LDĀDESIGN

Design for Future Climate: Oakham North

Final report for the Technology Strategy Board

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Project Name	Oakham North
Project Number	400250
Submitted by	Helen Pearce, LDA Design

A 14–17 Wells Mews
London W1T 3HF
United Kingdom
T +44 (0) 20 7467 1470
F +44 (0) 20 7467 1471
W www.lda-design.co.uk

LDA Design Consulting LLP
Registered No: OC307725
17 Minster Precincts, Peterborough PE1 1XX

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Executive Summary

LDA Design successfully applied to the Technology Strategy Board Design for Future Climate (D4FC) programme for funding to develop an adaptation strategy for Phase 1 of Larkfleet Homes' Oakham North development. This report describes the work undertaken and the conclusions in terms of the adaptation strategy. Checklists providing an overview of the structure and content of the report are provided in Appendix 0.

We have assessed the likely impacts of climate change on the development and the potential for adapting the design of the building fabric and services, internal layout, structural design, site drainage, green infrastructure and public realm to reduce the vulnerability of new homes built on the site. The costs and benefits of the adaptation options have also been reviewed.

Our aim was to develop a realistic strategy which successfully manages the significant impacts on homes, can be confidently delivered by Larkfleet and can act as a model for other residential-led, timber framed construction projects. To do this our strategy must help create a more attractive and comfortable development that is resilient and flexible to on-going change. Our client, Larkfleet Homes, had a critical role to play in the development of the strategy as they were able to provide feedback on the feasibility and viability of implementing the adaptation options considered.

The Oakham North development will provide up to 1,200 new homes, a range of commercial buildings, a continuing care retirement community, new sports facilities and landscaping set over 60 ha, located in between Leicester and Peterborough. Phase 1 of the masterplan, which was the subject of this study, includes 135 houses and two areas of allotments in a public realm setting. Three house types were used throughout this study as being representative of the homes proposed for the site: a four bedroom detached house, a three bedroom semi-detached house, and a three bedroom barn-type dwelling. The homes are being built to meet the standards of Code for Sustainable Homes Level 3 and the Building Regulations Part L (2010) (the base construction case). Climate change projections for the area were taken from the UKCP09 high scenario, to obtain a conservative estimate of the potential impacts and reflect the current global emissions trajectory. The climate change projections were considered in relation to the site context and the development proposals to identify the range of potential climate change impacts relevant to the site. A risk assessment was used to rank the impacts, revealing the following priorities for the site:

- Overheating within homes
- The structural stability of foundations and above ground construction in homes
- Surface water flooding
- Water resource availability

Further detailed analysis of each of these impacts was undertaken in order to identify and assess a range of adaptation options, with reference to the Design for Future Climate categories of designing for thermal comfort, construction and water management. This analysis comprised the following elements:

- Thermal comfort modelling, undertaken by Buro Happold (Appendix 3.1)
- Advice on foundation and superstructure options, by Capita Symonds (Appendix 3.2)
- Assessment of the proposals for surface water drainage and water conservation, by Wormald Burrows (Appendix 3.3)
- Advice on selection and specification of climate change resilient trees for development, by LDA Design (Appendix 3.4)
- Cost analysis, by Capita Symonds (Appendix 3.5)

The outcome of each of these technical studies is presented in a suite of reports provided as attachments to this main report (see the relevant sub-sections of Appendix 3, as listed above).

The aims of the adaptation strategy for Oakham North are to reduce the impact on the development of changes to the climate which are happening now, and to increase resistance and resilience to future impacts. The adaptation strategy has been structured to respond to the key areas of risk and consider the design opportunities set out in the TSB's Design for Future Climate guide.[i] A checklist has been provided alongside this report which sets out which of those design opportunities have been considered, recommended or implemented.

It is essential that the priority measures which are fundamental to the design and layout of the development are integrated from the outset, as the cost and practical implications of retrofitting them are prohibitive. For Oakham North these include:

- Resilient foundation designs, including deeper raft foundations, piles or basements where appropriate depending on localised ground conditions
- Surface water drainage systems, which have been designed to comprise SUDS and permeable surfaces sufficient to attenuate run-off to greenfield rates including an adequate allowance for increased rainfall intensity associated with climate change
- Green infrastructure, in particular including private garden space and advanced planting of a suitable mix of tree species in relevant parts of the site

A number of other measures are practical to implement from the outset, provide an immediate benefit to residents, and have been recommended for installation in new homes at Oakham North. These include:

- Locating high heat gain spaces such as kitchens on north or eastern elevations
- Using open plan spaces to enhance cross ventilation
- Using thermal mass with night cooling where feasible
- Fitting simple shading devices, especially west and south orientations and rooms where heat gains and occupancy levels are high, such as living rooms and kitchens. External shuttering preferred to simple internal blinds if viable
- Fitting mechanical ventilation with heat recovery (MVHR) or ensuring sufficient space for future installation, including an allowance for larger ventilation ducts
- Educational material on climate change and how behaviour affects thermal comfort
- Installing good practice low water-use fittings and water meters
- Providing rainwater butts for outdoor irrigation

Alongside these we have listed measures which are not necessary under the short term climate projections and are not currently considered viable for this development, but may be retrofitted in future as and when the need is demonstrated. This includes mechanical cooling and external shading devices.

There are a number of options for how some of the measures in the adaptation strategy are implemented, for example different types of shading devices, which differ in performance and cost. The minimum additional cost per dwelling of installing the adaptation measures proposed would be £16,365 for the detached dwelling, which represents an increase of around 16% compared to the base construction cost of achieving Code 3 and Building Regulations Part L (2010) compliance. This would provide for the basic raft footing foundations, increased thermal mass, increased ceiling heights, stack ventilation, reflective lining under the roof, low-G glazing and standard internal

blinds. If the highest specification options were implemented from the above list the maximum over-cost per detached home would be £73,500 based on the cost analysis, or an increase of 68% compared to base construction costs. This would provide for the basement box foundations, increased thermal mass, increased ceiling heights, stack ventilation, mechanical ventilation and heat recovery with cooling, reflective lining under roof, low-G glazing and electronically controlled external blinds. The impact on construction costs is similar for the other house types.

The most significant elements of the above costs are the enhanced foundation options, the mechanical ventilation and cooling, and the external shading devices. While these are the most expensive items, they also provide the greatest benefits in terms of ensuring that the homes are resilient and well adapted to the long term impacts of climate change. Of these, the mechanical ventilation and cooling systems, and the external blinds are not considered to be essential in today's climate and they can be retrofitted at a later date when the need becomes more apparent, provided sufficient space is provided and the structural design of the property allows for future retrofit. This is therefore the recommended strategy for Oakham North.

Site-wide infrastructure and external adaptation measures including the SUDS strategy and green infrastructure were already incorporated into the masterplan for Oakham North, and are not considered to be additional cost items compared to the base construction case. In addition, the installation of low-flow water efficient fittings has not been included in these costs as it would be necessary with or without the adaptation strategy to enable the Code for Sustainable Homes target to be achieved for the site.

