D4FC PROJECT

EXTRACARE4EXETER

A REPORT FOR THE TECHNOLOGY STRATEGY BOARD

Exeter City Council

Gale & Snowden Architects & Engineers

Exeter University

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St Loyes ExtraCare4Exeter

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Executive Summary

This report shows that:

- The St Loyes Extra Care project can be designed passively and simply to ensure that the building remains at optimum comfort levels for many years to come when taking into account current projections of climate change
- It is important to include climate change adaptation considerations at the earliest stages of a project to maximise cost effective design opportunities
- Climate change adaptation considerations need to be based on good sound quantifiable building physics
- Having a comprehensive climate change strategy for the building enables long term cost savings
- Designing with Passivhaus principles can reduce the risk of overheating of buildings in the future
- Close Client and End User involvement in climate change adaption considerations enables clients to understand the importance of ensuring that our buildings are fit for the future and is an important aspect as part of the overall client decision making process
- Further detailed research is required into future climate predictions for wind and rain, in a format for building professionals to be able to use with current design tools and software

The design for St Loyes Extra Care has been fundamentally influenced by undertaking the TSB Climate Change Adaption work. Both concept and detailed design have incorporated a range of climate change adaption measures, many of which not added any significant capital costs to the project because they have been included at the start of the design development process. Life cycle cost analysis shows that the design solution will save money over time compared to a project that is not robust for future climate change. The project team, including the client, has learnt much that can now be applied to future projects. This report details the team's findings and conclusions for the implementation of a comprehensive climate change strategy for the St Loyes Extra Care facility, focusing on thermal comfort.

Contents

Foreword / Introduction

Current climate change projections show that in the UK average temperatures are expected to rise by 4-6^{0}C during the next 100 years. In addition UV radiation will increase, air quality will change, driving rain and wind patterns will become more severe and it is predicted that summers will become drier and winters will become wetter. The South West represents a region of the UK which is already at the higher end of weather severity for solar irradiance and driving wind and rain. Future weather changes will push this severity even further.

Unless climate change adaptation strategies are incorporated into designs and existing buildings excessive overheating will occur during summer periods, building fabrics and details will become more prone to weather damage, and droughts and flooding will affect landscape and water usage. Buildings, that house the most vulnerable in society to the affects of overheating, such as the elderly or people with health issues, will either become unusable or require capital and energy intensive air conditioning systems to be installed.

Today about 18.5% of citizens in Exeter are over 65. By 2030 over 25% of the population of Exeter are likely to be over 65. This growing elderly population needs consideration in terms of housing options, support and services. This client group is most at risk from extremes of temperature. The Government stated in 'Lifetime Homes, Lifetime Neighbourhoods: a national strategy for housing in an ageing society' that they have made housing and planning communities for an ageing population a national priority.

Devon County Council and the district councils in Devon have produced an Extra Care Housing Commissioning Strategy. Research carried out for this strategy identifies that based on 2008 population estimates, a total of 1,101 extra care housing units (22 schemes at 50 beds each) are required to meet the needs in Devon. Therefore learning points from the design of this building can be applied to a potential 21 other Extra Care Facilities in Devon alone. Across the whole UK this could easily run into hundreds.

There are learning possibilities for other health care sector buildings both within the public and private sector. There is scope for sharing the work undertaken on this project with other Local Authority Partners throughout the South West and beyond. There are potential economies of scale from the duplication of design features, techniques and materials through the supply chain.

The Extra Care Facility in Exeter is to house people with housing needs often on low incomes, as well as being elderly and with health issues. This will project will address fuel poverty by the nature of the low energy measures included. This design will result in reduced running costs for the occupants and common areas together with reduced maintenance costs by relying on passive techniques to allow adaptation to future climate change. Designing adaptation strategies at the outset will prolong the usefulness of the building over time with likely future changes in the climate. A robust building design and scheme that is flexible for future change will ensure the building requires limited retrofitting and reduced refurbishment in the future.

It is important to stress that the work contained in this report detailing the team's approach towards a climate change adaptation strategy for the St Loyes Extra care project is part of a much wider environmental and social approach to the project. This project, based on Permaculture principles, has put climate change mitigation measures and environmentally restorative design at the heart of its design, placing great importance on the health and wellbeing of the buildings' occupants as well as to the wider ecology.

Some of the designers of the project have had personal experience of living with close family members who have suffered from dementia for a long time and are consequently familiar with a range of existing care facilities. This personal experience has enabled a strong set of design principles that are aimed at enhancing the lives of those that are to use the building. The team has used the climate change adaptation measures to enhance their holistic approach.

This project and the integration of a comprehensive climate change adaptation strategy has been made possible by the strong lead and the full involvement of the client, Exeter City Council, who has participated at every stage and fully engaged with the climate change adaptation work.

Section 1
Building Profile

1.0 The Building Profile

1.1 The Building Project

1.1.1 Mission Statement and Objectives

The Mission statement for the scheme was 'To design a new state of the art, exemplar Extra Care Facility in Exeter'. The key client objectives for delivering an exemplar care home were as follows:

- To incorporate the latest thinking with regards to elderly and dementia care
- To incorporate low energy and healthy building design
- To employ high quality design and materials
- To achieve a homely, non institutional and secure feel to the building

The care home accommodation consists of 50 self-contained accommodation units with supporting accommodation as follows:

- 20 x 1 bedroom (51sqm)
- 30 x 2 bedroom (64sqm)
- Supporting communal facilities and staff accommodation for the elderly and catering
- High level Dementia Care. High Dementia Care is understood to mean mild to severest dementia care.

The Extra Care Facility is a 5 storey building located on a site which is sloping by about 1 metre to the south and offers views over the Exe Valley and River Exe Valley Park to the south.

The name of the scheme is St Loyes Extra Care Facility. The project title under the CCA contract is ExtraCare4Exeter. Throughout this document reference is made to both titles.

1.1.2 Context and Site

The Extra Care Facility forms part of 'Millbrook Care Village' development which aims to create a new high quality retirement development incorporating:

- an Extra Care Facility of 50 beds;
- 252 two bedroom retirement units, (128 cottages, 124 apartments);
- a Central Facilities Building to include: restaurant, bar, snooker room, library and meeting/activity rooms, welfare and administrative functions;
- an Estate Manager's Unit;
- and a shop and doctor's surgery on site.

This project is for the Extra Care Facility of 50 beds.

The site for the St Loyes Extra Care Facility forms part of the 'Millbrook Care Village' development on the former St. Loyes College site on Topsham Road, Exeter.

The Millbrook Care Village site was granted outline planning permission in September 2010 under reference number 09/0832/01 and the St Loyes Extra Care Facility site is part of this approval.

1.1.3 Budget

The client's budget for the scheme is £6 million in construction costs not including High Dementia Care which has not been defined and excludes consultants' fees, VAT etc.

1.1.4 Environmental Requirements

The client's brief for the project includes the following environmental requirements:

- Low energy and passive design measures:
  - The building design is to meet Passivhaus standard
  - 25% of energy usage to be generated on site by low to zero carbon technologies
  - To be an exemplar Extra Care Facility in low energy design
- Healthy Building design to:
  - Incorporate low VOC materials and components
  - Ensure optimum indoor air quality all year round
  - Minimise the build up of particulates and therefore minimise the production of dust mites
  - Include radial wiring to reduce low frequency EMFs
  - Include good levels of daylight throughout
  - Thermal comfort
  - Non PVC materials
  - Natural building materials
- Employ Permaculture design principles to:
  - Create external spaces for people to keep cool
  - Incorporate pleasant and green external spaces for people to relax in
  - Ensure an integrated building, landscape and planting design
  - To provide plant species that are robust to climate change
- Climate Change Adaptation Design:
  - To ensure the build design is robust to take account future changing climates (see section 1.1.5 below)

1.1.5 Extra Care Assisted Living

The project brief includes for 50, 1 and 2 bedroom flats. These flats, being fully functional self contained flats, will allow the residents to lead independent lives for as long as it is possible. Each resident will be able to received assistance and the degree of assistance can be tailored to residents' specific needs. It is therefore likely that assistance will be at hand to help residents whenever it is required and that there will be a degree of surveillance of the residents to ensure that residents well being is maintained.

1.1.6 Technology Strategy Board – Design for Future Climate Change

The project received additional funding for design work from the UK Government through the Technology Strategy Board's (TSB) Climate Change Adaptation programme. The team undertook design work in accordance with Exeter City Council TSB application number 2701-23232 which was incorporated into the building and landscape design. The project title for this element of works was ExtraCare4Exeter.

The main emphasis of this adaptation and research work was to address the issue of overheating in building design for a vulnerable user group which primarily focused on:

- Increased internal and external temperatures
- Unstable / changing surface temperature levels resulting in uncomfortable internal conditions
- Unstable internal temperatures and fluctuating humidity levels
- Heat stress in individuals

To a lesser extent the following areas were also investigated as part of this adaptation work:

- Increased weather severity – wind and rain
- Reduced rainfall in summer, increased rainfall in winter affecting water supply and landscape and increased costs

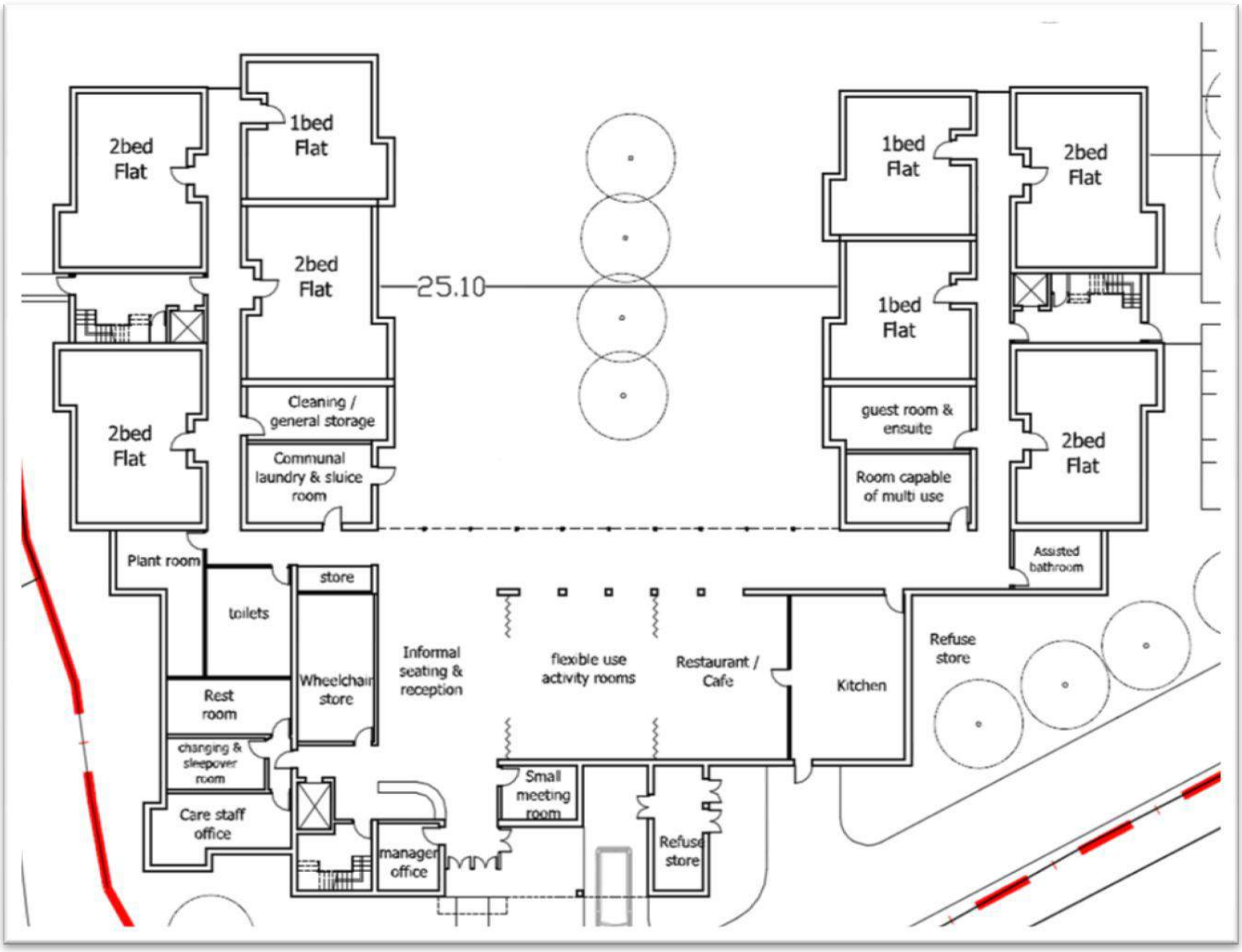
- Increased pollen count, airborne particulates and manmade pollutants due to higher external temperatures and at times less wind to help clear localised air quality
- Flooding

Residents are likely to be frail and elderly and will require appropriate levels of thermal comfort. The building was designed to maintain appropriate temperature and humidity levels throughout the year. With increased temperature rises due to climate change the building will need to be designed to be future proofed for internal thermal stability (minimising daily and seasonal temperature fluctuations).

1.2 Original Building Design and Associated Features

1.2.1 Original Planning Drawings and Typical Extra Care Facility Design

Figure 1: Drawings of Outline Planning Application Design Given to the Team by the Previous Developer of the site. This scheme like most other care facilities is designed with a central corridor and therefore relies on single sided natural ventilation



The original planning drawings (designed by others) dated 25/09/09 detailed an Extra Care Facility with flats located on either side of a long central access corridor. This only allows the flats to have opening windows on one side of the property, which in turn limits the natural ventilation available for that flat. Cross ventilation in a flat, when windows on both sides of the flat are opened and air flows from one side to the other, is therefore not possible. In this report this has been called single sided ventilation. This is typical of many

Extra Care Facility Designs across the UK. Figure 1 illustrates the arrangement for this planning design. There are various reasons why this approach is adopted:

- Cost
- Fire Access
- Design and building simplicity
- Planning requirements
- Ease of use by Care Staff

This type of design however can lead to various issues which are not conducive to developing healthy environments such as :

- Poor ventilation due to single sided ventilation limitations
- Overheating
- Poor daylight levels and dark interior spaces
- The long central corridor arrangement gives an institutional feel to the building and can be detrimental to dementia suffers
- High lighting loads with internal corridors constantly artificially lit
- The external courtyard when modelled was found to be in shade most of the year making this space unusable
- Isolation of occupants in their flats

1.2.2 The Building Type and its Resistance and Resilience to Climate

A risk assessment has been carried out to identify risks from climate change that are apparent for the extra care facility. Please refer to Appendix 2 for the full risk assessment. The following points highlight these key risks:

- Elderly care facilities house the most vulnerable in society to the affects of summertime overheating and an increase in air bourne pollutants
- The site has been given to Exeter City Council by the Developers as part of a section 106 agreement; this has defined its size. The size is small for the client's brief which is for a 50-unit facility, which is the smallest size feasible for an extra care home to be economically viable. This will have consequences for climate change adaptation design.
- Planning constraints in terms of design, footprint, building height and orientation, had already determined the massing of the building and to a certain extent orientation. The design team had the challenge of maximising any passive strategies such as cross flow ventilation and building orientation within specific design constraints
- Domestic buildings are not normally air conditioned to combat overheating
- Typically care homes are naturally ventilated buildings which may lead to them overheating if not designed correctly
- The height of multi-storey buildings may lead to higher levels of weather exposure in terms of driving wind and rain
- The building height may contribute to overheating in the higher storeys if not designed correctly.
- Flash flooding could be an issue if not designed correctly as with any building design

Section 2

Climate Change Risks

2.0 Climate Change Risks

2.1 Risk Exposure

A qualitative risk assessment was carried out to identify the key future climate change risks for the Extra Care Facility Project. The full risk register can be found in Appendix 2.

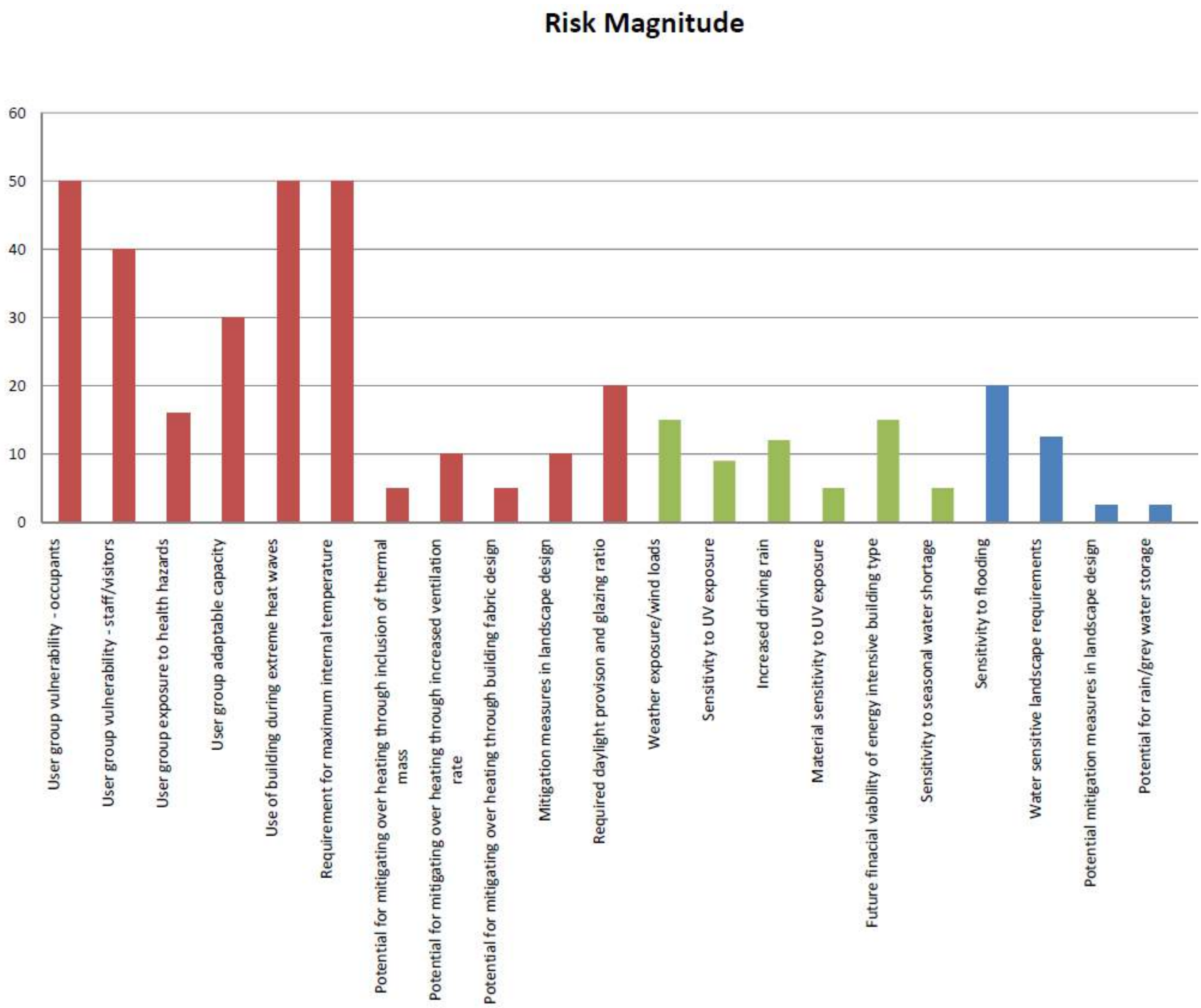


Figure 2 Key future climate change risks identified and their relative magnitude

The following sections expand on the key risk areas identified.

2.1.1 Vulnerable User Group to Heat Stress

The elderly along with children and individuals that are sick are considered to be the most vulnerable in society to the affects of overheating and are more likely to suffer heat stress as a result. The elderly in particular are also likely to be taking medications which can make them more vulnerable to dehydration thus increasing the risk of overheating in a hotter environment[14].

More than 40,000 deaths were attributed to the European Heat Wave of 2003 with almost 15,000 deaths in France alone[15]. These deaths were predominantly elderly people.

Thus the intrinsic nature of the building's occupants being elderly and likely to be on medication, with cases of moderate to high levels of dementia, put this user group into the highest levels of overheating risk exposure in warming climates. Increases in humidity may also impact on future comfort conditions and associated heat stress.

Importantly, in addition to this, there is no clear consensus in UK industry/government guidelines as to what are acceptable upper temperature limits in Extra Care Facilities for this vulnerable group. See section 3.2.1 on acceptable upper temperature limits.

Little research has been carried out as to how people will adapt to changing climates in particular the elderly in Extra Care Facilities. See report by Exeter University 'A Study of Possible Heat Stress as a Result of Climatic Change in the St Loyes Care Home'[10] Appendix 4.

Various studies have been carried out into the nature of heat stress in the elderly and individuals and what can be done to mitigate it. Key findings have found:

- The elderly find it more difficult to adapt to daily changes in temperature due to having less effective internal body regulation mechanisms
- The elderly tend to drink less than younger people and as thirst is not a good indicator of when you need to drink dehydration can occur more quickly than younger people who drink more frequently during the day. *"If you drink only when you are thirsty, you are dehydrated already. Thirst is not a good guide for when to drink water. In fact, in hot and humid conditions, you may be so dehydrated by the time you become thirsty that you will have trouble catching up with your fluid losses."* (Thygerson, 1997)

2.1.2 Vulnerable User Group to Air Pollution

The nature of the occupants also makes them more vulnerable to additional affects of climate change other than overheating and heat stress. The elderly are likely to have weaker immune systems than younger healthier individuals and will be more susceptible to contaminants and pollutants which may arise from warming climates. Increased pollen, outdoor contaminants from smog in towns and cities on hot still days, materials and furniture off-gassing VOCs in warmer environments may cause additional health problems for the occupants. Naturally ventilated buildings may also have to take measures in order to prevent the ingress of insects associated with warmer climates such as mosquitoes. An individual already under health stress will be more susceptible to the effects of overheating and heat stress.

