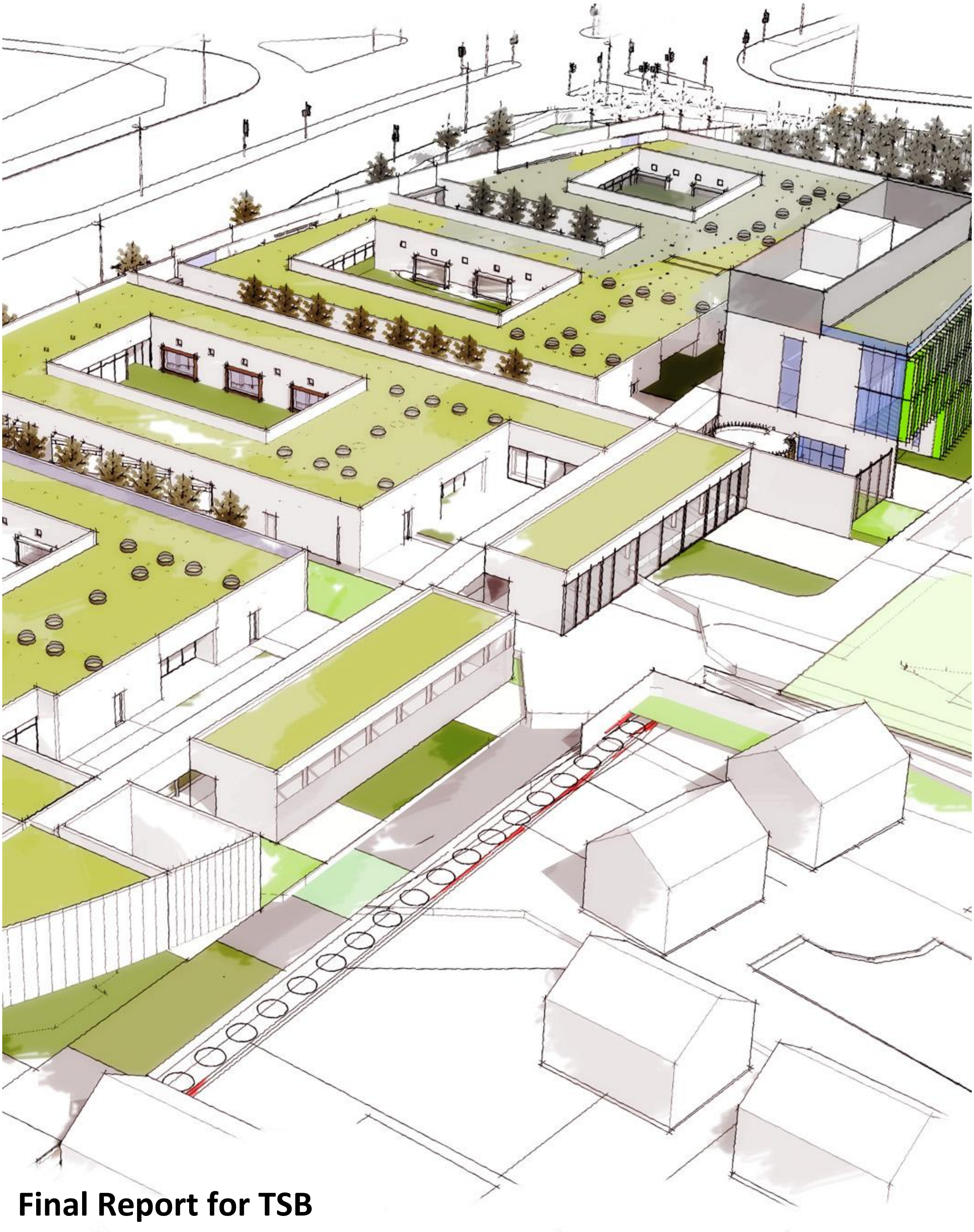
Edge Lane, Liverpool

Design 4 Future Climate Project



Final Report for TSB

by

Medical Architecture

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Executive Summary

Section 1

The Mental Health Needs Index for central Liverpool indicates a high and growing level of mental health need. The Edge Lane 85 bed adult mental health facility is one of five new proposed local mental health inpatient facilities to be procured through the TIME Project public-private partnership, in order to replace inadequate existing stock.

The scheme is located east of Liverpool city centre on Edge Lane, a busy arterial route. The site has a very prominent position at a 'gateway' to the city. There are significant issues with ground contamination, noise, air pollution, and level changes across the site, which are addressed by the scheme.

The ward accommodation is laid out on a single storey, with bedrooms (single with ensuite showers) arranged on the long sides of rectangular internal courtyards, with glazed day spaces and activity rooms at the short ends of each courtyard, maintaining a visually open feel within a safe and secure enclosing perimeter wall. A three storey support accommodation building marks the entrance and signals the building from a distance.

Section 2

To develop appropriate adaptation strategies, the hazards for the site were quantified, climate change impacts were defined and the local environmental features (LEFs) which can exacerbate or ameliorate the impacts were identified.

The UKCP09 weather data was used to analyse future climate.

To investigate the impacts of climate changes on buildings, four assumptions were made to choose suitable weather data. They are location, time periods, carbon emission scenarios and risk percentiles. The UKCP09 5km by 5km grid 3400395 covers the Edge Lane site. Three time periods were selected to present short, medium and long term climate condition.

UKCP09 provide projections for 7 time periods. For each time period, 30 years weather data are made available. They represent a sample of future time slices looking sufficiently far towards a time horizon likely to be of interest for the life span of buildings currently under development and construction.

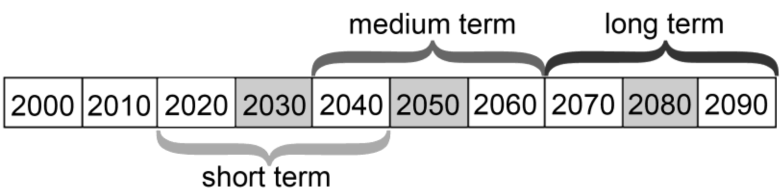


Figure 1 Climate time scale diagram (climate periods cover 30 years of climate data)

The building was tested for overheating risks based on the UKCP09 high carbon emission scenario. The 50 percentile weather data was selected to conduct simulation. The Design Summer Year for Manchester was selected as 1999.

Based on the above, the weather data files in Figure 1 were used for overheating analysis in this report. Note that two baseline files were used for testing, CIBSE historical DSY and the control DSY from PROMETHEUS data. The CIBSE weather data location is Manchester and the PROMETHEUS weather data location is Liverpool.

Table 1 Weather data for simulation

Location	Timelines	Name of weather files	Description of weather data
Manchester	Baseline	ManchesterDSY05.fwt	CIBSE DSY 1999 (1983-2004)
Liverpool	Baseline2	WG_COMBINED_cntr_3400395_DSY.EPW	Prometheus 1961-1990 50% DSY
	Short term (2030s)	WG_2030_3400395_a1fi_50_percentile_DSY.EPW	Prometheus 2020-2049 high emission 50% DSY
	Medium term (2050s)	WG_2050_3400395_a1fi_50_percentile_DSY.EPW	Prometheus 2040-2069 high emission 50% DSY
	Long term (2080s)	WG_2080_3400395_a1fi_50_percentile_DSY.EPW	Prometheus 2070-2099 high emission 50% DSY

The following summaries outline the climatic variables for the Edge Lane site;

Temperature
Increase in maximum temperatures of approximately 2°C by 2030s rising to approximately 3°C by the 2050s and 5°C by the 2080s. Summer mean and summer minimum temperature increases are almost identical at 1.7°C by 2030s rising to approximately 3°C by the 2050s and approximately 4°C by the 2080s.

Precipitation
Increase in mean winter precipitation of approximately 7% by 2030s, rising to 12% by the 2050s and 24% by the 2080s. Decrease in mean summer precipitation of approximately 9% by 2030s, 16% by the 2050s and 24% by the 2080s.

Solar radiation
Minimal to no change in winter net surface shortwave flux. Increase in summer net surface shortwave flux of 4 W/m2 by 2030s, rising to 6 W/m2 by the 2050s and 8 W/m2 by the 2080s.

Cloud cover
Minimal to no change in winter mean cloud cover. Decrease in mean summer cloud cover of 3% by 2030s, 5% by the 2050s and 9% by the 2080s.

Humidity
Negligible change in winter mean RH. Decrease in mean summer RH of 1% by 2030s, 2% by the 2050s and 4% by the 2080s.

Wind Speed
Winter 2050s: No change to -0.1m/s change in wind speed for low, medium and high emissions. Summer 2050s: No change to -0.2m/s change in wind speed for low, medium and high emissions.

The vulnerability of the patients within the building and their reduced ability to adapt to climate changes was of primary concern. It has been shown that pre-existing medical conditions such as neurological diseases and mental illness increase the vulnerability of individuals to environmental exposures. People with severe mental illness are more vulnerable to the effects of heat because of medications that potentially affect renal function, the body's ability to sweat, thermoregulation or electrolyte balance. There is also evidence that having a disability or being bed bound make this group less able to adapt to warmer environment.

The bedrooms will have long hours of occupancy and the patients are particularly vulnerable.

Section 3

The aims of the study are to identify the appropriate adaptation measures in order to maintain thermal comfort levels until 2080 for a particularly vulnerable user group; and to examine any sensible measures to be taken to guard against the lesser risks of flood and wind damage. The Design Opportunities Checklist on pages 5/6 clarifies which climate change adaptation measures have been considered, recommended and implemented.

Designing for Comfort

Keeping cool - Shading and ventilation were identified as the key measures which could be exploited to alleviate overheating in the building. Specific areas of investigation were: shading devices to the windows; the use of the external spaces; soft landscape planting to courtyards; the immediate local micro-climate and green roof technologies.

Keeping warm - The building has been designed to super-insulation standards, with a high degree of air-tightness. Heat recovery and controlled and uncontrolled ventilation techniques were examined.

Designing for Construction

Structural stability – consideration was given to modular construction with much pre-fabrication in the context of wind loadings and applied loadings imposed by future sequential upgrading.

Fixings and weatherproofing – consideration was given to accessible and usable timber flat roof construction, with risks of water or snow disposal and applied loadings.

Materials behaviour – consideration was given to the cladding materials albedo effect in connection with reference to maintenance cycles and overall robustness.

Work on site – consideration was given to the cradle to cradle advantages of lightweight pre-fabricated construction against the thermal mass advantages of heavy weight construction.

Designing to Manage Water

Water conservation – consideration was given to the incorporation of low water use fittings and rain water harvesting.

Drainage – designed to a very high capacity, to store the 1 in 100 year storm with no flooding including a 20% allowance for climate change. The roof plays a key role in the future proofing which has been built into the scheme to allow future adaptation. The design of all roof and surface water drainage elements allow the greatest potential adaptability.

Flooding – the site is identified as a low risk flooding zone, but a plan is nevertheless needed for an extreme flood event situation.

Landscape – extensive absorptive planting has been incorporated, also providing shading and transpiration cooling.

Section 4

The Case Study team comprised Medical Architecture, Oxford Brookes University and Mott MacDonald Fulcrum. Medical Architecture had been previously commissioned by the Mersey Care NHS Trust to undertake a number of feasibility studies across the Trust’s estate and had already completed an inpatient mental health facility on the adjoining site for them. There was therefore a useful common understanding and expectation that this new facility would be innovative, whilst also learning lessons from previous experience. A number of useful lessons were learnt during the project.

The timing of the professional team’s interventions can be critical to the implementation of adaptation strategies. The earlier in the process, the better. Ideally at or before the briefing stage. With larger public sector projects, procured through a public private partnership there is potential to require certain strategies to be adopted, or at the very least considered and reported on.

Medical Architecture were well placed and pre-disposed to incorporate adaptability in its broadest sense into the early strategic design stage of the project. Although Oxford Brookes University's Low Carbon Group had not been involved in the pre-planning design stage of the project, they reinforced and validated this early thinking when they joined the D4FC case study project in 2010.

The need for good knowledge and communication of design intent at the outset of a project is key to achieving buy-in from the client body. An enhanced use of predictive energy and operational modelling by the project team would strengthen and validate design decisions. Medical Architecture explored the use of these new tools – albeit at a late stage in the design development. There is no doubt that such work would have had a greater effect if undertaken earlier.

The interoperability of the design tools used by architects and engineers is inadequate but improving. Mott MacDonald Fulcrum and Medical Architecture attempted to refine the working methods through the D4FC case study project without success, having to resort to separate platforms. We believe this is about to change dramatically with increased and better use of Building Information Modelling (BIM) by the whole construction industry supply chain.

Section 5

As a research team we are well placed to disseminate and transfer the knowledge and awareness gained through the course of the research project.

Oxford Brookes University's Low Carbon Group are already leaders in the field and are regularly writing, speaking, consulting and presenting their research work to an international audience.

Medical Architecture are applying the strategy and specific lessons learnt to other similar projects in the UK at a direct and practical level. Also through attendance and presentations at conferences, seminars and NHS forums MA have a strong influence and can raise awareness with other practitioners and client groups.

The design of health buildings is complex and functional relationships relating to the current model of care and its delivery, are the overriding driver of a project. This is particularly true of mental health accommodation where vulnerable occupants need special consideration. The challenge for design teams is to balance the need to fulfil such functional requirements whilst maximising the incorporation of best-value adaptation measures. Improved legislation, standards and best practice guidance can improve the chances of this happening.

Design Opportunities Checklist

Adaptation design challenge	Design opportunity	C - considered R - recommended I - implemented
Keeping cool - internal		
	Shading - manufactured	R
	Shading - building form	R
	Glass technologies	R
	Film technologies	C
	Green roofs/ transpiration cooling	R
	Shading - planting	I
	Reflective materials	I
	Conflict between maximising daylight and overheating (mitigation vs adaptation)	C
	Secure and bug free night ventilation	I
	Interrelationship with noise & air pollution	I
	Interrelationship with ceiling height	C
	Role of thermal mass in significantly warmer climate	R
	Enhancing thermal mass in lightweight construction	R
	Energy efficient/ renewable powered cooling systems	R
	Groundwater cooling	C
	Enhanced control systems - peak lopping	C
	Maximum temperature legislation	C
Keeping cool - spaces around buildings		
	Built form - building to building shading	C
	Access to external space - overheating relief	I
	Shade from planting	I
	Manufactured shading	R
	Interrelationship with renewables	R
	Shading parking/ transport infrastructure	I
	Role of water - landscape/ swimming pools	R
Keeping warm at less cost		
	Building fabric insulation standards	I
	Relevance of heat reclaim systems	I
	Heating appliance design for minimal heating - hot water load as design driver	C
Structural stability - below ground		
	Foundation design - subsidence/ heave/ soils/ regions	C
	Underpinning	C
	Retaining wall and slope stability	C
Structural stability - above ground		
	Lateral stability -wind loading standards	C
	Loading from ponding	C
Fixings and weatherproofing		
	Fixing standards - walls, roofs	R
	Detail design for extremes - wind - 3 step approach	C
	Lightning strikes (storm intensity)	C
	Tanking/ underground tanks in relation to water table- contamination, buoyancy, pressure	R
	Detail design for extremes - rain - thresholds/ joints	C

	Materials behaviour in high temperatures	C
Construction -materials behaviour		
	Effect of extended wetting - permeability, rotting, weight	C
	Effect of extended heat/ UV - drying out, shrinkage, expansion, de-lamination, softening, reflection, admittance, colour fastness	C
	Performance in extremes - wind - air tightness, strength, suction/ pressure	C
	Performance in extremes - rain	C
Construction - work on site		
	Temperature limitations for building processes	C
	Stability during construction	C
	Inclement winter weather - rain (reduced freezing?)	C
	Working conditions - Site accommodation	C
	Working conditions - internal conditions in incomplete/unserviced buildings (overlap with robustness in use)	C
Water supply/ conservation		
	Low water use fittings	I
	Grey water storage	R
	Rain water storage	R
	Alternatives to water based drainage	C
	Pools as irrigation water storage	R
	Limits to development	C
	Water intensive construction processes	C
Drainage - external/building related		
	Drain design	R
	SUDS design/ Soakaway design	R
	Gutter/ roof/ upstand design	R
Flood - Avoidance / resistance/ resilience		
	Environment Agency guidance - location, infrastructure	I
	Combination effects - wind + rain + sea level rise	C
	Flood defence - permanent	C
	Flood defence - temporary - products etc	C
	Evacuation/ self sufficiency	R
	Flood tolerant construction	R
	Flood tolerant products and materials	C
	Post-flood recovery measures	C
Landscape		
	Plant selection - drought resistance vs cooling effect of transpiration	I
	Changes to ecology	C
	Irrigation techniques	R
	Limitations on use of water features - mosquitoes etc	C
	Role of planting and paving in modifying micro climate & heat island effect	I
	Failsafe design for extremes - water	C
	Firebreaks	C

Section 1: Building Profile

Edge Lane forms part of the TIME (To Improve Mental health and learning disabilities Environments) by MerseyCare Trust. The TIME project covers five sites in total, with 285 beds of new build accommodation across the wider Liverpool area. Any findings from the Edge Lane site case study will inform the projects on the other four sites and will help to enhance the therapeutic environment whilst future proofing the buildings.