Adaptation to climate change can avoid significant costs in future. However, there is a substantial increase in construction costs associated with implementing the range of measures described above. This must be reconciled with the commercial realities of development, where there is pressure to keep build costs down. This requires a creative approach to developing adaptation strategies, focusing on measures which improve the overall quality of new development through the multiple social, environmental and economic benefits which can provide and maximise value. For example, increasing the amount of urban greenery can help absorb floodwater and can help make buildings and public spaces more comfortable in hot weather. They can help improve air and water quality, and encourage use of public spaces, all while adding to the value of nearby homes[ii].

One of the weaknesses of cost-benefit analysis is that it does not prioritise the non-monetary benefits of climate change adaptation, which are sometimes more important to the occupants of the development and other stakeholders in the long run but do not accrue to the developer, such as improved health and well-being. Related to this, there may be a difference between who incurs the costs of adaptation and who reaps the benefits, or vice versa, depending on when adaptation measures are implemented during construction or retrofitted at a later date. If all of the benefits of adaptation accrue to future residents of the site and other stakeholders such as the local authority or water company, and these do not result in higher demand for the properties or higher sales values, there is little incentive for the developer to invest unless compelled to do so by planning policy or regulation.

It has not been possible to implement most of the measures recommended in the adaptation strategy for houses in Phase 1 of Oakham North due to the advanced stage in the planning, design and development process. Larkfleet has however confirmed that it will provide information about climate change impacts and adaptation as part of the homebuyers guide, such as guidance on how to manage internal heat gains and maintain a comfortable indoor environment or a description of the water-efficiency features in the property. Larkfleet has also agreed that it will offer internal blinds and rainwater butts to homebuyers as optional extras as part of the fit out.

Further measures will be introduced in future phases of the project. The tree planting schedule for future phases of Oakham North is being changed to reflect recommendations from the adaptation

strategy. Location of high heat gain spaces on north or east facing elevations will also be considered actively in the design of future phases of Oakham North. MVHR is being proposed for the social housing in the next phase of Oakham North, as the role of the Housing Association in managing tenant relationships and providing maintenance services is helpful in managing risk. MVHR will only be installed in market housing by Larkfleet Homes when the Building Regulations energy efficiency and carbon targets are tightened to the point where it becomes a regulatory requirement.

Other measures are not currently considered to be viable, given the impact on costs, the lack of housebuyers' willingness or ability to pay for adaptation, the absence of regulatory requirements and lack of impact on insurance premiums or the valuation of properties by mortgage lenders. The main drivers for buyers of new homes are often ability to buy, price, ability to secure an attractive mortgage deal and location, so adaptation is not a sufficient priority at present to influence values. A more comprehensive range of adaptation measures will be implemented in future phases of the Oakham North development and on other Larkfleet Homes schemes, if some of these barriers can be overcome.

Our approach was designed to identify the potential impacts of climate change on the Phase 1 development at Oakham North and assess the options for adaptation. We used the available published information on climate projections and the associated risks to identify and prioritise key risks for the site, then undertook more detailed modelling to design and validate adaptation measures based on their contribution to risk reduction. Throughout the project we worked with the client to review the results, discuss the options and agree the adaptation strategy, culminating in the conclusions presented in this report.

The approach can be broken down into the following stages:

- Climate change risk assessment
- Options appraisal
- Detailed testing
- Forming the strategy
- Dissemination

In general, we found the approach taken to develop the adaptation strategy to be effective within the current context, particularly the current pressures on development viability, uncertainty in the climate projections, and the lack of a strong regulatory driver for climate change adaptation. We would recommend the methodology set out above to others, with the following caveats.

The preparation of an adaptation strategy should start as early as possible in the development process, at the feasibility stage when a site is being considered if not before this during site selection. Our ability to influence the proposals for Oakham North Phase 1 was significantly limited as key decisions had already been made prior to our involvement. Fortunately some of the critical elements of site infrastructure, particularly the drainage strategy and green infrastructure proposals, were subsequently found to be sufficient to provide resilience to future climate based on the projections used in this study.

Related to this, we also found limitations as a result of working with standard house types which had already been fixed for the development. An adaptation strategy is likely to be more successful and affordable if there is flexibility to modify built form and fabric.

A further challenge to our approach was the length and variability of the development programme for large sites. Although our D4FC project had a duration of almost two years, it was still found to be insufficient to be able to see the adaptation strategy through to practical on-site testing, implementation and occupant feedback, which would be instrumental in refining and delivering a

successful adaptation strategy. Larkfleet have however confirmed that they will continue to monitor developments in the housing market and supply chain, and test new technologies and techniques beyond the end of the D4FC project, prior to any larger roll out or change in their standard practice in future.

Although it is important to recognise the wider benefits of adaptation and find a way to incentivise building in resilience from the outset of built development where possible, cost benefit analysis was found to be of limited use in the development of the adaptation strategy. This is because:

- It is difficult to quantify many of the benefits of adaptation
- They accrue to future occupants and other stakeholders potentially some years beyond the construction of the homes
- These beneficiaries do not yet recognise the importance of climate change adaptation and are not willing to pay for it
- As a result the developer has no way of recovering the costs of their investment

Oakham North is similar to other greenfield housing developments across the UK in terms of housing density, mix and size of the dwellings proposed, with the exception that homes are of timber frame construction rather than the more common masonry brick and block construction.

The learning points from the adaptation strategy for Phase 1 of Oakham North should be relevant to future phases of development at Oakham North, other future projects undertaken by the client Larkfleet Homes and new housing schemes by other developers, particularly those who also specialise in timber frame housing, provided the barriers raised in this study can be addressed. The findings of this study should also be of interest to planning authorities and relevant trade associations, including the UK Timber Frame Association. In addition, the lessons learnt will be carried forwards in the professional advice given on future projects by the consultant team engaged in this study.

1.0 Development profile

1.1. Site context

Oakham is a growing town of 10,000 people and is expected to deliver most of the new housing needed in Rutland. The majority of new development in Oakham will be accommodated in an extension to the town, known as Oakham North.

Oakham is located in a predominantly rural area, roughly half way between Leicester and Peterborough. Around a mile to the south east of Oakham lies Rutland Water, a major reservoir owned by Anglian Water. The reservoir and surrounding land are used for water sports, fishing, walking and cycling and it is also one of the most important wildfowl sanctuaries in the country, designated as a Site of Special Scientific Interest, a European Special Protection Area and an internationally important wetland RAMSAR site.