As there is no way of assessing this using the UKCP09 data it is to be assumed that this could be an issue and measures have been investigated as part of the design process to mitigate its effects.

2.1.3 Building Type – 5 storeys

Overheating and Comfort

Due to planning and site constraints the base design was to be a high rise 5 storey building. The headlines from the European 2003 heat wave was that in Paris the majority of victims of overheating were those who were elderly, living in high rise apartments:

"Of the victims 92% lived alone and 41% resided in one room apartments...Just over half the victims lived on the 2 highest floors of Parisian buildings"[15]

This was recognised as a risk at the outset, as the scheme comprised of a high rise storey building. It was decided therefore to investigate further the nature of why these high rise apartments overheated so much, to ensure that any particular risk is designed out for this scheme.

Higher storeys in a typical multi-storey building are at risk of overheating due to increased solar gain through the roof and heat rising in a building. Therefore potentially the occupants at the top of the building will have an increased risk of exposure to overheating and unstable internal temperatures.

Upon investigation it was found that the buildings in the Paris heat wave were typical of the ageing building stock of Paris – mainly made of stone, brick and concrete, single glazed with little to no insulation. One of the key lessons learnt amongst many of other factors was that the 2003 heat wave affected the elderly population living in high rise poorly built and ageing apartment buildings in towns and cities the most.

The weaker the insulation and the higher the building the more at risk to overheating the occupants are at the higher storeys. Therefore the adaptation strategy needs to address this risk if it is found that current building regulations standards are insufficient to address it.

Weather Exposure Wind and Rain

The building, being 5 storeys in height and size, has an increased risk to changing wind and rain patterns.

Structurally the envelope of the building due to its height, shape and massing is at risk as a result of increased wind loadings. In addition elements such as gutters, window openings, roofing systems will need to consider increases in wind speeds beyond those detailed in the basic wind speed maps.

The building design again due to its height, shape and size is at risk as a result of increases in driving rain patterns beyond those detailed in the wind driven rain maps. Finishes to render and timber cladding systems, wall and construction types, and window reveals will need to consider these possible changes in wind driven rain patterns.

2.1.4 Wetter Winters / Drier Summers

It is currently predicted that whilst rainfall patterns will not increase over a typical year in the UK, summers are likely to be drier and winters are likely to be wetter. Normal collection of rainfall by conventional means to current Building Regulation Standards might be inadequate to cope with future severe rainfall events. Exeter University has provided predicted depths of daily rainfall data for the next 70 years (2080) and this suggests *"winter rainfall increasing by up to 54% and summer rainfall decreasing by up to 49% by the 2080s under the medium emissions scenario"*[11]. (Eames, 2010) This paper goes on to state:

"Some projections have indicated that while the total summer rainfall is decreasing, giving an increased potential for drought, the rainfall is concentrated into a few high intensity events. Hence, climate change could have a significant effect on future return periods of extreme rainfall events."[11]

2.1.5 Courtyard Garden Design

In order to meet the brief of providing sufficient accommodation and communal facilities, the constraints imposed by planning and site space and the requirement to provide pleasantly landscaped secure external spaces for people to cool down may lead to an enclosed courtyard garden design. The enclosed courtyard may trap the heat, and therefore unless carefully design may increase the risk of overheating.

The impact of more intense rainfall and greater depths of daily rainfall gives rise to the need to fully assess the raised flood risk which this particular development effectively generates by its enclosed layout.

'Climate change will have a strong influence on the return periods of extreme daily rainfall events but the event is highly dependent on the climate change scenario. The results show that a 1 in 100 year event as observed could become more like a 1 in 50 year event, a 1 in 50 year event could become more like a 1 in 20 year event by 2030 and a 1 in 20 year event could become a 1 in 10 year event by 2030.' (Eames, 2010)[11]

Droughts and Water Shortages

The predictions of drier summers may result in reduced availability of water for non essential human activities. Landscapes and plants and the cool external spaces may have to rely on other strategies such as water storage and attenuation devices and drought resilient plants. If external cool spaces and planting is a key strategy for reducing heat stress in dry summers, this is an important consideration with this aspect of the design.

Incorporating low water usage devices in buildings and reducing water consumption will also help with water storage levels across the UK.

2.1.6 Flooding

The southwest peninsula in particular where Exeter is located, is considered to be in one of the highest climate exposure zones for prevailing rain and wind speeds in the UK. Within a small region it also has a wide range of micro climates which potentially can produce very localised flood conditions. Exeter in particular is in the rain shadow of Dartmoor where over 2 metres average rainfall falls annually compared to 0.9 metres in Exeter. However, the flood risk to a large part of Exeter is considered significant, hence the EA have recently constructed a 2D hydraulic model of the potential flooding through its area to predict river flows for up to a 1 in 1000 year rainfall event. The digital terrain model of the catchment produces the latest generation of flood maps which are considered best information to date.

The building design as with any other building has a risk of future flooding due to climate change.

2.2 Climate Scenarios and Climate Data

2.2.1 Increased Temperatures

Various thermal modelling assessments carried out by Gale & Snowden Architects and Exeter University using IES and the Passivhaus Planning Package (PHPP) have used weather files that have been generated for the Exeter region by the Prometheus project at Exeter University. The Prometheus project using UKCP09 climate change projections has created a methodology for the creation of future weather files for a range of future time slices, emissions scenarios and probabilities.

All weather files used were based on the high carbon emissions scenarios (A1F1).

Weather files scenarios thermally assessed as part of the building design process are as follows:

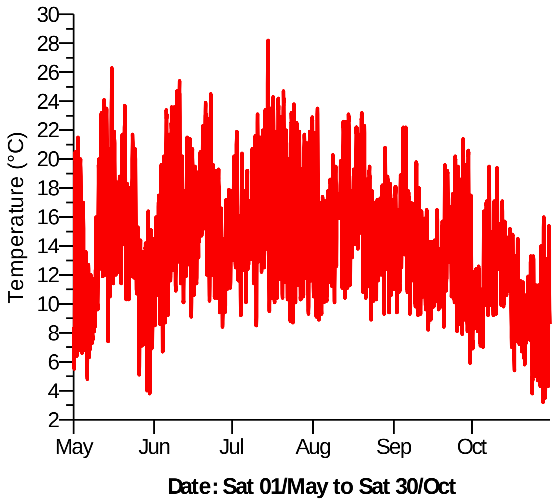
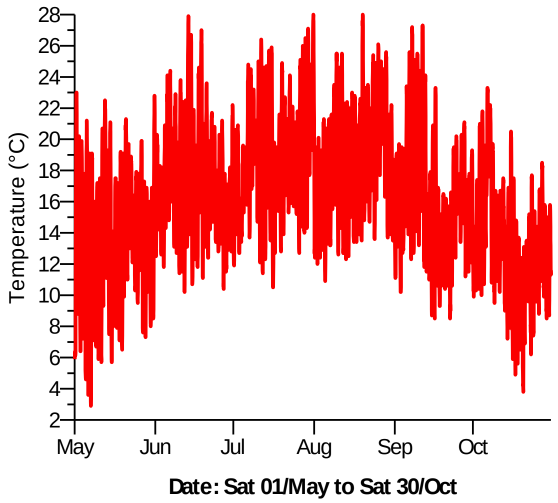
Scenario 1 – Exeter 1961-1991 DSY

Scenario 2 – Exeter 2030 DSY, 50% percentile (A1FI).

Scenario 3 – Exeter 2050 DSY, 50% percentile (A1FI).

Scenario 4 – Exeter 2080 DSY, 50% percentile (A1FI).

Figure 3: Current and future climate change external air temperatures

<table>
<tr><th>Scenario 1: Dry-bulb temperature Exeter 1961-1991 DSY</th><th>Scenario 2: Dry-bulb temperatures Exeter 2030 DSY 50%</th></tr>
<tr><td>
</td><td>
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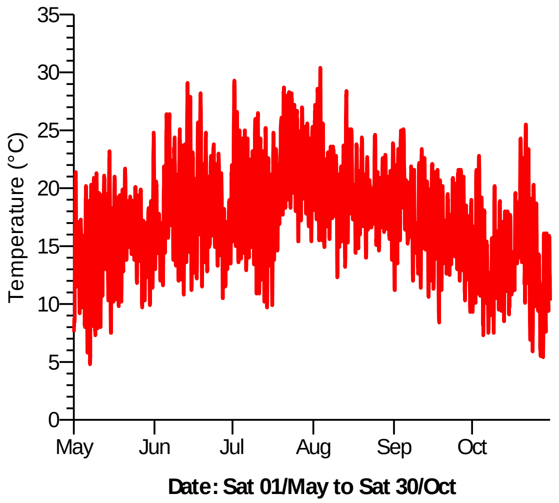
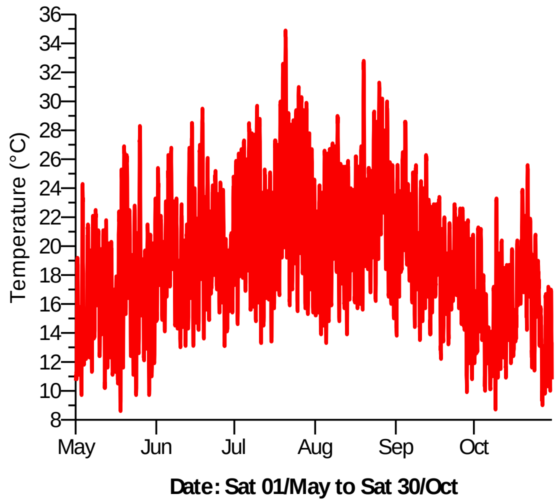
Scenario 3: Dry-bulb temperatures Exeter 2050 DSY 50%	Scenario 4: Dry-bulb temperatures Exeter 2080 DSY 50%
	

Initially it was thought by the design team that designing into a 2050 weather scenario would be sufficient as this would be 40 years into the future. However, it was decided by the design team that as the end users were in the high risk group to the effects of overheating to simulate into a 2080 scenario which took the design 70 years into the future representing a higher risk category. The 50^{th} percentile was chosen by the design team as it represented the median of the distribution of possible climate change. Further details can be found in the various thermal modelling reports to be found in the appendices. See Gale & Snowden Architects reports *‘St Loyes CCA Thermal Modelling - ExtraCare4Exeter’*[2] and *‘Rennes CCAThermal Modelling – ExtraCare4Exeter’*[1] in Appendix 4 for further details

2.2.2 Increased Wind Speed

It was discovered by the design team that there is uncertainty in predicting future wind patterns and no clear methodology to follow when designing for climate change adaptation to take account increased wind loadings.

Currently structural engineers use wind speed data taken from the ‘Basic Wind Speed Map – 1997’ as is detailed in BS 6399 Part 2 which provides wind speeds for various locations across the UK. No clear method has been detailed for future climate change.

Interpolating between the isopleths the data from the wind speed maps gives a basic wind speed for Exeter at 22.3 m/s. As part of the design process a higher figure of 23 m/s was used which increases wind pressure by 6%. In the design of structures, the pressures derived from the wind speed are increased by 20% to represent the ultimate limit state if acting with other imposed loads, or increased by 40% if acting alone.

Reviewing the equivalent map in the Euro code which is based on more extensive data, this gives a slight increase in wind speeds so that the 23 m/s isopleth is closer to Exeter. However if the building were to be designed to the Euro code the resulting wind pressures would be slightly less than is detailed in the British Standard.

In the absence of future wind speed data it was agreed that the slight overestimate of wind speed plus the 20 or 40% increase for structure design gives a buffer against wind speed increase due to climate change.

2.2.3 Increased Driving Rain

A similar method to asses wind loadings is used to determine driving rain patterns on building designs across the UK which is taken from the ‘Wind Driven Rain Map’. It was discovered by the design team that there is uncertainty in predicting future driving rain patterns and no clear methodology to follow when designing for climate change adaptation to take account changes in driving rain patterns.

The wind driven rain map puts Exeter in the 'severe' exposure zone of 56.5 to less than 100 litres/m^2 per spell. In the absence of future driving rain data it was agreed to design the building and its details to the 'very severe' exposure zone 100 or more litres/m^2 per spell.

2.2.4 Wetter Winters / Drier Summers

The prediction of wetter winters and drier summers has an element of uncertainty and is not clearly defined. Whilst methods have been developed to predict changing CO_2 and temperature patterns such as those developed by UKCP09 and Exeter Universities Prometheus project more work is required to provide prediction tools for changes in future rain patterns.

Return Periods of Extreme Events – Daily Data

A strategic flood risk assessment was carried out on the scheme based on Environment Agency (EA) flood maps. Due to the flood risks for Exeter the EA 2D hydraulic model of the potential flooding was used. In addition to this and in light of no clear industry guidance on climate change scenarios affecting flooding the return periods of extreme daily events as suggested by Exeter University were also investigated, detailed as follows:

1 in a 100 year event becomes a 1 in 50 year event,

1 in 50 year event becomes a 1 in 20 year event

Return Periods of Extreme Events – Hourly Data

There is more uncertainty in predicting hourly data than there is daily data.

Standard rainfall data issued from Met Office produces rainfall tables based upon National Grid Reference and are based upon rainfall durations and the rainfall intensities per hour. This is used to determine the Time of Concentration (TOC) of a catchment or development site to calculate the maximum flows generated by various rainfall return periods. Hence this current methodology is incompatible with the requirements of the future to cope with the expected changes in rainfall patterns and needs to be updated to cater for the extreme rainfall events based upon future depths of rainfall, either hourly or daily. This becomes particularly important where there is a drainage strategy involving site attenuation or certain Sustainable Urban Drainage Systems (SUDS).

What is needed is that the rainfall data is made fully comparable/compatible between the national historical observed data and that which can be confidently generated by climate change predictions to use the maximum perceived increase in rainfall as an allowance to allow for future climate change.

Alternatively, the methodology for calculating drainage systems needs to be overhauled and updated to ensure that both roof systems and underground systems are assessed on a different approach involving the potential daily depths of rainfall and not just maximum intensities.

The Extra Care Facility drainage strategy will also be a key influence to the type of landscape regime proposed to be used as this will very much impact upon the potential irrigation systems that would be needed to sustain the planting stock through the various and extreme weather conditions.

The Exeter University paper '*Changes in Extreme Rainfall Events Under Climate Change in Exeter*'[11] (Appendix 4) suggests as a rule of thumb to double the daily return period when designing drainage systems to take account the affects of climate change. This is the approach the design team adopted as part of the building design process.

Section 3: Building Physics

3.0 Building Physics

3.1 Introduction

This chapter describes the Climate Change Adaptation methodology used by the team to investigate the building physics of the design during the design process.

Due to the high risk identified, thermal comfort was decide to be the most pressing climate change issue that would need to be investigated by the team. This following section outlines the key Building Physics analysis for the project using both IES (Integrated Environmental systems) and PHPP (Passive House Planning Package) software.

Some of the key findings are detailed in this section and have been included here as they will help the reader to understand why certain climate change adaptation strategies have been adopted in the following chapter.

This following section details some of the highlights from the Gale & Snowden Architects CCA thermal modelling exercise. More detail can be found in the separate report *St Loyes CCA Thermal Modelling – ExtraCare4Exeter*[2] *(appendix 4)*

3.2 IES Analysis

Detailed modelling and future weather simulations were undertaken using IES software to investigate issues of overheating for the project.

3.2.1 Overheating criterion

For IES modelling the overheating criterion used was:

spaces not to exceed 25^{0}C for more than 1% of the time[16]

3.2.2 Keys areas assessed

The key areas assessed were:

- Single sided ventilation vs. cross flow ventilation
- Construction strategies – heavy weight, medium weight, light weight
- Passivhaus 'super' insulated and air tight envelope vs. standard UK building regulations (2006) envelope
- Intelligent ventilation control – windows closing when external air temperature is hotter than inside
- Solar shading strategies
- Relocation of heat gains and reducing them by locating plant external to the flats
- The role mechanical ventilation heat recovery (MVHR) can play to support passive ventilation strategies in a mixed mode approach
- The role of MVHR coupled with ground cooling

3.2.3 Initial IES Analysis

It was decided at early concept stages of design and thermal analysis that one of the simplest and most effective passive approaches would be to design out single sided ventilation and design the building to encourage cross flow ventilation in all of the flats. Early thermal modelling simulations concentrated on analysing singled side ventilation vs. cross flow ventilation. Figures 4-7 provide some of the results from these initial simulations. All weather files used are based on high emissions scenarios at 50th percentiles.

Flat ventilation input details:

- Flat 1 - full cross flow ventilation with opening restricted duct and windows
- Flat 2 - single sided ventilation
- Flat 3 - full cross flow ventilation restricted night ventilation
- Flat 4 - full cross flow ventilation with opening windows either side

All flats were insulated and made air tight to the Passivhaus standard – walls, floors, roofs approximate 0.1 U-Value W/m^{2}K. Infiltration rate of 0.6 ac/h at 50 Pa.

Further details of input parameters can be found in Gale and Snowden report 02 *St Loyes CCA Thermal Modelling – ExtraCare4Exeter*[2]

Figure 4 Percentage of hours internal temperatures exceed 25^{0}C in 2050 for different construction techniques.

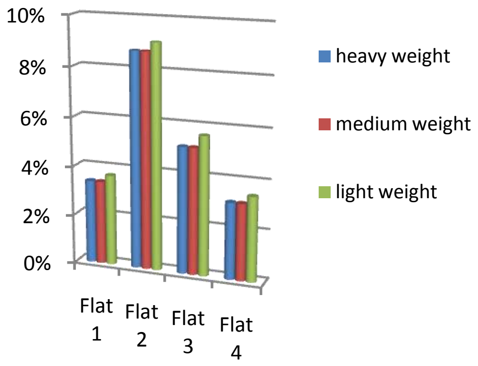


Figure 5 Peak internal temperatures in 2050 for different construction techniques.

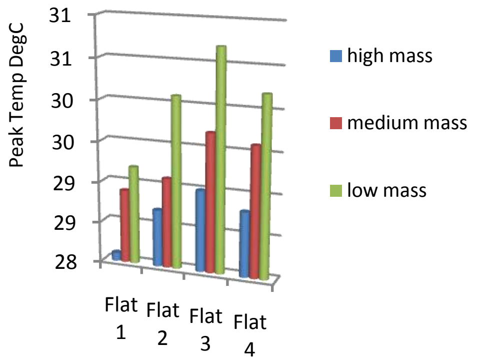


Figure 6 Percentage of hours internal temperatures exceed 25^{0}C in 2080 for different construction techniques.

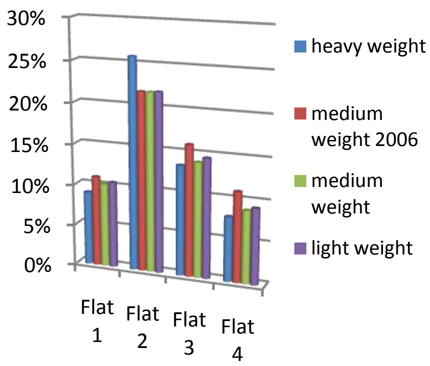
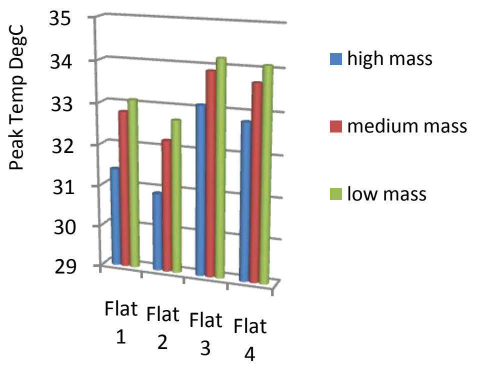


Figure 7 Peak internal temperatures in 2080.



Some of the conclusions of this initial analysis were:

- Single sided ventilation will not be an effective means for ventilating buildings for summer time overheating control in changing climates especially with heavy weight buildings. Overheating could be in the 22-26% region.

- Upper temperature limits are equally as important as number of hours exceeding a given temperature
- Sufficient ventilation is required for a heavy weight building to be considered more effective than a light weight building. The single sided heavyweight building performs worse than the other construction techniques when ventilation is limited and out performs the other constructions when cross flow is introduced.
- Night time ventilation is a crucial element in controlling overheating
- The best performing flats will still require further adaptation strategies to limit overheating
- In 2080 a comparison was made against standard Part L 2006 building regulations envelope detailed in figure 10 in red. It can be seen for flats 1, 3 and 4 that the passivhaus super insulated approach can be considered an effective adaptation overheating strategy when compared to standard building regulations envelope. The Passivhaus approach was found to be an effective means of maintaining comfort levels in changing climates during summer periods when compared to the standard building regulations approach. Better insulation, air tightness and the use of MVHR (for minimum fresh air during hot periods) all assist with better stability of internal temperatures by limiting both solar gain through the fabric and gains from external air temperatures. This appears to be contrary to the Technology Strategy Board's 'Design for Future climate Report', however it is supported by findings in warmer climates than the UK (Feist, 2005). The study tour in Cologne, Germany found several Passivhaus Extra Care Facilities in a climate that is similar to a UK future 2050 50th percentile high emissions scenario. The weather file for Cologne was obtained and compared with the UK 2050 one.

3.2.4 Detailed IES Analysis

As flats 1, 3 and 4 were still overheating in 2050 (3-5%) and in 2080 (7-10%) a more detailed assessment was carried out to determine effective adaptation strategies to limit the overheating.

Flat 4 with cross flow ventilation was identified as the flat to focus on for this more detailed study. CCA strategies simulated were as follows:

- Window opening either 5% free area or 10% free area when internal temperatures exceed 25^{0}C. A conservative opening area was included to allow for the unknown element of different user behaviour.
- Intelligent ventilation control where windows shut when external air temperatures are too hot and MVHR is enabled for minimum fresh air requirement
- Solar shading

Table 1: Simulated Scenarios for Flat 4

Scenario	Area of window open when Ti > 22^{0}C	Ventilation control when Te < Ti = windows shut MVHR on	Solar shading g-value
S1	5%	No	0.5
S2	10%	No	0.5
S3	5%	Yes	0.5
S4	10%	Yes	0.5
S5	5%	No	0.2
S6	10%	No	0.2
S7	5%	Yes	0.2
S8	10%	Yes	0.2

Ti – internal temperature, Te= external temperature

Figure 8 Percentage of hours internal temperatures exceed 25⁰C in 2050.