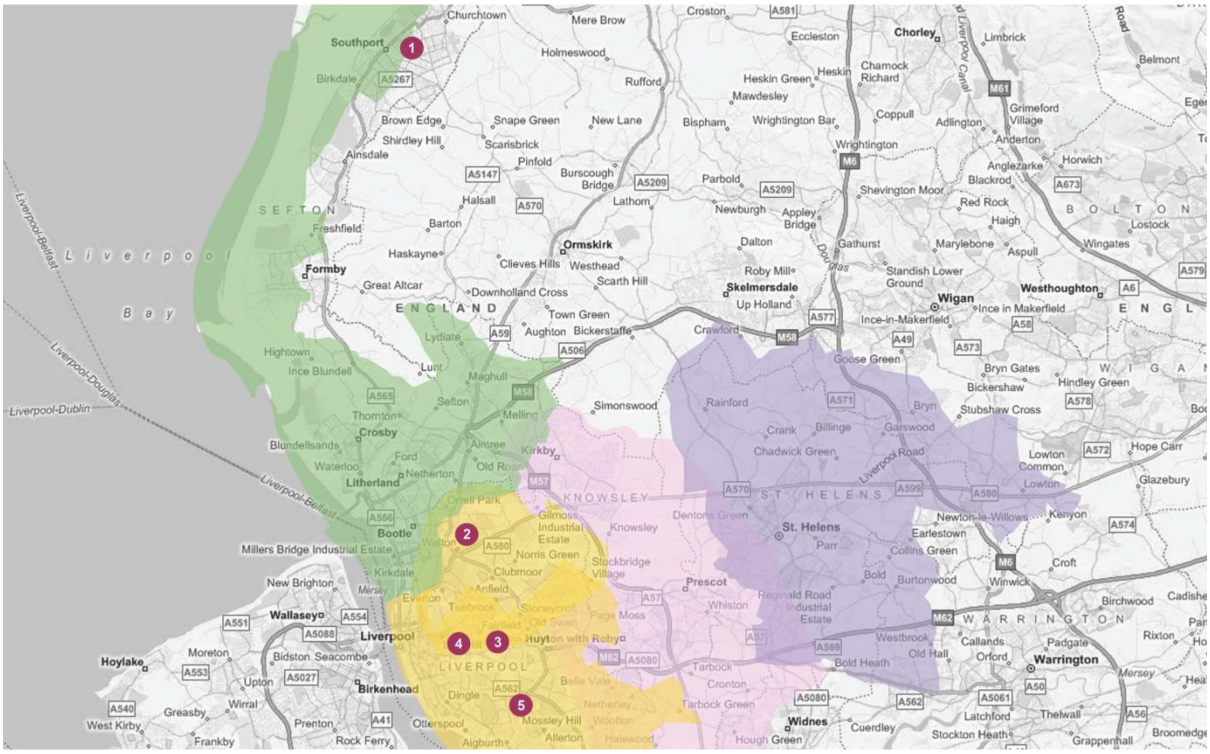


Figure 2 Location of the 5 MerseyCare TIME Project

1.1 Context – social & physical

The Mental Health Needs Index for central Liverpool is more than twice the national average and indicates a high and growing level of mental health need. Edge Lane is one of 5 proposed local mental health inpatient facilities to be procured through public-private-partnership to replace inadequate existing stock. The new facilities will reduce stigma and improve inclusion and accessibility, in comfortable, safe, non-clinical and healing environments that support recovery and care.

This case study site has a very interesting and challenging location east of Liverpool city centre (see location and context plans – Appendix 1.1). Some of the issues to addressed by the design included;

- Site location between major arterial route and existing hospital site. Access to the site.
- Noise and air pollution from the adjacent busy transport corridor; consideration in relation to room layout and orientation; privacy for the inpatient units; need for a calming, therapeutic environment.
- Ecology; creation of an improved micro-climate.
- Contamination from earlier glass and paint manufacture, a dye works, and a used car showroom. A future proof solution on how to deal with this contamination had to be designed.

- A major level change across the site; this issue is exacerbated by the extent of contaminated soil and the need to tie into current site levels; to minimise disturbance to existing ground; and keep as much contaminated soil on site as possible.

- Significance of project; aspiration to address the 'gateway' to Liverpool; create a landmark building on site; enhance the character of the site and contribution to local regeneration.

The site sits in between mainly residential developments further east on Edge Lane and retail/ commercial developments further west. It lies on a ridge enjoying views of central Liverpool and is described as being at a 'gateway' into the city. This is a very prominent location, which is not only of importance to Mersey Care NHS Trust, but also to the wider urban and local context.

Derelict for a number of years, the site is now in a state of disrepair. The 'gateway' is currently defined by a poor urban environment with vacant buildings and underused land – a building with a strong presence is needed to raise the profile of the location.

A landmark building will give Mersey Care NHS Trust a strong presence both in the local and urban context, but also in peoples' minds. The above factors, together with client requirements regarding clinical and functional relationships have driven the design process.

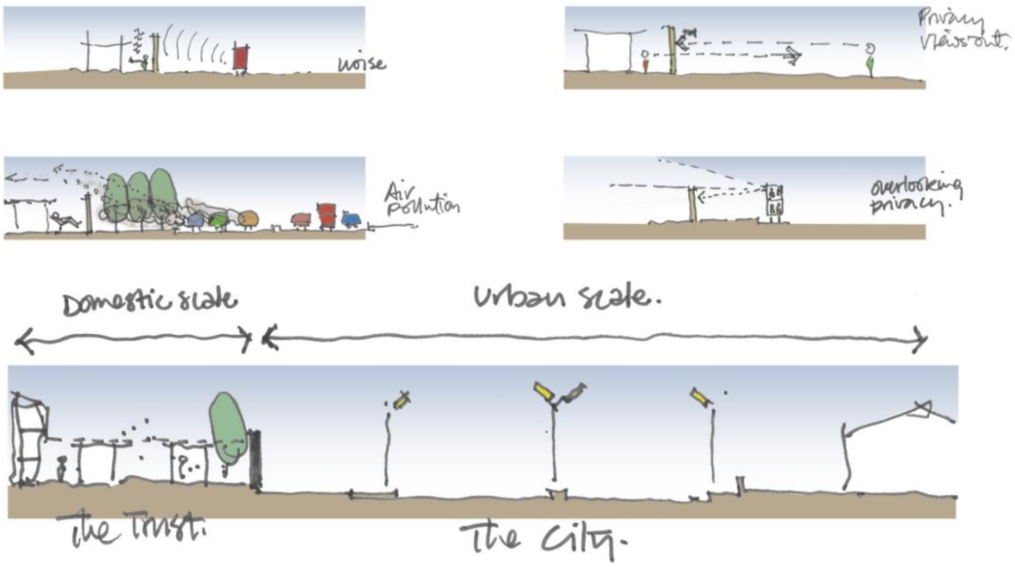


Figure 3 Constraints associated with the adjacent busy road

1.2 The Project

These are the key project facts;

- 23,245m^2 site area
- 6,000m^2 new build area
- 4,100m^2 inpatient accommodation; 85 beds for adult acute and dementia patients, with day and activity/therapy spaces
- 1,900m^2 support accommodation; cafe, reception, offices, facilities management and plant
- Project procured by Liverpool and Sefton Health Partnership (LSHP)
- LIFT "Local Improvement Finance Trust" co provider which is a Public-Private-Partnership
- The scheme must achieve a BREEAM Healthcare excellent rating (see BREEAM 2008 Healthcare Interim Certificate Report - Appendix 1.5)

Under NHS LIFT procurement a LIFT Company is created that becomes the owner of the premises being developed. The Department of Health, the Strategic Health Authority (via a Trust) and a Private Sector partner come together to plan, build and operate premises for a defined length of time. A number of schemes can be combined within one LIFTCo.'s remit and they can be delivered in a series of tranches, the first of which must have a combined project value of at least £15M. Liverpool and Sefton Health Partnership (LSHP Ltd.) is the LIFT Co. in this case and this project together with another 85 bed mental health inpatient facility form the first tranche of a number of projects for Mersey Care NHS Trust, called TIME projects.

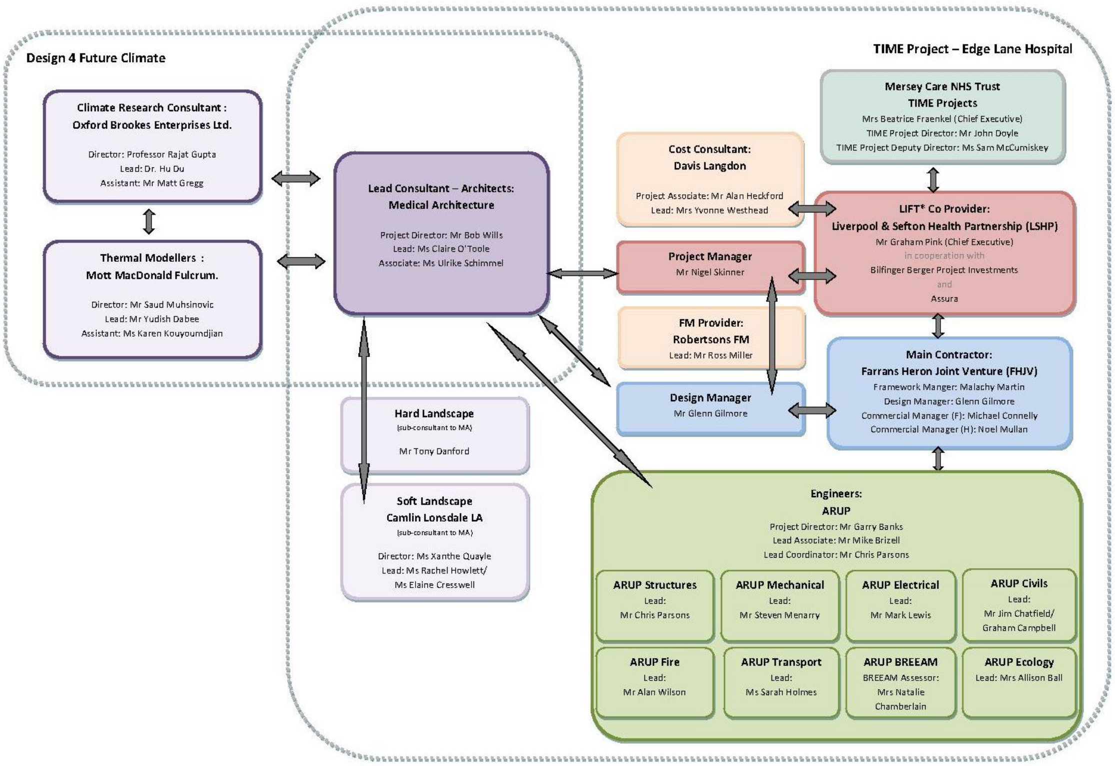


Figure 4 Project Organogram

The overall layout of the buildings is informed by a drive to find the optimum internal layout to provide the best care for service users. The organisation of clinical functions means that the ward buildings are located away from the more public zone and main entrance (see building plans – Appendix 1.2).

The whole facility has been designed so that all buildings are enclosed by a protective shell – the elliptical brick wall. A particular feature of the inpatient units is the use of the building itself to create secure external gardens and courtyards without the need for high security fences. All ward units are accessed via a landscaped 'front garden' to the buildings. These front gardens sit in between the external covered walkway and the ward buildings themselves. All the inpatient living accommodation has access to external gardens (see elevations and sections – Appendix 1.3).

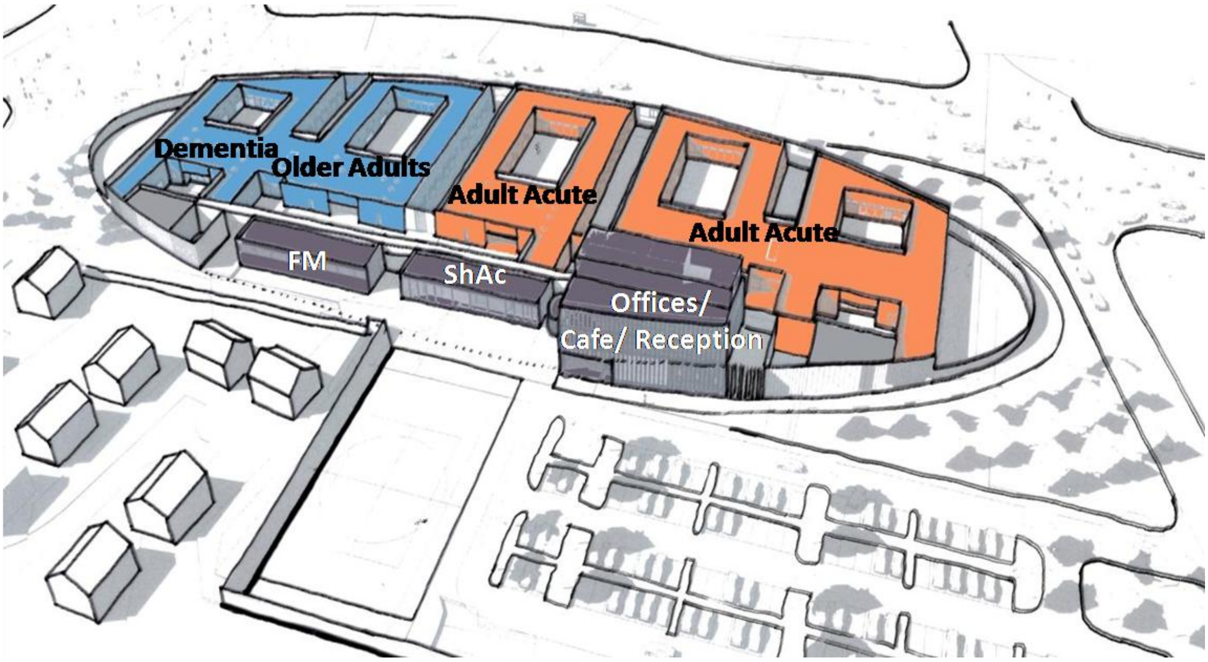


Figure 5 General arrangement of the facilities in 3D

The ward buildings have been designed to have as much natural daylight and sunshine penetrating the spaces; The bedrooms are arranged along single loaded corridors which increases the open feel, allows for views and easy access into external spaces and helps with supervision and passive observation. Patient rooms have been arranged to allow everyone a long view toward Edge Lane (see elevations and sections – Appendix 1.3).

Figure 6 Entrance view

Standard room modules have been used throughout with a variety of room sizes accommodated, thus supporting a broad range of activities and providing future flexibility. The design incorporates lots of open space which will positively affect the healing process and the well-being of staff and patient alike. All but one of the buildings, are single storey. The multi-storey element of this proposal has three storeys plus open plant space on top. This taller building has been placed at the heart of the plan, to signal the entrance when entering the site and also to be tall enough to be seen from both major junctions along Edge Lane Drive (see building plans – Appendix 1.2, and 3D images – Appendix 1.4).

The elliptical wall plays contradictory roles of enclosing the whole facility while simultaneously being open and permeable enough to avoid creating an institutional feel. The relationship between inside and outside and the way that translates into the architecture is of vital importance. The elliptical wall prevents people and harmful substances from getting in or out through the shell. At the same time it must allow beneficial sensory stimuli to pass through, sights and sounds pass through the glass; air, smell and small creatures penetrate by means of the biomes and the same plants can thrive inside and out.

Figure 7 Ground floor plan

The dual aims of the landscape concept for the site are the healing of 'place' and the healing of patients. The external planting strategy delivers a scheme that delights and stimulates the senses but is in itself robust enough to survive the environmental stresses of a busy site.

Three distinct biomes and two managed landscape types are proposed as an integral component of the scheme. The concept is for these landscapes to become colonised by nature over time which in turn will support local and national biodiversity objectives as well as providing the therapeutic environments that service users require.

The building shell is surrounded by a protective 'nest' planting providing protection against the busy Edge Lane thoroughfare. Its materials are drawn from the surrounding landscapes – from gardens, retail and industrial sites. Ribbons of varied textures, forms and sizes of planting are woven together to form the whole and hold the 'delicate' façade (see 3D images – Appendix 1.4).

Section 2: Climate Change Risks

2.1 Risk exposure of the building to the projected climate

The approach to analysing the risk posed by climate change is based on the risk triangle developed by Crichton (2001). With this approach, adaptation is successful when it is able to eliminate or reduce any one side of the triangle.