Oakham North is located within the Anglian Water supply area. This is the driest region in the UK, with annual rainfall almost 30% less than the long-term average for England. In addition, the region contains a number of internationally important wetland sites and other water dependent habitats, which must be protected from the impacts of climate change and increasing demand for water. For these reasons, the area is designated an area of serious water stress.[iii]

The development site is situated on the north western edge of Oakham. The site broadly slopes in a south-easterly direction, ranging from 127m above ordnance datum (AOD) to 112 m AOD. The majority of the site comprises medium sized fields which are well defined by hedges and trees, with occasional stands of coniferous or mixed tree planting. Part of the land south of the bypass was occupied by the Barleythorpe Stud and has since been redeveloped to provide housing. The southern area of the site formerly accommodated the Rutland County Show. The grounds are currently used as sports pitches for local football and rugby clubs.

Ground condition surveys have found the site geology to include areas of clay to different depths across the site. The southern part of the site is bisected by Barleythorpe Brook, a large watercourse running west-east across the site, set within a natural valley. The Brook is culverted for approximately 50% of its length. This area will form the basis of Hawksmead Park with the eastern section being a deep, open watercourse maintained by the Environment Agency. An ornamental pond lies adjacent to the Brook. Other small field ponds are scattered across site but these are dry most of the year.

Based on local knowledge the site has never flooded in the past. Examination of the Environment Agency flood maps shows that the site is entirely located within Flood Zone 1, which indicates a low probability of flooding, having less than 1 in 1000 year annual probability of river or sea flooding.

1.2. Development proposals

The Oakham North development will eventually include up to 1,200 new homes, a range of commercial buildings, a continuing care retirement community, new sports facilities and landscaping set over 60 ha. The outline masterplan design has been given planning consent and proposes a phased sequence of construction delivering approximately 100 homes per year.

The Reserved Matters Application was lodged in August 2011 with detailed design and production information prepared November 2011 to April 2012. As of June 2012, the first Phase 1 units are under construction with the remaining sub-phases to be built between 2012 and 2014. The adaptation strategy is focused on Phase 1 because the availability of detailed design information will allow a more comprehensive adaptation strategy to be explored at the building scale. However,

because this phase of the development is relatively well advanced the opportunity to influence the site layout and major features has been limited.

The masterplan layout has been greatly influenced by need to retain the majority of mature native trees and hedgerows on site, which together with the retained ponds and Barleythorpe Brook promote biodiversity within the site and provide amenity to the proposed housing areas. The primary streets are designed as tree, hedge and verge lined avenues. A secondary network of narrower 'village streets' provide access to the remainder of the site.

Figure 1: Illustrative Oakham North masterplan from the Oakham North design code, October 2011

Phase 1 of the masterplan includes 135 houses and two areas of allotments in a public realm setting. The layout of development in Phase 1 is shown in Figure 2. Homes are primarily detached or semi-detached with a small number of terraces and flats. The houses within Phase 1 sit within distinct character areas with a range of building density:

- Low density, 20-30 dwellings per hectare (dph), with primarily detached homes
- Intermediate density, 30-40dph, with terracing and courtyards, and some detached homes
- Higher density, 40-50dph, a mix of terraced, semi-detached homes with some apartments

Figure 2: Oakham North Phase 1 plan

1.3. House types

A number of different house types are being used in Phase 1, all of which use a timber frame construction with brick cladding. Three types have been selected as representative of the majority of onsite construction and used as the basis for detailed modelling and assessment throughout this report:

- A detached house with 4 bedrooms, assumed to be occupied by six people with a net floor area of 107.4 m² (type 2308)
- A semi-detached house with 3 bedrooms, assumed to be occupied by 5 people, with a net floor area of 84.7 m² (type 2422)
- A terraced barn-style house with 3 bedrooms, assumed to be occupied by 5 people, with a net floor area of 104m² (barn type)

Drawings of the elevations of each of the above house types are included in Appendix 1.1, Figure 9 to Figure 11.

Homes in Phase 1 of the development have been designed primarily to meet Code for Sustainable Homes Level 3. Later development phases are expected to be built to increasing standards, however, local planning policy and the approach to Building Regulations and the Code for Sustainable Homes at the national level are being reviewed, and decisions on higher targets for the development in future will need to reflect any changes to policy and regulation.

A 'fabric first' approach has been taken to achieve energy efficiency targets, which uses high levels of insulation, low air permeability and mechanical ventilation with heat recovery. This approach allows higher scores in the energy components of the Code to be met without using renewable energy and is more representative of the proposed construction standards for Part L 2013. Figure 12 in Appendix 1.2 presents U-values and technical performance standards for each of the major building elements.

2.0 Climate change risks

2.1. Introduction

We are increasing the amount of greenhouse gases in the atmosphere faster than ever before[iv]. The International Energy Agency has warned that to avoid 'catastrophic and irreversible' global warming this trend must be reversed quickly. In spite of this, there is a growing consensus that a comprehensive global agreement to reduce our emissions is unlikely to be in place soon[v]. As a result, we are following an emissions trajectory similar to the Intergovernmental Panel on Climate Change's A1F1 scenario, commonly described as 'business as usual'[vi]. This emissions trajectory is the basis for the UKCP09 'high scenario'.

To continue following our current path would mean around a 50% chance of a rise in global average temperature of more than 4°C by 2100[iv]. The projected impacts associated with an increase of this magnitude are severe, particularly as even higher levels of change may be experienced locally. Sea level rises, desertification and the increasing likelihood of extreme weather events[vii] have the potential to cause the migration of millions of people around the world and severe and sustained conflict[viii].

Limiting temperature rises to 2°C has long been the principal target of international debate. Intensifying our efforts to mitigate climate change is essential but an increasing awareness that this target is likely to be exceeded makes adaptation an urgent concern.

2.2. Selecting climate change scenarios

The strategy will make use of the UKCP09 high scenario, data availability permitting, to obtain a conservative estimate of the potential impacts and reflect the current global emissions trajectory. For next 50 years, it represents an upper central estimate of temperature change. For the second half of the century and beyond, it provides a plausible upper estimate of temperature change, which is used to test whether a suitable retrofit option could be deployed should this temperature change become a more likely outcome. Details of the climate change scenarios considered for the project and the basis for this selection are provided in Appendix 2.1.

2.3. Climate change projections

UKCP09 provides probabilistic projections[ix] of key climate variables at a higher geographic resolution then has ever been available before. The Weather Generator allows the UKCP09 projections of long term trends to be used to interpret likely changes in weather patterns. It can be helpful in assessing vulnerability to impacts which occur over shorter time periods.

The detailed data behind our analysis of climate change projections is provided in Appendix 2.2. In summary, the UKCP09 projections confirm that the national climate trends are broadly applicable to Oakham North:

- Warmer wetter winters
- Hotter drier summers
- A higher likelihood of extreme weather events including heatwaves and intense rainfall
- The impact of climate change on wind speeds is uncertain and little confidence is assigned to existing projections

2.4. Climate change risk assessment

2.4.1. Initial risk assessment

The climate change risk assessment is based on the methodology promoted by UKCIP. An initial risk assessment is used to qualitatively identify the key risks which should be addressed as a priority. These issues are then investigated further, using more detailed analysis and modelling to characterise the risks further and to design and validate adaptation measures.