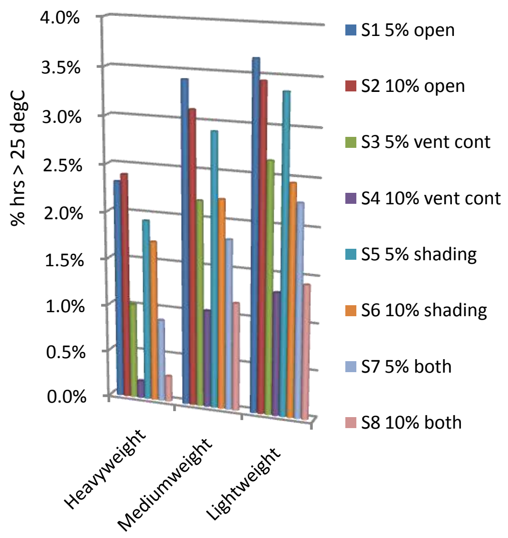
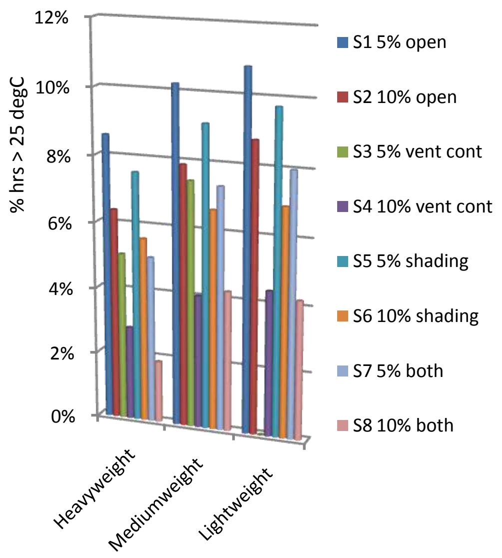


Figure 9 Percentage of hours internal temperatures exceed 25⁰C in 2080.



Some of the key conclusions of this detailed analysis were:

- The most effective strategy after cross flow ventilation is intelligent ventilation control. Closing windows and enabling the MVHR system when external air temperatures are hotter than inside across all construction techniques can reduce overheating by approximately 2% in 2050 and 4% in 2080.
- By adopting intelligent window control as an adaptation strategy also makes the MVHR system an adaptation strategy as this will provide minimum fresh air provision when windows are closed.
- Provided that there is sufficient ventilation i.e. windows are opened and night cooling is enabled a heavyweight building meets the overheating criteria in 2050 and only slightly exceeds it in 2080.
- The results from IES found that shading appears to be the least effective overheating strategy and it is suspected this is because of how perfectly IES simulates ventilation control. When solar gain enters the window the simulation responds in window opening and ventilation control accordingly in response to the gain. In essence the ventilation modelling is too perfect at removing the effect of solar gain in order for the impact of solar shading to be assessed realistically. In addition there might be periods when windows remain closed by occupants or ventilation is limited due to poor user control. Due to this solar shading is still to be considered an effective overheating strategy. When assessing overheating using the PHPP solar shading was found to be more effective than IES gave credit for. Passivhaus Institute *in-situ* studies on domestic buildings in Germany have found that occupants do not open windows to provide the air change rates as is suggested in dynamic simulation software. In most measurements air change rates have been below one air change per hour[25].

3.2.5 Further IES Analysis

Further analysis was then carried out to look into the importance of limiting internal gains and the impact ground cooling could have linked into the supply air of the MVHR system.

So far simulations have concentrated on internal gains in the region of 5 W/m^2. In some flats this figure could be higher depending on the equipment used and building services equipment leaking heat in summer such as pipes, hot water cylinders and boilers. It was therefore decided to increase internal gains to assess this impact to 10 W/m^2 and compare to the 5W/m^2 analysis. Figure 10 provides details of this analysis.

Figure 11 details how the MVHR system will perform when compared to a naturally ventilated flat with shading and ventilation control for a lightweight building in 2080. Pre-cooling from the ground for the MVHR system can be either by an underground air duct or a ground to brine piped heat exchanger. Manufacturer's technical data sheets for the piped system stated that external air temperatures could be reduced by up to 15^{0}C during summer periods. For the purpose of this analysis it was decided to simulate with a more conservative 5^{0}C reduction and 10^{0}C reduction.

The simulation scenarios represented in Figure 11are as follows:

Table 2: Simulated scenarios for MVHR and ground cooling

Scenario	Controlled natural vent & shading	Pre-cooling Temperature condition	MVHR cooling on Temperature condition
1	100%	-	-
2	Ti<25^{0}C	Te - 5^{0}C	Ti>25^{0}C
3	Ti<25^{0}C	Te - 10^{0}C	Ti>25^{0}C
4	Ti<22^{0}C	Te - 5^{0}C	Ti>22^{0}C
5	Ti<22^{0}C	Te - 10^{0}C	Ti>22^{0}C

Ti – internal temperature, Te= external temperature

Note: When MVHR is not on in cooling mode natural ventilation is enabled.

Figure 10 - % of hours Ti > 25^{0}C in 2080 for different internal gains

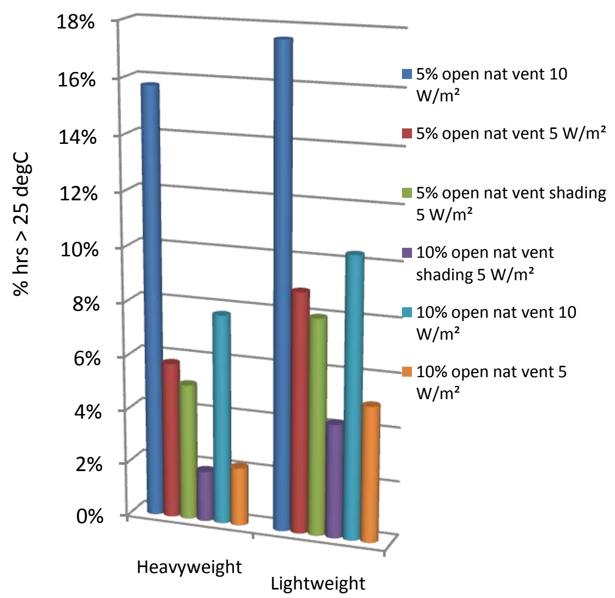
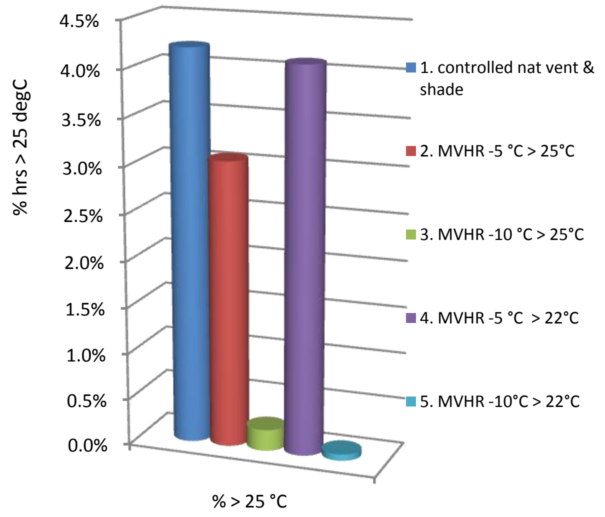


Figure 11 - % of hours Ti > 25^{0}C in 2080.



3.2.6 Conclusions of IES analysis

Some of the conclusions of this initial analysis were:

Limiting internal gains

Internal gains and intelligent control of them in changing future climates will be an important adaptation strategy in any building. Doubling the internal gains results in a 10% addition to overheating for a naturally ventilated scenario that assumes a 5% window opening. This is for both the heavyweight and light weight building. Figure 10 details various comparisons: 5% opening, 10% opening and with or without shading. In all scenarios there is significant uplift when the internal gains are increased which is to be as expected.

Internal gains can be reduced by implementing the following adaptation strategies:

- Switching equipment off during heat waves
- Limiting hot cooking and in the care facility encourage the use of the cafe
- Purchasing and encouraging the use of energy efficient A++ rated equipment

The following adaptation measures can also reduce internal gains.

- The use of the MVHR system to extract heat at source
- A centralised hot water system linked into plate heat exchanger technology system. The heat exchanger would be located at the entrance of the flat. This would reduce standing losses from hot water pipework in the flats and standing losses associated with hot water cylinders.

The impact of ground cooling

The main finding was that the ground cooling coupled into the supply air of the MVHR system is very effective at reducing levels of overheating within acceptable limits even at an air change rate of 0.5 air changes per hour. This is provided sufficient ‘coolth’ can be obtained from the ground to produce a 10^{0}C temperature drop off the incoming supply air temperature.

3.2.7 Heat Stress Modelling

Building overheating and the associated health implications are becoming an increasing concern especially for vulnerable groups such as the elderly or infirm. Where the environment (in terms of air temperature radiant temperature, humidity, air velocity clothing and activity) provides a tendency for heat storage, the body’s thermoregulatory system responds to attempt to increase heat loss. This response can be effective at removing stored heat but can also incur a strain on the body (and sufficient heat may not be removed), which can become unacceptable and eventually lead to heat illness and death. The work presented in appendix 4 *“A Study of Possible Heat Stress as a Result of Climatic Change in the St Loyes Care Home”*[10] presents an analysis of possible heat stress on the care home occupants. The methodology is based upon the international standard ISO-7933; however heat stress analysis is usually associated with miners and factory workers who work in constant conditions. Therefore a new dynamic version of the heat stress calculation had to be devised by the University of Exeter to allow for changing environmental conditions.

The analysis shows that design of the building and the levels of occupancy, heat gains and ventilation indicate that an average healthy person should not be at risk of harmful heat stress. However, it is known that the elderly can exhibit a more pronounced response to elevated temperatures that is not accounted for in ISO 7933. The effects of disabilities or infirmness are also not well understood and are not accounted for in the model. Therefore the analysis should be treated as a lower estimate of possible heat stress and that staff remain vigilant and take measures to rehydrate and cool occupants as necessary during warm periods particularly for the more at risk inhabitants.

3.2.8 Green Roof and External Planting Modelling

The building thermal model was adapted to incorporate a representation of green roofs and courtyard planting. The model was adapted such that the plants within the courtyard area cooled the surrounding air and cool the adjoining rooms. Further details can be found in the report "*A Study of the Impacts of External Planting on the St LoyesCare Home*"[9]. It was found that the courtyard was unsuitable for the creation of a microclimate and the cooling power of the plants had little effect on internal air temperatures. This was likely due to the dimensions of the courtyard and the relatively high average wind speeds experienced in the South West of the UK. It should be noted however, that while plants were unable to actively cool the air they still provide shade for the building façade making the building and courtyard area cooler than if it were just an open paved space. The magnitude of this effect is ~3°C compared to just open space, further details can be found in appendix "*A First Look At The Effects Of Outdoor Planting On The Indoor Environment of St. Loyes Residence*"[8].

Green roofs were found to be suitable as a climate change adaptation. The effectiveness of the green roof at cooling the room below was found to be dependent on the air speed above the surface of the roof as this would remove the coolth. Air speed above a surface varies with height and the roughness of the surface for this reason it is *hard* to estimate exactly how effective the green roof would be so a range of values were chosen. The effectiveness of the green roof varied hour by hour as the wind speed and direction varies with no noticeable effect on windy days. On a still day when the cooling will be most effective the green roof as modelled was found to reduce temperatures in the room below by between 0.5-8°C. It is unlikely that a green roof will be able to cool an adjacent room by 8°C but the range of values produced highlights that more research is required in this area to fully understand how the cooling power of the roof is transferred to the internal spaces. Once more information is available this new methodology can be used to investigate the use of green roofs as an adaptation option for building designs.

3.3 PHPP Analysis

The building design has been modelled using the Passivhaus Planning Package (PHPP). A detailed report is available with the findings of this analysis - *St Loyes CCA PHPP Thermal Pre-Assessment – ExtraCare4Exeter*[4].

The PHPP is a design tool allowing designers to assess and calculate the energy demand for low energy buildings. It was developed using dynamic simulations that were then validated by monitoring results of completed Passivhauses over the last 20 years. The PHPP which uses a different methodology and algorithms to IES stipulates for spaces not to exceed 25^{0}C for 10% of the time.

The main conclusions were:

All three construction methods will result in Passivhaus compliant designs for *space heating demand, primary energy demand* and *overheating* when modelled with the current weather file and without a requirement for additional shading.

The heavy weight construction without additional shading performs better with regards to overheating and will result in a lower daily temperature swing from solar gains than the light weight or medium weight approach.

The effect from devices that control solar gains in summer and also adequate ventilation appear to have a greater impact on reducing overheating in summer than thermal mass.

If a successful strategy to control solar gains in summer can be implemented (e.g. overhangs and/or shutters) then a natural ventilation strategy via opening windows is sufficient to limit overheating in summer to acceptable levels for all four weather scenarios and independent from the method of construction.

This analysis arrived at a slightly different conclusion to the IES analysis suggesting that solar shading is more effective at reducing internal gains than the IES analysis gives credit for. The PHPP methodology inputs a more conservative natural ventilation air change rate which is said to be based on in-field studies on occupant behaviour in the continent and how often and how wide they open windows in a domestic situation. It is possible that the IES methodology is too perfect at ventilation opening control for a domestic situation.

More research is required in the UK into occupant behaviour and window opening control in domestic situations as has been carried out on the continent. This will help realistically inform thermal modelling inputs for domestic window opening in a UK context.

Another area where more research is required is that of future wind speeds. Wind speed data and direction is based on what has been observed by the Met office in the UK historically. Assumptions have been made that the UK will receive similar weather patterns in the future as has been observed in the past. However the change in wind speed as a result of climate change is not clearly understood. If wind speed data is based on what has been recorded historically then this does not include many days above a future climate change scenario of for example 30^{0}C. More work is required in this area to ensure thermal modelling D4FC design work is resilient and takes account of increases in wind speed and decreases if necessary. This is especially so if thermally modelling for passive ventilation strategies and ensuring fixtures, fittings and details on buildings are sufficiently robust.

3.4 Conclusion

The building physics investigations undertaken in this Chapter at the outset of the project were key to guiding the design process as outlined in the following chapter. By employing sound building physics using industry standard tools the team has been able to underpin the climate change adaptation strategies adopted for this project.

Section 4: The Design Process

4.0 The Design Process

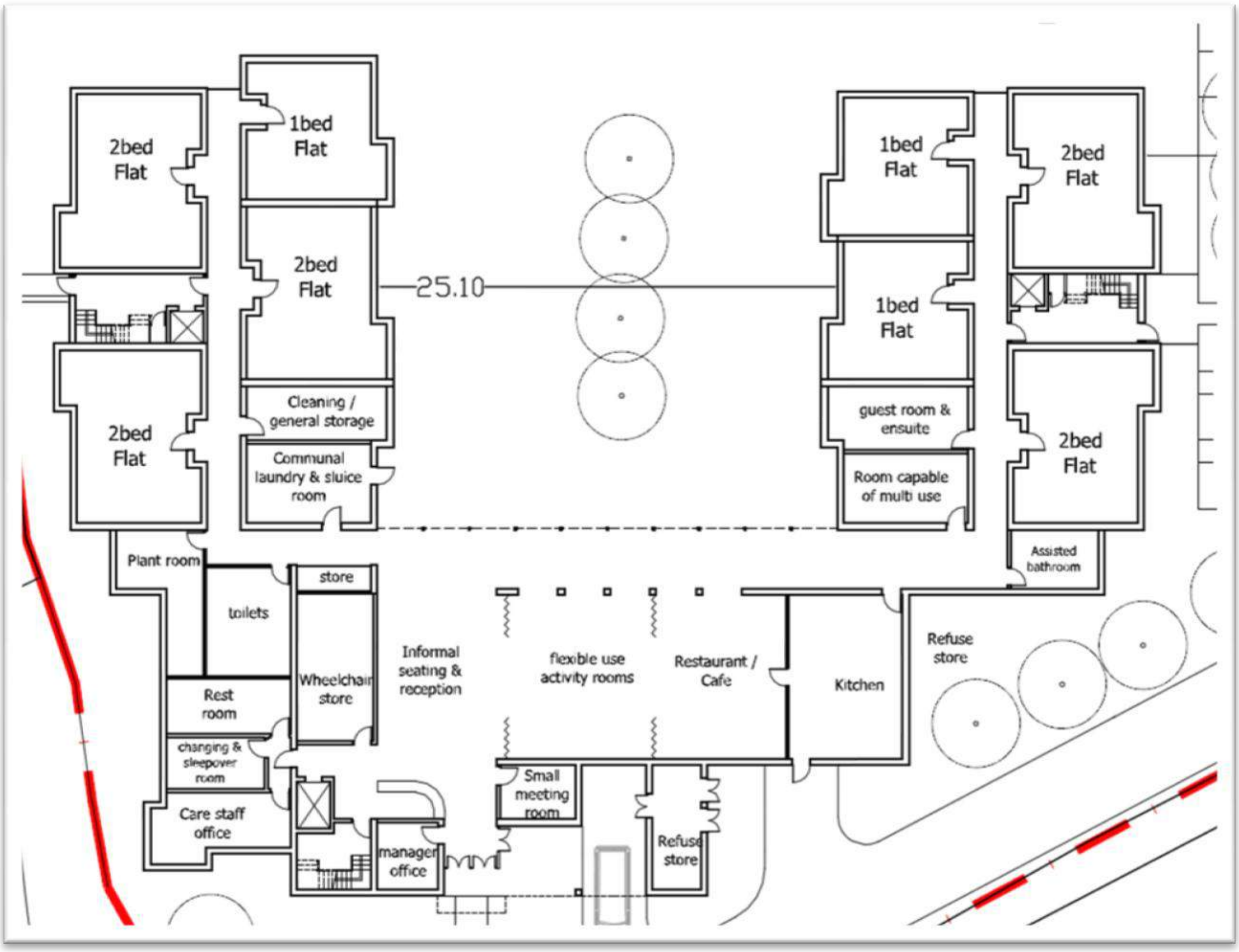
The following section describes how the thermal modelling influenced the design of the building in order to address future overheating by passive design means.

4.1 Outline Planning Application Design

The team inherited a design that has been undertaken by the previous developer of the site in order to gain outline planning permission. This courtyard design was based around a central internal corridor. The central corridor has the following disadvantages associated with it:

- Institutional in its design and feel
- With long artificially lit central access corridors which enforces the institutional look
- Single sided ventilated which limits its capacity to keep interiors cool and well ventilated
- Has dark interior spaces with no windows on one elevation and poor daylight levels
- Has poorly laid out communal areas which limit access
- External spaces and how they integrate with the building are not clearly defined
- Lack of planting and green spaces
- Shading of internal and external spaces

Fig 12: Outline planning application design as submitted by previous developer of the site



The following image is taken from a 3D shading analysis exercise as part of the analysis of the existing site and the outline planning application scheme. This analysis showed that large areas of the buildings elevations and the courtyard arrangement would be in shade. The shading was caused by the design of the new care facilities itself and would have a detrimental effect on the quality of the courtyard space from the building users i.e. it would be in shade most of the year. This orientation did not work well for Passivhaus solar gains needed in the winter months.

Figure 13 Drawing Taken from Shading 3D Analysis of the Outline Planning Application Design. The Shading in this Example is taken for 21st Dec at 1.00pm.

Appendix 1 provides further details

Following this shading exercise it was decided to develop a design that would open the building up to solar gains in the summer and prevailing summer winds to the South West thus creating a secure space in front of the building that could be usable by the building occupants.

4.2 Design Progression

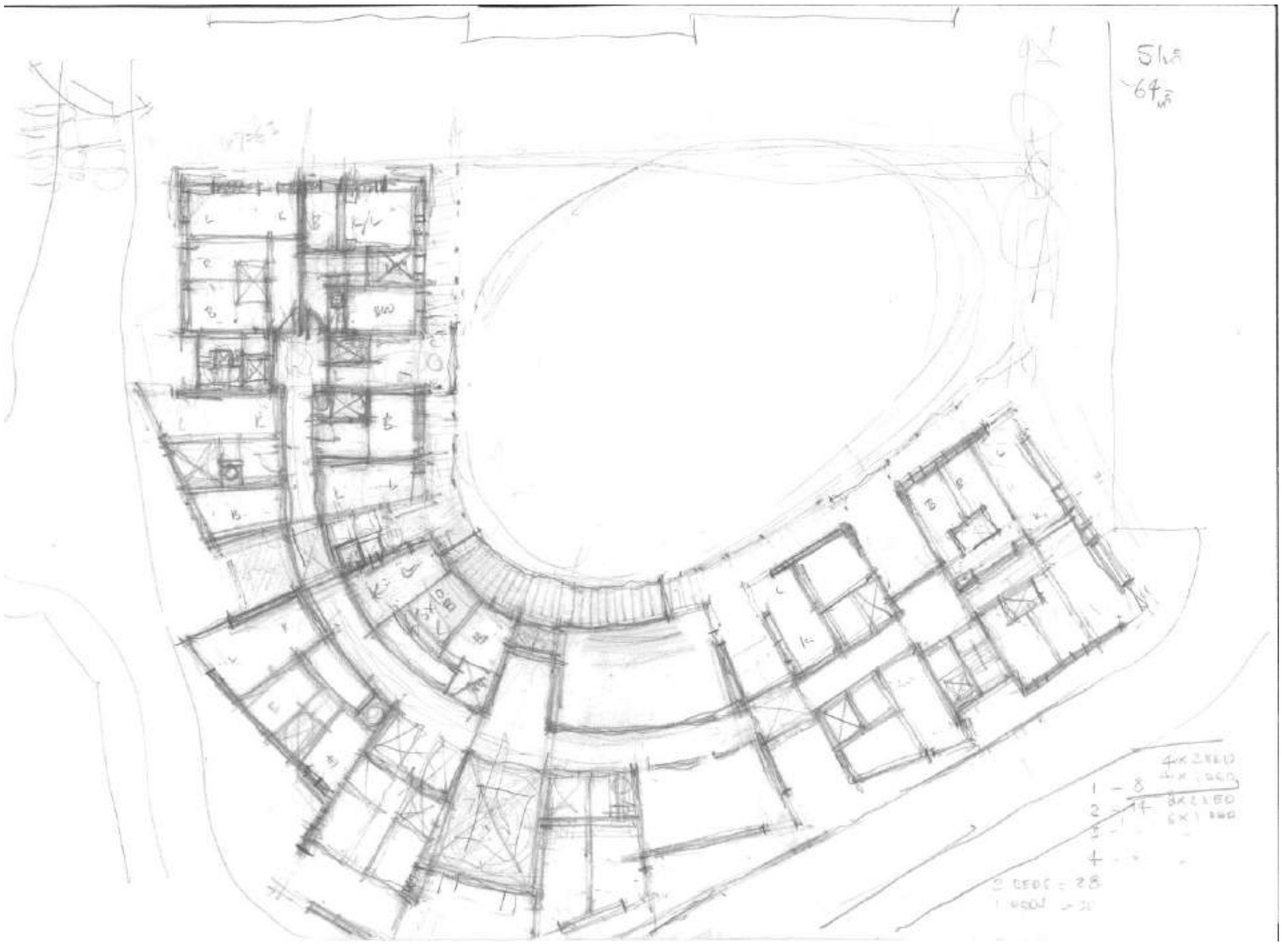
The following figure details one of the early design concepts as part of the initial design development prior to the thermal modelling outputs. An approach with central corridor with singled sided ventilation can be seen.