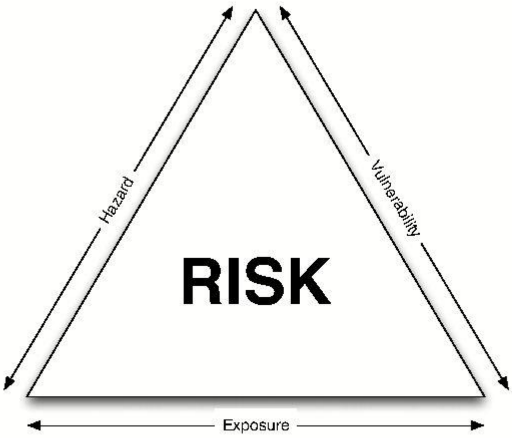


Figure 8 Risk based analysis approach

To develop appropriate adaptation strategies, three steps were taken. First the hazards for the site were quantified at an appropriate scale, this entailed analysis of probabilistic climate change projections developed by the UKCP09. Second, climate change impacts were defined and third, the local environmental features (LEFs) which can exacerbate or ameliorate the impacts were defined for their potential influence and finally the general adaptation strategies were detailed (see Appendix 2.1 – where risks of Exposure, Hazard and Vulnerability are analysed - and the table in Section 3.7, where risk levels prioritised adaptation measures).

Table 2 categorises the characteristics of LEFs of the site that could positively or negatively affect or be affected by the impacts of climate change hazards.

Table 2 Local environmental features for Edge Lane, Liverpool

LEFs	Edge Lane	Hazard relevance
Latitude	53° 25' N	Temperature change and solar intensity change
Proximity to coast	3 miles to coast	Temperature increase and precipitation increase
Urban cover[1]	Average urban cover with sparse green cover surrounding the site. The site specifically has a couple of existing buildings, no green cover or trees.	Temperature increase, solar intensity increase and precipitation increase
Elevation (Edina, 2011)	60m above sea level: the site is located on a hill	Temperature change and precipitation increase
Fluvial flood risk (EA, 2011)	No flood risk	Precipitation increase
Groundwater level (BGS, 2005)	Height of water table above sea level – 0-50m	Precipitation change
Landslide potential (BGS, 2005)	Low-nil	Precipitation increase

Geology (clay soil – swell or shrink potential) (BGS, 2005)	Moderate	Precipitation decrease/ground moisture content fluctuation
Water stress (EA, 2007)	Low	Precipitation decrease and temperature increase
Wind driven rain potential (Graves and Phillipson, 2000)	Moderate: 33 to less than 56.5 litres/m^2/spell	Precipitation increase/wind speed change

[1]Urban cover refers to built-up areas, e.g. asphalt, concrete and buildings and has many implications for proximity to green space and urban heat island potential.

2.2 Identify climate scenarios and climate data used

2.2.1 Climate data

The UKCP09 provides the best insight into how the climate system works and how it might change in the future. UKCP09 presents data as a result of three different possible future climate change scenario levels; low, medium and high greenhouse gas emissions up to 2099. Based on evidence, the UKCP09 provides a range of possible outcomes defined regionally across the UK with varying probabilities linked to each outcome.

The key findings of the UKCP09 are represented as an aggregated collection of 25km x 25km squares covering 16 administrative regions of the UK. Individually defined probabilistic climate projections are available for each 25km x 25km square in the grid (Figure 9).

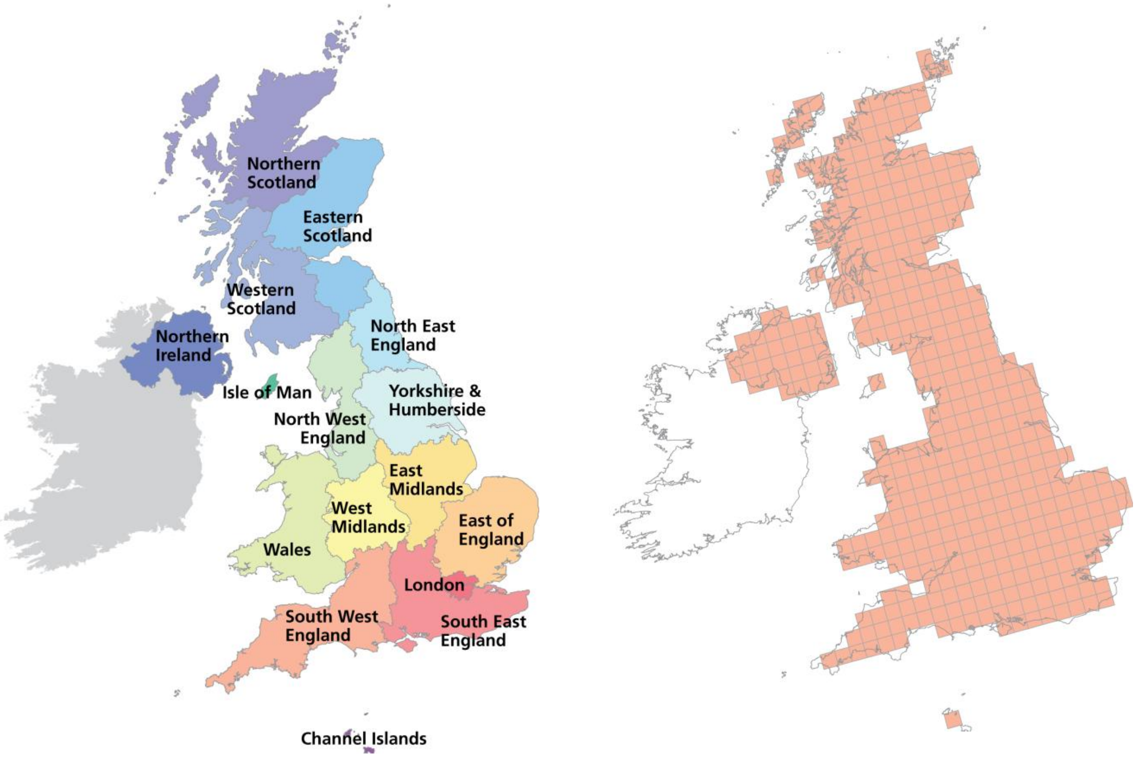


Figure 9 Map of UK administrative regions and Map of 25km2 grid covering the UK (Jenkins et al., 2009).

Climate is an average of the activity of the weather of a place over a 30-year period. 30-year time periods remove most of the effect of natural variability allowing the GHG climate change effect to be realised. Mid-decades are used as shorthand for 30-year periods therefore, for example, the climate period 2010 – 2039 is represented by 2020. The time variable of climate change is mapped by UKCP09 as an average over a 30-year period. UKCP09 provides climate data in seven 'time slices' to the year 2099 (2080s) (Figure 10) (ARUP, 2010; DEFRA, 2009; Murphy, 2009).

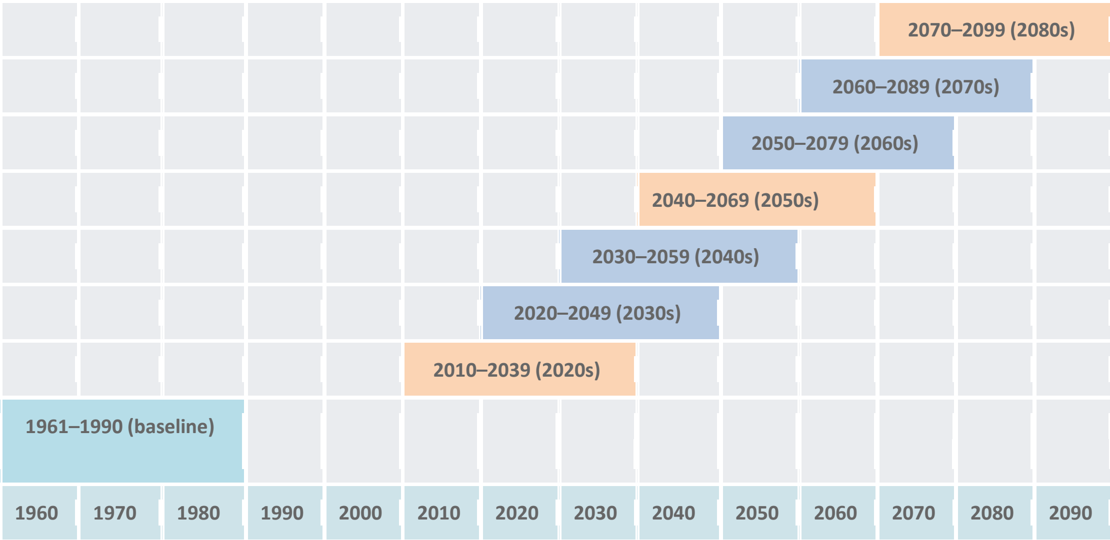


Figure 10 Seven 30-year time periods *(Murphy et al., 2009).*

Climate parameters are the physical measurements of weather variables which define a climate. There are two sets of climate parameters defined by UKCP09. They are for absolute climate projections and climate change projections (Jenkins *et al., 2009)*.

Future ***absolute*** (absolute probabilities) climate values (7 variables)

- Mean temperature (annual)
- Mean daily maximum temperature (summer)
- Mean daily minimum temperature (winter)
- Precipitation (mm/day)
- Mean sea level pressure (annual)
- Relative humidity (annual)
- Total cloud (annual)

Table 3 Edge Lane site changes of climate parameters

Climate parameters	Description of high emission scenario central estimate trend
Temperature	Increase in maximum temperatures of approximately 2°C by 2030s rising to approximately 3°C by the 2050s and 5°C by the 2080s Summer mean and summer minimum temperature increases are almost identical at 1.7°C by 2030s rising to approximately 3°C by the 2050s and approximately 4°C by the 2080s.
Precipitation	Increase in mean winter precipitation of approximately 7% by 2030s, rising to 12% by the 2050s and 24% by the 2080s. Decrease in mean summer precipitation of approximately 9% by 2030s, 16% by the 2050s and 24% by the 2080s.
Solar radiation	Minimal to no change in winter net surface shortwave flux. Increase in summer net surface shortwave flux of 4 W/m2 by 2030s, rising to 6 W/m2 by the 2050s and 8 W/m2 by the 2080s.
Cloud cover	Minimal to no change in winter mean cloud cover. Decrease in mean summer cloud cover of 3% by 2030s, 5% by the 2050s and 9% by the 2080s.
Humidity	Negligible change in winter mean RH. Decrease in mean summer RH of 1% by 2030s, 2% by the 2050s and 4% by the 2080s.
Wind Speed	Winter 2050s: No change to -0.1m/s change in wind speed for low, medium and high emissions. Summer 2050s: No change to -0.2m/s change in wind speed for low, medium and high emissions.

2.2.2 Weather data for building simulation

To investigate the impacts of climate changes on buildings, four assumptions were made to choose suitable weather data. They are location, time periods, carbon emission scenarios and risk percentiles.

The latitude and longitude of Edge Lane – TIME project are 53.41N, 2.92W. The UKCP09 5km by 5km grid 3400395 covers the development area (Figure 11).

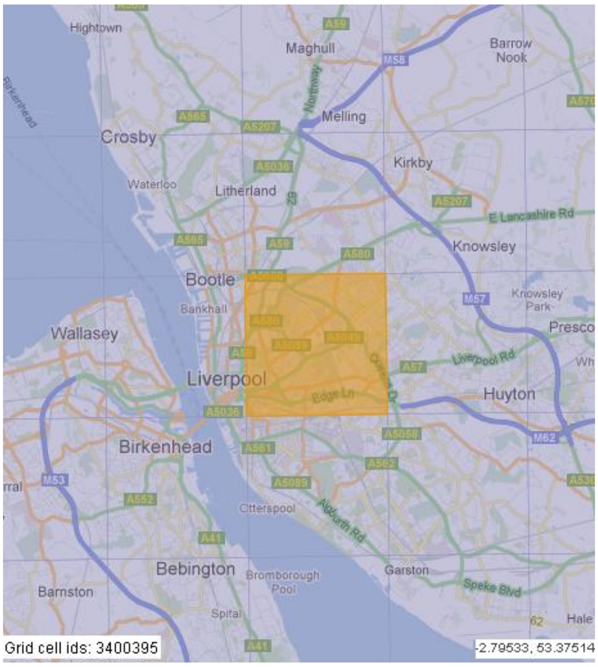


Figure 11 UKCP09 5km grid for Edge Lane – TIME project

UKCP09 provide projections for 7 time periods. For each time period, 30 years weather data are made available. The authors select three time periods (Figure 12) to present short, medium and long term climate condition. They represent a sample of future time slices looking sufficiently far towards a time horizon likely to be of interest for the life span of buildings currently under development and construction. The new buildings constructed today will have replacement of building services assets typically every 15-20 years (short term). The buildings themselves would have minor refurbishment at every 35-45 years (medium term), and normally major refurbishments would occur in 60-100 years (long term).

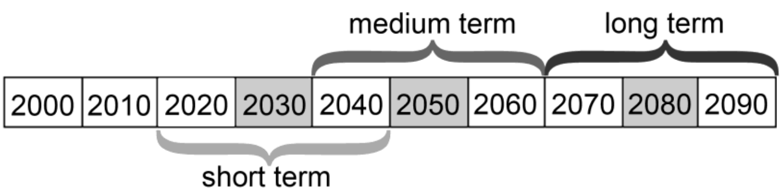


Figure 12 Climate time scale diagram (climate periods cover 30 years of climate data)

UKCP09 offers climate projections based on three carbon emission scenarios (low, medium and high). The authors decided to test building overheating risks based on the high carbon emission scenario; because the buildings designed for high carbon emission would stand at medium or low emission scenario.

Due to the probabilistic feature of UKCP09 projections, several risk levels were nominated by the research group who generated weather data for building simulation. By examining the process of generating PROMETHEUS future weather data, the authors selected the 50 percentile weather data to conduct simulation. PROMETHEUS used 2 steps to select Design Summer Year (DSY). Firstly, they selected the fourth warmest year from 30-year period, then 12-months at a certain percentile were selected based on month mean temperature ranking. The warmth of 50 percentile DSY is equal to the level of warmth which traditional DSY's have. The level of warmth of 90 percentile DSY is significantly higher than traditional DSY's.

Manchester Ringway (53.36N, 2.28W) is the nearest location which has CIBSE historical weather data available. The Design Summer Year for Manchester is selected from 1983 to 2004. The year with the third warmest April-August period during 1983 and 2004 is 1999 which is the Design Summer Year.

Table 4 Weather data for simulation

Location	Timelines	Name of weather files	Description of weather data
Manchester	Baseline	ManchesterDSY05.fwt	CIBSE DSY 1999 (1983-2004)
Liverpool	Baseline2	WG_COMBINED_cntr_3400395_DSY.EPW	Prometheus 1961-1990 50% DSY
	Short term (2030s)	WG_2030_3400395_a1fi_50_percentile_DSY.EPW	Prometheus 2020-2049 high emission 50% DSY
	Medium term (2050s)	WG_2050_3400395_a1fi_50_percentile_DSY.EPW	Prometheus 2040-2069 high emission 50% DSY
	Long term (2080s)	WG_2080_3400395_a1fi_50_percentile_DSY.EPW	Prometheus 2070-2099 high emission 50% DSY

Based on the above, the weather data files in Table 4 were used for overheating analysis in this report. Note that two baseline files were used for testing, CIBSE historical DSY and the control DSY from PROMETHEUS data. The CIBSE weather data is for the location of Manchester and the PROMETHEUS weather data is for the location of Liverpool.

A brief comparison of all weather data above was made to show the increase of average temperature during April-September period from baseline to 2080s. As shown in Figure 13, the April-September average temperature increases 4.14 ^{0}C from Prometheus baseline to 2080s.

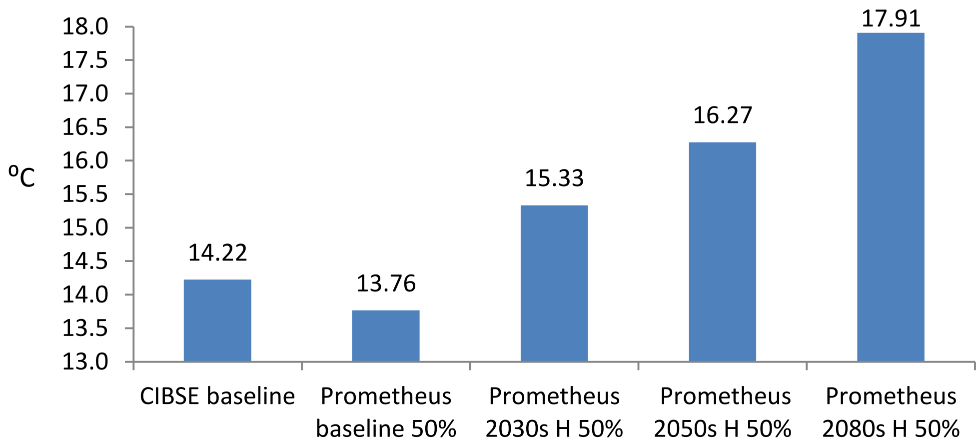


Figure 13 Apr-Sept average temperatures (^{0}C)

The numbers of hours of external temperature over 25, 26, 27 and 28 ^{0}C during April-September period are illustrated in Figure 14. Both figure 6 and 7 indicate that a warming climate will occur in later part of this century. Note that the numbers of hours experiencing high temperature (>25 ^{0}C) at 2030s is less than the numbers of baselines, though Apr-Sept average temperature at 2030s is higher than baselines' average temperatures.