A risk matrix approach incorporates both the uncertainty of future outcomes and their consequences into account in the decision making process. The components of risk are:

- Likelihood: the probability of an event occurring as well as its frequency and duration
- Consequence: the impact on buildings, infrastructure and people (taking into account their vulnerability) of that event

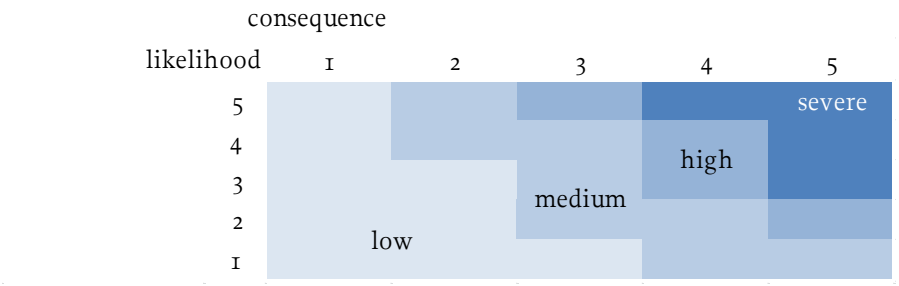


Figure 3: Risk matrix used to classify risks according to its severity

The list of initial risks taken into consideration has been drawn from *Design for future climate – opportunities for adaptation in the built environment.* The assessment at this stage is both relative and subjective but has been based on the site and its context through discussions with the developer and the design team. It has also been supported by the findings of the *UK's Climate Change Risk Assessment*[x].

Designing for comfort	likelihood	consequence	risk
Keeping cool - internal daytime	5	3	high
Keeping cool - internal night time	3	4	high
Keeping cool - public realm	3	3	med
Construction			
Structural stability - below ground	3	3	med
Structural stability - above ground	2	2	low
Structural stability - roads and hard surfaces	3	2	low
Structural stability - slopes and embankments	1	3	low
Weatherproofing, detailing and materials	2	2	low
Construction - materials behaviour	2	2	low
Construction - work on site	1	2	low
Managing water			
Drainage - fluvial flooding	1	4	low
Drainage - groundwater flooding	2	3	med
Drainage - surface water flooding	3	4	high
Drainage - building related	3	2	low
Drainage - foul sewer failure	1	3	low
Drought - domestic water resources	3	3	med
Drought - landscape	4	2	low

Figure 4: Summary of the initial risk assessment

The following potential risks have been identified as priorities for the Oakham North development in light of this initial risk assessment:

- Overheating within homes
- The structural stability of foundations and above ground construction in homes
- Surface water flooding
- Water resource availability

Further detailed analysis of each of these areas of risk is provided in the following sections.

2.4.3. **Overheating within homes**

Higher summer temperatures will increase the likelihood and intensity of overheating in homes and in the public realm. Homes at Oakham North will be well insulated, which can trap solar gains. In addition, they will be timber framed, potentially creating a greater risk because of their relatively low thermal mass.

Due to the potential high risk exposure to rising summer temperatures, all three dwelling types have been assessed for overheating risk against 2005 and future weather data, using dynamic thermal modelling software. The assessment was undertaken by Buro Happold and the details are provided in their technical report, which has been submitted as Appendix 3.1 to this main project report (see Designing for Thermal Comfort: Final Report, Buro Happold (March 2013),).

The results of this assessment suggest that the current design proposals for the three dwellings vary in their response to the three future climate scenarios tested. These responses can be summarised as follows:

- Most dwelling spaces (with the exception of kitchens) are effective against overheating criteria in the current climate.
- All spaces fail to comply with overheating criteria for 2050 extreme weather – this is considered representative of the extreme nature of average and peak temperature increases in this climate scenario.
- Bedrooms in the detached and semi-detached house types typically pass the overheating criterion for current, 2030 median and 2050 median weather.
- Bedrooms in the terraced barn-type house tend to fail the overheating criterion under the 2050 median scenario as well as 2050 extreme weather conditions – this is likely to be due to the limiting opening area of windows in these spaces where roof-lights only are provided and relied upon for natural ventilation, as well as increased conduction gains due to lack of a buffer roof void.
- Non-bedroom occupied spaces perform significantly worse than bedrooms against the overheating criterion under both 2030 and 2050 weather scenarios, typically due to daytime occupation (i.e. during the assessed period) and high levels of solar gain. Where these spaces are located on west and south facing elevations they should be prioritised in terms of measures that prevent solar gains (internal / external shading, solar control glass) before addressing reduction of internal gains.
- Kitchen spaces perform particularly poorly – these areas have very high internal gains and short periods of occupancy typically during times of high solar gain. Both of these factors contribute to making overheating targets difficult to meet.
- Orientation should be considered for high heat gains spaces such as kitchens, where location facing north or east is preferable to south or west. This may make a tangible (if not very significant) contribution to reducing risk of overheating.

2.4.4. **Structural stability**

The main structural risk to the homes at Oakham North as a result of climate change is related to the impact on the building's foundations, which will be affected primarily by the bearing capacity of the ground and the behaviour of the ground under fluctuations climatic and sometimes related ground water conditions. Analysis of the potential structural risks to the homes in Phase 1 at Oakham North has been undertaken by Capita Symonds. Their findings are set out in the document entitled Technical Report on Construction Standards, Capita Symonds (2012), which is provided in Appendix 3.2 of this main project report.

Ground condition surveys have found the site geology to include areas of clay to different depths across the site, which could affect the below ground stability of foundations, roadways and hard external surfaces. Residential foundations tend to be relatively shallow strip footings. Because clay soil shrinkage may lead to subsidence, deeper or more expensive foundations may become necessary.

Foundations on most rocks, sands, gravels and chalk are generally unaffected by climatic conditions as the ground does not gain or lose strength or move as a result of these conditions. Foundations on some carbonate rocks and chalk can be affected by changes in ground water level and flow leading to the formation of voids in the founding stratum which may lead to sudden subsidence. At the time of reporting it is uncertain what the general effect climate change in the UK will have on groundwater levels and flows in such strata and many changes are likely to be both region and site specific. The Natural Environment Research Council's Centre for Ecology and Hydrology in association with the British Geological Survey is undertaking a detailed study on future river flows and ground water levels results of which are expected to be published in October 2012.

Foundations of shrinkable clays are often severally affected by climatic conditions as in summer water is drawn from the clays leading to shrinkage which results in settlement of the ground. This is by both evaporation for the ground surface and transpiration of vegetation, often referred to as evapo-transpiration. Swelling occurs in winter leading to heave of the ground. The depth of these effects is dependent on the local climate and vegetation but in southern and central England away from the roots of trees and large shrubs seasonal desiccation and heave occur up to 1 to 1.5m depth, the latter depth being in current extreme years. Current foundation guidance for high plasticity clays is that foundations should be set at least 1m below existing ground levels away from trees and large shrubs as the movements associated with desiccation in current 'extreme' years will not cause significant damage and any cracks will close in the following winter.

