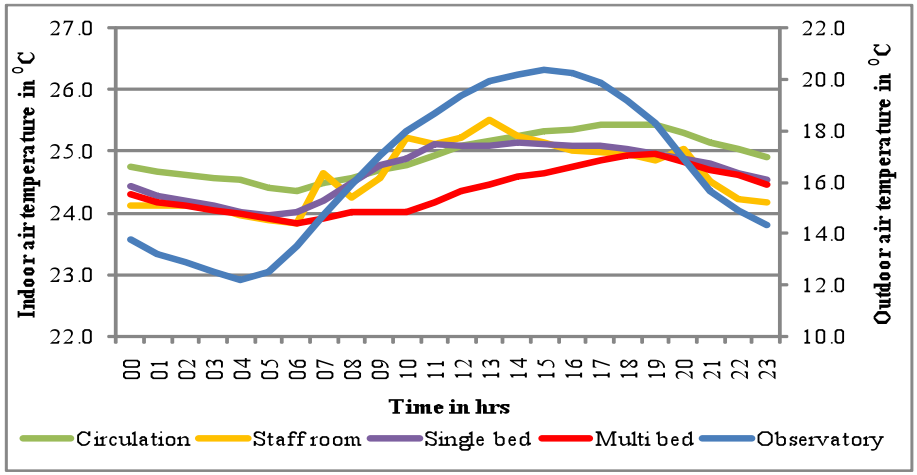
Glenfield Hospital. 'Nucleus' type. Built 1984



*Mean hourly temperature profile ward 27, June to August 2010 A 'Nucleus' type hospital, (**100+**) low-rise with many courtyards. The plan form maximises daylight and natural ventilation but is threatened by infilling of the courtyards for extra space.*



St Albans City Hospital, Runcie building (1980s mid-rise)



Mapping the patient journey

Where are the bulnerabilities to climate change?
What impact will refurbishment have on the life of the hospital?
Without adequate decanting space, are the only options external?

Precedents for this work:

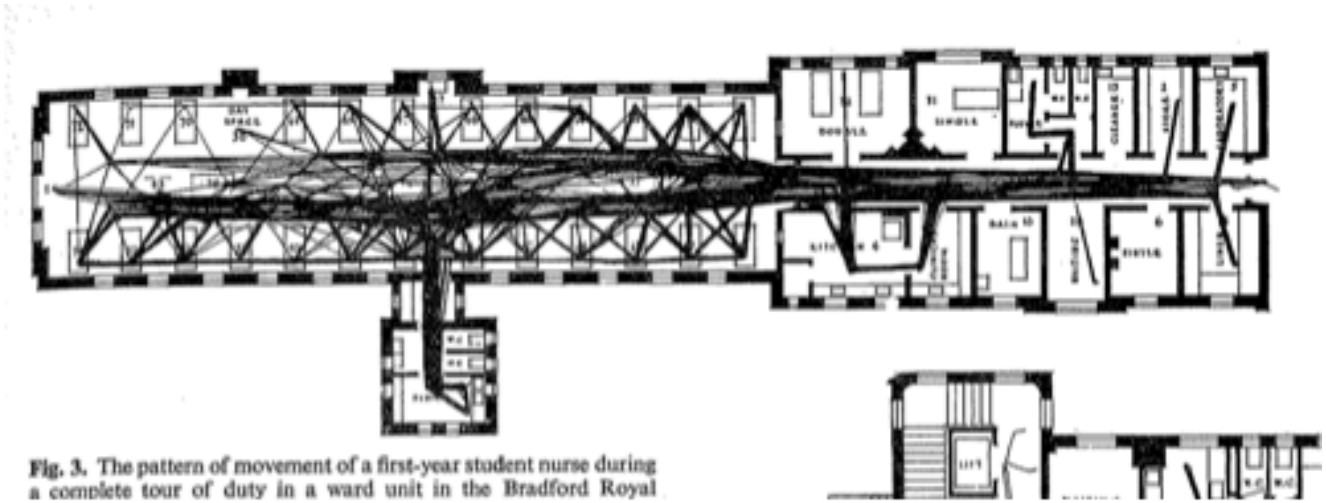
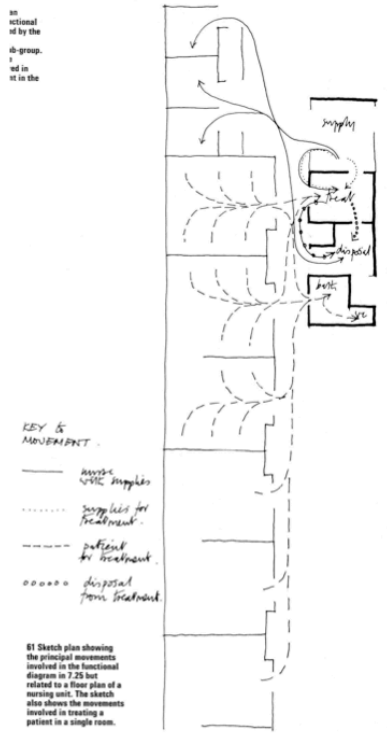
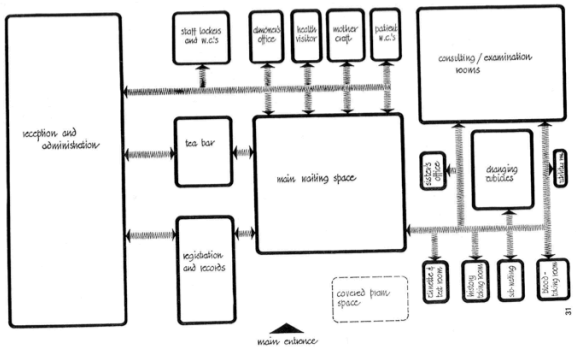