At this stage it became apparent from the thermal modelling simulations that a single sided ventilated building would not be a robust strategy for coping with overheating in warming climates due to the heat build up in the south and west facing rooms without cross ventilation. More detailed information can be found in the following Gale & Snowden Architects Reports.

1. Rennes CCA Thermal Modelling – ExtraCare4Exeter[1]
2. St Loyes CCA Thermal Modelling – ExtraCare4Exeter[2]
3. St Loyes CCA PHPP Thermal Pre-Assessment – ExtraCare4Exeter[3]

The results of these simulations led to a rethink of the design approach to the building to incorporate not only a building design that was healthier and a better place to be in but also one that had an improved ventilation strategy.

Figure 14 Early Concept Sketch Design with Central Corridor Arrangement which was dismissed following the initial results of thermal modelling using the future weather data



The central corridor approach was therefore dismissed as both the IES modelling and PHPP initial analysis with future climate files showed single sided ventilation would result in overheating of the building.

The new concept design had the following advantages:

- Each flat could achieve a degree of cross flow ventilation to help reduce overheating
- The flats were orientated so that some of the bedrooms were located on relatively cooler northern façades and livings rooms on southern facades.
- The scale of the building could be broken down to three smaller clusters or vertical communities
- The removal of a central corridor helped to reduce the institutional feel
- Each flat has a view onto the green spaces of the secure courtyard and turf roof of the single storey element and into the main communal activity spaces, helping to avoid the feeling of loneliness that some care facilities engender by having flats looking onto blank walls or such like.

Figure 15 Early concept sketch design with cross flow ventilation strategy with three 'clusters' or 'vertical communities' which was influenced by the Climate Change Adaptation strategy work. Note the first cross flow ventilation sketch section sketch towards the bottom left hand side of the drawing. The building has been separated into three clusters or vertical communities with shared facilities. The main communal facilities, entrance and care staff accommodation is now a single storey building set in the gardens but linked to the residential three residential clusters.

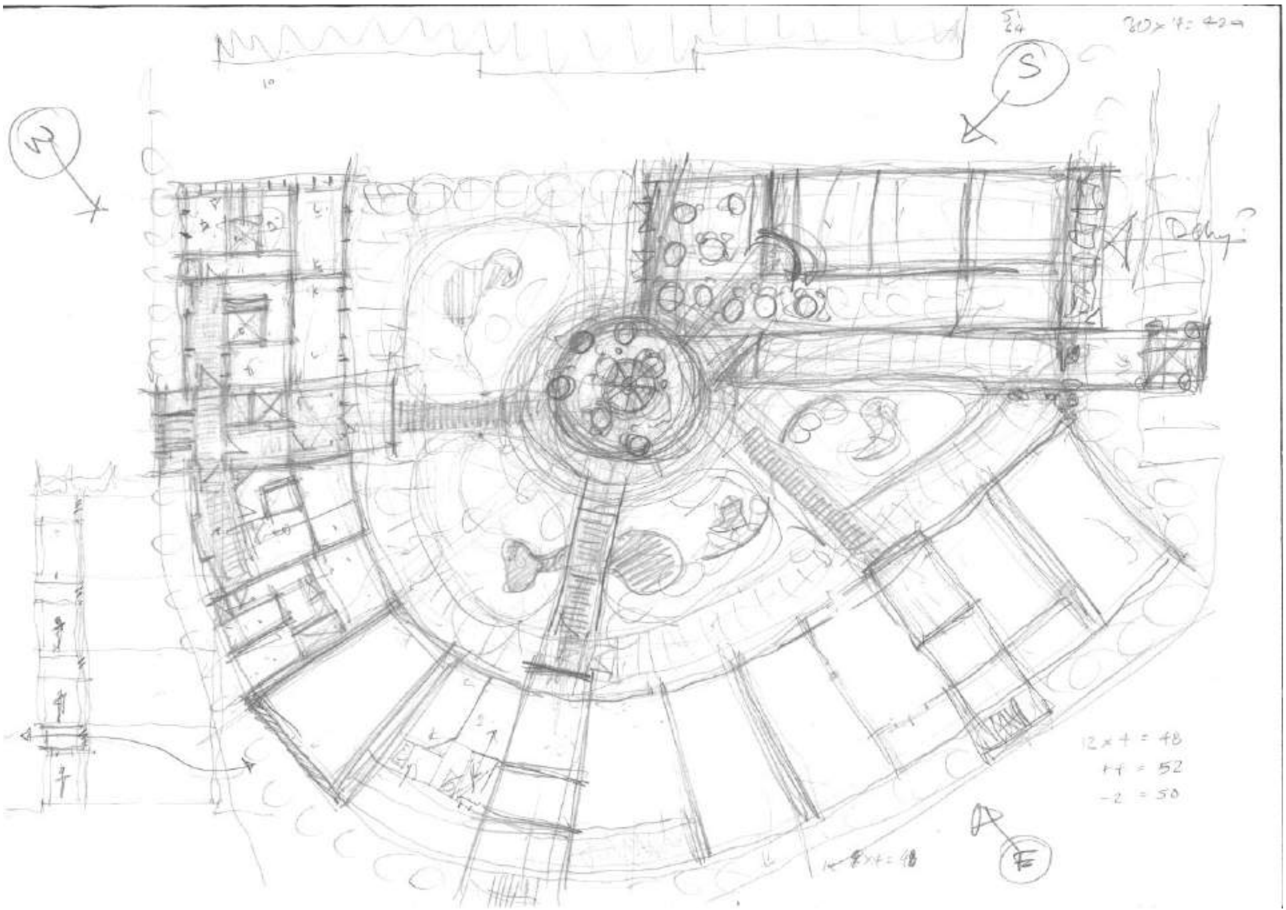
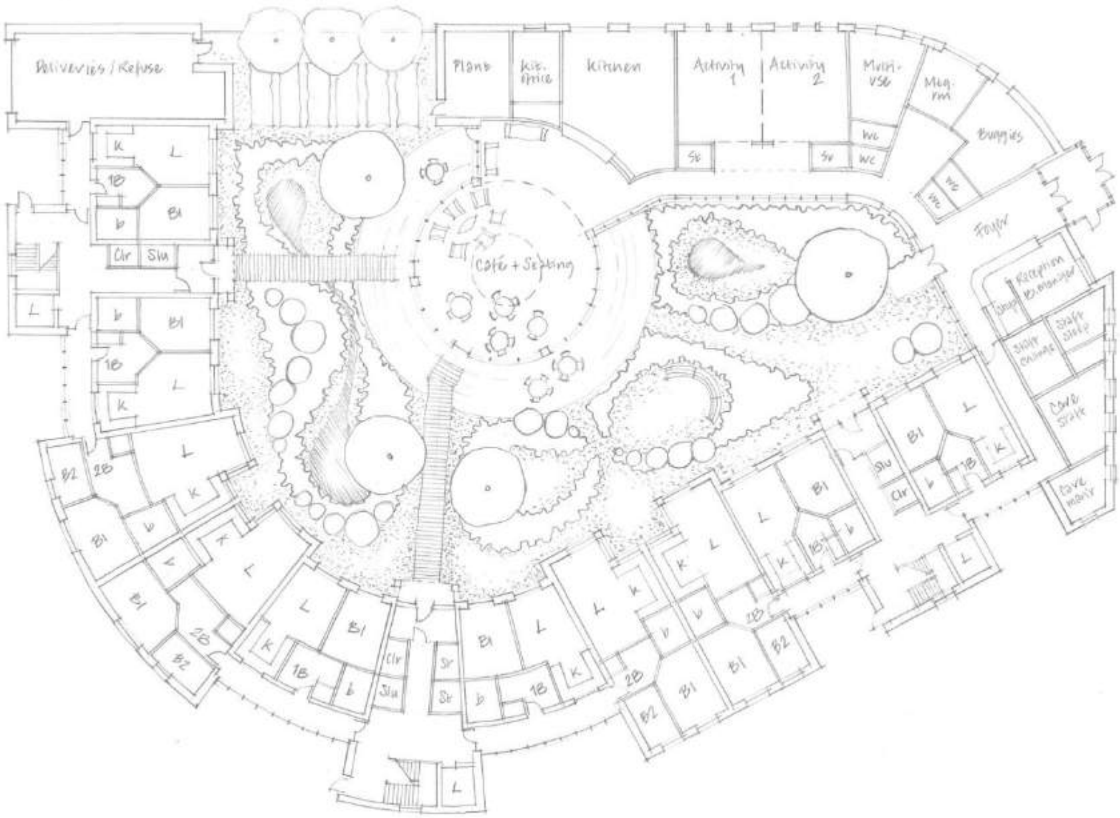


Figure 16 Drawing taken from shading 3D analysis of the initial cross flow ventilation design. The shading in this example is taken for 21st Dec at 1.00pm.

Figure 17 The development of cross flow ventilation approach. The three self contained 'Clusters' or 'Vertical Communities' approach enabling the building to be broken down in scale and avoid the institutional feeling that a central corridor approach results in.



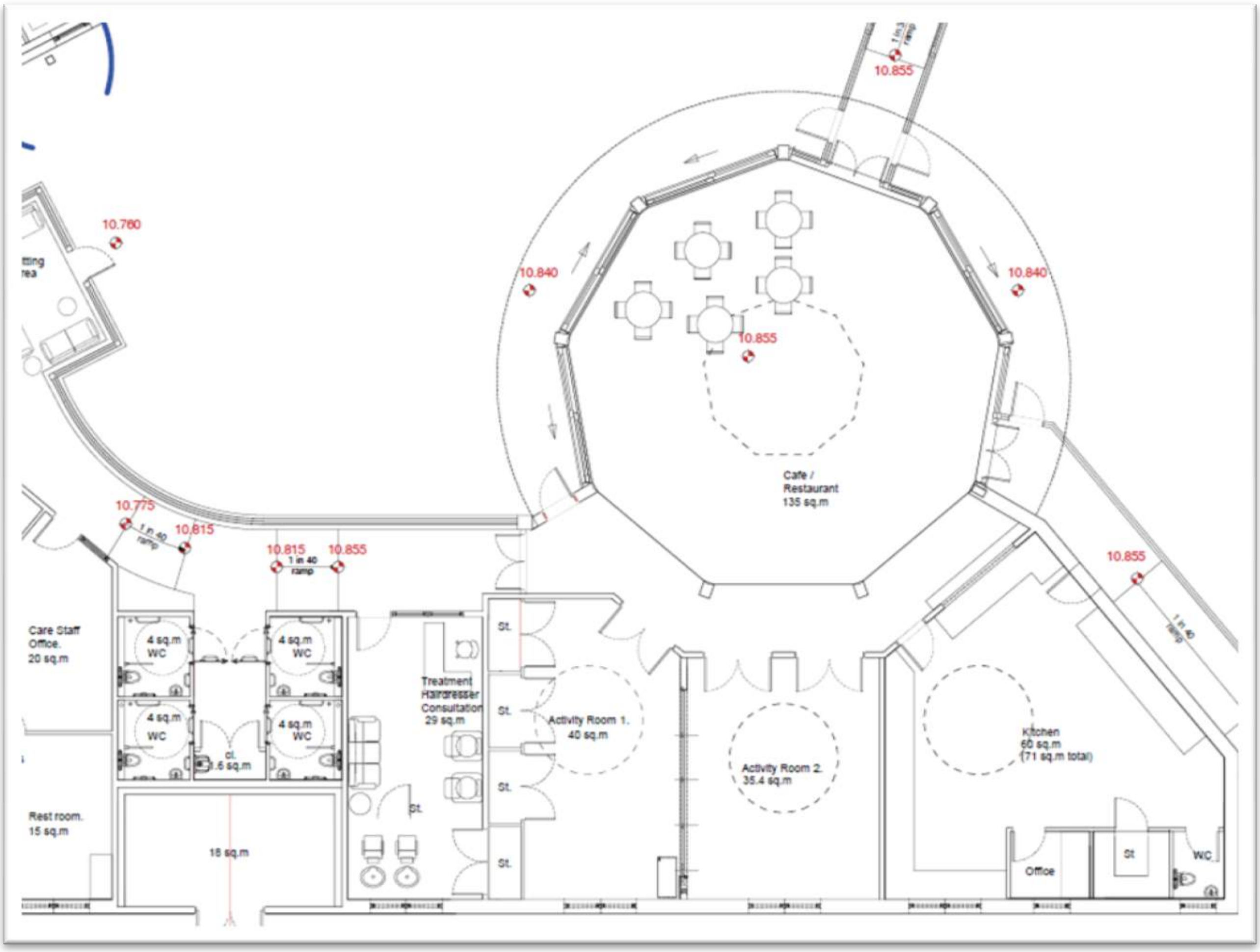
4.3 The Community Building and Cafe and Cluster Approach

After the heat wave in Paris 2003 various studies were carried out as to the causes. One study[15] cited the fact that a certain percentage of the individuals were isolated and not part of a social network or community and this was a contributing factor. Belonging to a community not only has a positive effect on an individual's mentality and general well being but also networks people together to support each other during times of crisis. With no social network individuals remained isolated and secluded from the rest of society suffering the effects of overheating alone. Whilst this is an Extra Care Facility and it is expected that carers will be monitoring the occupants, there will still be health and psychological benefits to designing the scheme with a community and cafe at the heart of the building. The cafe and community building has been designed to form part of the landscape which then also links by access walkways into the flat areas. The cafe is also designed to open up to the outer environment to merge with the external green spaces thus increasing a connection with nature when conditions are favourable. All the flats have been designed to view into the cafe and community space. Both the cafe and community activity rooms have also been designed with roof glazing systems so that people can see various activities taking place from their flats, so that residents in their flats do not have to feel that they are alone or isolated.

In addition to this the 50 flats have been broken down into 3 'clusters' or 'vertical communities' that break down the scale of the building, in effect helping to de-institutionalise the building; each with their own entrance, communal laundry rooms and shared lounge areas. This creates smaller groups within the larger community so that individuals can make social connections within smaller family scale groupings.

The emphasis here as an adaptation strategy is to create a building that can create a sense of community with its architecture and space layout so that occupants do not be become isolated in their individual flats and a greater sense of well being is created.

Figure 18 St Loyes Design Drawings Community Cafe and Communal Space



4.4 Permaculture Designed Landscape and Building Integrated Design

The design of the site follows Permaculture design principles and provides an integrated landscape design that links the main building with community building and central cafe.

"Permaculture offers a radical approach to food production and urban renewal, water, energy and pollution. It integrates ecology, landscape, organic gardening, architecture and agro-forestry in creating a rich and sustainable way of living. It uses appropriate technology giving high yields for low energy inputs, achieving a resource of great diversity and stability. The design principles are equally applicable to both urban and rural dwellers" Bill Mollison

A species specialist was employed as part of this process to ensure the optimum mix of plant species was included for, taking into account the occupants and effects of climate change.

Planting and landscaping were to provide cooler external spaces for people to relax enjoy and keep cool when conditions are favourable. Research has found that plants can have a positive effect on the health and well being of individuals. Studies carried out by Fjeld 2002[22] found that less stress was reported with office workers who had a view out to plants and green areas compared to those whose window view consisted of non green spaces. The same carried out in hospitals, offices and schools and all found a 21-45% decrease in health complaints with the introduction of plants.

The landscape and enclosed garden area was also designed to take into account drought and flood risk, which is covered in more detail in later sections and in the following Gale & Snowden Architects report:

05.’Landscape Design Response to Climate Change at St Loyes – ExtraCare4Exeter’[5]

An additional report by Gale & Snowden Architects also provides details on the health benefits of plants for the occupants as a CCA strategy:

06. ‘Plants and Green Spaces - their effects on health and wellbeing at St Loyes - ExtraCare4Exeter’[6]

The external landscape area and planting was seen as a key adaptation strategy in order to maintain health, physically and psychologically, and in turn reduce the risk of heat stress and provide spaces for occupants to cool down in.

In addition the enclosed garden / courtyard area was designed to provide a secure means for occupants to open windows during the day and at night for night cooling. The care home and enclosed garden is to be managed 24 hours a day by care staff and will not be accessible to outsiders unless on visiting the occupants.

It was found via thermal modelling and CFD analysis *(see paper 09 The Thermal Impacts of External Planting on the St Loyes Care Home by Exeter University – Appendix 4)*[9] that the green roof system does have some cooling potential on spaces below with the potential to lower temperatures as much as 4-5^{0}C.

Figure 19 St Loyes Extra Care Landscape and Ground Floor Plan

Figure 20 St Loyes South Elevation Drawings

Figure 21 St Loyes Extra Care Facility 3D Design Exploration Drawing

Details of further concepts designs can be found in Appendix 1.

Section 5: Adaptation Strategy

5.0 Adaptation Strategy – Comfort

5.1 Introduction

To address the risks identified, three strategy groups have been identified to provide comfortable internal temperatures for users:

- Passive strategies – developed at the outset of the design process to identify strategies that can be readily incorporated into the design of the building for example by ways of massing, orientation, building fabric and layout. These measures can be best included at the outset and as part of the building concept design.
- Active strategies - once passive design strategies have been optimised, building mechanical systems can be identified that work in consort with the passive strategies.
- Management strategies - building and user management strategies have been identified that ensure that the first two strategies can operate optimally. If the Passive and Active strategies are termed the 'hardware' for climate change adaptation, the building and user management strategies could be termed the 'software' to enable the hardware to work effectively.

The following sections will detail these strategies and discuss the thermal modelling that was used to assess the effectiveness of both the passive design adaptation strategies and mechanical systems recommended. All adaptation strategies detailed herein are based on technology available today.

5.2 Comfort - Passive CCA Strategies Identified

The following passive adaptation strategies have been identified to enable the vulnerable user groups to best achieve optimal comfort levels:

- Cross flow ventilation design
  - Actuated window system to shut down in the event of a fire.
  - Enclosed secure courtyard design provides secure means for occupants to open windows and ventilate during the day and at night.
- Passivhaus super-insulated and air tight envelope, compact design
- Heavyweight construction
- Minimise internal heat loads
- Cooling effect of external spaces including green roofs and courtyard planting
- Solar shading

5.2.1 Cross Ventilation

Flats to be designed to allow cross ventilation between the northern and southern facades. This involves redesigning the flat layouts and removing internal corridors. In some instances actuated window systems to shut down in the event of a fire will be required.

Enclosed courtyard design provides secure means for occupants to open windows and ventilate during the day and at night. The facility is to be managed by care staff and no access will be allowed into the courtyard area to outsiders

5.2.2 Passivhaus super-insulated and air tight envelope

The Passivhaus approach maximises the buildings energy efficiency and is sufficiently insulated, compact, solar orientated and air tight to ensure in winter the heat load is no more than 15 kwh/m^2/yr and that solar gain is limited during the summer. For this scheme this will be achieved by adhering to the following Uvalues

– walls 0.13 W/m^{2}K, roof 0.11 W/m^{2}K, floor 0.11 W/m^{2}K, and triple glazing minimum Uvlaue 1.0 W/m^{2}K. In addition to this air tightness to be in the region of 0.6 ac/h at 50 Pa to reduce unwanted infiltration both in summer and during winter. By adhering to these principles in a future climate scenario at peak external temperatures the Passivhaus approach is sufficient together with adequate ventilation strategies. Ventilation would consist of natural day and night time ventilation and at times using the MVHR system in summer bypass mode. This will ensure that internal temperatures are stabilised below 25^{o}C and external heat gains are limited. This is illustrated further in section 3.5 and 3.6. These finding are reinforced by Passivhaus design across Europe in climates warmer that the UK that have not only been designed in this manner but have been monitored to establish their comfort performance across the seasons.

5.2.3. Heavyweight Construction

The future climate files show that at the warmest periods in the summer months in 2080 there is a reduction in temperature at night-time. This temperature reduction can be made use of if a building has been design with thermal mass and ventilation for night-time cooling. The inclusion of thermal mass will contribute to a degree of internal temperature stability.