Where trees or larger shrubs are present there is deeper, sometimes persistent, desiccation associated with roots of trees and large shrubs. Design of foundations where trees and large shrubs are present are necessarily site-specific as they are dependent on the type of trees and large shrubs, the degree of shrinkability of the founding clays and the distance the vegetation is from buildings.

The amount of evapo-transpiration that occurs is controlled by the ambient temperature and most importantly wind speed as well as the ground's ability to release moisture. There are a number of major papers that have been examining the effects of climate change on evapo-transpiration and soil moisture deficits (a measure of the suction in the ground as a result of desiccation). In examining the likely effect of climate change on the foundation design of residential housing we have examined a number of reference documents.[xi] On the basis of this review, it is apparent that there remains at this time considerable uncertainty as to the level of risk associated with changes that will occur with soil moisture deficits and evapotranspiration as a result of climate change, not least because of the uncertainty as to the likely change in wind speeds that will occur in future.

We have deduced that for Southern and Central England there is expected to be wetter winter/springs – on a mean basis 13 to 16% wetter in winter/spring and 15 to 18% drier in summers by 2080. Given the uncertainty with regard to wind speeds assuming that these do not change significantly it is likely that the depth of seasonal desiccation will increase. There has been no published detailed research as to how this will impact on foundation depths to minimise the risk of significant damage and determining the depth is beyond the scope of this work. We have assumed for this study that the mean depth of seasonal desiccation will increase by 500mm by 2100 and in extreme years by greater than that, possibly 1m.

2.4.5. **Surface water flooding**

Although the site is not in an area of fluvial or coastal flood risk and there are no records of it having flooded in the past, the risk of surface water flooding is projected to become more severe as climate change brings more intense rainfall. The potential impacts of climate change on surface water flooding for Oakham North have been considered by Wormald Burrows, and their findings are reported in Managing Water Technical Report, Wormald Burrows (2013), which is provided in Appendix 3.3.

There is potential for surface water flooding on or around the site in future if the site and its drainage systems are not adequately designed to cope with the projected increases in rainfall rates. This could include localised surface water flooding on-site. Where this causes foul sewers to overflow, floodwaters can be polluted by domestic sewage. In addition, as the whole of the site eventually drains to Barleythorpe Brook, increasing rates of run-off could increase flood risk in Barleythorpe Brook or at other sites downstream.

A Defra and Environment Agency study has used extreme value analysis to characterise the probability and magnitude of extreme events[xii]. The project assessed the likely vulnerability of individual catchments by looking at the catchments properties and the response of the flood regime to a range of climatic changes. The change in the return period of rainfall events is then calculated. The analysis of individual catchment flood responses identified five main families of response patterns. Two catchments near to Oakham were tested in the report and were defined as enhancing and sensitive, which means they are "relatively vulnerable to small changes in rainfall" and "very vulnerable to almost any increase in rainfall" respectively.

To prevent increasing risk of flood risk downstream or on other sites as a result of the development at Oakham North, the Environment Agency requires the surface water run-off rates after the development is completed to be no greater than for the greenfield site. The Environment Agency guidance on the assessment of flood risk and the design of surface water drainage systems recommends that an allowance is made for rainfall intensities to increase by 30% compared to current rates to account for the potential impacts of climate change.

These industry standard design assumptions for flood risk have been reviewed for Oakham North, to determine if they are sufficient compared to the projected extreme rainfall events based on data from the UKCP09's weather generator. If precipitation at the study site increases in line with the projections set out in Section 2.4.4, the peak surface-water run-off rates from the site would be less than that generated by applying the Environment Agency's recommended allowance of a 30% increase on current rates. This confirms that designing the site and its surface water drainage systems to comply with the Environment Agency guidance should be more than adequate to manage the increasing surface water flood risk associated with the projected increases in rainfall intensity. This allowance has therefore been used in the development of the adaptation strategy for the site and the design of hard landscaping, green infrastructure and sustainable drainage systems.

2.4.6. **Water resource availability**

Spring and summer droughts in the UK are becoming increasingly common and climate change projections suggest summer rainfall will decrease, or that there will be more sporadic periods of heavy rainfall interspersed with dry spells. This, coupled with projected increases in summer temperatures and population growth, could result in a significant problem with water shortages throughout the country.

The risk associated with the availability of water resources is a question of supply and demand and addressing both short and long-term scenarios. According to the Environment Agency, the worst case scenario is that total water demand in England and Wales could increase 35% by the 2050s.

This increase in demand could result in widespread water rationing if reservoirs, aquifers and rivers are already below normal levels as a consequence of drier and hotter summers.

Working with the Environment Agency, Anglian Water has undertaken an assessment of how climate change is likely to affect its groundwater and surface water resources and also how it could affect demand for water. The assessment considers the supply and demand balance through to 2039, which is the period covered by the new Water Resources Management Plan. It also looks at the longer term impacts particularly on vulnerable surface water resources, using UKCP09 projections for the 2050s.

Under the worst case climate change scenarios considered for the 2050s, the water resource zone in which Oakham is located is at risk of being under a supply-demand deficit. Although Anglian Water has identified the potential to resolve this deficit by developing the South Lincolnshire Reservoir, installing infrastructure to enable water trading between different water companies in the East of England, and reducing leakage in the system, the Water Resources Management Plan also notes that large reductions levels of consumption would also be required. Water efficiency will therefore be an important aspect of the climate change adaptation strategy for new housing, including development at Oakham North.

3.0 Adaptation strategy

3.1. Adaptation strategy

The aims of the adaptation strategy for Oakham North are to:

- Reduce the impact on the development of changes to the climate which are happening now
- Increase resistance and resilience to future impacts

The persistence of carbon dioxide in the atmosphere gives global warming inertia, so temperatures are projected to continue rising for decades after greenhouse gas emissions peak. The change will be incremental and will result in an on-going process of change and uncertainty[xiii]. Adaptation needs to be a dynamic and flexible process, with decisions made in light of the lifetime of buildings and infrastructure, and what opportunities might be exploited to enable adaptation retrofit in future.

Adaptation of our homes will be an on-going process of change. We recognise that any additions to construction costs now should be focussed on addressing significant risks in the short to medium term while enabling future retrofit and behavioural responses to adaptation. To this end, where possible we have considered the most appropriate timing for implementing measures, based on when the risks are projected to occur, the lifetime of products and opportunities to retrofit adaptation measures during normal replacement/maintenance cycles.

The adaptation strategy has been structured to respond to the key areas of risk and consider the design opportunities set out in the TSB's Design for Future Climate guide.[xiv] D4FC Checklist 3: Design Opportunities Exploited, provided in Appendix 3.9 of this report, sets out which of those design opportunities have been considered, recommended or implemented.