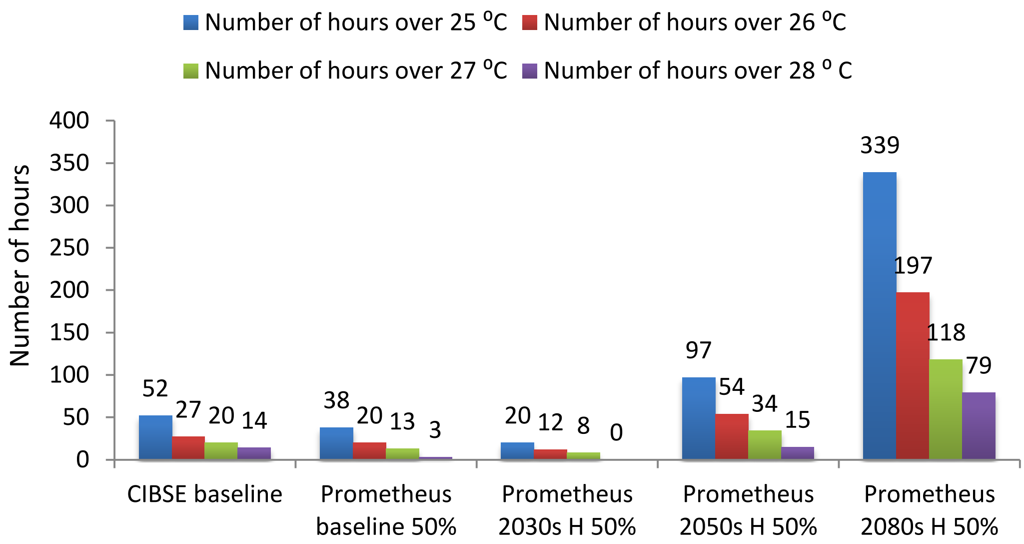


Figure 14 Number of hours over 25, 26, 27 and 28 °C

(For more detail on this section, see Appendix 2.1 – OBU's report on Climate Change Risks and Appendix 2.2 – MMF's Thermal Model Report).

2.3 Other features significant to the adaptation strategy developed

The site will accommodate a mental health facility for adults with acute disabilities, and an adult service staff, for which age can vary widely.

Pre-existing medical conditions such as neurological diseases and mental illness increase the vulnerability of individuals to environmental exposures. According to a study of heat-related and cold related deaths in England and Wales, people in nursing homes were most vulnerable to the dangers of hot and cold weather because of being frailer. Many heat-related deaths are caused by heat (and pollution) exacerbating existing illness (Hajats, Kovats, & Lachowycz, 2007).

There are certain factors that predispose people with mental health problems to heightened vulnerability during a heat wave as following (Department of Health, 2010):
• Certain medications: People with severe mental illness are more vulnerable to the effects of heat because of medications that potentially affect renal function, the body's ability to sweat, thermoregulation or electrolyte balance.
• Inability to adapt behaviour to keep cool: Having a disability or being bed bound make this group less able to adapt to warmer environment.

Age can be an additional factor affecting the patients' vulnerability. A study of vulnerability to heat related mortality in three Latin American cities confirms that the greatest number of deaths was from the age group 65 and over. An example of the distribution among adults was 16-64: 29%, and 65+: 67% in Santiago (Bell *et al*., 2008). In ages 65 and above Hajat, Kovats and Lachowycz (2007) found that risk to heat-related death had a greater impact on women than men and that risk to cold-related death (not showing as wide a gender gap as heat risk) provided much greater risk for all ages above 65 years.

Section 3: Adaptation Strategy

3.1 The adaptation strategy

As observed in Section 2 the primary climate change risk to this project is maintaining comfort levels with increased overheating. Therefore the main focus of the adaptation measures explored was to maintain an acceptable comfort level throughout the building but especially in the patient wards due to the vulnerability of the building occupants. Adaptation measures for comfort were tested by dynamic building simulation software IES VE.

It is more difficult to predict accurately the risks associated with flood and wind damage. The data provided from UKCP09 indicates that there is low risk of increased wind speed and the site is defined by the Environment Agency as having a low probability of flooding. Although the risk of flood and wind damage is minimal, given the vulnerable nature of the building users, it is advisable to take sensible precautions and develop strategies to deal with future developments. Adaptation measures for construction and water are given based on empirical experience.

3.2 Comfort – keeping cool

The performance of the most suitable adaptation measures were tested on the building model. The selected individual measures were categorised in 6 groups: high albedo surface, window and film, thermal mass of fabric, ventilation, shading and orientation. The ward buildings were identified as the most sensitive area of the development due to the vulnerable nature of the patients and the continuous occupancy. The performance of these individual measures was tested based on overheating percentages of the wards. CIBSE bedroom overheating guidance was selected as the evaluation metric for the wards, because it is an efficient and transparent resource and it is widely used by practitioners. The CIBSE guidance of overheating for bedrooms is 1% annual occupied hours over operative temperature of 26 ^{o}C (CIBSE 2006).

Eight packages which are the combinations of the most effective individual adaptation measures were proposed for Edge Lane. The performances of eight adaptation packages were then tested on the building model under current, 2030s, 2050s and 2080s' climate.

All adaptation packages allow most of wards to stay within comfort limits in 2050s. For package 1-6, only one ward bedroom out of 85 cannot stay within comfort range; package 7 and 8 could allow all wards stay within comfort in 2050s. The most effective adaptation package is package 7 which includes external shutters with control at 100 W/m2, conditional windows opening, white paint, triple glazing and heavy weight constructions.

Adaptation measures	**Base**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
Base model									
High albedo surface - white paint						X	X	X	X
Windows - Triple glazing				X	X	X	X	X	X
Thermal mass - Heavy weight construction								X	X
Shading - External shutter w control at 100 W/m3		X	X	X	X	X	X	X	X
Ventilation - Five air change rate			X		X		X		X
Ventilation - Conditional windows opening		X		X		X		X	
Average overheating percentage									
CIBSE baseline	4.6%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.0%	0.0%
Prometheus 2030s H 50%	7.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Prometheus 2050s H 50%	13.1%	0.4%	0.4%	0.3%	0.4%	0.3%	0.3%	0.0%	0.0%
Prometheus 2080s H 50%	20.8%	3.0%	3.3%	2.9%	3.2%	2.6%	3.0%	1.5%	2.0%

It is shown that even the most effective package could not avoid overheating issue for most of wards in 2080s. Therefore air conditioning must be introduced before 2080s. Reducing cooling energy consumption then becomes the adaptation target for 2080s.

3.2.1 Shading

Solar energy is the most important factor causing overheating in building spaces. To avoid overheating, shading devices can be used to reduce the total amount of radiation entering the room by reflection and absorption, and they also help improve the distribution of the light in room.

Shading devices can be categorised into 2 types: internal shading and external shading. In this study, 4 types of internal shading and 5 types of external shading were tested.

The internal and external shading impacts were tested for devices with differing levels of control, operated by building occupants when incident radiation is higher than 100 W/m^2; operated by building occupants when incident radiation is higher than 300 W/m^2; and without control (operated between 10am and 6pm.)

The average overheating percentages of the ward buildings at current, 2050s and 2080s are listed in the following table. The results show that external shading devices have better performance than internal shading devices. External shutters can significantly reduce overheating percentages and external shutters with control at 100 W/m^2 have the best performance compared with all other shading adaptation options.

Shading strategies	Current	2050s	2080s
Base model	4.6%	13.1%	20.8%
External shutter with control at 100 W/m2	0.7%	1.5%	8.0%
External shutter with control at 300 W/m2	2.1%	7.1%	14.2%
External shutter without control	1.5%	4.2%	10.9%
Internal blinds with control at 100W/m2	3.2%	10.0%	17.3%
Internal blinds with control at 300W/m2	3.7%	11.6%	19.1%
Internal blinds without control	2.1%	6.5%	13.2%

The current design does not make a structural allowance for additional shading to be fixed externally. Our adaptation recommendation is to include this potential additional load in the original structural calculations.

There are a number of issues particular to this project which must be taken into consideration when choosing the appropriate shading device. The potential ligature risk posed by the device must be assessed and eliminated.

3.2.2 Glass/film technologies

Reflective solar film, also known as "mirror" film, is designed to ward off the sun's glare and heat and to keep building space cooler. The film can be applied to most glass surfaces. Two types of windows films were tested in IES, light reflective window film which allows 48% of light through and dark reflective window film which allows 18% of light through. At the same time double glazing with a lower G-value of 0.35 and triple glazing options were tested.

The results show that double glazing with lower G-value and triple glazing can help reduce overheating percentages at current climate and in the future. The window film technologies have a limited effect on reducing overheating for this project. The table below shows the overheating percentages of the adaptation measures.

Time lines	Base model	Double glazing G-value 0.35	Triple glazing	Light film	Dark film
Current	4.60%	2.60%	2.40%	2.50%	2.40%
2050s	13.10%	8.10%	7.70%	7.80%	7.60%
2080s	20.80%	15.00%	14.60%	14.70%	14.60%

Our recommendation is to upgrade the current window specification to triple glazing in areas that are particularly exposed or sensitive i.e. the patient areas where the occupants may be vulnerable and the staff offices where the heat gains from equipment will exacerbate the overheating problem.

3.2.3 Green roofs/transpiration cooling

Green roof technology was an integral part of the original vision for the scheme. It was seen as an important part of the urban design strategy, a boost to the local ecology and a visual amenity from the multi- storey building. The decision to remove the sedum roof from the project proposal came about as the extent of the required photovoltaics was realised. Through subsequent value engineering exercises it was agreed that the requirement for renewable energy could be met by a comparable reduction in carbon emissions, thus the photovoltaic were removed. Although it did not survive design development the structural allowance for the green roof remains with the intention that it may be added at a later date.

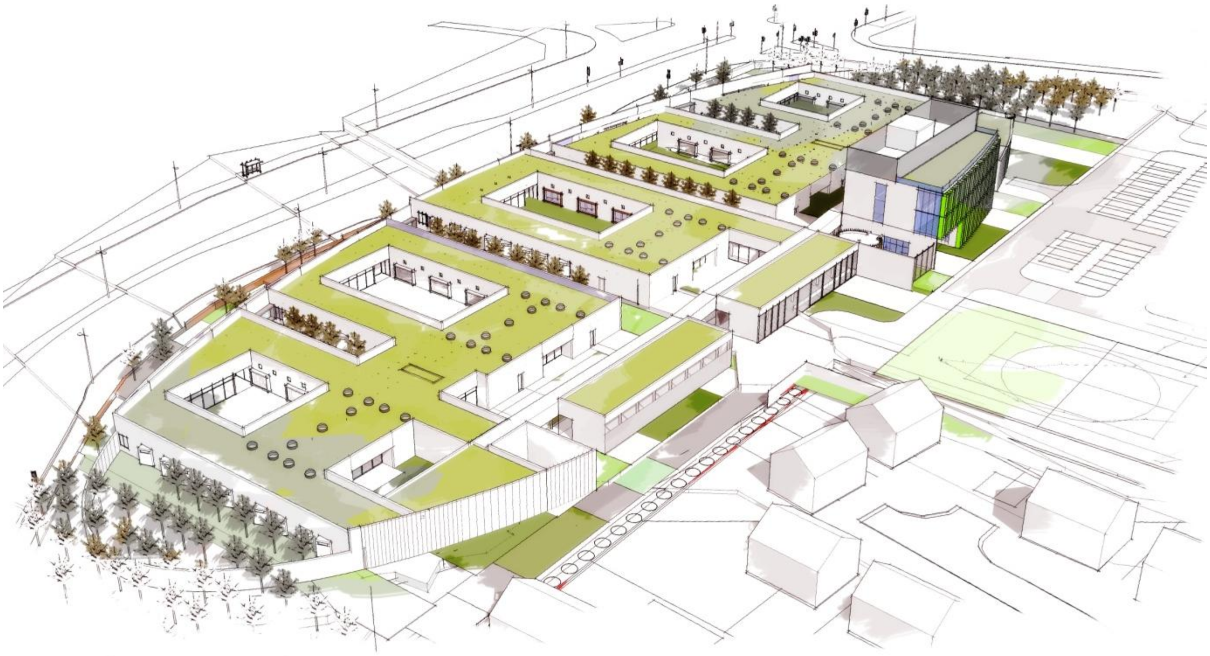


Figure 15 Early visualisation of the scheme showing the extent of the green roof

It was not possible to quantify the performance of green roof in the quest to maintain comfort levels in the IES study model. Research has shown that a green roof allows 40%-60% attenuation of the thermal gain entering the space beneath. (Lazzarin, Castellotti, & Busat, 2005).

3.2.4 Shading – planting

While it was not possible to quantify the effectiveness of the shading provided by planting in the IES model it has always been an important part of the scheme. Appendix 3.10, Camlin Lonsdale's planting plan illustrates the extent of the tree planting to the biomes. These trees will provide valuable shading and transpiration cooling to the bedroom spaces in particular.

3.2.5 Reflective materials

There are multiple benefits to the use of high albedo/reflective external surfaces (light-coloured roof and walls). Firstly by reducing irradiative gains and thus reducing interior air temperature and peak cooling demand. Secondly, reflecting solar radiation they keep roof and walls cooler, thus increasing the lifespan. Thirdly, they help reduce the urban heat island effect.

The diagram below demonstrates these phenomena. The surface of a black roof heats up 43^{o}C above the air temperature, while the surface of a white roof heats up only 7^{o}C. Additionally, with a black roof, far more heat flows both to the surrounding city, arrow lengths are proportional to energy radiated, thus contributing to the urban heat island effect.

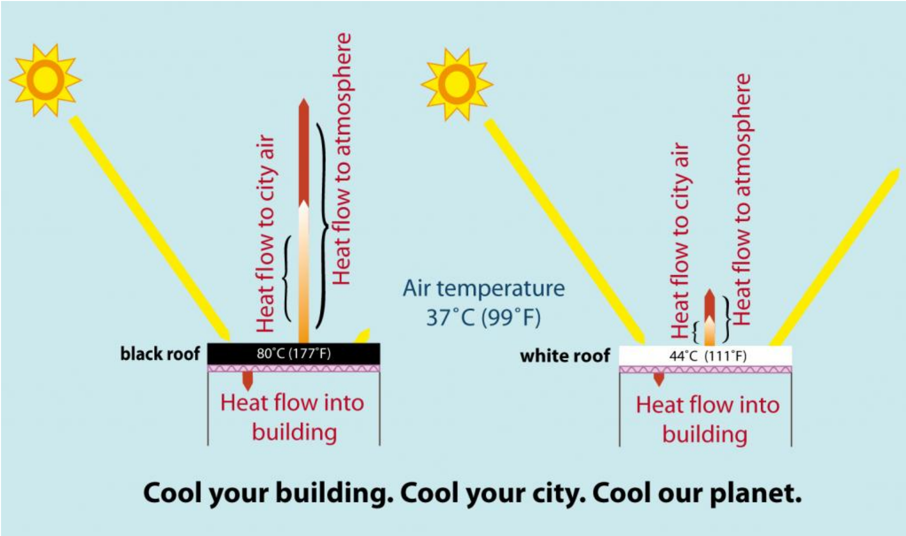


Figure 16 Diagram illustrating the cool roof phenomenon from Berkeley Lab, California (U.S. Department of Energy national laboratory

The effect of applying light coloured high albedo surfaces to the walls and roofs were tested in the IES model. The percentages of annual occupied hours over operative temperature 26 ^{0}C of the ward buildings were calculated. The average value of overheating percentages of the wards at current, 2050s and 2080s are listed in following table;

Time lines	Base model	Albedo Surfaces
Current	4.6%	4.2%
2050s	13.1%	12.4%
2080s	20.8%	19.8%

The results show that the light surfaces do help relieve overheating issue now and in future. However the improvement was quite minimal. Given the cost of applying a paint finish at a later stage and continuously maintenance it was agreed that the external walls finishes should be specified as highly reflective as possible at the design stage.

A number of options for the brick and mortar type have been reviewed and a light brick and matching mortar have been specified. The render finish has not yet been chosen but the design intent is for a white finish.

Figure 17 Samples of the brick and mortar types considered

Various techniques for whitening the roof surface of the proposed building were reviewed. They involve either coating existing surfaces or modifying the makeup of new surfaces so that they incorporate light-coloured ingredients. (Taha, Sailor, & Akbari, 1992)

Methods of whitening the roof surface of the proposed building;

1. Adding light-coloured aggregate to the roofing material. For example modified bitumen where the black bitumen is covered with a granular layer of a light colour. This procedure has added benefits of protecting the bitumen from the damaging effects of UV radiation.