Figure 22 External Day and Night Temperatures in 2080

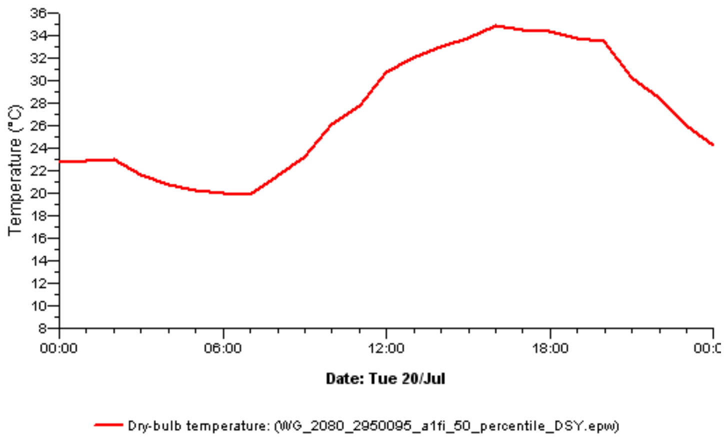


Figure 22 shows an extreme hot day in 2080 with a significant temperature drop at night. No periods were found in the 2080 50th percentile weather file where day and night temperatures remain the same. No extreme heat waves were evident in this weather file.

The following heavy weight construction is recommended to enable night time cooling and day time heat adsorption:

- dense block work walls with external wall insulation
- solid internal render and plaster to exposed walls
- solid concrete floors
- solid floor finishes
- the avoidance of plasterboard, carpets etc in order to reduce decoupling from the buildings thermal mass

5.2.4 Minimise Internal Heat Loads

Minimising internal heat loads have been adopted so that internal heat gains are kept to a minimum when external temperatures are high. Heat loads have been minimised by including energy efficient lighting, maximising natural day light levels; relocating heating and hot water plant to a centralised plant room, encouraging the use of energy efficient appliances and reducing cooking at high temperatures during hot periods.

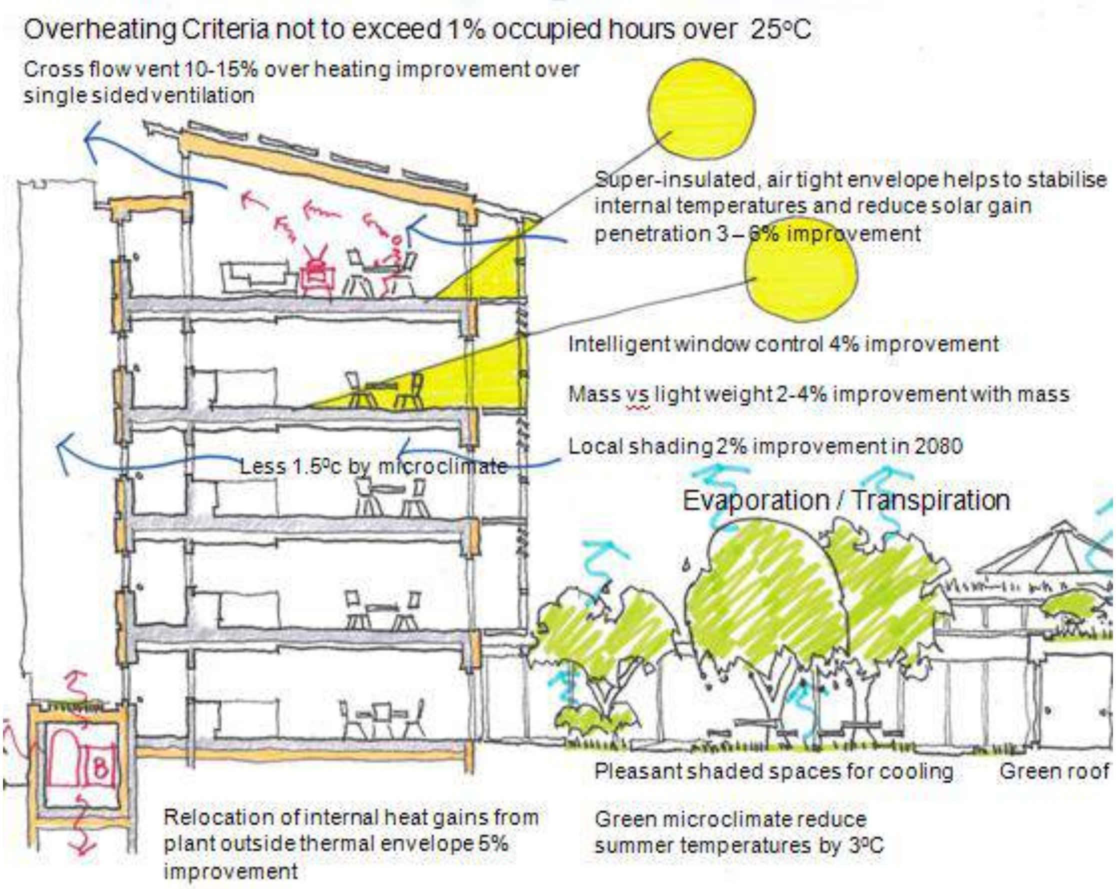
5.2.5 Landscape, Green Roof and Courtyard Design

To provide local green spaces for users to cool down in and relax in – plants and trees will provide shading and cooling via evapo-transpiration. A green roof has been investigated for the community building and in areas of the main residential building and, as well as reducing run off, may be able to reduce the internal temperature of the building below. See also section 5.8.2 and 5.9 for further landscape design strategies.

5.2.6 Solar Shading

Solar shading has been identified as an adaptation method strategy that can be included as part of a future window replacement strategy, specifying triple glazed units with internal blinds in the mid panes. The trigger to invest in this strategy would be at the end of the windows' useful life. For a robust triple glazed unit this would be every 20-25 years. Hence, the second generation of windows are likely to be replaced during the time period 2050-2060.

Figure 23 Summary of Passive Design CCA Strategies Identified for this Scheme



5.3 Comfort - People Centred Strategies Identified

The following people care management strategies have been indentified to enable user groups to maximise the passive and active strategies for the building and to best achieve optimal comfort:

- Energy awareness and heat stress awareness and training
- Monitoring of internal temperatures by occupants and staff
- Cool drinking points
- Room ceiling fans
- Reduce heat generating activities

5.3.1 Energy Awareness and Heat Stress Awareness and Training

For the residents the spacing heating system in their flat is very simple to use. The controls have been designed to be as simple as possible. There will be one dial in the living room that will control the air temperature within the flat. The sophistication comes with opening and closing the windows optimally in the winter and summer months to ensure that the natural ventilation is assisting and not opposing the comfort levels.

Buildings that are designed with natural ventilation as the prime overheating strategy often overheat in use. A key factor contributing to this is that the people using the building even immediately after hand over do not understand what type of building they have and how to optimise its comfort conditions. This is likely to be emphasised all the more when operating buildings in 25 years time. **Ongoing training** will be required for care workers as well as maintenance staff as it will be the care workers who will need to engage with natural ventilation systems when visiting occupants in their flats. **Building manuals and simple user guides** will also be kept fully up to date.

It is recommended that:

- Residents receive specific advice on how to maintain the optimum temperature in their flat when they first move in, to be supported by an easy to understand information pack about their flat.
- During hot periods residents receive ongoing advice and information on heat stress and how this can be reduced, e.g. adequate drinking, loose and light clothing, window ventilation, etc.
- Carers and maintenance staff receive regular training on how to maintain the optimum temperature in the flats and in the rest of the building, to be supported by easy to understand manuals. This training would also include general energy efficiency advice and how to provide energy efficiency advice to the residents.
- Carers and maintenance staff provide ongoing advice to residents on how to operate their heating, ventilation and cooling system as required, as part of their day-to-day responsibilities.
- Staff at the extra care facility to receive specific training on heat stress management in the run up to the summer period.

5.3.2 Monitoring of Internal Temperatures by Occupants and Staff

The human body is not always good at warning us when we are under thermal stress. Therefore it is recommended that simple temperature displays should be provided for each flat at the outset in easy to read locations, so that the occupants are able to see the temperature of their surroundings on a regular and frequent basis and respond as necessary. Staff would also be able to see the temperature displays when visiting the occupants.

It is recommended that a more sophisticated wall mounted temperature warning system is installed in 2030 to encourage better use of natural ventilation strategies and also inform occupants when to shut windows and enable MVHR if external air temperatures are hotter than inside.

It then recommended to install a centralised monitoring system in 2060 that could be linked into the Telecare system (see section 5.4.3). Simple monitoring of internal space temperatures by staff can highlight any issues of overheating at an early stage and also identify any ‘problem’ flats which are repeatedly overheating. Staff can then assess what is causing the overheating and advise accordingly. For example overheating could be caused by ventilation control issues, excessive internal gains due to equipment, poor understanding of how to ventilate and cool the flat, or the occupant might be too sick to manage independently.

5.3.3 Cool Drinking Points

In the paper on Heat Stress Modelling *(see paper A Study of Possible Heat Stress as a Result of Climatic Change in the St Loyes Care Home by Exeter University*[10]*)* it is highlighted that the elderly tend to drink less than younger people and as thirst is not a very good indicator of when to drink water, encouraging better drinking habits and fluid intake on warmer days would be a beneficial strategy. One adaptation strategy to take account of this is to install cool water drinking points around the building in all the communal areas. This is to ensure fluid intake and is to be installed now as part of this design process and not at a future date.

5.3.4 Room Ceiling Fans

It is recommended that room ceiling fans be introduced in the future so as to aid cooling of the building occupants by encouraging air flow over the people to increase skin evaporation and therefore cooling, Electrical wires can be included at the initial build stage ready to take fans when they are required in the future.

5.3.5 Reduce Heat Generating Activities

It is recommended that during a heat wave heat generating activities, such as cooking, tumble drying and ironing are kept to a minimum in the individual flats. Occupants requiring a cooked meal would be encouraged to use the café which is located in a separate building from flats.

5.4 Comfort - Active CCA Strategies Identified

Active strategies were considered after both passive and people centred strategies

The following CCA active strategies were identified to respond to the risk of future overheating of the building occupants;

- MVHR system (Mechanical Ventilation Heat Recovery)
- Early warning temperature system
- Early warning temperature and monitoring system
- Ground cooling system

5.4.1 MVHR System

The MVHR system can assist with night cooling in summer, can ensure minimum fresh air requirements during hot still days and when windows close due to high external air temperatures, and can assist with pollution free ventilation

5.4.2 Early Warning Temperature System

This would consist of a wall mounted temperature warning system to encourage better use of natural ventilation strategies and also inform occupants when to shut windows and enable MVHR if external air temperatures are hotter than side.

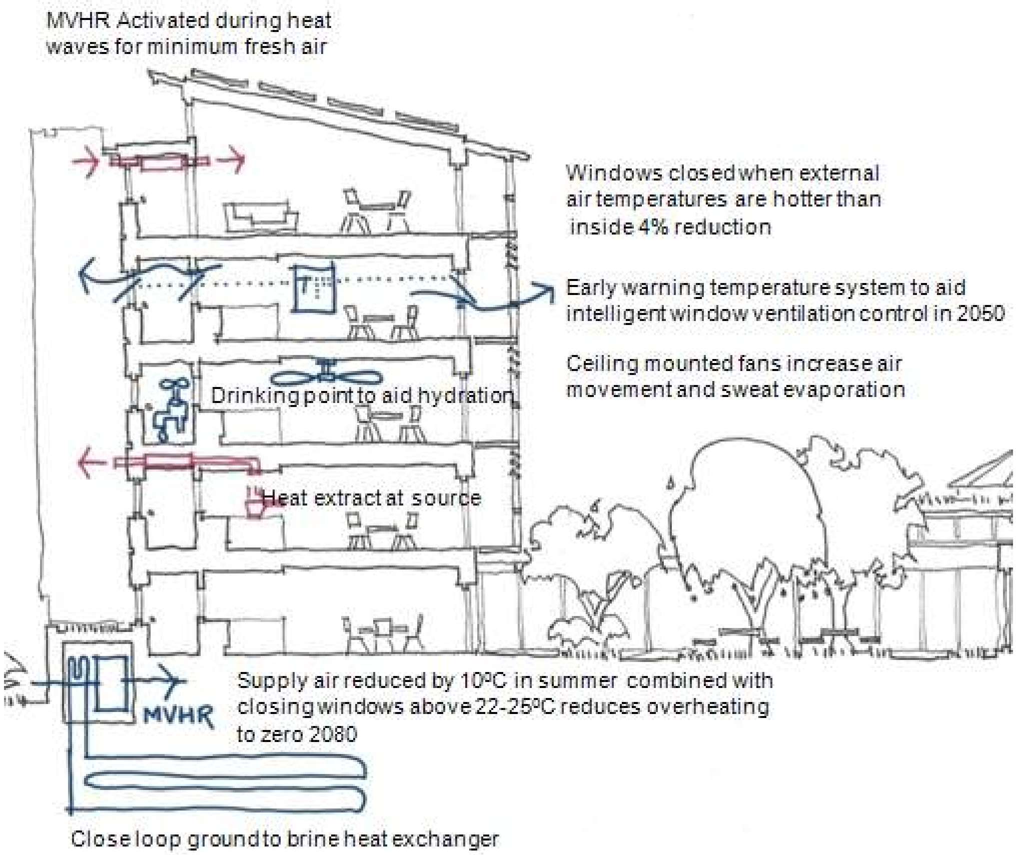
5.4.3 Early Warning Temperature and Monitoring System

This is a more sophisticated early warning temperature and monitoring system that can link into the infrastructure of the Telecare system. As well as encouraging optimum ventilation habits it will also enables staff to monitor flats to determine which ones are having problems

5.4.4 Ground Cooling System

This has been investigated and consists of a ground to pipe heat exchanger linking into the supply air of the MVHR unit. A pump enables coolth to be pulled out of the ground when external temperatures are above a set limit.

Figure 24 Summary of Active CCA Design Strategies Identified for this Scheme



5.5 Comfort - Indoor air quality CCA Strategies Identified

The following details the CCA pollution strategies adopted or considered an option for this scheme:

- MVHR system to filter pollutants
- Plants to modify internal air quality
- Insect nets

5.5.1 MVHR System to Filter Pollutants

It is likely that rising temperatures will cause a rise in pollen counts and particulates in the air. Particulates in the air increase as temperatures rise and wind speeds drop producing Smog. There is also likely to be an increase in VOC offgasing as temperature rise from surrounding materials. The MVHR system can be used to filter out pollen and particulates when required and remove VOCs (Volatile Organic Compounds such as formaldehyde in glues) as well as removing CO_2.

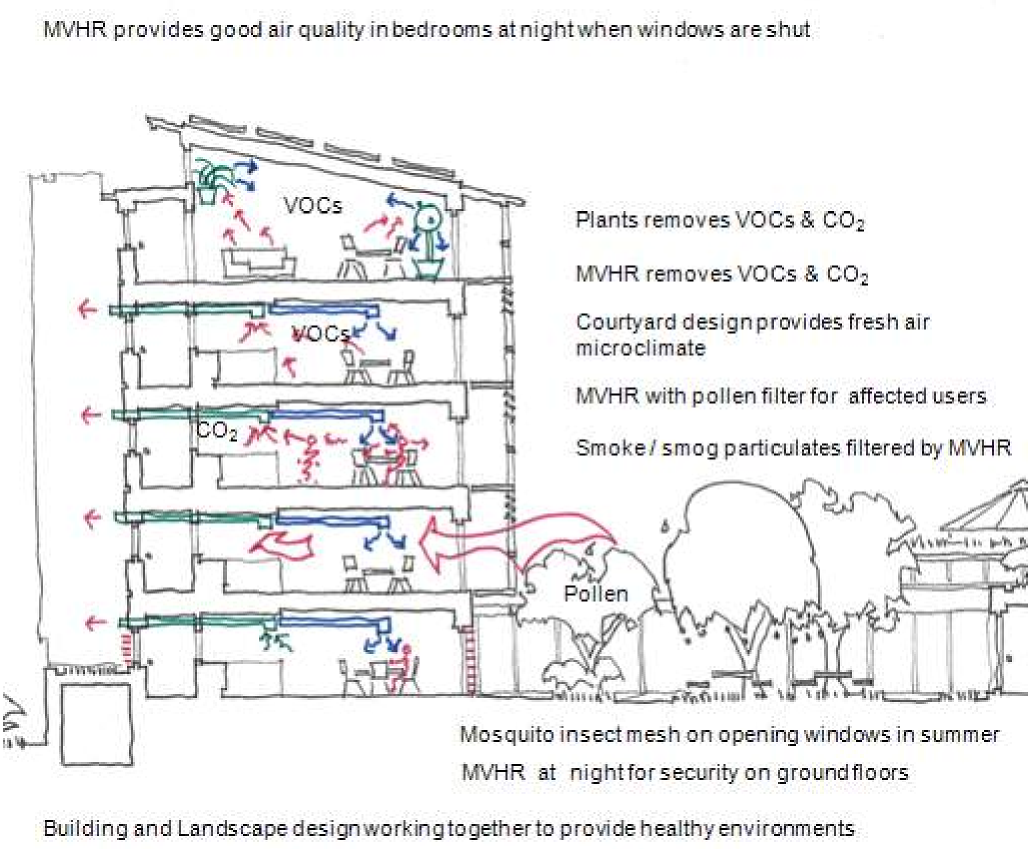
5.5.2 Plants to Modify Internal Air Quality

From research undertaken by Bill Wolverton at NASA[39] it can be seen that one of the beneficial affects of introducing plants into internal spaces is the removal of VOCs from the surrounding air.

5.5.3 Insect Protection

It is likely that insects will be more plentiful in a warmer climate as can be seen now on the continent. It is recommended that in the future protection such as netting to openings, especially in individual flats, are introduced as part of the adaptation strategy for the building. The timing of this strategy will be dependent on the degree of nuisance that occurs. The air tight building strategy should also contribute to the reduction of possible entrances for insects.

Figure 25 Summary of CCA Air Quality Strategy



This diagram illustrates the active role the MVHR system can have at helping to address pollution from outside and inside. As well as providing minimum fresh air the MVHR can also pre-filter particulates and pollen that could be entering from external sources.

5.6 Construction – CCA Strategies Identified

It was previously highlighted in section 2.2.2 that in the absence of clear future wind speed guidance, to design elements of the building to take account of a windspeed of 23 m/s which increases wind pressure by 6%.

In the absence of future driving rain data it was highlighted in section 2.2.3 to design the building and its details to the 'very severe' exposure zone 100 or more litres/m^2 per spell.

The following CCA strategies are recommended:

- External walls - enhancing the EIFS system to sever weather rating
- Windows and doors – severe weather rating
- Roof – robust material and fixing specification

5.7 External Walls

The main building strategy adopted for scheme to help deal with future wind speeds and changes in driving rains patterns is to apply a proprietary external insulation finishing system (EIFS). A particular system has been investigated for its appropriate use in changing UK climates. This system is the StoTherm system. StoTherm systems are frequently used in countries where weather conditions far exceed those ever likely to be experienced in the UK.

It was recommended by the supplier that the following is designed in with the EIFS system:

- Stooled ends be incorporated into any cills,
- Overhangs such as parapet cappings, cills, etc. are a minimum of 35mm forward of the face of the render with a vertical leg of at least 40mm (for cills) or 75mm for cappings.
- Utilize a silicone resin based render finish. Silicone render finishes have a high silicone resin content within the binder, and this serves to give the render hydrophobic properties.

The resistance to wind suction of the EIFS system is not expressed in relation to the site wind speed, but to the negative pressures (suction) created by the vortices that occur, mainly at the building extremities. All StoTherm systems have been tested in relation to wind suction.

The EIFS system proposed has been tested to the standard "CWCT Standard Test Method for Building Envelopes 2005 for Wind Resistance", and has then been further testing to ultimate failure. The CWCT standard calls for a general safety factor of 1.5, whereas the proposed EIFS has a safety factor of 3 imposed for systems fixed by mechanical means and a safety factor of 9 for those systems fixed by adhesive means.

The EIFS system in question has been tested and adhesively fixed where the ultimate failure load is in excess of -95 kN/m² (without the use of supplementary mechanical fixings), thereby providing a safe working wind suction load of -10.68 kN/m². In the UK, it is unusual for wind suction values to exceed -3.5 kN/m² with maximum gusts unlikely to exceed -4 kN/m². Therefore, taking a worst-case scenario wind suction of say -4.5 kN/m² applied against the ultimate failure load for the EIFS adhesively fixed system of -96.16 kN/m², the actual factor of safety achieved would be just over 21.

Discussions with suppliers and manufacturers found that there were no noticeable additional costs with these approaches.

5.7.1 Windows and Doors

Windows and doors have been identified that will be able to resist severe weather rating. They have been specified to be Passivhaus compliant and therefore are robust both thermally and for air tightness.

5.7.2 Roof

The roof to the single story element of the building is designed to be constructed from timber with a Green roof system. The roof of the 5 storey element is also of timber construction but roof covering has been specified as sheet metal profile with robust fixings to eaves and verge.

5.8 Water Management and Landscape – CCA Strategies Identified

A strategic flood risk assessment was carried out on the scheme. In light of no clear industry guidance as highlighted in section 3.4.3 the return periods of extreme daily events as suggested by Exeter University were used, detailed as follows:

1 in a 100 year event becomes a 1 in 50 year event,

1 in 50 year event becomes a 1 in 20 year event

It was also highlighted in section 3.4.3 that there is more uncertainty in predicting hourly data than there is daily data.

The following strategies have been recommended:

- Gutters, downpipes and drainage
- Landscape design for water
- Planting and landscape design

5.8.1 Gutters, Down Pipes, Drainage

Sizing of gutters and down pipes is carried out in accordance with Building Regulations Approved Document H3 section 1. This states in diagram 1 rainfall intensities for the design of gutters and downpipes (l/s/m^2) and for the Exeter region it is 0.02 l/s/m^2. Table 2 with the roof area being approximately 900m^2 suggests using a gutter size of 150mm half round in conjunction with 9 x90mm down pipes would be sufficient to discharge peak flow rates from the roof. It was decided to increase this capacity by approximately 50% in the absence of clear guidelines by utilising 250x200 box section gutter in conjunction with 15 x 100mm downpipes.