3.1.1. Designing for comfort

The options for designing homes at Oakham North to ensure thermal comfort in the future climate have been assessed by Buro Happold as part of this study. Their analysis and detailed findings are presented in the Thermal Comfort Analysis and Recommendations report, which is provided in Appendix 3.1.

The following options were considered for improving thermal performance:

- Glazing solar performance
- Thermal mass
- Thermal mass plus night-purge
- Mechanical ventilation flow rate increase
- Pre cooling of mechanical ventilation air
- Evaporative cooling
- Stack ventilation
- External shading
- Internal shading
- Green infrastructure
- Adaptive thermal comfort

A description of each of these options including key assumptions used in thermal modelling is provided in Appendix 3.6.

On the basis of the technical analysis undertaken for this study, the following elements are recommended for inclusion in homes in Oakham North Phase 1 from the outset to ensure that they are designed for thermal comfort:

- Provide educational material on climate change, the adaptation strategy and how behaviour and use of appliances affects thermal comfort
- Integrate shading devices for increased occupant control of the indoor environment to limit summertime solar gains, especially on west and south-facing glazing, and rooms where heat gains and occupancy levels are high, such as living rooms and kitchens. External shuttering should be considered as more effective compared to simple internal shading (i.e. roller or reflective blinds)
- Develop window opening strategy based on dwelling type - e.g. rooms such as barn bedrooms where free area is potentially limited by opening type (roof-light)
- Use open plan spaces (e.g. where kitchen, living, dining are open to each other) to enhance cross ventilation potential
- Incorporate green infrastructure at the individual building level (e.g. green roofs, green garden space allowance) as well as at the master-planning level (green communal areas, tree-planting), with an appropriate maintenance strategy
- Consider locating high heat gain spaces such as kitchens on the north or eastern elevations to reduce solar gains
- Use thermal mass with night cooling where feasible, focusing on dwellings such as the barn where opportunities for increasing the proportion of heavyweight elements within the scope of the design are greatest

In the medium term, considering the 2030s timescale, the following measures are recommended for Oakham North:

- Additional internal and/or external shading
- Retrofit of phase change materials to increase the thermal mass of the lightweight structures
- Retrofit of improved mechanical ventilation, use of evaporative cooling and/or mechanical cooling to kitchen/living areas
- Significant progress in green infrastructure development at a dwelling and master-plan level
- Re-assess dwellings under improved/updated climate predictions for 2050 to validate or revise impact of adaptation measures

In the long term, through to the 2050s and beyond mechanical cooling is likely to be required under extreme weather conditions for living spaces and kitchens and a comprehensive green infrastructure strategy should be in place across the development.

To develop the adaptation strategy for thermal comfort, the impact of the above measures on overheating risk in the three building types was tested individually and in combination in three different adaptation packages, as set out in Figure 5.

Package 1: Passive option	Solar control glazing Stack ventilation Supply air pre-cooling (earth tubes)
Package 2: Mechanical option	Solar control glazing External shutters Mechanical ventilation rate increase Evaporative cooling
Package 3: Thermal mass option	Solar control glazing Thermal mass (with night cooling) Reflective internal blinds Evaporative cooling

Figure 5: Adaptation packages for thermal comfort

The packages tested differ in terms of deliverability and complexity. Package 1 is considered a passive option, where there is little 'active' operation or management required by building occupants. The stack measure, although potentially limited in terms of comfort performance past the 2030 climate, is technically simple to integrate into a typical house although extra detailing may be required during design and construction at roof/attic level. Use of earth tubes to pre-cool incoming air is technically simple and likely to be financially viable where significant volumes of dwellings are built. Solar glazing aside, all of the package 1 measures are likely to be difficult to retrofit in future, because they are integral to the structure and fabric of the building. As a result it would be more technically feasible and financially viable to build in these measures from the outset rather than retrofit them in the future.

Package 2 focuses on 'active' options that relate both to occupant-controlled external shading and use of mechanical ventilation with heat recovery (MVHR) in a way that is adapted to reduce overheating risk. Key to this is a combination of increases in supply air flow rate and use of evaporative cooling. This case assumes that future advances in ventilation technology will deliver MVHR systems that can deliver higher flow rates of air without compromising unit/duct size, acoustics and fan power (energy consumption). Of the packages tested this appears to be the most effective in terms of meeting the comfort temperature criterion as most of the spaces will comply against the 2030 climate case and some spaces (bedrooms and some living spaces) will comply against the 2050 median climate case.

The mechanical ventilation measures should be considered in terms of future-proofing dwellings for adopting these measures at the 2030 stage. These may include allowing additional space (for example in the roof space as opposed to kitchen cupboards) for a larger unit to be added at a later date, easy access to the MVHR unit, and potentially additional space (e.g. in ceiling voids) for increasing duct size. Package 2 also allows occupants to maintain a certain degree of control over their environment, allowing good potential for adaptive thermal comfort. Modifications to MVHR systems to incorporate an element of evaporative cooling are likely to require additional space at the MVHR unit itself, or a connection to external space (through roof or wall elements, for example) to increase the evaporative cooling effect.

Package 3 includes the use of thermal mass with night cooling, with some degree of limiting solar radiation penetration and evaporative cooling. This option relies on a high level of occupant awareness and control over their environment through lowering and raising of internal blinds during peak periods of solar gain and assisting the 'recharge' of the thermal mass elements during periods of low air temperature during the night. The results suggest that this package is limited in reducing the risk of overheating compared to Package 2 for dwellings where heavyweight elements are limited, such as the detached and semi-detached house types considered in this study. The barn dwelling has a higher overall application of heavyweight construction elements which improve the effectiveness of this measure.

This package could however be considered appropriate for construction of dwellings at present as use of heavyweight construction in place of lightweight is technically feasible and robust. Additional thermal mass could be added as a retrofit measure through the use of phase change materials as the impacts of climate change increase and phase change materials become more common and cost-effective in the market. Although the general principles of phase change materials are well understood, additional investigation of a more appropriate way of applying phase change materials, such as wall panels, ceiling tiles or floor tiles and the associated impact should be carried out to determine a better understanding of their overall benefit.

This package of measures provides benefit to the occupants in terms of the degree of control over their environment, allowing the impacts of adaptive thermal comfort to be considered. The use of internal blinds will contribute to adaptive thermal comfort (as well as protection from visual discomfort caused by glare) despite their limited contribution to meeting the operative temperature comfort criteria requirements.

Analysis of the baseline case, each adaptation measure and three packages of measures for the 2050 90th percentile weather tape show that the overheating criteria cannot be met at 2050 90th percentile and there is a significant risk of overheating. It is therefore recommended that under the near extreme future climate projections, it is likely that an active mechanical cooling may be unavoidable, using high efficiency air conditioning or heat pumps.

3.1.2. **Construction**

Recommendations for adapting the construction of the buildings, specifically the foundations and the building superstructure, were provided by Capita Symonds in their Technical Report on Construction Standards (see Appendix 3.2). Their recommendations are summarised below.