2. Applying light-coloured rocks to the roof finish. This has the advantages of the first option but it does not require special materials. However, the roof structure must be designed to take the additional load.
3. Coating with elastomeric coatings and single plies. This procedure does not require extensive roof preparation; most elastomeric coatings can be applied directly to existing. Mechanically attached or adhered EPDM with light-coloured coating i.e. acrylic, can also be used.

The current specification for the project is for a grey coloured mechanically attached single ply membrane, Firestone Ultraply TPO. This product also comes as standard in white which provides greater reflectance. As this change is cost neutral we would recommend that a white membrane is chosen.

Firestone also offers a special product with enhanced albedo properties. The ReflexEON TPO is significantly more reflective than standard TPO membrane and it retains its solar reflectivity for longer. This product is not readily available in Europe as there is currently limited demand for the very high reflectivity. After the first replacement cycle (approx 20 years) we would recommend that the requirements be reconsidered and if appropriate a more advance product like ReflexEON TPO could be chosen.

A single ply membrane is suitable for combination with green roof systems. This is an important consideration to ensure that the adaption measures are not in conflict.

3.2.6 Ventilation – secure and bug free

When external air temperature is lower than indoor air temperature, increasing the ventilation rate in the building could help reduce indoor air temperature. The base model was assumed with a constant 2.5 air change rate ventilation rate and five alternative ventilation strategies were tested in IES;

- **Three/Four/Five air change rates**: Building space with constant 3/4/5 air change rate ventilation rate.
- **Night time ventilation (four air change rate)**: Building space with 4 air change rate ventilation rate at night-time only (21:00-09:00) which provided by exhaust fans or windows opening.
- **Conditional windows opening**: This ventilation strategy assumes that windows open when indoor air temperature is higher than 23 ^{0}C and higher than external air temperature. The opening could be implemented by building occupants.

The average overheating percentages of the ward buildings at current, 2050s and 2080s are listed in the following table.

Ventilation strategies	Current	2050s	2080s
Base model (2.5 air change rate)	4.6%	13.1%	20.8%
Three air change rate	3.4%	10.1%	17.3%
Four air change rate	2.2%	6.1%	12.6%
Five air change rate	1.5%	4.0%	9.9%
Night time ventilation (four air change rate at night time only)	6.9%	18.3%	24.7%
Conditional windows opening	1.8%	3.3%	9.3%

The results show that conditional windows opening could significantly reduce overheating percentages. It is the most effective measure so far. However, window opening may be not suitable for the activity rooms facing Edge Lane due to associated security, noise and air pollution.

Security issues in relation to ventilation are of a vital concern, due to the nature of the building use. None of the windows from the secure patient wards to the outside of the facility are openable. Therefore it may be more appropriate in these areas that the increased ventilation rate is achieved by mechanical methods. The windows to the bedrooms will have an anti-contraband mesh panel with 25% free air perforated 2mm stainless steel sheet with 2mm maximum diameter holes. The image below illustrates the type of window designed for the bedrooms at Edge Lane.

Figure 18 Example of a suitable secure window with mesh for a mental health patient bedroom

3.2.7 Thermal mass lightweight vs heavyweight

Increasing thermal mass is effective in improving building comfort in any place that experiences daily temperature fluctuations. A type of heavy weight construction was tested for the external walls, ground floor, roof and floor slabs in IES. The average of overheating percentages of ward buildings at current, 2050s and 2080s are listed in following table.

Time lines	Current	2050s	2080s
Base model (light weight)	4.6%	13.1%	20.8%
Heavy weight construction	3.3%	12.9%	22.0%

The results show that heavy weight construction helps reduce overheating percentages under current climate condition and 2050s; but in 2080s heavy thermal mass makes overheating worse. However when the increased thermal mass was tested in combination with an increased ventilation rate the measure produced significant reductions in the overheating.

Introducing heavy weight construction to a building at a later stage is not a an easy measure to implement. If it is considered vital to the adaptation strategy it must be an integral part of the project from the early concept design stage. However, there are methods of enhancing thermal mass of a lightweight structure which are more feasible. Adding another layer of dense plasterboard to the internal partitions would increase the thermal mass throughout the buildings. However, this is an expensive and highly disruptive retrofit.

3.2.8 Energy efficient/ renewable powered cooling systems

By 2080s, active cooling has to be introduced because all adaption packages fail to provide a comfortable environment according to the standard used. The impacts of adaptation packages on annual cooling demand and peak cooling load in 2080s were investigated. It shows that the suggested packages could reduce annual cooling demand at least 27% and also can reduce peak cooling load by 23%.

There are a number of energy efficient cooling systems available but the technology is so rapidly improving that it is fair to assume that by the time air-conditioning is becomes necessary they will be even more effective, efficient and affordable.

Renewable strategies should be sought to deal with the additional energy load of the cooling requirement. The scheme has been designed to allow photovoltaic's to be fitted at a later stage. There is an extensive flat roof which has the capacity to take the additional load and is accessible for the required monitoring and maintenance. The location and orientation are ideal; it sits in an area with very little surrounding shading from buildings with a roof aligned with south-facing a grid. As with the cooling systems continuous development it can be assumed that the available photovoltaic panel technology will be more advanced and efficient by the 2080s. On the question of feasibility, ARUPs confirmed that photovoltaic panels would currently be 'a good investment' for the client on this scheme (PV report Appendix 3.3). The potential benefits and value of implementing this measure will only improve with time.

3.2.9 Maximum temperature legislation – adaptive comfort/vulnerable users

The Adaptive Thermal Comfort theory suggests that a connection to the outdoors and control over their immediate environment allows humans to adapt to a wider range of thermal conditions than is generally considered comfortable. As the climate gets warmer, the average person's tolerance for higher temperatures will increase.

It was considered to use adaptive thermal comfort levels in our analysis but due the vulnerable nature of the user group this was deemed not appropriate. As identified in Oxford Brookes Climate changes hazards and impacts report, adaptive capacity is intimately linked with vulnerability. Adaptive capacity for people is strengthened by social memory and the existence of social networks or bonds and shared knowledge (Smith & Hopkins, 2010). Pre-existing medical conditions such as neurological diseases and mental illness increase the vulnerability of individuals to environmental exposures. These conditions can create an inability to adapt behaviour to keep cool.

3.2.10 Access to external space

The internal courtyards are a vital part of the building design. The sketches below illustrate the design concept developed by Medical Architecture for the use of courtyards within mental healthcare buildings.

A therapeutic environment

Good natural daylight and ventilation

Privacy and observation maintained

Figure 19 Medical Architecture courtyard design concept for Mental Healthcare buildings

In addition to the considerable therapeutic benefits of providing access to secure outdoor spaces, there is potential to exploit the courtyards to provide relief from overheating to the patients and staff. Extensive planting will provide shade and transpiration cooling. There is a requirement that the courtyard have a secure line at 5.2m. There is an opportunity to exploit the high walls of the courtyards by fixing controlled shading devices at the parapet level.

Figure 20 Textile River designed by Performance for the World Expo Zaragoza 2008

The example shown above is inspired by the tradition in Seville of stretching sheets of canvas from rooftop to rooftop, in order to provide shade to the street below.

3.2.11 Shade from planting - parking/ transport infrastructure

Tree planting to the car park was an integral part of the landscape proposals. As illustrated in the section below where possible the trees are planted by the parking spaces to provide shading.

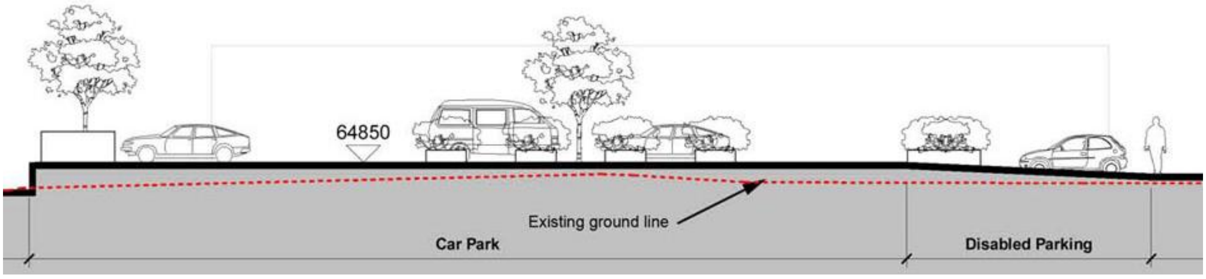


Figure 21 Extract indicating the planting dispersed throughout the car park

3.2.12 Interrelationships with renewables

As mentioned in section 3.1.1.8 there is an allowance for photovoltaic cells to be added at a later stage. As detailed in ARUPs energy statement (Appendix 3.5), the original brief called for 20% renewable energy to be incorporated into the design. After investigation and design development, the cost and design impact of renewable technologies was deemed unacceptable. An alternative brief was established with the client to provide a 20% reduction in carbon emissions through an improved energy performance. This was achieved with cost effective passive solutions (increased insulation) and low carbon technologies (Combined Heat and Power).

3.2.13 Role of water in the landscape

Introduction of blue amenity space can significantly reduce the urban heat island effect. Within the Edge Lane project there is a possible synergy between the use of courtyard and gardens as therapeutic space and incorporation of water features. There are significant management and maintenance obstacles to the use of water features at present. However, if it could be demonstrated that these features help to maintain comfort levels of the building users an argument could be made to prioritise these elements.

The use of six small attenuation tanks in the raised planters within the biome spaces was explored but the addition capital and maintenance cost proved to be too high. There was also a proposal for a wetland feature within the 'nest' landscaping zone, see the rainwater harvesting sketches (Appendix 3.7).

3.3 Comfort – keeping warm

3.3.1 Building fabric insulation standards

The scheme has been designed to super insulation standards. The building fabric has been improved by 40-50% over the minimum Part L 2010 requirements in order to meet the requirement for 20% reduction in carbon emissions; see ARUPs energy statement (Appendix 3.5).

3.3.2 Heat reclaim systems

ARUPs Energy Statement describes how heat recovery plate heat exchangers will be provided as appropriate to recover heat from the exhaust air systems and transfer it to the supply air stream in the HVAC air handling units. These systems include dampers for bypassing the plates when heat recovery is not required.

The bedrooms will be mechanically ventilated using an MVHR unit with outside air intake via louvres at high level on the façade routed to an MVHR unit located in the associated service zone above the en-suite (see Figure 22).

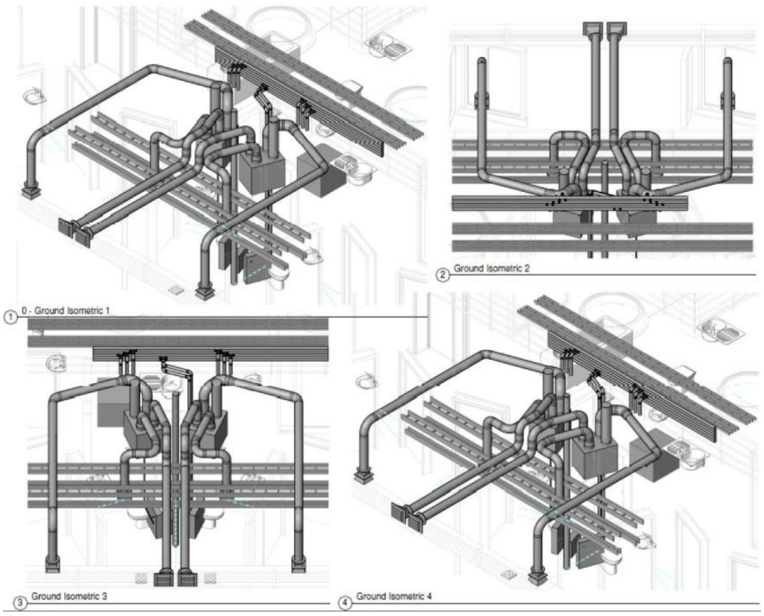


Figure 22 Image from ARUPs BREEAM Man 11 FINAL Evidence document

Manually openable windows to the bedrooms provide the patient with supplementary ventilation and give them an element of control over their environmental conditions. Ventilation systems will be controlled to ensure that the MVHR units do not run in conflict with opened windows.

3.4 Construction

The substructure and superstructure of the buildings have been designed to accommodate changes in ground level and contamination of the made ground. Most of the buildings are low rise and not exposed to extraordinary wind loads. The foundations and framing structures also have spare capacity within them for the addition of future heavier roof coverings or renewable technologies, with external fixings through the insulated fabric of the timber framed buildings easily provided at a later date.

The concept of the protective brick wall that wraps around the whole scheme will be carried through to the detailed design. The finishes and detailing are all intended to be of a highly robust nature.

- The specified brick Ibstock Smooth White Pear is classified as F2 durability ie it is suitable for severe exposure.
- The chosen Envirowall render wall system is anti-crack and high impact resistant. And the EnviroSil silicone based top coat has very high resistance to environment pollutants and is weatherproof, rot resistant, non swelling, low stress and UV-stable. The overall system has a life expectancy of 50 years.

It is recommended that the following relatively low cost measures, to protect against increased intensity of wind driven rain, are implemented.

- Recessed window and door reveals - where climbing is not a risk factor
- Projecting sills with drips - where climbing is not a risk factor
- Greater laps and fixings to roof and cladding fixings

3.5 Water management

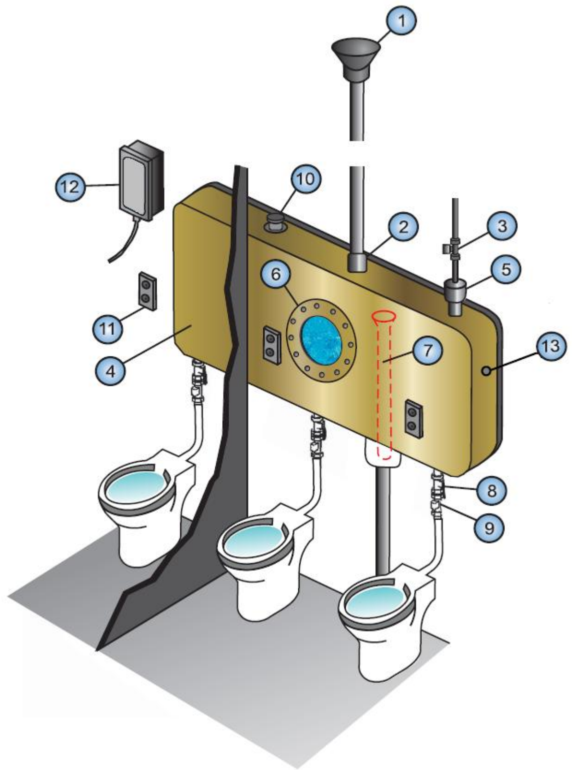
Water management has been carefully considered in the scheme and maximum BREEAM credits have been achieved for four of the water management items. A water meter has been provided on the mains supply to the building with a detector for major leaks specified in line with BREEAM requirements.

3.5.1 Low water use fittings

Low water use fittings have been specified where possible. All WCs have an effective flush volume of 4.5 litres or less. They are all dual flush with the exception of the dementia ward, where a more traditional flush control is required due to the nature of patients being treated. Taps have been set with a maximum flow and are timed automatic shut off or electronic sensor taps except to scrub facilities in clinical areas, cleaners taps, kitchen and external taps and dementia ward. Showers have specified flow rates and baths have required capacity and are fitted with the required devices.

3.5.2 Grey water/rain water storage

Grey water and rain water systems are a very effective way of reducing the demand on the potable water supply. There was a proposal to use the Pipex rainwater harvesting system to all WC’s in the building. This was deemed impossible due to the risks of patients ingesting foul water. The scope of the rainwater harvesting has been reduced to the staff only areas of the FM block and the second floor offices. The following diagram illustrates how the system works.



Pipex px® FLOWSTOW® system

1. Rain water outlet with filter conveys rain water direct from the roof into the flushing tank
2. Rainwater inlet 50,63,90 or 110mm diameter
3. 24v Solenoid valve for mains water top up
4. Flushing tank, options for single, twin and multiple WC's.
5. Main water inlet tundish
6. Inspection cover
7. Overflow
8. Flush pipe isolation valve
9. Flush pipe 24v Solenoid valve
10. Tank level sensor controls flush time against static head of rain water in tank
11. Full and half button mounted in stainless steel backplate
12. Control system
13. Ultraviolet light for keeping tank clean from bio-fouling

Figure 23 Pipex System developed in conjunction with Arup

3.5.3 Pools as irrigation water storage

As discussed in section 3.1.1.13 there was a proposal to combine smaller attenuation tanks within the landscape but the addition capital and maintenance cost proved to be too high. There was also a proposal for a wetland feature within the 'nest' landscaping zone, see the rainwater harvesting sketches (Appendix 3.7).