Removal of all the rain water away from site in pipe work was part of the legal land sale agreement for this site. However, as part of the climate change discussions, it was considered that this would not be beneficial to the soils within the courtyard which would dry out and in time increase pressure to irrigate planting. Therefore rain water collection and management was considered diverting water into a series of storage crates allowing water to percolate into soil with excess stored in deep crate to allow reuse to planted areas in times of need. See drainage drawing 65804/100/4 which details this strategy. Costs are detailed in the *St Loyes Cost Report*[13]

5.8.2 Landscape Design for Water

Changes in climate will result in different rainfall patterns, more extreme rainfall events, and summer 35-50% drier with more consecutive dry days. Plants need water. The potential to harvest and recycle rainwater for use in ponds or to irrigate plants, as part of the SUD and water management approach has been considered.

The landscape and garden area has been designed to take into account future drought and flood risks. The full details of this D4FC strategy can be found in the Gale & Snowden Architects Report:

05. Landscape Design Response to Climate Change at St Loyes – ExtraCare4Exeter[5]

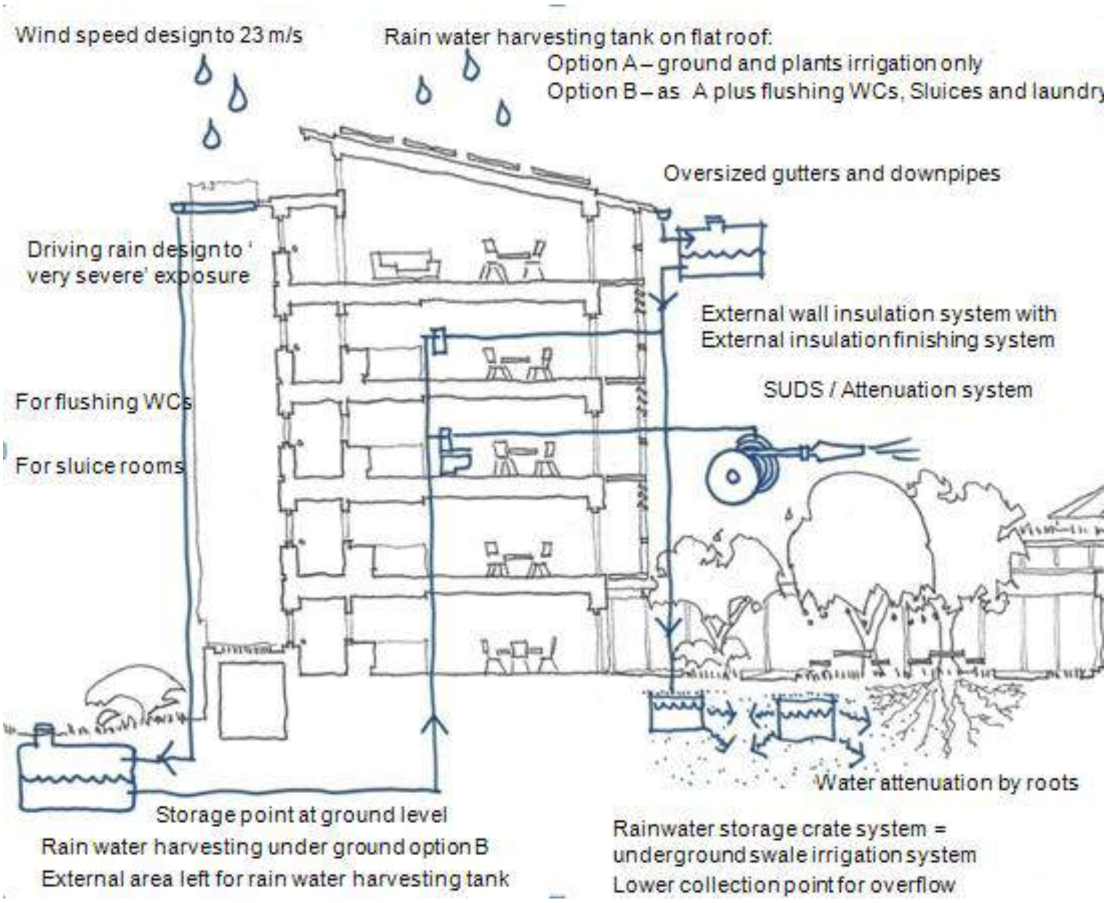
The courtyard is enclosed by buildings. The inward sloping roofs creates a potential to accentuate flooding within the courtyard. The direction of the roof pitch is architecturally important. Therefore discussions considered a number of solutions, to reduce the amount of flow of water into the courtyard, especially in extreme conditions.

A green roof is proposed on the single storey building, with most of its downpipes located to take runoff away from the courtyard. The green roof will reduce runoff and control flow. Rain water collection from the main building will be collected in oversized gutters, with the possibility of diverting excess water in extreme events to the back of building to reduce concentration in enclosed courtyard. Permeable paving allows water to percolate to soils and areas are laid to falls to centre of courtyard, with some beds laid with shallow dip to centre to act as small planted swales. The runoff from the roof and excess from the courtyard will be collected and stored in a sequence of underground drainage crates. The green roof would primarily consist of a 70-200mm deep substrate with a mix of sedum, herb and grasses. The benefits it will provide are:

- 50-60% reduction in annual surface runoff and reduce peak flow rate.
- Evapo-transpiration will provide cooler surfaces that will impact on the air quality and cooler internal temperatures
- Visually the roof will increase the amount of green space visible from the flats, having psychological benefits to occupants.

On the southern and eastern side of the single storey building, a planted swale or concrete channel to collect and attenuate roof water from the green roof and a portion of the main roof was considered. This would provide an attractive habitat, reduce runoff, and manage more extreme events when green roof are less able to cope. However the tight nature of the site meant there was not adequate space to make it feasible in this project.

Figure 26 Summary of Water Management CCA Design Strategies Identified



5.8.3 Planting and Landscape Design

External spaces need to be considered in a holistic way meeting the varying challenges of change in climate. Increased temperature will increase the role of external space as places to escape the heat; change in rainfall patterns and more intense rainfall will lead to external spaces providing for water management; longer growing seasons and warmer climates provide opportunities for food production:

The external design for St Loyes has been developed to:

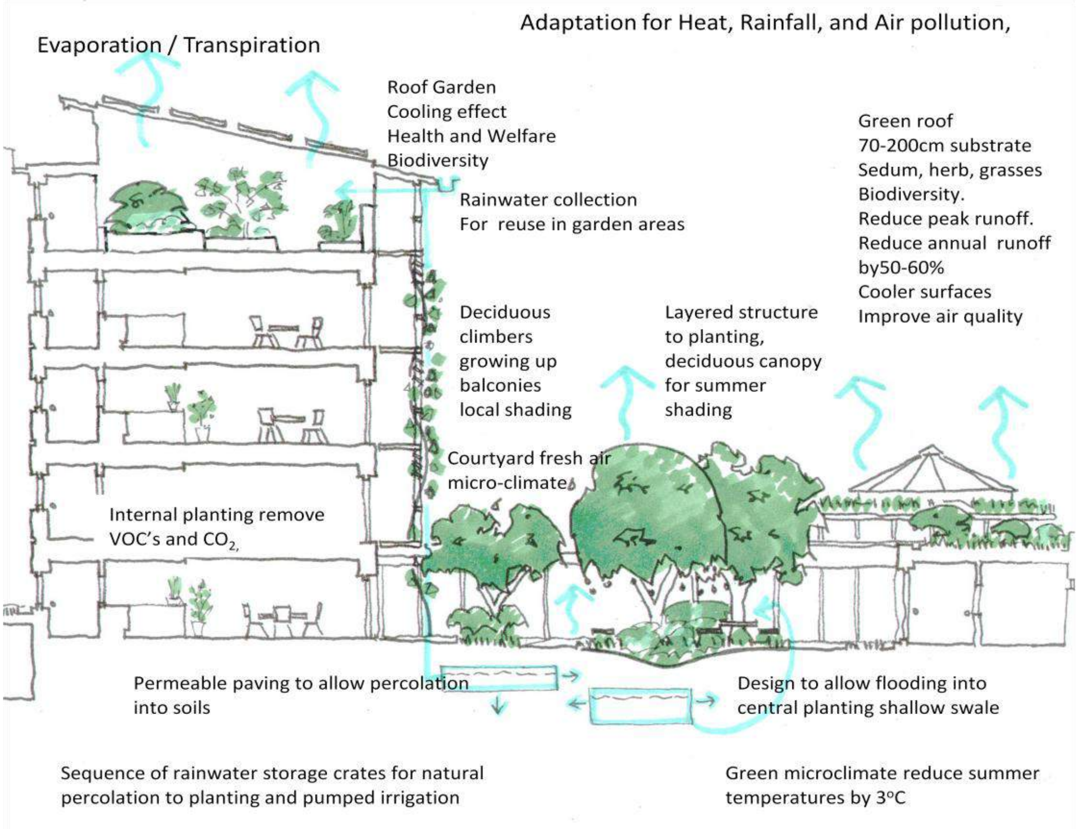
- maximise the green space and people's contact with plants. Maximise the amount of accessible outdoor space: balconies, roof garden, and courtyard.
- provide an extensive green roof on low building, to increase "greened" surface area of site, reduce runoff and reduce heat absorption and glare.
- provide good visual and physical connection to the green spaces from the building, through building design layout.
- provide internal planting to communal areas for wellbeing and improve air quality.
- collect, manage and store water on site to benefit the planted landscape to maintain moisture in the soils, and use permeable paving and shallow planted swales.
- provide a layered structure to the planting including climbers, small trees and tall shrubs, low shrubs, and perennials, to allow a large amount of foliage for catching and intercepting moisture and shading the ground and to provide a comfortable external environment.

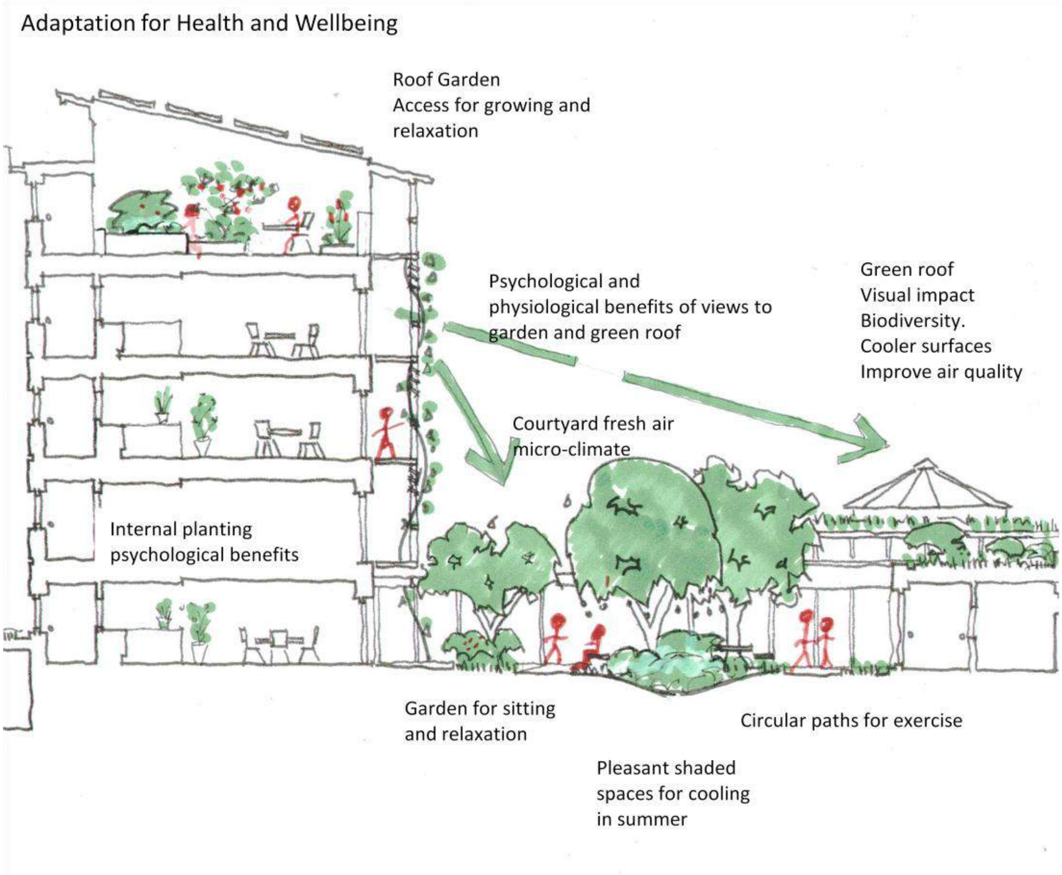
- plant deciduous climbers on the walkway structure to provide summer shading to the building.
- provide planting with maximum leaf surface area for $C0_2$ absorption, and to improve humidity
- use plants to improve microclimate, for sound absorption and for health benefits
- provide species that can cope with challenging conditions and edible plants to benefit from longer growing period.

The landscape has an important role as part of the St Loyes Extra Care project, being integrated with the building, to create a safe oasis of beauty and comfort to enhance the welfare and health of the occupants and staff. With climate change, both the physical role of plants and the external environment, and the psychological and physiological impact they have improving people's feeling of well being, are important. By providing an improved feeling of wellbeing and comfortable environment, the body should be better able to cope with consequences of climate change[52].

Planting will be designed using species that can cope with the site conditions resulting from climate change. However the strategy proposed, helps to replenish water content in the soil and provides potential for watering if required i.e. for growing food in the enclosed courtyard and on the roof terraces and for climbers providing shade growing up the walkway. Dripper/Trickle irrigation system using low water rates directed at plants and watered in early morning or late evenings would be installed as an adaptation strategy to water were required.

Figure 28 Planting and Landscape Adaptation Strategies





5.10 Cost Analysis and Adaptation Strategies Adopted

5.10.1 Introduction

Cost analysis has been carried out to:

- Establish the costs associated with the various climate adaptation strategies recommended in this report.
- Establish the cumulative costs for an extra care home, built to 2010 Building Regulation requirements, for heating, cooling and additional future investments required to maintain adequate comfort conditions under future weather scenarios over the lifetime of the building.
- Establish the cumulative costs for an extra care facility, including the adaptation strategies detailed in this report, for heating, cooling and additional future investments required to maintain adequate comfort conditions under future weather scenarios over the lifetime of the building.
- Compare the two sets of cumulative costs to demonstrate to the client the long term benefits of the climate change mitigation and adaptation strategies

5.10.2 Adaptation Strategies Adopted by Client and Associated Costs

The following strategies have been approved by the client following the modelling of strategies and cost analysis.

Category	Adaptation Strategy	Measure adopted	Additional capital cost to project for adaptation strategy
Comfort and energy performance - passive	Cross flow ventilation design	Yes	N/A incorporated into design
	Actuated window system to shut down in the event of a fire	Yes	£10,000
	Enclosed secure courtyard design provides secure means for occupants to open windows and ventilate during the day and at night	Yes	None – designed into scheme
	Passivhaus super-insulated and air tight envelope, compact design	Yes	£216,000
	Heavyweight construction	Yes	Inc. in £216,000 above
	Minimise internal heat loads	Yes	None
	Cooling effect of external spaces including green roofs and courtyard planting	Yes	None
	Solar shading	To be introduced in 2060 as part of window replacement programme	£80,000
Comfort and energy performance - active	MVHR System	Yes	Inc. in £216,000 above
	Cold drinking points	Yes	£10,000
	Early warning temperature system	In 2030	£7,800
	Early warning temperature and monitoring system	In 2060	£20,800
	Ground cooling system	No	£201,800
Comfort and energy performance – people management	Training for care and maintenance staff on how the building's heating and ventilation systems work	Yes	None
	Simple to understand and use, operation manuals	Yes	None
	Monitoring and record internal temperatures of flats by staff to identify 'problem' flats in a heat wave	Yes	See £20,800 above
	Training for care staff on the effects of climate change and how to manage heat stress in people	Yes	None
	Regular health checks of occupants to determine vulnerability to heat stress	Yes	None
	Encourage occupants to use the garden, café and cool spaces; dress appropriately for temperature	Yes	None
	Regular training for occupants on heat stress and how to manage flats effectively	Yes	None

Construction	Apply EIFS that is appropriate for use in changing climates • Stooled ends be incorporated into any cills, • Overhangs such as parapet cappings, cills, etc. are a minimum of 35mm forward of the face of the render with a vertical leg of at least 40mm (for cills) or 75mm for cappings. • Utilize a silicone resin based render finish.	Yes	Inc. in £216,000 above
	Specify passivhaus certified windows and doors for severe weather rating	Yes	Inc. in £216,000 above
	The roof to the single story element of the building is designed to be constructed from timber with a green roof system.	Yes	Inc. in £111,000 below
	The roof of the 5 storey element is also of timber construction but roof covering has been specified as sheet metal profile with robust fixings to eaves and verge.	Yes	Inc. in £216,000 above
Water	Oversized gutters and downpipes	Yes	Inc. in £216,000 above
	Rain water harvesting tank on flat roof ends and pipework infrastructure	In 2030	£130,000
	SUDS attenuation system	Yes	Inc. in £216,000 above
	Rainwater storage crate system, underground swale irrigation system	Yes	£25,000
	Green roof to community building to reduce surface runoff and reduce peak flow rate	Yes	£111,000
	Careful landscaping and planting	Yes	None

Many of the adaptation measures did not add extra capital costs and in some cases made the scheme simpler. The following points provide further explanation of the associated additional capital costs.

- Incorporating the Passivhaus requirements of extra insulation and air tightness and the MVHR system was approximately £216,000 or an additional £4,320 per flat when compared to 2010 building regulations envelope base case. It was also found that the Passivhaus design saved £16,847 a year in heating energy. Ignoring rising fuel prices this equates to £336,940 over 20 years.
- The heavyweight design for a block of 50 flats was found to be £75,000 cheaper to build on a £5.5M build cost when compared to lightweight. Whilst the lightweight was slightly quicker to build its material costs were higher. In addition, for a light weight construction, more elements and costs were associated with the thermal, acoustic and fire separation requirements between the flats.
- The ground cooling system was not included in this scheme due to cost and installation implications. See Ground Cooling cost Benefit Analysis in Appendix 4.

The total additional capital costs for the thermal comfort adaptation measures to be adopted at the outset of the project are £236,000. A further £7800 has been identified in 2030 and a further £100,800 in 2060.

The total additional capital costs for the construction and water adaptation measures to be adopted at the outset of the project are £136,000. A further £130,000 has been identified in 2030. Further details and cost benefit analysis can be found in Appendix 4.

5.10.3 Costs Associated with a Typical Extra Care Facility

It was found that an extra £216k was required for thermal comfort adaptation strategies over and above an extra care facility built to 2010 Building Regulations. However this design whilst meeting Building

Regulations will not be as thermally comfortable as the adaptated design and in 2030 will require a full air conditioning system, with associated capital costs of £250,000, which will require replacing / upgrading at the end of its useful life. This result in further capital costs of £140,000 to £180,000 in 2050. Air conditioning will also incur associated running costs for the remaining duration of the building. Further cost benefit analysis can be found in the graphs below and Appendix 4.

5.10.4 Cost Benefit Analysis

The graph in Figure 28 shows the cumulative costs for an extra care home, built to 2010 Building Regulation requirements, for heating, cooling and additional future investments required to maintain adequate comfort conditions under future weather scenarios over the lifetime of the building. All costs have been discounted at 5% to represent present value. An annual increase in fuel costs of 4% has been allowed for and a reduction of heating demand of 30% from 2050 to 2080 has been included. In 2030 an air conditioning system will need to be installed to maintain acceptable internal temperatures that again will need to be upgraded in 2050.