Foundations

A number of options have been considered for foundation design:

- Traditional mass concrete and ground beams
- Deeper mass concrete and ground beams
- Basement box
- Piles and ground beams
- Deep raft option

Further detail is provided in Appendix 3.7 for each of these options. Each of the different foundation designs would have advantages for different sub-areas of Oakham North Phase 1, due to the variations in ground conditions across the site. The assessment of foundation suitability has been undertaken on the basis of information provided in the Ground Conditions chapter of the Environmental Statement for Oakham North.[xv]

The area of the site on which Phase 1 will be built is traversed by a stream running west to east, has numerous unknown existing building foundations and a large number of semi mature or mature trees. The Environmental Statement states that localised soft ground, in the form of alluvial silts and clays can be expected and underlying this the ground is expected to comprise of variable ground with clays and silts. In these variable ground conditions piled foundations are likely to be the most appropriate option, with deep raft foundations also being appropriate further away from the stream. A basement box foundation is unlikely to be suitable due to high groundwater levels and flows.

The land directly to the north of the Phase 1 site is currently greenfield land, except for an old quarry. There are isolated semi mature or mature trees in the area and partially filled-in former ponds. The south eastern boundary has a well-established tree lined field boundary. The Environmental Statement states that ground conditions here generally comprise of highly plastic Upper Lias clays, and in those areas remote from trees appropriate foundation options would include deeper mass concrete and beam foundations, a basement box or a deep raft foundation. Where existing trees are within one times the mature tree height of any part of the building, a basement box, piled or deep raft foundation would all be appropriate. In the area of the quarry and old ponds Option 4 is likely to be the most appropriate foundation option as the made ground may vary considerably in depth over short distance and Option 4 can allow for such rapid variation.

The area directly to the south of the Phase 1 site is underlain by the Marlstone Rock Bed and, where this is close to the surface, traditional mass concrete and beam foundations or a deep raft are most appropriate. A basement box foundation is unlikely to be feasible or appropriate here as ground water levels and flows can be expected to be high.

Building superstructure

The building superstructure for the houses built at Oakham North will be timber framed, in line with Larkfleet's base construction model. Where residential properties are built with timber there are considerable advantages with regards to the loads applied to the foundation, the amount of embodied carbon (assuming the timber is supplied from sustainable resources), speed of construction and cost. A masonry wall compliant with current thermal performance requirements likely weighs in at around 4kN/m^2 compared to under 1kN/m^2 for the equivalent rendered timber panel construction. Given a construction height of 4.5m for a two storey house this would reduce foundation loads by 1.35tonnes per metre of foundation length and thus would potentially reduce the cost of a piled and beam option as the piles would not be carrying as a high a load and could be shorter or wider spaced to ensure the efficient use of the connecting ground beam and reduction in overall pile numbers.

Timber construction is often combined with a single skin external masonry cladding that nullifies the weight advantage illustrated. Given a render or timber cladding finish the advantage remains. The masonry dressing placed in front of the timber frame has a largely cosmetic function. There are also advantages with fire resistance, where the fire is external, and a small thermal advantage. Noise transmission may also be reduced and longer term weathering resistance may be improved. The wall may be constructed of rendered blockwork or an externally expressed brick finish. The masonry will be dependent upon the timber structure for strength and stability.

Where the residential property is to be built with traditional brick walls, lime mortars are recommended if the foundation is expected to move gradually with time. Lime mortars, unlike cement mortars, are less brittle and can accommodate gradual movement without cracking. Lime mortar has been traditionally considered to have an advantage over a cement based render in accommodating movement. As cracking is less of an issue with lime mortar, water is less likely to collect behind the render and therefore damp tends to be less of a problem than in a traditionally

constructed building. Timber buildings with a flexible cladding, e.g. timber sheathing, can accommodate much more movement.

3.1.3. **Managing water**

Surface water drainage

The surface water drainage strategy for Oakham North had already been agreed prior to the commencement of the D4FC project. The work was undertaken by Wormald Burrows, who have been engaged as part of this study to review the design in light of the available information about climate change projections. Their findings are presented in the Managing Water Technical Report, which is provided in Appendix 3.3.

Guidance on designing to mitigate flood risk is provided by the Environment Agency, and meeting these requirements is supported by the National Planning Policy Framework (NPPF) with the design criteria set out in the associated Technical Guidance[xvi]. It requires the annual flow rate probabilities up to and including the 1% annual probability (1 in 100 year event) the rate of surface water runoff from the developed site into a watercourse should be no greater than the undeveloped or "greenfield" rate of runoff for the same event, and that no dwelling should be subject to flooding. The calculation of greenfield runoff from the study site at Oakham has been agreed with the Environment Agency as 5 l/s per hectare. Thus for this site, comprising an area of approximately 4.8 hectares, a maximum runoff rate of 24 l/s should be applied.

The purpose of this is to retain a natural flow regime in the receiving watercourse and not increase peak rates of flow for events exceeding the 1% annual probability. In discussing the surface water drainage system based upon current design criteria it is necessary to consider three annual probabilities:

- 100% annual probability (1 in 1 year event)
- 3.33% annual probability (1 in 30 year event), and
- 1% annual probability (1 in 100 year event)

The 1 in 1 year event is the highest probability event, ensuring that flows to the watercourse are tightly controlled for the more frequent events. The 1 in 30 year event is significant to our design because the water authority that will adopt the sewers, Anglian Water, requires that surface water sewers should be capable of carrying the 3.33% annual probability event within the system without causing flooding to any part of the site.[xvii]

As aforementioned, the Environment Agency requires that in extreme storm events such as the 1 in 100 year event, the site layout and drainage design should be such that internal property flooding does not occur. For these more extreme events, the capacity of the surface water sewers may be inadequate, and the additional runoff generated should be disposed of by way of infiltration, or if this is not feasible due to soil type, then an attenuation solution should be provided, with a control device fitted such as a hydro-brake to restrict the flows to the agreed peak rate of discharge, ie 24 l/s for this site. The surface water drainage system for Oakham North Phase 1 has been designed to ensure that these requirements can be achieved, while allowing for an additional 30% rainfall volume on top of the current peak to account for the impacts of climate change.

The use of SUDS is promoted and where viable, the design utilises soakaways in rear gardens of the new development, to which runoff is directed from private roof areas and driveways. Soakaway test results reveal good infiltration results over the majority of the site, however in the northern part, closer to the Brook, soakaway results are poor. In this area, the use of soakaways would not be viable. In accordance with 'Building Regulations' and 'BRE Digest 365 – Soakaway Design', soakaways have to be located at least 5 metres away from building foundations. This is to prevent

the saturation of foundations and any potential reduction in bearing capacity of the surrounding soils, which could cause settlement. In the event that piled foundations are used, an assessment of the impact on soil properties can be made by the structural engineer in deciding if soakaways can be positioned closer.