3.5.4 Drain design

The flood risk assessment carried out for the project set up the parameters for the drainage design. The design requirement is that flooding may occur during events in excess of the 1 in 30 year storm, as long as the water is retained on the site without affecting the neighbouring buildings. Analysis proved that it is not possible to allow flooding to occur on site without affecting the adjacent properties. As a result, the drainage system has been designed to store the 1 in 100 year storm with no flooding. In effect the system has been designed to a very high capacity and includes a 20% allowance for climate change. Appendix 3.8 ARUP Drainage Layouts, show the location and capacity of the attenuation tanks.

3.5.5 Gutter/ roof/ upstand design

The roof plays a key role in the future proofing which has been built into the scheme to allow adaptation for climate change. The spare structural capacity and the access arrangements which have been carefully designed into the roof arrangement will allow the addition of a green or sedum roof, and renewable technologies (photovoltaic panels) as and when they are required. As such we recommend that the detailing of all elements i.e. gutter, parapets etc should be maximised to allow that greatest potential adaptability. The roof should be prepared for exposure to a changing climate and the demands of changing uses.

3.5.6 Environment Agency guidance - location, infrastructure

According to the Environment Agency (2010), the development site in Liverpool is not currently at significant risk for flooding. The flood risk relative to the development site is shown below.

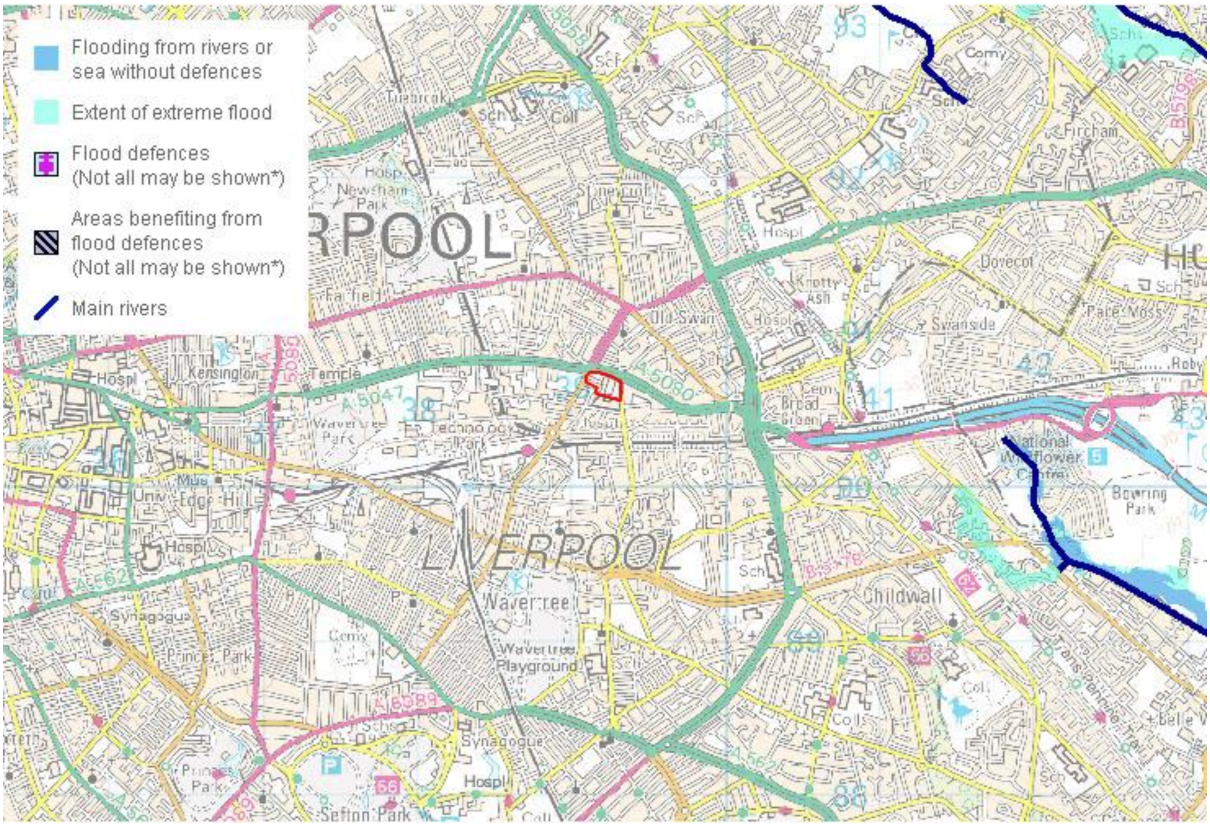


Figure 24 Environment Agency Flood risk map for Liverpool L13

3.5.7 Evacuation/self sufficiency

Although the flood risk is low given the vulnerability of users a sensible 'be prepared' approach should be taken by the building managers. In the same way that there are procedures in place to deal with an emergency fire situation a similar plan should be developed to deal with an extreme event flood incident. The design team is responsible for developing a fire escape strategy which deals with the specific security issues and sensitivities of the mental health facility. A carefully considered approach allows managed horizontal evacuation of the occupants to areas of safety within the building without causing undue distress to the vulnerable patients.

3.6 Landscape

3.6.1 Plant selection - drought resistance vs. cooling effect of transpiration

When considering the issues around selection plants which are drought resistant against the need for transpiration cooling the priority should be given to the climate change issue which poses the most risk. As identified in the Oxford Brookes Climate change hazards and risk assessment report (Appendix 2.1) the increase in temperature is a greater threat than the reduction in precipitation in the Liverpool area. As such, the plants should be chosen in order to maximise transpiration cooling effect with drought resistance as a secondary concern.

3.6.2 Role of planting and paving in modifying micro climate & heat island effect

The creation of a positive microclimate was is a key aspiration of the project. The building sits within a densely planted landscape 'nest' which has a strong relationship with the slot garden biomes with their line of trees providing shade and cooling. The soft landscape masterplan figure 25 illustrates the extent of planting to the courtyards, gardens, biomes, nest and car park. These trees will provide valuable shading and transpiration cooling to the bedroom spaces in particular.

Figure 25 Soft landscape masterplan

3.7 Timescale for implementation, cost benefit analysis and risk mitigation of adaptation measures

The adaptation measures matrix here assesses each measure on the basis of the risk level of the climate change aspect, effectiveness of the measure and capital and running costs. As outlined in section 2 the risk assessment is based on Crichton's triangle.

With this approach hazard, exposure and vulnerability are considered to establish the level of risk for each aspect: Comfort (keeping cool and keeping warm); Construction (stability) and Water (drought and flood). The risk levels were determined by Medical Architecture using Oxford Brookes University's Climate Change Hazards and Risk Assessment (Appendix 2.1).

The effectiveness rating is based on the analysis of adaptation strategies carried out by Oxford Brookes University (Appendix 3.2) using the IES model prepared by Mott MacDonald Fulcrum (Appendix 2.2).

The relative costs are not based on detailed Life Cycle Cost analysis as this information was deemed too commercially sensitive to share by the preferred FM provider. They are therefore estimates derived from Medical Architecture's best knowledge and experience in the context of a limited cost tracking spreadsheet circulated to the Design Team by the Trust's Quantity Surveyor, and discussions in Design Team Meetings. This spreadsheet is also deemed to be commercially sensitive and so is not included here or as an appendix.

In order to prioritise and rank the strategies, a scoring formula was developed by assigning a rating to each of these parameters by multiplying the risk rating 1, 2 or 3 (3 being the highest risk) by the effectiveness rating 1, 2 or 3 (3 being the most effective), and dividing this by the cost rating 1, 2 or 3 (3 being the most expensive)

$$\text{Adaptation score} = \frac{\text{Risk x Effectiveness}}{\text{Cost}}$$

This ranks the adaptation measures with a number score and a traffic light colour code thus:

Table 5 Adaptation measures matrix key

▲	Risk is considered in terms of hazard, exposure and vulnerability
👍	Effectiveness rating is based on the outcomes of testing in the IES model
£	Cost - assumptions of the relative capital and maintenance costs

C	Measure has been considered but not recommended for implementation
R	Measure has been recommended but not implemented
I	Measure has been implemented

↑	9	Most desirable measures
↑	8	
↑	7	
↑	6	
↑	5	
↑	4	
↑	3	
↑	2	
↑	1	Least desirable measures

The status of each measure is given in the last column to record whether the measure was Implemented (I) and included in the costed scheme; Recommended (R) but not included in the scheme yet, or Considered (C) but not recommended as good value.

Adaptation measures assessed on the basis of the risk level of the climate change aspect, effectiveness of the measure and capital and running costs											Status
	Rating	Risk level	Adaptation measure	Implementation timescale				Effectiveness	Cost	Score	
	1	LOW						👍	£		
	2	MEDIUM		now	2030	2050	2080	👍👍	££	(risk x effectiveness)	
	3	HIGH						👍👍👍	£££	cost	
Comfort	keeping cool	HIGH	Shading - manufactured		X			👍👍👍	££	5	R
			Glass technologies - films			X		👍	£	3	C
			Glass technologies - triple glazing	X				👍👍	££	3	R
			Green roofs/ transpiration cooling			X		👍👍👍	££	5	R
			Shading - planting			X		👍👍👍	££	5	I
			Reflective materials	X				👍	£	3	I
			Secure and bug free night ventilation	X				👍👍👍	££	5	I
			Interrelationship with noise & air pollution	X				👍👍👍	£££	3	R
			Thermal mass - heavy weight construction	X				👍👍👍	£££	3	R
			Enhancing thermal mass in lightweight construction				X	👍👍	££	3	R
			Energy efficient/ renewable powered cooling systems				X	👍👍👍	££	5	R
			Access to external space - overheating relief	X				👍👍👍	£	9	I
			Shading parking/ transport infrastructure		X			👍👍	£	6	I
			Role of water - landscape/ swimming pools	X				👍👍	£	6	R
			Role of planting and paving in modifying micro climate	X				👍👍👍	££	5	C
			Maximum temperature legislation			X		👍	£	3	I
	keeping warm	MEDIUM	Building fabric insulation standards	X				👍👍👍	£	6	I
			Heat reclaim systems	X				👍👍👍	£	6	I
Construction	stability	LOW	Recessed window and door reveals	X				👍👍👍	£	3	I
			Projecting sills with drips	X				👍👍👍	£	3	I
			Greater laps and fixings to roof and cladding fixings	X				👍👍👍	£	3	R
			Foundation design - subsidence/ heave/ soils/ regions	X				👍👍	£££	1	C
			Underpinning	X				👍👍	£££	1	C
			Retaining wall and slope stability	X				👍👍	££	1	C
			Lateral stability -wind loading standards	X				👍👍	££	1	C
Water	drought	MEDIUM	Low water use fittings	X				👍👍👍	£	6	I
			Grey/rain water storage	X				👍👍👍	£	6	R
			Pools as irrigation water storage	X				👍👍👍	££	3	R
			Plant selection - drought resistance vs transpiration cooling			X		👍👍	£	4	I
			Irrigation techniques			X		👍👍	£	4	R
	flood	MEDIUM	Increased capacity drain design	X				👍👍👍	£££	2	I
			SUDS design/ soakaway design	X				👍👍👍	£££	2	C
			Increased capacity gutter/downpipe/upstand design	X				👍👍	£	4	R
			Environment Agency guidance - location, infrastructure	X				👍👍👍	£££	2	I
			Flood defence - permanent				X	👍👍👍	£££	2	
			Emergency Plans - evacuation/self sufficiency			X		👍👍👍	£	6	R
			Flood tolerant construction	X				👍👍👍	££	3	R

3.8 Recommendations implemented and barriers to implementation

The following measures have been successfully integrated into the project proposals. We describe the issues which most affected client and design team decision making and explain why some recommendations were not adopted yet;

Shading – planting
Extensive tree planting to the landscaped areas throughout the scheme will provide shading to the building and the external amenity space. Whilst the client has little control over the immediate neighbourhood's planting – they do have some control of an adjoining site within their possession. The overall site is large and the client recognises that some positive benefits to counter the urban heat island effect have been designed into the scheme.

Reflective materials
High albedo finishes have been specified for the external walls. Further consideration was given to the roof's reflectivity. The specified roofing is reasonably effective and when next replaced could be upgraded with a similar product from the same manufacturer that has a higher albedo effect (not currently marketed in the UK). When the time comes to replace the roof covering this will be reconsidered but also with respect to whether a sedum roof is applied (thereby negating the need for the more reflective material.

Secure and bug free night ventilation
Bedrooms have filtered and screened ventilation primarily through the MVHR unit, but secondarily through openable windows fitted with security mesh that will also keep larger bugs out. The openable windows are counter to the concept and science of a sealed envelope and managed heat recovery, yet the benefit to patients of feeling a breeze and being able to directly affect their environment is paramount.

Interrelationship with noise & air pollution
The activity rooms facing the busy carriageway have been designed to allow ventilation from the less exposed faces of the building. It is a design aspiration that there is a visual link to the active road from the patient day spaces to reduce any feeling of isolation and provide therapeutic opportunities to re-engage with the outside world as recovery progresses.

Access to external space - overheating relief
Secure courtyard and garden spaces are provided for patients, staff and visitors. This is a necessary and vital part of any secure mental health accommodation. You will see from the table it also has the highest rating on our matrix of measures. Client concerns about patient safety had to be addressed in the choice of soft landscape, whereby climbing and ligature risks were minimised. The layouts had to also allow passive observation of vulnerable patients from within the building whilst being therapeutic spaces.
There is the possibility to provide high level shading devices hung from the parapets around the secure courtyards. This can be reviewed at any time in the life of the building and could be introduced at relatively low cost.

Shading parking/ transport infrastructure
Covered cycle parking and extensive tree planting have been provided to the car park. There is a therapeutic value to being able to test one's recovery from mental illness by making staged forays into the wider world. Providing pathways through shaded landscape has a wider non-economic benefit to patients.

Building fabric insulation standards
The building has been designed to super-insulation and air-tightness standards. This keeps the temperature of the building reasonably constant, in summer and winter. Most areas of the building are occupied 24 hours a day and 7 days per week. As such, the use of thermal mass is not as easily applicable and a faster thermal response is needed. That said, the addition of further layers of dense material to the internal linings could be considered at a later date to assist temperature moderation.

Relevance of heat reclaim systems

MVHR (Mechanical Ventilation with Heat Recovery) systems have been incorporated in the M&E strategy for the ward buildings. This clearly has a positive part to play in the cooler periods when the heat recovery is effective and the windows are likely to be closed. The higher risk to occupants is that of overheating and here any heat recovered will be purged to the outside air whilst drawing in cooler air from locally cooled landscape.

Low water use fittings
Efficient water use fittings have been chosen for WC's, basins, showers and baths. There are a large number of showers in the building, as every patient has an ensuite shower room. This is a requirement for reasons of privacy and dignity of the patients. A greater use of grey or rainwater harvesting and storage was considered and to a small degree implemented in non-patient areas only because of a perceived infection control risk. Our matrix shows it as recommended, and at a later date a greater volume of water could be harvested.

Environment Agency guidance - location, infrastructure
The site is located in a low flood risk area so no special measures were taken beyond that necessary to achieve level thresholds at all entrances to the buildings. To reduce any stigma there might be to being in a wheelchair or being unable to easily ascend steps, all thresholds are level. This creates a risk of water ingress at doorways in times of high rainfall. Slot drainage is provided at all thresholds to deal with this.

Plant selection - drought resistance vs cooling effect of transpiration
The priority has been given to the transpiration benefits of the trees and plants. Early design suggestions included rainwater storage and 'river biomes' between wards in the visually buffering landscape that separates bedroom windows. The higher maintenance costs that this would be incurred were not seen as having sufficient value at this stage. Fear of drought and large volumes of standing water for reasons of drowning risk or mosquito breeding areas also mitigated against the proposal.

Role of planting and paving in modifying micro climate & heat island effect
Extensive planting has been assigned to courtyards, gardens, biomes, nest and car park. The benefits of this have been described above.

There are often a complex set of issues which will have an impact on the implementation of the recommended measures. We have concentrated here on the measures that were fully implemented and outlined the practical issues relating to them. There are more nuanced process-driven issues that can impede implementation. These are expanded upon in sections 4.5 and 4.6.

The Appendices to this section include: Oxford Brookes University's overheating report and their adaptation report and checklist; Arup's (Design Team Engineers) option report for Photovoltaics, their Energy Statement and drainage layouts, as well as various product manufacturers datasheets that were considered during this stage of the project. We also include our Adaptation Measures Matrix as a stand-alone file. (Appendix 3)

Section 4: Learning from work on this contract

There have been two strands to the work we have undertaken for this contract. The expectation was that both strands would be more or less parallel and synchronised in a logically linear process. It must be said that the procurement route (an NHS LIFT project) has its own dynamic and workflow, and this research project has a different one. (Department of Health, 2001)

The LIFT procurement has been a stop-start process with long periods of inactivity followed by urgent flurries of activity which have not always coincided with the original D4FC Technical Project Plan that we anticipated. As a result, many of the adaptation strategies that we have explored and sometimes implemented were necessarily guessed at early on in the design process and only tested or validated subsequently.