Figure 28

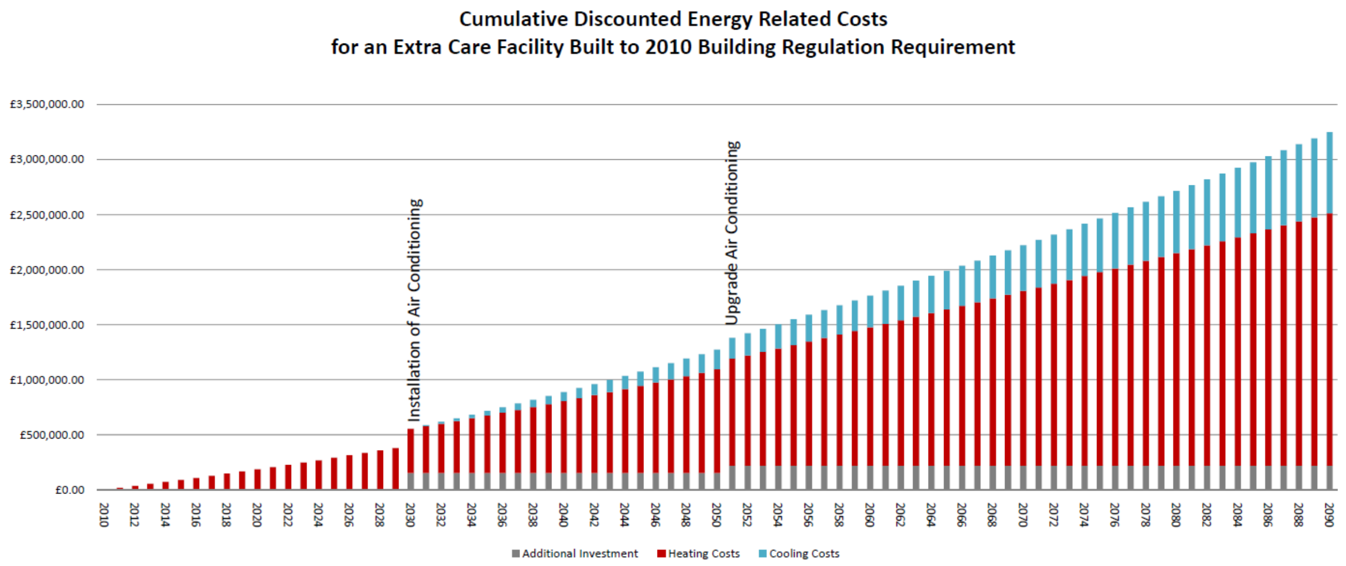
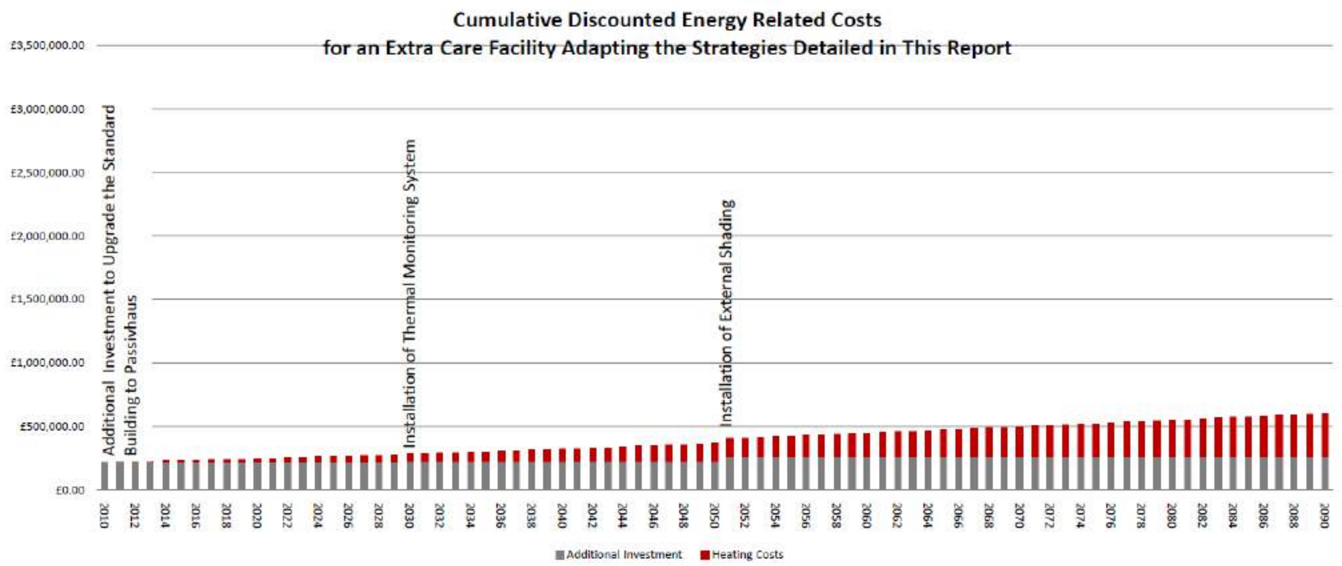


Figure 29



The graph in Figure 29 shows the cumulative costs for an extra care home, including the adaptation strategies detailed in this report, for heating, cooling and additional future investments required to maintain adequate comfort conditions under future weather scenarios over the lifetime of the building.

All costs have been discounted at 5% to represent present value. An annual increase in fuel costs of 4% has been allowed for and a reduction of heating demand of 30% from 2050 to 2080 has been included.

The building is to be constructed to Passivhaus standard, high mass solid construction, optimised cross-flow ventilation strategy and integrated landscape design. It is proposed to install a temperature monitoring system in 2030 and additional external shading in 2050.

This graph shows that over the lifetime of the building the net present value of the cumulative heating costs of the CCA Extra Care Facility are approximately £300,000 compared to £2,250,000 for the Extra Care Facility built to 2010 Building Regulation Standards. This illustrates that it is also cost effective to design to mitigate climate change from the outset. The net present value of the cumulative cooling costs of the CCA Extra Care Facility are zero compared to approximately £750,000 for the Extra Care Facility built to 2010 Building Regulation Standards. The net present value of the cumulative investment costs of the CCA Extra Care Facility are approximately £250,000 compared to £200,000 for the Extra Care Facility built to 2010 Building Regulation standards.

Figure 30

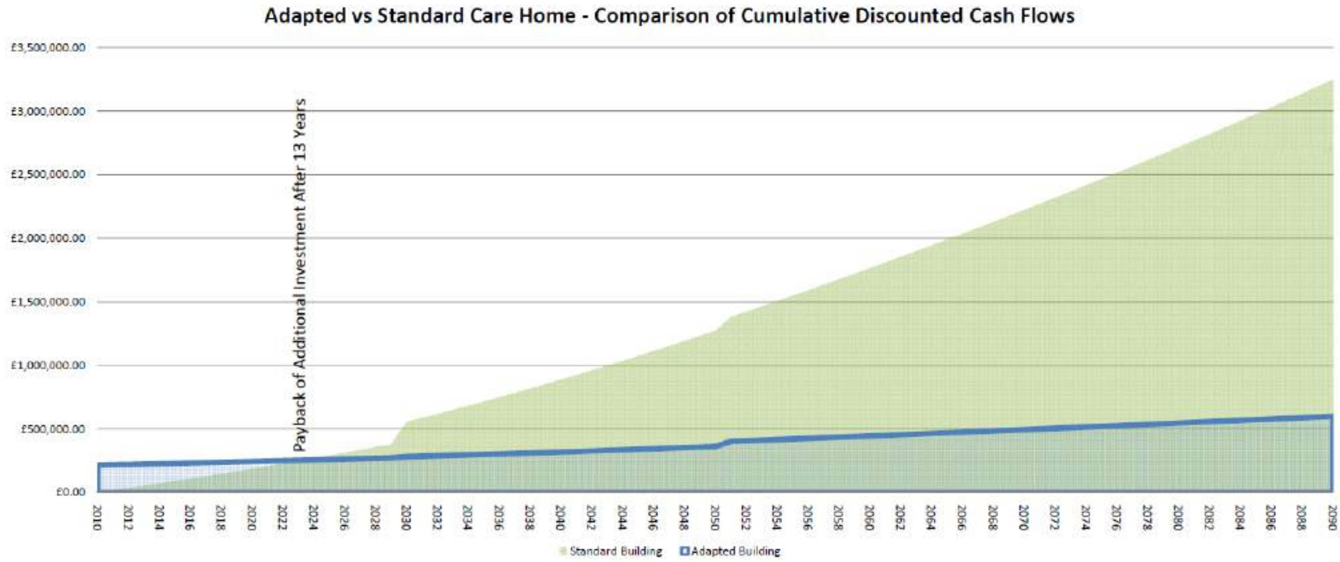


Figure 30 is an overlay of Figure 28 and Figure 29. The comparison of the cumulative discounted cash flows for both options shows that after 13 years the additional energy costs of the standard built will exceed the additional investments related to the adaptation strategies detailed in this report.

Section 6

Learning From Work on this Contract

6.0 Lessons Learnt

6.1 The Approach to Adaptation Work

6.1.1 Integrated CCA Team Approach at Early Design Stages

Fortunately for the project and project team the D4FC contract was awarded at the very early design stages of the project. Thus from the outset the client agreed that the building was to be designed with climate change adaptation (CCA) as one of the key driving influences in the design process. A team of experts in their respective fields was put together to carry out the CCA investigations and this consisted of:

Gale & Snowden's in house integrated design team including: Permaculture Designers, Architects, Landscape Designers, Passivhaus Designers, Building Physicists, Species Specialist, Mechanical & Energy Engineers. This team was already fully experienced in designing passive low energy buildings having been following this design approach for 20 years.

The architectural designers and passivhaus designers brought to the design the following:

- Experience of designing and building both passivhaus and naturally ventilated passive and low energy buildings
- Healthy building design principles
- Ensuring any low energy and passive overheating strategies were developed in an aesthetic manner to create a low energy and comfortable building that will be a pleasure to be in
- An integrated landscape and permaculture design approach which links the building and external spaces together as part of the design process
- In depth knowledge of plants, species and landscape design to assess how climate change may impact on the landscape and planting strategy
- Experience of monitoring low energy buildings after they have been built and handed over to the end users

The building physicists, passivhaus designers and mechanical engineers brought to the project:

- Experience of thermal modelling and the PHPP and designing for summertime overheating in a wide range of both commercial and domestic buildings
- Linking outputs from thermal simulations into the design process to help inform key D4FC design decisions at early stages
- Using both IES and PHPP in conjunction to provide a robust analysis methodology into assessing overheating in building designs
- Investigating active strategies such as the MVHR system that could link in with passive strategies and the early temperature warning system
- Experience of designing low energy mechanical systems in buildings and in this instance developing the CCA strategy of relocating heating plant outside the flats
- Experience of designing passivhaus mechanical systems such as the MVHR
- Experience of designing and implementing ground cooling systems

In addition to this the following disciplines also contributed to the project:

Academic Institution (Exeter University), Civils Engineer & Structural Engineer, Quantity Surveyor and Project Manager.

Exeter University provided the following:

- In depth knowledge with regard to the future weather files and UKCP09 data
- Thermal modelling experience to assess in house thermal outputs

- CFD (computational fluids dynamics) assessment of external green spaces – a new method was developed
- Investigations into the thermal and air quality impacts that plants could have on the scheme
- Heat stress analysis methodologies

The client (ECC) brought to the CCA project:

- An enthusiasm and engagement in the CCA project work and design development
- Participation in the workshops and design input
- Commitment to implement the findings wherever possible
- Commitment to delivering low energy and low carbon buildings
- They also brought an appropriate level of staff to all CCA meetings to make decisions for the design team to implement CCA measures as the design was ongoing

The civils and structural engineer whilst having a more limited role contributed in the following manner:

- Worked with Exeter University at assessing the quality of the future rain and wind files and how the information available could inform the design.
- Helped to develop water attenuation and rainwater harvesting strategies
- Participated in CCA workshops

The quantity surveyor participated in the CCA process by providing capital costs and life cycle costs against CCA measures. As the CCA research commenced at early RIBA stages A/B it was possible with cost input to design many CCA strategies into the building with little extra costs. It was also possible to highlight potential savings that CCA strategies would eventually lead to.

Bringing the CCA element in at early stages clearly defined the high aspirations for the project everybody was engaged in and set the tone for the working brief and agenda for the team and the rest of the design development that was to follow:

6.1.2 Regular D4FC Workshops

Cleary defined D4FC workshops with agendas and minutes were set where the adaptation project team would meet and focus on climate change design measures and approaches. These workshops were separate from the usual design team meetings and therefore climate change design matters were not seen as a small part of a larger design team meeting.

The agenda after the first workshop was to investigate the nature of the future weather files and to report back.

Each workshop also involved the client whereby climate change risks were presented along with suitable adaptation measures that could be implemented. The client was then able to make clear decisions as to which CCA measures to adopt in the building design.

6.1.3 Building Physics and Thermal Modelling

Understanding the weather files practically

At the first D4FC workshop the nature of the future weather files in terms of external temperature increase became clear for any given future climate change scenario. The probabilistic weather files were input into IES and the future temperature graphs were assessed. It was not clear, however, what the impact these weather files would have on buildings in terms of overheating. It was therefore decided to take a previously designed small apartment building and run some simple simulations in IES to investigate quickly the impact these weather files had on an existing building. This proved to be a valuable experience for the design team as it enabled the team to understand the weather files at early stages in terms of overheating and design implications rather than just a graph which detailed external temperature over a particular year.

Concept designs – thermal modelling

After this, initial concept designs were developed and thermally assessed using IES and the PHPP software. Findings from this analysis were then fed back into the architectural and mechanical engineering design process to help inform appropriate adaptation strategies.

6.1.4 Research and Analytical Approach

A research and analytical approach was also taken with the project. The D4FC aspect of the project was not just seen as means to design adaptive measures it was also treated as an independent separate research project to help educate and inform the design team and wider industry. Eleven separate papers and reports have been developed with this approach.

6.1.5 Learning from Building Designs in Warmer Climates / Site Visits / Master Class Training

It was decided at early design stages to research low energy building designs that have been implemented in warmer climates than the UK. Research was carried out on various case study buildings around the world to investigate their design principles, mode of operation and any innovative and practical techniques that had been used to limit overheating.

One aspect of this involved visiting Extra Care Facilities in Cologne Germany that had been designed to the Passivhaus standard. An IES weather file was obtained for Cologne and it was found to be very similar to a 2050 (50th percentile) UK scenario. The following report provides further details:

04. CCA Passivhaus Care Home Tour for St Loyes – ExtraCare4Exeter[4]

During the visit to Cologne the design team attended a master class in Passivhaus Extra Care Facilities design by a Passivhaus design consultancy that had been responsible for design and building several Extra Care Facilities in Cologne. These facilities had also been designed to cope passively with a warmer climate than the UK. The design team also had the opportunity to go and visit these buildings and interview the occupants and staff who occupied these buildings.

This proved invaluable for the design team to help develop key adaptation strategies and to also have the confidence that these measures would work. This saved a considerable amount of time investigating and modelling and designing theoretical measures that either would not work or would not be practical to implement

6.2 Resources and Tools Used

6.2.1 Project Team Experience

Gale & Snowden Architects

The key resource used for this D4FC project was the knowledge and experience of designing and building passive and low energy buildings contained within the multi-disciplinary design team of Gale & Snowden Architects. Gale & Snowden have been designing exclusively low energy architecture incorporating passive design measures and permaculture design principles for over 20 years. This experience ranges from commercial buildings such as schools, offices, museums and hotels to also the domestic sectors - houses and apartment buildings. Gale & Snowden Architects also has in-house mechanical and energy engineers, building physicists, passivhaus designers and permaculture designers all of which provide a complete integrated team at early concept stages. As well as designing and following building designs through to being built and implemented experience also includes monitoring low energy and passively designed buildings during occupation. Hence knowledge and experience is not just limited to the design stages of any project.

This in-house experience has brought to the project an invaluable resource for carrying out the adaptation work.

Exeter University

The resources and knowledge of physics in buildings from Exeter University also proved to be beneficial when carrying out the D4FC work.

Exeter City Council – Civil and Structural Engineers and Client Project Management

ECC had a good understanding and practical experience of designing structurally and for flood risks assessments for a wide range of buildings in the South West. The southwest peninsula in particular, is considered to be in one of the highest climate exposure zones for prevailing rain and wind speeds. Within a small region it also has a wide range of micro climates which potentially can produce very localised flood conditions. The City Council is a stake holder in the Multi-agency Flood Plan for Devon & Cornwall. The Clients experience in Project Management enabled the smooth flow of information and client decision making.

6.2.2 IES Thermal Modelling Software

The IES software is a useful design tool at assessing the thermal performance and comfort conditions of building design for a wide range of thermal and passive strategies:

Details as follows:

1. Calculation engine: Apache
2. Calculation engine (version): v6.0
3. Interface to calculation engine: IES Virtual Environment

The thermal modelling software tools utilised to assess the buildings' thermal performance include:

1. Calculation engine (version): v6.0
2. Interface to calculation engine: IES Virtual Environment
3. Model tool: ModelIT Building Modeller
4. Thermal tool: Apache Thermal Calculation and Simulation
5. Solar analysis tool: Suncast Solar Shading Analysis
6. Wind & air movement tool: Macroflo: Multi-zone Air Movement
7. CFD tool Microflo: Computation Fluid Dynamics

Outputs:

- Advanced dynamic thermal simulation at sub-hourly timesteps for better computation of building components
- Assess solar gain on surfaces, surface temperatures and radiant exchanges
- Extensive range of results variables for buildings and systems
- Building and room-level annual, monthly, hourly, and sub-hourly analysis
- Assess passive performance, thermal mass, and temperature distribution
- Link results from ApacheHVAC, MacroFlo, Suncast & RadianceIES and use as integral thermal simulation inputs
- Export results to MicroFlo as boundary conditions for detailed CFD analysis

Strengths:

- It is a powerful design tool at assessing the thermal performance and comfort conditions of building designs for a wide range of thermal and passive strategies.
- Can assess mechanical active strategies as well as passive
- Can assess energy performance as well as overheating
- Can be used as a concept design tool as well as compliance checking
- Can be used as a whole building approach analysis and can also be zoned to investigate individual spaces in more detail
- Is industry recognised software which has been developed in conjunction with industry guidelines such as those produced by CIBSE.

Weaknesses:

- Wide range of user experience inputs required so relies heavily on user competence when assessing future climate change overheating.
- There is currently no clear industry guidance and methodology on using dynamic simulation software when assessing future climate change impact on building design.
- It is difficult to simulate manual control realistically of passive systems such as opening windows – a wide range of control parameters can be input into the software based on temperature, solar gain, CO_2 etc to open windows which can lead to near perfect results. In some instances windows might not be opened manually in the manner simulated by IES. The IES simulations found shading to be the least effective adaptation strategy. It was assumed however that this was due to how perfectly IES simulates ventilation control. When assessing overheating using the PHPP solar shading was found to be more effective than IES gave credit for. Passivhaus institute in-situ studies on domestic buildings in Germany have found that occupants do not open windows to provide the air change rates as is suggested in dynamic simulation software. In most measurements air change rates have been below one air change per hour[23].
- Can be sometimes cumbersome to use as a concept design tool for inexperienced users
- It is difficult to assess the impact some simple adaptation changes have when simulating dynamically - for example when including solar shading with windows also opening automatically when temperature conditions dictate. Adding solar shading also changes the way windows open automatically when dynamically simulating as the internal temperature conditions will change with the lower solar gain. This can prove difficult to compare the full impact of some measures.
- The IES software is unable to analyse the impact of latent heat and therefore it is difficult to fully analyse the benefit of green roofs. Further research is required to develop methodologies to assess the role plants can play at producing cooling effects inside and around buildings
- The heat stress model used was based on the ISO 7933, "Ergonomics of the thermal environment - Analytical determination and interpretation of heat stress using calculation of the predicted heat strain." The human element is not currently included in thermal modelling of buildings, so the outputs had to be considered within a separate model. However although this heat stress model is able to consider exposure of humans over time in a quasi-dynamic, the model is calibrated for normal, healthy people in work environments. Although it is possible to consider vulnerable groups, other variables such as inability to maintain internal temperature or reduced circulation amongst these groups is not considered. The model can infer that if healthy people are overheating then the effects on the infirm will be considerable. A better description of people within buildings is therefore required.

6.2.3 Passivhaus Planning Package PHPP

Details:

- Simulation is based on calculations of monthly energy balances
- It treats the whole building as one zone
- It takes into account internal casual gains and solar gains
- It takes into account building orientation and properties of the materials used
- It utilises local weather data

Outputs:

- calculates energy balances (including U-value calculation)
- specifying and designing building envelope components
- designing the comfort ventilation system
- determining the heating load
- determining primary energy demand
- estimating the summer comfort
- design the heating and hot water supply

Strengths:

- simulation tool developed through empirical research and monitoring results of completed Passive Houses over the last 20 years
- simplified model which pairs reliable results with justifiable effort for data acquisition
- has proven track record of predicting the average energy demand of a low energy building

Limitations:

- only suitable/reliable for low energy buildings with an annual heat demand of less than <40kWh/sqm year and an airtighness <1ac/hr
- summer comfort calculation represent only an estimation and for more complex designs a detailed dynamic simulation is advisable
- currently no future climate data files available for the PHPP but it is understood that a research project at Cardiff University has been set up with the aim to generate this data
- the majority of papers/research are only available in German

6.2.4 Architects Tools / Other Software

In addition to thermal modelling and building physics software other tools used include:

- Vectorworks
- Sketchup – 3d visualisation tool
- Therme (thermal bridging analysis)
- Powerpoint for presentations and dissemination

Vectorworks and Sketchup were useful at initial design stages to help form the massing and shape of the building for the cross flow ventilated design. Sketch up also provides details of the sun path and shading analysis for a range of design concepts. The Sketchup visualisation software was found to be an important tool to help the client understand visually the impacts on the design various CCA strategies were having. Other tools such as PHPP and IES were found to be limited at providing 3d visualisations of CCA designs to present to the client. Sketchup as with any 3d visualisation tool helps to present CCA ideas visually to the client.

The following figure details various CCA strategies that were presented to the client including the flat roof areas either side of the building for future rainwater harvesting tanks; the permaculture designed green spaces; the green courtyard area that each flat looks onto as part of the healthy building design approach and the green roof CCA strategy.

Figure 31: Sketchup 3d Visualisation

6.2.5 Prometheus Weather Files

The Prometheus weather files generated by Exeter University have proven to be a useful tool as part of the thermal modelling process.

Strengths:

- Very easy to access from the Prometheus website and download for the location concerned
- In easily accessible format to incorporate into the IES software
- They are free which would encourage designs teams to use them in modelling software
- Are backed up with support by Exeter University

Limitations:

- File extension names could be made clearer as it is easy to use the wrong weather files in IES when simulating
- Although future years and high and medium emissions scenarios have been narrowed down from 3000 weather years, it is felt there are still too many for design teams to choose from. Choices for particular

scenarios become subjective for design teams and building types. It would be helpful to either narrow down the weather files or provide guidance from industry as to which weather files are appropriate for particular building types.

- The Prometheus weather files include both wind speed and wind direction which is consistent with the rest of the weather signal. However, the climate change signal of these variables is much more uncertain with very little change currently expected in the winter and a very small negative change in the summer. Also there is little evidence to suggest that the future weather patterns will be fundamentally different to those which are currently experienced so the wind field provided within the weather file is likely to be fit for purpose. The natural variability is more likely to dominate over any climate change signal so the analysis of wind used within the models is robust given current knowledge of future climates. Better knowledge of future weather patterns would be of benefit. Limitations in predicting future wind speeds in changing UK climates and rain patterns to be made clear to design teams at the outset especially if designing natural ventilation strategies in buildings in warmer climates. Future wind patterns are part based on past UK observations; considering there have not been many days above 30^{0}C in the past in the UK caution is to be exercised when assuming a business as usual approach. This is more a limitation of the UKCP09 data rather than the Prometheus weather file.