Fig. 3. The pattern of movement of a first-year student nurse during a complete tour of duty in a ward unit in the Bradford Royal

Nuffield Provincial Hospitals Trust
Studies in the functions and design of hospitals,
Oxford, 1955





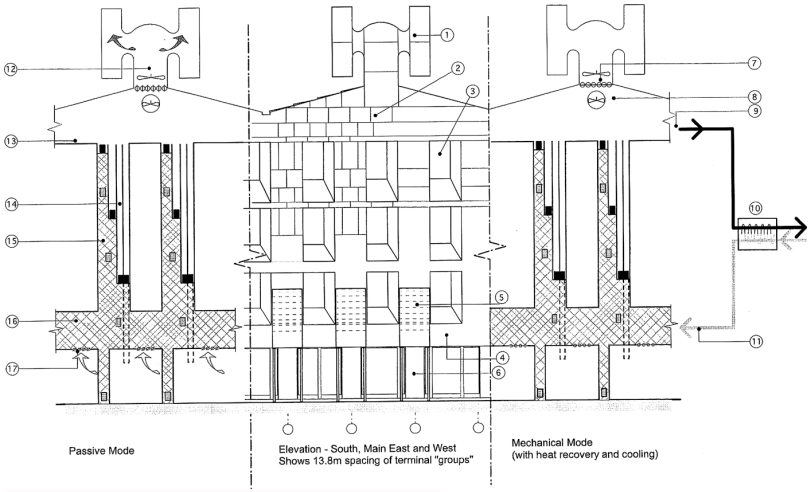
Green et al., Hospital Research and Briefing problems,
London, 1971

Agent based model

Next steps: designing and costing refurb options. A catalogue for NHS Trusts
Learning from hospitals – and other types

Controls/M&E ‘quick wins’
Shading
Double facades
Strip to frame and reclad

DOUBLE FACADES WITH LESS GLASS IN BEIJING AND NORTH LONDON
Facades contain supply and extract ducts and shade windows



Northwick Park Hospital
Modelling suggests that this scheme could yield as good energy performance as new construction

Impact – Ian Hinitt
Deputy Director of Estates, Bradford Teaching Hospitals NHS Foundation Trust

Communication and impact

1. Research team commissioned by Skanska as Sustainability Advisers to their bid for the new Papworth PFI hospital
2. Engagement with DEFRA, DCLG, UK Climate Change Risk Assessment
3. Engagement with Department of Health, NHS Sustainable Development Unit, NHS Trusts, healthcare providers in the US and Australia, IHEEM
4. Papers in progress, including for *Building and Environment*
5. Broadcast-quality film

The project film, for NHS Trusts, policymakers and health professionals: a taster

One of the refurbishment case studies: Neo-natal Unit, Leicester

De²RHECC

Design and Delivery of Robust Hospital Environments in a Changing Climate