Design Team meetings were conducted at least every fortnight throughout the active periods of the project, with the key stakeholders present or represented and latterly hosted by the preferred main contractor. Designing with future climate in mind was already tacitly understood by the experienced design team, led by Medical Architecture.

The lesson here is to make sure that firstly, everyone around any project team table know that they should be thinking about adaptation and mitigation, and secondly, that locally specific risks should be identified as early as possible, for adaptation strategies to be fully implemented.

4.1 Approach to the adaptation design work

4.1.1 Comfort Control – Keeping Cool

To design buildings without overheating issues under a future climate, the following steps were conducted to develop adaptation measures for Edge Lane – TIME project.

a) Adaptation measures for comfort mentioned in Design for Future Climate report (Gething 2010) were considered.
b) The adaptation measures which are applicable for Edge Lane – TIME project were selected (highlighted table 2).
c) To test the performance of these adaptation measures, detailed building level energy models were built in the building thermal simulation package IES (This was done by Mott MacDonald Fulcrum see Appendix 2.2). IES was selected partly due to the wide international usage by both research and practice communities, and partly due to the extensive historical testing and verification (Gough and Rees 2004).
d) The performance of individual measures was tested on the building model. CIBSE bedroom overheating guidance was selected as evaluation metric for the wards, because it is efficient and transparent, and it is widely used by practitioners. The CIBSE guidance of overheating for bedrooms is 1% annual occupied hours over operative temperature of 26 ^{o}C (CIBSE 2006).
e) Eight packages which are the combinations of the most effective adaptation measures were proposed for Edge Lane – TIME project. The performances of eight adaptation packages were then tested on the building model under current, 2030s, 2050s and 2080s' climate.
f) Due to the need of active cooling in 2080s, 6 more packages for air conditioned spaces were tested. The performance of these adaptation packages were summarised at the end.

4.1.2 Comfort Control – Keeping Warm

The buildings are designed to be extremely well insulated (beyond minimum Building regulations standards) and to be air tight to reduce heat loss. The Mechanical Ventilation and Heat Recovery (MVHR) units rely on this. Individual rooms have separate controls, but there is a risk that some patients may leave windows open in extreme cold conditions. Mid-season fluctuations of temperature may also be difficult to manage for the same reason. The client is very much aware that the system expects the windows to be closed at all times to be able to efficiently manage any heat loss, but openable windows will be useful in heatwave conditions later in the life of the building.

4.1.3 The Use of Landscape

The scheme has a highly developed landscape design and a larger than average budget for landscape. The therapeutic value of landscape to improve healing outcomes is widely advocated. The layout of the buildings allows 24 hour access to external landscaped gardens for patients. Overall the extensiveness of soft landscaping around the perimeter of the building and within the courtyards improves the microclimate and has a beneficial effect on patients. It is a vital part of the scheme.

4.1.4 The Use of Water

It is quite common in mental health facilities to exploit the therapeutic aspects of running water – normally in the form of a water feature paid for out of the art budget. Historically, these fail within a short time frame and there is a reluctance to specify and then maintain such features within the client body. Ways of incorporating water in the landscape and in terms of surface water run-off management, rainwater harvesting and irrigation, were discussed at design team meetings at some length. No specific measures such as evaporative cooling ponds or fountains were incorporated into the design. Every courtyard has a mains water tap provided for irrigation purposes and so the infrastructure would allow some future features to be added to assist with cooling or transpiration in extreme heatwave conditions.

4.1.5 Team Interactions

The Design Team and the Climate Change Adaptation study team were distinct entities bridged only by Medical Architecture. The timing of the study and the design team programme were not synchronised. The design of the scheme was largely undertaken by the time the climate risks were identified and any adaptation strategies were discussed. Pre-emptive work by Medical Architecture and Arup anticipated much of what the study team established with their work. The stop-start nature of the LIFT project further undermined the synergy of the two teams. Dissemination of this report will be a key way to realign the teams.

4.2 Project participants and what they brought to the project

4.2.1 Medical Architecture

Trading as Medical Architecture (MA), Medical Architecture and Art Projects Ltd. is a multi-disciplinary company committed to well-considered planning and design of buildings for leading healthcare providers worldwide; with projects across the UK, Australia, Canada and Europe. MA has offices in London and Newcastle and subsidiary companies in Australia and Canada. MA's approach is centred on people and the belief that research and excellence in design can create better medical and therapeutic environments for patients, staff and the public to experience and enjoy.

Established in 1991 the Founding Directors are former members of the Medical Architecture Research Unit (MARU) in London; the Directors are regularly present at international healthcare conferences, workshops and peer reviews. Today MA design buildings, undertake research, consultancy and provide advice to professional bodies in the sector. MA collaborate with some of the best construction and clinical teams worldwide to benchmark and promote good design and practice.

Through years of experience, audits and evaluation of completed projects, MA has accumulated a significant knowledge-base of healthcare design. MA is committed to improve outcomes through research and the application of evidence based design. MA is conversant with current health building standards and have assisted in the preparation of technical guidance by the Department of Health. As specialists in medical architecture MA recognises the importance of developing environments that are exposed to constant change, use of resources and service delivery and design buildings which are functional, affordable, flexible and sustainable.

MA led the case study research project. Director Bob Wills, Associate Ulrike Schimmel (until April 2012) and Architectural Assistant Claire O'Toole were the MA team. See Appendix 4.1 for team profiles. Many references are made to Arup documents within this report. They are the project engineers for the case study project. The structure of the project team – including Arup - is shown in the organogram in Appendix 4.2.

4.2.2 Oxford Brookes University

The Oxford Institute for Sustainable Development (OISD) at Oxford Brookes University is the largest academic research institute in the UK dedicated to research on sustainable development in the built environment. The Low Carbon Building (LCB) research group at OISD holds world-leading expertise in carbon counting and climate change adaptation of buildings and cities. Professor Rajat Gupta, Director of OISD and LCB group is the Principal Investigator (lead) on this project from OISD. Professor Gupta is supported by Dr Hu Du (Lecturer in Architecture and Climate Change) and Matt Gregg (Research Associate in Architecture and Climate Change).

The University's contracting arm - Oxford Brookes Enterprises Ltd. - were appointed as a sub-contractor to MA. See Appendix 4.1 for team profiles.

4.2.3 Mott MacDonald Fulcrum

Mott MacDonald Fulcrum (MMF) is recognised at industry and government levels, as one of the UK's leading providers of sustainable energy solutions for buildings and the built environment. MMF spent over 25 years shaping the sustainability agenda by designing high performance, low carbon built envionments.

MMF adopts a 'whole of life' approach to develop outstanding low-impact built environments that combine comfort, function and beauty whilst remaining efficient, cost effective and future-proof. The company is a founding member of the UK Green Buildings Council and advisor to the UK government's Secretary of State for Energy and Climate Change. It also has a number of policy analysts seconded to the government's Zero Carbon Hub and is helping deliver the massive step change required to make zero carbon homes a reality by 2016. Director Andy Ford was CIBSE President in 2011.

Mott MacDonald Fulcrum as a buildings sustainability specialist, mainly focused on the thermal modelling of the case study project. Saud Muhsinovic (MMF Lead), Susie Diamond (until October 2011) with Yudish Dabee and Karen Kouyoumdjian were the team. See Appendix 4.1 for team profiles

4.3 The initial project plan and changes through the course of the project

4.3.1 Programme Synchronisation

The Project Technical Plan was revised 5 times during the course of the project. This was a reflection of a stop-start to the case study LIFT project and a compression of the research project programme. As described above the two work streams became unsynchronised. By the time OBEL were starting work on climate risk modelling the costs, the Planning Application was submitted and permission received in June, before OBEL's risk report was issued.

4.3.2 Procurement Method

The NHS LIFT form of procurement requires a good deal of the project costs to be determined to a reasonable level of accuracy prior to the Planning Application being made. This of course reduces risk for the Main Contractor and the LIFT Co who are channelling the funds. As a result many of the design decisions made to reach and agree a construction cost figure were made before we had developed adaptation strategies to address the climate change risks that OBEL had identified.

Because the private finance component is working at some risk, the investment of resources to explore options is limited and unless the case study research timing is right it is extremely difficult to expect the team to revisit areas of design that are thought to be complete, or that might cause extensive reworking from first principles. (see weblink for a description of NHS LIFT:

http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Aboutus/Procurementandproposals/Publicprivatepartnership/NHSLIFT/index.htm)

4.3.3 Reality Check

There then followed a constrained period where the designers were working within an overall cost envelope, suggesting adaptation measures to future proof the building, which the client was not always willing to discuss or agree to. Through this period, the BREEAM Healthcare assessment process raised further awareness of the issues, whilst Value Engineering forced overarching best-value decisions to be made.

The BREEAM Design Stage Assessment workshops became risk management workshops. There was an obligation to provide an 'excellent' rated scheme with enough BREEAM credits spare to be able to afford to lose a few through the construction phase. The risk to be managed was balanced with least cost and maximum effectiveness. Adaptation measures were not ticking the right boxes in this context.

The Value Engineering work had been done before the study had been concluded and the cost envelope was set prior to any recommendations. The work done by the design team had secured a good number of the measures already within the cost envelope and these were at least validated by the client's preliminary acceptance of what is now formally named the 'Contractor's Proposals' a set of detailed documentation describing what will be provided for the money available.

4.4 Strengths and limitations of the resources and tools used

4.4.1 Overheating Guidance

CIBSE Overheating Guidance

The CIBSE benchmark of overheating for bedrooms, the benchmark is 1% annual occupied hours over operative temperature of 26 ^{0}C (CIBSE 2006). It is a simple definition of overheating and widely used by practitioners.

BS EN 15251 Overheating Guidance

The adaptive comfort limits mentioned in BS EN 15251 standard are based on a daily running mean outdoor temperature. It could allow part of building spaces to stay within comfort range to some extent.

HTM03 Overheating Guidance

Health Technical Memorandum 03-01 – 'Specialised ventilation in healthcare premises' Part A (Department of Health 2007) which deals with the design and installation of ventilation systems for healthcare buildings recommends that internal dry bulb temperatures in patient areas should not exceed 28 ^{0}C for more than 50 hours per year. This is the only document which highlights the overheating criterion for healthcare buildings.

4.4.2 Climate and weather data

UKCP09

The UK Climate Projections (UKCP09) gives climate information for the UK up to the end of this century. Projections of future changes to our climate are provided, based on simulations from climate models. The purpose of providing information on the possible future climate is to help those needing to plan how they will adapt to help society and the natural environment to cope with a changing climate.

UKCP09 Weather Generator

UKCP09 Weather Generator is a downscaling tool that can be used to generate statistically plausible daily and hourly time series. These time series comprise a set of climate variables at a 5 km^2 resolution that are consistent with the underlying 25 km^2 resolution climate projections.

UKCP09 Threshold Detector

The UKCP09 Threshold Detector is a post-processing tool that can be applied to the output from the Weather Generator. It allows users to define their own basic weather events made up of simple conditions such as temperatures or daily rainfall totals greater/lower than a certain threshold. The Threshold Detector could count the number of occurrences of the prescribed event. It also produces a set of summary statistics across all the runs.

PROMETHEUS weather data
PROMETHEUS weather data is created at Centre for Energy and the Environment, University of Exeter under EPSRC funding. The weather data is in EPW format which is already for use for most of building simulation tools.

DView
DView is free software developed by US National Renewable Energy Laboratory. The epw weather files could simply be loaded for visualizing hourly, monthly values and cumulative distribution of hourly values. Graphic comparisons of different weather data are also can be made in this tool.

MATLAB
MATLAB is a powerful numerical computing programming language developed by MathWorks. A function was created by author to quickly calculate adaptive thermal comfort limits based on external weather data. MATLAB also helps post-processing numerical outputs from thermal modelling software.

4.4.3 Thermal modelling

IES ApacheSim
IES is market leading environmental building modelling software. Detailed room level climate change impact analysis is being undertaken through building thermal simulation modelling in IES ApacheSim. IES ApacheSim was selected partly due to the wide international usage by both research and practice communities, and partly due to the extensive historical testing and verification (Gough and Rees 2004).

4.4.4 Recommended resources

The resources listed in sections 4.4.1/2/3 are recommended for practitioners. The following publication and reports are also recommended for practitioners who conduct climate change adaptation analysis for healthcare buildings.

Gupta, R. ,Gregg, M. and Du, H., 2012. *Comparative application of future weather years, using building simulation, constructed using state-of-the-art downscaling approaches based on UKCP09 projections* (Submitted for a journal publicaiton, under review)

Gupta, R. and Du, H., 2012. *Climate change adaptation report - Edge Lane - TIME project.* Submitted to Medical Architecture and Art Projects Ltd., London on 24 July; Funded by TSB under Design for future climate: adapting buildings competition.

Gupta, R. and Du, H., 2012. *Overheating metrics and base IES model report - Edge Lane - TIME project.* Submitted to Medical Architecture and Art Projects Ltd., London on 02 May; Funded by TSB under Design for future climate: adapting buildings competition.

Gupta, R. and Gregg, M., 2011. *Future climate changes projections for Edge Lane, Liverpool: Climate changes hazards and impacts*. Submitted to Medical Architecture and Art Projects Ltd., London on July 2011; Funded by TSB under Design for future climate: adapting buildings competition.

Gupta, R and Gregg, M (2012) Using UK climate change projections to adapt existing English homes for a warming climate, *Building and Environment*. 55: Special edition: Implications of a Changing Climate for Buildings, 55, 20-42.

4.4.5 Limitations of resources and tools

All resources and tools used in this project are carefully selected based on our knowledge; therefore they are recommended for other projects. The limitations of these resources and tools are listed in following table.

Resources and tool	Limitations

UKCP09 Weather Generator	Time consuming when generating hourly and daily data; Does not support batch processing.
MATLAB	Programming experience is needed.
IES Vista	Do not support batch post-processing of simulation results.
BREEAM Healthcare	Credit allocations for adaptation strategies are inadequate.

4.5 Recommended methodology - what worked well/badly

OBEL developed a methodology for climate change risk analysis based on UKCP09 Weather Generator, which is described in more detail in Section 2.1. Below is a recommended methodology for an overall framework, with a commentary about what worked well or badly *in italics*:

1. CLIMATE RISK ASSESSMENT FOR THE BUILDING, CONSIDERING FUTURE USERS: We identify the risks and exposure of the building to the projected future climate by modeling the impact of climate change scenarios (medium and high emissions; 2030s, 2050s and 2080s; probability levels of 10%, 50% and 90%) and data from UKCP09 and informed by CIBSE and ISO methods. This is combined with a vulnerability assessment of the future users. Suitable criteria are developed for winter and summer external conditions, internal comfort conditions, rainfall intensity and wind loading using statistical techniques and in conjunction with the design team and client.

   This method worked well to identify the high, medium and low climate change risks to a particularly vulnerable user group. As the general population is aging and there are an increasing number of elderly mental health service users with organic dementia as well as functional disorders – the risk profile might appear slightly exaggerated. However, an adaptable and sequentially upgradable building that can work well for this group would have an even longer life or alternative future use for less vulnerable people.

   It must be said that the technical language used to communicate the results and the complexity of the science underpinning these results is quite opaque to many clients and some consultants. A lesson to draw from this perhaps is to use analogy or metaphor to a greater extent when describing concepts. To get an idea across, it can be useful to liken scenarios to already known experiences that most people will be familiar with to some extent. This is difficult to do for fear of being either patronising or facile and unrigourous.

2. OPTIONS APPRAISAL OF SUITABLE ADAPTATION MEASURES: To improve the resistance and resilience to climate change now and in the future, the adaptation strategy incorporates the following:
   - Impact on comfort levels: This will address: orientation + shading + facade design; cooling load – options; ventilation strategies to be tested; natural + passive stack concept against low voltage mechanical; optimization of ceiling heights; heat recovery in winter; passive solar in winter - impact on fuel saving.
   - Building Structure: This will include exposed internal thermal mass - optimum areas required; use of reflective materials; design for storm water; oversized rainwater goods; attenuation vs. collection; green roof vs. quick run-off and collection; frame design and durability; foundation design and soil conditions; as well as performance in extremes - wind, rain, heat waves - air tightness, strength, suction/ pressure.
   - Open space design will include role of: landscaping - planting and paving strategy in modifying micro-climate and heat-island-effect; seasonal robustness of hard paved areas - flood/ heat/ ice; outdoor comfort.
   - Water management strategies to include: flood resilience and resistance measures; roof design and rainwater collection; irrigation and recycling; sustainable urban drainage systems and soakaway design; grey water recycling and grey water heat recovery.

   Most of the above is analysed through scenario testing of variables within a dynamic thermal modeling programme (such as IES) and empirical evidence to develop a holistic adaptation strategy. A stakeholder review workshop is undertaken prior to incorporating adaptation measures into the design.