6.2.6 Rainfall and Flooding

Strengths:

- Current legislation, Floods and Water Management Act 2010 is addressing a lot of the problems highlighted by the Pitt Review put forward as a result of the serious flooding events throughout the Country in 2007. Part of this change has put the County Councils and Unitary Councils as the Lead Local Flood Authorities (LLFA) who are now responsible for all flooding incidents and resolving them in the future. Part of the strategy is the proposed introduction of the adoption of SUDS systems by the local authority as part of the planning procedure for all new development. This will via a SUDS Approval Body (SAB) which the LLFA will be responsible for but are likely here in Devon to provisionally delegate to the District Councils, such as Exeter City Council where the knowledge and expertise currently exists.

Limitations:

- Short but intense rainfall events such as those of five minutes duration are very difficult to predict under future climates. The hourly weather generator provides a disaggregation of the predicted future daily rainfall and as such does not contain explicit new types of hourly weather. However, these events on a shorter time scale are not available from climate models either. The extreme rainfall analysis therefore had to concentrate on extreme daily weather events with the likelihood of more extreme events at any other timescale inferred from the daily timescale. It is possible that the shorter time scale events are going to scale differently to the daily extreme events and as such it is also possible that the full extent of climate change has not been considered with the biggest risk being that drainage could be undersized accordingly. More detail of how the shorter more intense future rainfall relates to the future daily rainfall would therefore be required.
- Suggested future weather patterns and associated rainfall prediction files do not yet provide clear and compatible data with current industry design requirements for the future design and provision of suitable drainage / SUDS facilities i.e. provide sufficient capacity and hence property protection – hence very basic rules of thumbs were used to allow for future change.
- Current lack of guidance on the national criteria to be used for future drainage design and any allowance for future variation of climate change scenarios.
- Clash of flood protection design standards which allow the national water companies to limit their systems to only a 1 in 30year rainfall event.
- Limitations to the current design software used and tools. The shorter the time of concentration (ToC) involved for a particular development or catchment area, the greater the margin of error that may occur. Climate change is likely to significantly affect small developments such as the Extra Care

Facilities Project, which will make the prediction of very localised extreme rainfall events excessively difficult. This will potentially result in large variations, even locally, due to the many variable but influential factors. i.e. topography, wind direction, tidal conditions, seasonal variation.

- Limitation in assessing the future flooding risk due to the change in return period – i.e. expected current return periods for particular rainfall events will gradually diminish and may half i.e. Some research scenarios suggest that a 1 in 100year event may soon become say 1 in 50year.
- Limitations on the design capacities of standard drainage products to adequately intercept contain and manage the direction of flows or runoffs from roofs, hard standing areas, roads and footway surfaces and into the receiving underground systems. Bespoke design requirements may eventually need to be introduced to meet individual conditions.
- Climate change is currently suggesting greater extremes to weather patterns ranging from prolonged dry summers to shorter very wet winters. Such variations make the design and dependence upon facilities such as rainwater harvesting and their future viability, far more difficult to determine.

6.2.7 CIBSE TM36: 2005 Climate Change and the Indoor Environment: Impacts and Adaptation

Strengths:

- Very clear guide with examples of thermal modelling techniques, case studies and results for both commercial and domestic buildings
- Clear passive adaptation strategies detailed for domestic buildings
- A must read for any design team commencing CCA design work and thermal modelling

Limitations:

- Now out of date with UKCIP02 climate change scenarios
- Some case study buildings have provided results based on air changes per hour rather dynamic ventilation simulations. Further studies are required in UK dwellings as to how occupants are likely to operate windows and what the likely air changes rates will be in during hot periods. No such studies have yet taken place for domestic buildings in the UK.
- Clearer guidance is required on window openings for dynamic ventilation simulations when windows are manually controlled by occupants.
- Guidance on overheating criteria in different building types is not clear and fixed

Appendix 4 provides details of other guides used throughout this project work.

6.3 What Worked Well

What worked well?

- The designers and D4FC team working together at a very early stages of the design as this fundamentally steered the design in the right direction
- Integrated design approach at early concept stages – having the full team engaged at these stages in D4FC strategies
- The use of thermal modelling software at early stages helped inform decisions based around building physics rather than it being based on assumptions
- Research into case study buildings and technologies and strategies that have been found to work in warmer climates other than the UK
- Visiting the Extra Care Facilities in warmer climates helped inform key design decisions during the design process

- The Passivhaus approach and the use of MVHR systems as initially it was thought that this approach might not be suitable in changing climates in the UK
- Full client engagement in D4FC workshops throughout the design
- Having funding to carry out the D4FC research in the first place. The team have learnt an enormous amount with regard to passive design and climate change adaption which will help inform designs for many years to come
- Having access to the Prometheus weather files which were used for summertime overheating modelling and Exeter University providing support in this area
- It allowed the design team to explore a whole range of new design ideas which have not all been incorporated as part of this work but would help inform future designs for years to come. This would not have been possible without the D4FC contract
- Separate D4FC workshops to design team meeting which helped focus the design team and client

What did not work well?

- Some of the available weather data into changing climates such as wind speed and driving rain and rainfall patterns was limited and not in a useful format for designers to work. More research is required in this area as to how wind speeds and rain patterns will change in the future. Time would have been saved had it been clear at the outset the limitations and weaknesses in this UKCP09 data.
- Lack of clear industry guidance into acceptable overheating limits in Extra Care Facilities

On the whole the D4FC work was found to be a positive experience for the design team and it had a genuine and positive impact on the design and there is little that did not work well.

6.4 Client Decision Making Process

The most effective ways of influencing the client were:

- To fully engage the client in the process at the outset and involvement in all D4FC workshops and to contribute with design ideas and adaptation strategies
- To clearly present ideas and climate change risks with a range of visualisation tools such as Sketchup and power point
- To provide lifecycle cost analysis of D4FC strategies to be adopted
- To design adaptation measures passively into the building at little to no extra cost. It was found that if CCA is thought about at the outset of the design process and it is used to help influence the design, this building if designed robustly and correctly in the first place requires very little in the way of CCA strategies.

6.5 Recommended Resources

- Fully integrated design team approach will all design team members including engineers involved at early concept stages
- All design team members having the required level of competency, experience and proven track record
- Thermal modelling tools such as IES, PHPP
- 3d visualisation tools to present CCA concepts
- The documents listed in section 4.2.6

Section 7

Extending Adaptation to other Buildings

7.0 Application to Other Buildings

7.1 Domestic Sector - Overheating

The CCA strategy approach detailed herein will be applicable to any domestic building design and a range of commercial buildings. This strategy has been developed for the most vulnerable in society to the effects of overheating living in a domestic capacity. From this perspective this CCA strategy should therefore cover all users' types in domestic buildings young and elderly alike. Whilst these strategies have been developed for a new build scheme they could also be applicable to retrofit applications. This is provided that ageing building stock in the UK is refurbished to a suitably correct standard such as the Passivhaus insulation and air tightness standard or similar. Providing high levels of insulation to save energy in the winter also provides a strategy for limiting solar gain during the summer periods.

The Passivhaus design approach has already been applied on the continent for many domestic buildings in climates much warmer than the UK which represent future UK climates. The buildings have not only been designed and built they have also been monitored during occupation.

In addition if existing building are insulated with external wall insulation system (EWI) an opportunity presents itself to install a render system that is robust to increasing driving rain patterns such as the silicone one detailed herein.

The CCA overheating measures detailed herein are designed to work in conjunction with each other – mass, MVHR, triple glazing, super insulation, temperature warning systems etc. It does not mean that if one of these is taken away that the building will not work. This is important when considering mass, as some new build designs are lightweight and so too are existing buildings. It essentially means if one CCA measure is removed then more attention is required in the other areas such solar shading and ventilation control and limiting internal gains. The only exception is ventilation design; single sided ventilated buildings both new and existing will struggle to cope in changing climates unless additional measures are incorporated to limit overheating.

One limitation with this approach and extending it to all domestic buildings is that of occupancy patterns and ventilation control. This Extra Care Facility relies on user control and opening windows. It is assumed that the flats will have higher occupancy patterns compared to an average home due to the nature of the occupants. Normal dwellings can have a wide range of occupancy patterns and internal heat gains throughout the day and night. For example some people could be out at work during the day and windows might remain closed. In addition this facility is to be managed by care staff who can monitor overheating and ventilation control and open and close windows if necessary. It is also considered to be a securely managed facility which will have fewer issues with night security when night cooling is implemented than other domestic buildings. This strategy therefore relies on effective window opening and effective ventilation control. If this is not implemented for some building designs then the CCA measures detailed herein might not be fully realised.

7.2 Commercial Sector – Overheating

The majority of overheating strategies detailed herein such as mass, shading control, temperature warning systems, and window control are equally applicable to a wide range of commercial buildings to limit overheating. Each building type however would have to be climate change and thermally assessed in its own right. Thermal overheating analysis for this project has focused on the domestic application. The fundamental difference between domestic buildings and commercial buildings when carrying out thermal simulations is the nature of internal gains and occupancy patterns and control. For example a typical office will operate during the hours of 9 and 5. The predominate heat gains will be during the day and will switch off at night. In an office with high mass night cooling can commence to purge the daily heat gains. A dwelling on the other hand might have the same internal gain 24 hours a day and with this scenario night cooling would not be as effective as it is for an office which has no nightly gains. In addition greater control could be exercised over the window opening strategy for an office building which could be delegated to a ‘natural ventilation’ champion or facilities manager. The windows for an office could even be automated which would be difficult for occupants to accept in a domestic situation due to issues of lack of control and noise.

The strategy of relocating or removing internal heat gains is applicable to all building types. In offices for example IT equipment such as printers and servers could be moved to cooler parts of the building on Northern façades away from people and could have localised extract to remove equipment gains during hotter periods.

7.3 Green Spaces / Healthy Buildings / Heat Stress Awareness

The green spaces and landscaping strategy and healthy building design strategy can be applied to any type of building design within the UK. It has been found that buildings and landscapes that are pleasant places to be in whether in the work environment or at home can have a positive impact on the health and well being of an individual.

In the work environment raising awareness of the issues and effects of heat stress will also help individuals cope. Relaxed attitudes during heat waves to dress codes, working patterns providing external green spaces to cool down in and cold water drinking stations are all strategies applicable to any building type.

7.4 MVHR and Ground Cooling

Thermal modelling has found ground cooling to be a viable strategy at reducing overheating in future climates for this scheme. However, due to the nature of the building and fire compartmentation across the various flats and zones costs associated with this approach are significant. In addition an initial assessment found that due to limited space externally and competition with other ground services a ground pipe array is not a viable option for this scheme. For buildings other than apartments and flats which do not have extensive zoning and fire compartmentation for example large open space office buildings, schools etc ground cooling linked into MVHR systems could be considered a viable solution for dealing with overheating in changing climates. This is provided it can be simplified and that there is sufficient ground area. Of the 2 systems available, ground air ducts and ground pipe systems, the conclusions drawn from this analysis were that the pipe system would be the better option for the following reasons:

- It requires less ground space
- There would no issues of air contamination from bacteria developing in the underground ducts as the piped system is hydraulically separated from the supply air.
- The pump distributing ‘coolth’ or heat from the ground only enables when external conditions are not favourable. For example below 5^0C and above 22^0C. A ground duct system pulls air through the duct 265 days of the year even when not required to do so. This results in an oversized fan to overcome the added pressure drop and increased energy costs.

7.5 Resources Tools and Materials Developed

The main resources and tools that were developed:

- A thermal modelling methodology for assessing climate change impact on building designs at concept design stages
- A PHPP methodology for assessing climate change impact on building design at concept and design stages

- A methodology to run both methods above in parallel so that they complement each other at concept and design stages as a design tool. This method also provides a means for comparing the results of one against the other. The advantage PHPP for the domestic application has – it's simple to use and has been developed to design domestic buildings in warmer and colder climates than the UK
- A methodology for thermally simulating and assessing external green spaces and green roofs – further research is required in this area
- A full understanding of climate change and its impact on building designs and appropriate passive CCA strategies that can be used to limit its effects
- A better understanding of the role green spaces and plants can play for CCA
- A clearer understanding of how to design external landscapes to take account of CCA

7.6 Further Needs

- Development and research into the first stage methodology created by Exeter University regarding thermally modelling external green spaces and plants
- Further research into how windows are opened in the domestic application in the UK. Monitoring studies from the Passivhaus Institute is suggesting that windows in warmer climates are not opened as widely or as often as expected by occupants. This could be for various reasons – noise, culturally, habit.
- Clear industry guidance on window opening control parameters for simulation software
- Clear guidance on overheating criteria for different building types and users
- Research into how people are likely to adapt to climate change in the UK. Will they become more tolerant to hotter climates?
- Further development of future rain files and accuracy
- Further development of future wind speeds especially if designing for natural ventilation design

Appendices

Appendix 1: Building Profile Drawings

The following documents have been uploaded as separate documents:

1) Original Planning Drawings
2) Architectural Scheme Concept Plans
3) Initial Drainage Concepts

Appendix 2: Climate Change Risks

Thermal modelling of the building using IES software and overheating assessment and winter time assessment using the Passivhaus Planning Package has been covered in three detailed reports written by Gale & Snowden Architects.

1. *D4FC Rennes Thermal Modelling – ExtraCare4Exeter*[1]
2. *D4FC St Loyes Thermal Modelling Assessment – ExtraCare4Exeter*[2]
3. *D4FC St Loyes PHPP Thermal Pre-Assessment – ExtraCare4Exeter*[3]

Findings from these assessments helped form the adaptation strategies developed herein. For full details of the thermal modelling and simulations carried out as part of the D4FC design process refer to these documents.

A Passivhaus tour of Extra Care Facilities in Cologne, Germany with climates similar to a UK 2050 50th percentile summer year also helped to form the adaptation strategies detailed herein.

Key observations from this tour can be found in the following Gale & Snowden Architects' report:

4. *Passivhaus Care Home Tour for St Loyes – ExtraCare4Exeter*[4]

It addition, thermal modelling and CFD analysis was carried out by Exeter University mainly to assess the cooling potential of the external planting arrangement in the courtyard and to assess heat stress in individuals.

5. *The Thermal Impacts of External Planting on the St Loyes Care Home*[9]
6. *A Study of Possible Heat Stress as a Result of Climatic Change in the St Loyes Care Home*[10]

Two additional papers by Exeter University also assisted with the development of the adaptation strategies detailed herein:

7. *The Effects of Indoor Plants on the Indoor Environment of St Loyes Residence*[7]
8. *The Effects of Outdoor Plants on the Indoor Environment of St Loyes Residence*[8]

Two additional papers by Exeter University also assisted with the development of the adaptation strategies detailed herein:

A further paper by Exeter University helped inform the design process and team with regard to future rain patterns.

9. *Changes in Extreme Rainfall Events Under Climate Change*[11]

All of these reports and papers have been uploaded as separate documents to Design for Future Climate Change (D4FC) group website as part of this project:

The following papers and reports which were written as part of the CCA work for this project provide specific details of the UKCP09 weather data used to assess the risks for this project. These have all been uploaded as separate documents to Design for Future Climate group website as part of this project:

1) 1. D4FC Rennes Thermal Modelling – ExtraCare4Exeter
2) 2. D4FC St Loyes Thermal Modelling Assessment – ExtraCare4Exeter
3) 3. D4FC St Loyes PHPP Thermal Pre-Assessment – ExtraCare4Exeter
4) 9. The Thermal Impacts of External Planting on the St Loyes Care Home
5) 10. A Study of Possible Heat Stress as a Result of Climatic Change in the St Loyes Care Home
6) 11. Changes in Extreme Rainfall Events Under Climate Change in Exeter

Appendix 3: Adaptation Strategy

In the TSB upload folder for this project can be found the following drawings which incorporate D4FC measures adopted for this scheme:

1) Mechanical Drawings
2) Drainage Drawings
3) Landscape Layout Drawings
4) Architectural Drawings

Appendix 4: List of Papers and Reports Written as part of this CCA work / Bibliography

The following papers and reports have been developed as part of the D4FC research for the ExtraCare4Exeter scheme.

1. D4FC Rennes Thermal Modelling – ExtraCare4Exeter
2. D4FC St Loyes Thermal Modelling Assessment – ExtraCare4Exeter
3. D4FC St Loyes PHPP Thermal Pre-Assessment – ExtraCare4Exeter
4. Passivhaus Care Home Tour for St Loyes – ExtraCare4Exeter
5. Landscape Design Response to Climate Change at St Loyes – ExtraCare4Exeter
6. Plants and Green spaces - their effects on health and wellbeing at St Loyes- ExtraCare4Exeter
7. The Effects of Indoor Plants on the Indoor Environment of St. Loyes Residence
8. A First Look at the Effects of Outdoor Plants on the Indoor Environment of St. Loyes Residence
9. A Study of the Impacts of External Planting on the St Loyes Care Home
10. A Study of Possible Heat Stress as a Result of Climatic Change in the St Loyes Care Home
11. Changes in Extreme Rainfall Events Under Climate Change in Exeter
12. St Loyes Care Home Drainage Concepts
13. St Loyes Cost Report & Rainwater Harvesting Cost Analysis

Other documents that have been found to be very useful guides for this project and CCA design are as follows:

14. Gale Encyclopaedia of Children's Health: Infancy through Adolescence (2006 – Davidson, Tish, Larson, Jeffery).
15. The 2003 Heat Wave in France: Dangerous Climate Change Here and Now – Poumadere et al 2005
16. CIBSE TM36: Climate Change and the Indoor Environment: Impacts and Adaptation 2005
17. Beating the Heat: - Keeping UK Buildings Cool in a Warmer Climate – ARUP document 2005

18. Control of Overheating in Future Housing – Design Guidance for Low Energy Strategies – Orme / Palmer 2003
19. Control of Overheating in Well-insulated Housing – Orme /Palmer / Irving
20. CIBSE TM48 – Use of Climate Change Scenarios for Building Simulation – the CIBSE Future Weather Years
21. CIBSE TM37:2006 Design for Improved Solar Shading Control
22. The effect of Plants and Artifical Daylight on the Well-Being and Health of Office Workers, School Children, and Health Care Personnel. Proceedings for Plants for People International Symposium Floriade, Netherlands 2002. Fjeld T (2002)
23. 'Passivhaus summer climate' (Feist 1998)
24. Is insulating more effective than thermal mass. (Feist 2000)
25. Summer ventilation in passive houses. (Feist 2003)
26. 'Impact of improved Uvalues on summer comfort levels' (Hauser 1997)
27. 2009 Market Outlook International Energy Agency (IEA 2009)
28. Thermal analysis of buildings under summer conditions (Kolmetz 1996)
29. 'Natural Night time Ventilation, 'Passivhaus Sommerfall' (Schnieders1999)
30. PHPP Manual 2007 (PHI 2007)
31. CIBSE AM10:1997 Natural Ventilation in Non-Domestic Buildings
32. Life Cycle Costing of Sustainable Design RICS Research – Kelly / Hunter 2009
33. Investigating the Potential of Overheating in UK Dwellings as a Consequence of Extent Climate Change – Peacock et al 2010
34. Thermal Mass in Passive Solar and Energy Conserving Buildings
35. Suggestion for New Approach to Overheating Diagnostics – Nicol et Al 2008
36. Avoidance of Overheating and Air Conditioning in Urban Housing EST 2005
37. Green Roofs: Building Energy Savings and the Potential for Retrofit – Castleton et al 2010
38. Analysis of the Green Roof Thermal Properties and Investigation of its Energy Performance – Niachou et al 2001
39. NASA research and How to grow fresh air. Weidenfeld and Nicolson (London) Wolverton, B., (1996),
40. Improving the Indoor Environment for Health, Well-Being and Productivity - Wood 2003
41. Neighbourhoods, Cities and Regions Analysis Division (NCRA), 2007, Climate change and Urban Green Spaces
42. High Impact Low carbon *gardening*, Timber Press, Bowe, A., 2011,
43. Thermal comfort and psychological adaptation as a guide for designing urban spaces. Energy and Building 35, (95-101) Nikolopoulou and Steemers (2005),
44. Neighbourhood microclimates and vulnerability to heat stress. Social Sciences and Medicine 63, 2847-2863. Harlan, S., Brazel, A. Prashad, L., Stefanov, w., Larsen, L., (2006)
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46. Restorative environments. In: Spielberger, C. (Ed.), Encyclopedia of Applied Psychology, vol.3. Academic Press, San Diego, USA, pp. 273–278. Hartig, T., (2004)
47. Green space and quality of life: a critical literature review. Greenspace Scotland. Bell, S., Hamilton, V., Montarzino, A., Rothie, H., Travlou, P., Alves, S., (2008)
48. The links between greenspace and health: a critical literature review. University of York. Croucher, K., Myers, L., Bretherton, J., (2007)

49. “Health and Green: Living and working with plants” Collected research about the benefits plants can bring to the work environment. EILO Congress 2010. eFig, (2010)

50. Neighbourhood microclimates and vulnerability to heat stress. Social Sciences and Medicine 63, 2847-2863. Harlan, S., Brazel, A. Prashad, L., Stefanov, w., Larsen, L., (2006)

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52. Healing gardens-places for nature in health care. The Lancet 368, 36-37 Hartig, T., Cooper-Marcus, C.,(2006)

53. Restorative effects of natural environment experiences. Environment and Behavior 23, 3–26. Hartig, T., Mang, M., Evans, G.W., (1991)

54. TNO Study for the Dutch institute for work protection, Kaplan, R. (2001), The nature of the view from home. - Psychological benefits. Environment and Behavior, 33, 507-542. Hesselink. J., (1995),

55. Research from Bavarian State Institute of Viticulture and Horticulture Kotter, E., (2002),

56. Aggression and violence in the inner city: effects of environment via mental fatigue. Environment and Behavior, 33(4), 543-571. Kuo, F. E.; & Sullivan, W. C. (2001).

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58. Nikolopoulou and Steemers (2005), Thermal comfort and psychological adaptation as a guide for designing urban spaces. Energy and Building 35, (95-101)

59. Therapeutic Influences of Plants in Hospital Rooms on Surgical Recovery. HortScience 44 (1): 102-105 Park, Mattson (2009),

60. Health Benefits of Gardens in Hospitals. Paper for Conference Plants for People, International Exhibition, Floriade 2002. Ulrich, R., (2002).