We had high hopes for the interoperability of our Building Information Modeling (BIM) software and the thermal modeling software (IES). We found that the two were sophisticated in different ways and in the end had to resort to an older tried and tested method of transferring files to overcome the lack of interoperability. This interoperability is being developed at the time of writing and it is expected to be far easier and to yield far more sophisticated outputs in the near future. We were disappointed that abortive work had been done by both MA and MMF, but had thought the attempt was worth making.

We invited the key stakeholders to a review workshop to present and discuss these options. Many of the options had already been considered and some had already been implemented prior to the Planning Application and the work of OBEL. In the event this was so poorly attended and so a Briefing Paper was prepared to communicate the findings and the options. The case study project had gone cold at this time, with the design team almost stood down and the main contractor waiting for the Financial Close date to be confirmed.

3. DETAILED DESIGN OF SELECTED ADAPTATION MEASURES:
   - Using the feedback from previous stages, design options and construction detailing are drawn up at 1:50 (1:20) scale, where required larger details (1:5) are drawn.
   - Capital cost appraisals and whole life-cycle costing on design alternatives and options on specification changes are undertaken.

   Through this stage of the research project, some final proposals were being specified for the contractor to be able to prepare their 'Contractor's Proposals' - a full set of clearly defined and costed documentation. There was a sense of it being too late to make any significant changes. Instead we concentrated on those measures that were already designed and incorporated into the documentation and aimed to validate them by using the research findings.

4. UPTAKE OF RECOMMENDATIONS BY THE CLIENT: Meetings are held with the client to discuss actual costs and valuation of benefits of adaptation measures so as to explore take-up of recommendations.

   As the Contractor's Proposals were being finalised, the contractor had to demonstrate BREEAM Healthcare compliance with a pre-construction 'excellent' rating as required for all new build NHS projects. This led to a number of workshops to explore ways to achieve the necessary credits with an adequate cushion to allow for falling short during construction. This gave new impetus to reconsider adaptation measures that had been ruled out at earlier stages of the project. This was a good thing, and the client was excited at one point to think that an 'outstanding' rating might be attainable. The contractor would need variation payment to achieve some of the additional credits and the client felt the measures were not affordable. A positive outcome was the confirmation that the structural frame was designed to allow renewable technologies or sedum to be added to the roof at a later date.

5. REPORTING AND DISSEMINATION: The project is completed with the production of a costed strategic adaptations report for the client. Key conferences and events are identified for dissemination of good practice on climate change adaptation.

   This report and its appendices provide a useful checklist of strategic adaptation measures for the client to draw upon for future projects (this is one of 4 similar projects for the same client). Bob Wills of MA is writing a paper for presentation to the Health and Care Infrastructure Research Innovation Centre (HaCIRIC) conference in Cardiff in September 2012, which is intended to alert those involved in briefing and strategic thinking about the healthcare estate so that they are able to be more serious about design for future climate. The knowledge gained through the project has already transferred to other similar schemes currently in design development with other clients. Clients and design teams are now much more aware than they were just 2 or 3 years ago..

With this framework, we have also developed an approach for designing for comfort for single-building and multiple-building projects, given the risks posed by overheating in buildings:

- Select suitable adaptation measures for the project drawing from current literature such as those mentioned in Design for Future Climate report (Gething 2010);
- Build detailed room level energy model (s) in a dynamic building thermal simulation package (for hourly simulation) to test the performance of these adaptation measures;
- Select worst case building example (if necessary for a large development). The worst case building could be the one with the orientation that has the most insolation in summertime and/or a building with vulnerable occupants
- Select appropriate overheating metric;
- Develop adaptation packages which combine the most effective individual adaptation measures. The overheating performance of adaptation packages were then tested on the building model (s) under current, 2030s, 2050s and 2080s' climate;
- Develop adaptation packages for building spaces which need active cooling;
- Propose adaptation packages to designers;

Such methodological approaches will have a widespread application and were used as described in Section 4.1 of this report.

4.6 The client's decision making processes and how to influence them?

4.6.1 Success at implementation

There was buy-in from the client on a number of measures and in the early stages, the possibilities were fairly open, but the Value-Engineering process ultimately precluded them. For example the Tenant's Requirements (part of our brief from the client) required the designers to 'consider the effects of climate change'. Photovoltaic arrays and a sedum roof were proposed at the early stage of the project. These were thought to be essential pre-requisites in terms of climate change but were not actually implemented. An allowance for additional structural capacity has been made to install these during a future sequential upgrade of the buildings. If we had not had this early discussion, the allowance might not have been made.

4.6.2 Multi-headed client and the long view

There are many different parameters to respond to as a design team, and it can be difficult to achieve closure on adaptation measures with a large number of stakeholders. Liverpool & Sefton Health Partnership (LSHP) comprises Bilfinger Berger and the Mersey Care NHS Trust as the principal partners in the LIFT Co. Farrans Heron Joint Venture (FHJV) are the main contractor to whom the whole design team will be novated for the construction phase. See project Organogram in Appendix 4.2. Even when a whole life cost benefit can be demonstrated, in a climate of short term restriction of capital expenditure, there are difficulties in getting agreement of all parties that additional capital expenditure now is worth spending to be able to save later.

4.6.3 Influence at briefing stage

To have the greatest impact there is a need to influence the early briefing stage. If the Tenant's Requirements insisted on the generation of future weather years data as part of the project workflow, or commissioned these separately as part of the High Level Information Pack that is provided to design teams a significant shift of emphasis would be made. It would also necessitate due consideration at every design review, to demonstrate compliance with the brief.

4.6.4 Energy modelling prediction

There are a number of tools already available for predicting the ways in which buildings will behave thermally, acoustically, and operationally. These tend to be used late in the design process to prove Building Regulations compliance rather than to engineer the design. An enhanced and earlier use of such predictive software tools would help inform and test different design scenarios to arrive at an optimum design for future climate. The investment of time and resource is still seen as a 'nice to have' rather than an essential part of the design toolkit. As awareness is raised we expect that these will become more essential, again to validate decision making at an early stage. This work should be written into Service Agreements with reference to the checklist of possible adaptation measures.

4.6.5 BREEAM Healthcare compliance

Mersey Care NHS Trust is not a Foundation Trust (FT). It has applied for FT status and is expecting to have this by the end of 2013. We have found with other NHS Trusts that are Foundation Trusts are reluctant to fully embrace BREEAM Healthcare compliance, counter to the NHS 'requirement' to do so. This is particularly true of Mental Health NHS FTs. They see elements of the assessment tool as being either 'not value for money', or 'irrelevant to mental health facilities'.

Foundation Trusts, because of their semi-independent financial status, are forgiven this oversight by Monitor - the regulatory body that scrutinises them. A BREEAM Assessment is 'voluntary' from the BRE Trust's perspective, so there is little leverage that Monitor can apply. Non FT's are 'required' to undertake one by the NHS. Mersey Care NHS Trust have therefore fallen in whole-heartedly behind the directive and aided by Arup, FHJV, LSHP and ourselves, have achieved a pre-construction credit rating of 'excellent'.

Section 5: Extending adaptation to other buildings

5.1 Applying the developed strategy, recommendations and analyses to other building projects

5.1.1 Transfer to a concurrent project

Edge Lane is one of 5 similar proposed projects for the Mersey Care NHS Trust (collectively named the TIME Project). The Edge lane and Walton projects are the first two of the five to be developed. As such, there is immediate transfer of knowledge from Edge Lane to the Walton project - a concurrent project.

5.1.2 Subsequent projects

The 3 other subsequent TIME projects will also be able to draw on any lessons learnt through their procurement and construction phases. They will have the added benefit of any Post Occupancy Evaluation of the first two schemes.

5.1.3 A repeating typology

The building typology of the Edge Lane scheme is recurrent in Medical Architecture's portfolio of work – particularly for mental health projects. What we have been able to do at Edge Lane in terms of adaptation and mitigation strategies is transferrable to some degree to all subsequent projects of the same typology.

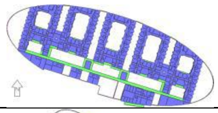
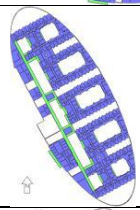
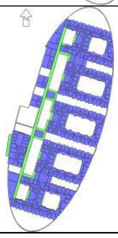
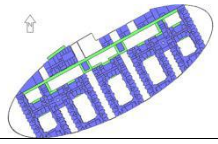
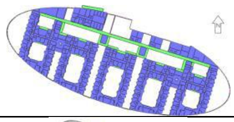
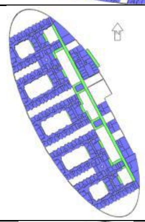
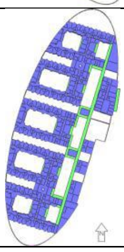
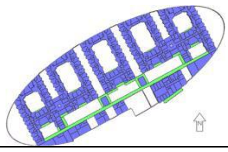
5.1.4 Awareness raising

As a practice, and through a continuing working relationship with the other members of the design team we have already noticed an increased awareness of the effects of climate change. We have a greater understanding of what it is that we, as professional consultants can do to influence decision-making at the front end of projects.

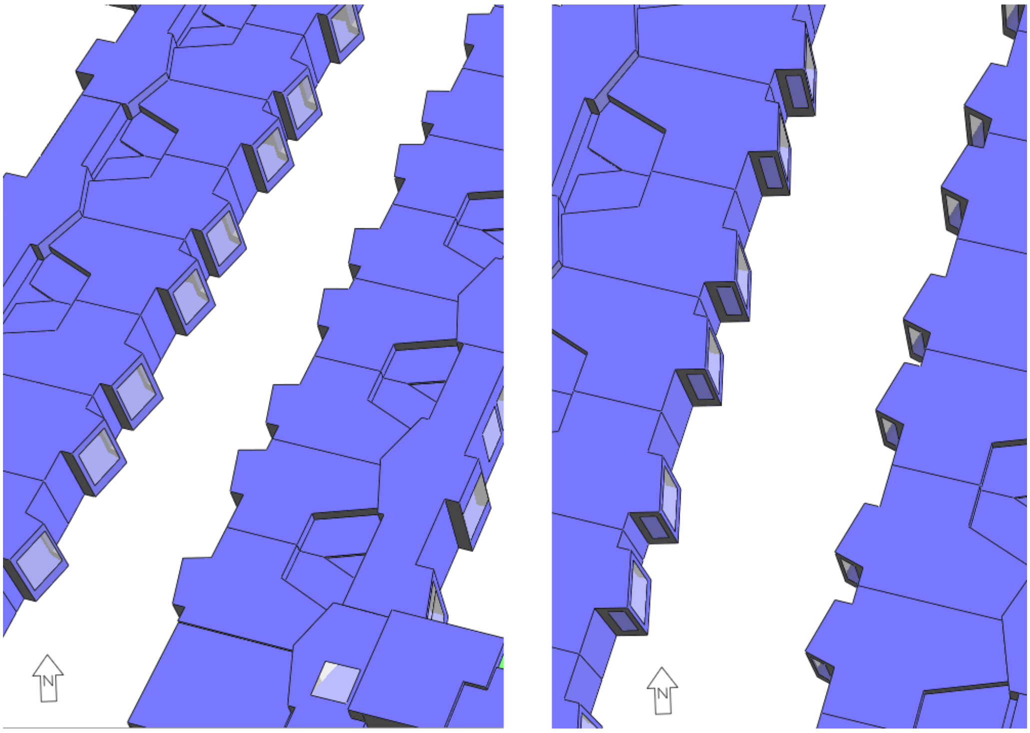
5.1.5 Orientation of the building – a study by OBEL

Building orientation and windows opening directions have significant impacts on building performance. They are often limited by land and existing surroundings. When this research was conducted, the site plan was already decided. Therefore, exploring the best orientation is the author's interest and it might be useful for similar developments in the future.

The results in the following table show that 180 degree rotation of the existing building could reduce the average overheating percentage of 85 bedrooms from 4.6% to 2.2% at current climate condition. The clinical need to orientate the accommodation as it currently is, overrides the climatic benefits of rotation. Other adaptation measures were selected to address overheating, but the point is well made and is included here to show the importance of orientation.

Site rotation angle in IES	Thumbnail (↑North)	CIBSE baseline	Pro 2050s	Pro 2080s
0^{o} (base model)		4.6%	13.1%	20.8%
45^{o}		3.5%	11.4%	18.9%
90^{o}		2.6%	8.8%	16.0%
135^{o}		2.2%	7.4%	14.5%
180^{o}		2.2%	7.1%	14.1%
225^{o}		2.2%	7.5%	14.5%
270^{o}		2.9%	9.5%	16.7%
315^{o}		4.2%	12.4%	20.1%

Another effective way to reduce overheating percentages is to flip the orientation of the windows, to make the shorter end face south, as shown below. However the design of the windows has been carefully developed to allow long views out of the patient bedrooms whilst maintaining privacy. To flip them in this way would seriously compromise the privacy and dignity of the patients.



5.2 Limitations of applying this strategy to other buildings

5.2.1 Site Specificity

A significant limitation will be the site specificity of any project. Whilst the application of the overall strategy will no doubt have a positive benefit to other building projects, the application of detailed adaptation and mitigation solutions may be limited by site location, and any constraints. That is to say, a holistic rethink will be required for any site – there are no universal quick fixes.

5.2.2 Software Interoperability

At present there is limited interoperability of modelling software with architectural design software. We are aware of the BRE Trust funded research work by PhD candidate, Alexandra Cemesova at Cardiff University, who is looking closely at improved interoperability of IES and BIM software tools in relation to PassivHaus systems. We are hoping that advances in predictive modelling techniques will soon facilitate such interoperability earlier in the design process.

5.2.3 Functionality

The building users are vulnerable in our case study and there are numerous carefully balanced factors in consideration when designing for this group. There is a tendency to concentrate on the functional relationships and adjacencies first and foremost for the effective delivery of the adopted model of care. This can result in a certain orthodoxy of prescriptive clinical planning that ignores the passive orientation of the building. This can be challenging for designers.

5.3 Which buildings across the UK might be suitable for similar recommendations

5.3.1 The Building Morphology

The building morphology of a low-rise (single storey) high density, courtyard building, with a large footprint and numerous small courtyards already exists for a number of modern buildings. Schools, 'nucleus' hospitals, hotels, and housing might all benefit from similar recommendations.

5.3.2 Accessible Roofs

Such buildings can have planted courtyards providing shade and evaporative cooling opportunities. They can also have accessible flat roofs planted with intensive, or more often, extensive green roofs. These can be additionally or alternatively used as surfaces for the installation of renewable energy technologies, which are both easily maintainable and easily replaced as technologies develop.

5.3.3 Usable Roofs

Safe access to such roofs must be considered at the outset, with high parapets, walkable stair access (not ladders) and spare structural capacity for the additional loading of equipment, the weight of saturated sedum roofs and storm water or significant snow loads. In much of the UK however, a flat, walkable flat roof is culturally difficult to accept, and sometimes precluded by the planning process.

5.4 Resources, tools and materials developed

5.4.1 A Checklist

We are developing an Adaptation Measures Checklist for use by project leads at the start up of any new project. This is effectively a template derived from the Design Opportunities Checklist included at the front of this report (after the Executive Summary). This can be used by product leads as an agenda item when establishing the project goals with the whole team. We will use this as part of our Environmental Management System as a measure of successful implementation and continuous improvement.

5.4.2 Integration with Environmental Management Systems

We have identified the power we have to influence design for future climate with clients as a Significant Aspect of our professional work. The successful implementation of adaptation measures will be monitored as part of MA's Environmental Management System for ISO 14001 accreditation.

5.4.3 Client Operational Strategy

We encourage clients to be clear about how they expect to use the building when preparing their brief. We have found that often this is nebulous and we are in a position to help to develop it. There is a reluctance to commit users of the buildings to have to behave in prescriptive ways, and for the building to be able to cope with the vagaries of human nature. The use of the Soft Landings Toolkit and building performance evaluation techniques should become more of a mainstream activity as part of a managed Post Occupancy Evaluation process.

5.4.4 A Design Manual

Buildings are becoming more sophisticated and less intuitive to manage. MA have prepared design manuals for buildings we have designed. These help clients and users understand the design intent and reflect the client brief at the start of a project. These can be a useful benchmark for building users later in the life of a building whereby the management – particularly of the building engineering services – can deviate knowingly from the way in which the building was conceived originally, or can enhance or extend the concept sympathetically.

5.5 Further requirements in order to provide adaptation services

Legislation, Standards and Guidance all contribute to the adoption or otherwise of adaptation strategies. All could be strengthened and the authors recommend that they are. Updates can be incremental rather than wholly new. For example the BREEAM Accredited Professional Examination curriculum could be amended slightly to improve awareness and promote use of the checklist that has emerged from the programme.

The Design for Future Climate programme has been an important catalyst for MA and we sense that it is an important game-changer for the construction industry.

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Appendix 4

4.1 Research Team Profiles
4.2 Project and Research Team Organogram

Appendix 5

Section 5 has no appended documents

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