Although the local highway authority, Rutland County Council, agreed to the use of soakaways for runoff from the main (adopted) roads, it proved difficult to locate them in public areas, whilst maintaining a 5m distance from buildings. Consequently, porous paving was considered for the main (adoptable) roads and discussions held with Rutland County Council confirmed that they would be willing to adopt this form of construction. The developer, Larkfleet Homes, subsequently carried out a costing exercise to compare porous paved roads against a traditional road and sewer system. The results for this particular site showed that porous paving was not as cost effective, when compared to a more conventional road and sewer system. Hence, surface water runoff from road areas would be positively drained and attenuated, prior to being discharged into the Brook at the allowable rate of discharge agreed with the Environment Agency.

In addition, the design of the site also allows for flood routing, so that in an extreme flood event, excess runoff or flood water would not be obstructed by the new development, but instead be able to follow a natural flow path to the brook. This is demonstrated by the floor levels of the proposed houses being carefully designed and set above road levels to reduce the risk of flooding to any properties. Also, road levels and alignments are designed to direct excess runoff from the carriageways towards the open space areas and the lower lying watercourse.

Water efficiency

In the UK, the average person uses approximately 160 litres of water per day. In order to ensure that future water resources are sufficient to meet demand, people will need to use less water. For new housing at Oakham North, recommended options for encouraging more efficient use of water include:

- Fitting water meters to make householders aware of the amount they use and relate costs directly to usage
- Low flow taps
- Low flow showers
- Low volume dual flush toilets
- Reduced volume baths
- More efficient appliances if provided

Installing a water meter is estimated to reduce domestic water consumption by around 10% on average. Low flow fittings and appliances should be considered as a minimum standard for Oakham North, enabling the development to comply with its Code for Sustainable Homes target in addition to support adaptation to climate change. Low flow fittings can provide savings of between 20 and 25% for most uses including toilet flushing, showers, taps and appliances, with little compromise to the perceived quality of service. Further savings, up to around 40 to 50%, can be made by using extremely low flow fittings and appliances. However, some users will perceive a reduction in the quality of service where these are fitted, which may encourage future residents to remove and replace fittings with higher flow devices. These are therefore not recommended.

In addition, water efficiency could be further improved by incorporating systems for rainwater harvesting or grey water re-use. If a water recycling system can be implemented on the study site to provide an alternative source of water for general household use, this will help to reduce the reliance on the public water mains. A successful water recycling solution could provide the new

development with further resilience to climate change in response to the projected summer water shortages, and provide an example of how water recycling systems can benefit other future development sites.

In rainwater harvesting systems, rainwater is collected and stored in a tank and then pumped on demand to dedicated supply points like toilets, washing machines, garden taps. If using water collected from roofs only, this water recycling solution can provide around 30% of domestic water consumption. In addition to reducing mains water use, it can also reduce surface water run-off as part of a SUDS scheme. As a more cost-effective solution, rainwater butts can be installed in gardens for outdoor use.

Grey water recycling systems collect water from baths, showers and basins for use in toilet flushing and, in some cases, washing machines or outdoor irrigation. The water is filtered and treated, and as a result more energy is used in grey water recycling than rainwater harvesting. The tanks needed for storage tend to be smaller than in rainwater systems, because supply is more predictable and better matched to demand. Grey water re-use systems are able to save around 30% of domestic water demand if just used to flush toilets, or up to 45% if used for toilets and washing machines.

3.1.4. **Green infrastructure**

Effective, well design and well maintained green infrastructure is essential to the adaptation strategy for Oakham North. Green infrastructure will have an important role in providing a comfortable living environment, managing water resources, maintaining stable ground conditions across the site and providing green spaces and corridors to enable local habitats and species to adapt to climate change.

Trees in particular can have a significant impact on climate resilience. As part of this study, a technical report has been prepared on the role of trees in the urban environment in terms of mitigation and adaptation to climate change, and how they can be incorporated in new development to maximum effect. The report, Review of Existing Research on Trees and Climate Change, LDA Design (2012), is provided in Appendix 3.4.

As the effects of climate change become better understood, it is becoming increasingly clear that one of the best ways to make towns and cities more hospitable over the next few decades is to increase the number and size of trees in urban areas. Over 80% of the UK's population live in urban areas and trees have been identified as being an essential element of any urban climate change adaptation strategy. Trees in and around built up areas, known as 'urban forests', are being recognised as a key component of the infrastructure that not only makes place work, but look and feel better too.

Whilst providing shade for buildings and streets, trees also increase evapo-transpiration and help to reduce local air temperatures as a result. During rainfall, tree canopies reduce the rate at which water reaches the ground, and thus slow the rate at which the water enters the drains. This gives the drainage system more time to distribute surface water away from the site, reducing the likelihood of flooding. This can be particularly effective as part of a SUDS strategy, which should also include infiltration measures and water storage on-site where appropriate (for details of the proposed drainage strategy see section 3.1.3).

It is also important to note that trees are vulnerable to the impacts of climate change. In particular, varying water availability, changes in soil moisture, heat stress and increasing risks associated with pests and diseases can all affect the health and lifespan of trees. This element of the adaptation strategy for Oakham North has therefore been developed to maximise the resilience of trees planted across the site. Enhancing ecological resilience to diseases and climate change requires a highly diverse local tree population. This is important to consider both at the species and genetic level.

Research suggests that diversity of species in terms of mix, age, genetics and management is a more sustainable strategy for successful implementing trees into the urban environment.

Tree species that are considered to be suitable for use on the Oakham North development and relatively resilient to the foreseeable climate conditions have been identified and are listed in Appendix 3.8. This diverse range of species forms a palette from which trees can be selected for the development. Note that this list is not exhaustive and other species may also be suitable for specific locations and requirements.

As trees generally form the dominant elements of the long-term landscape structure of a site, careful consideration needs to be given to their ultimate height and spread, form, habit and colour, density of foliage and maintenance implications, in relation to both the built form of the new development, and the retained landscape features. Where tree retention or planting is proposed in conjunction with nearby construction, the objective should be to achieve a harmonious relationship between trees and structures that can be sustained in the long term. The good practice recommended in this British Standard is intended to assist in achieving this objective.

There are both benefits and constraints to planting trees early on in the development process. Simply put, the earlier the tree in taken into consideration within the design process and is planted; the longer it has time to for considered as part of the whole design and to establish itself. However, implementing trees early in the design will provide some compromises with other services and functions within the design. Also, during the construction phase, great care is required to ensure the protection of the tree – the larger the tree, the greater the potential restriction on the construction activities on site.

New planting should normally be selected and located to ensure that adequate space is allowed for future growth of root systems, stems and canopies to maturity, without this causing direct physical contact with or damage to nearby structures, or causing obstruction of access, light or other avoidable nuisance. Exceptions could include planned short-term planting.

On shrinkable clay soils, account should be taken of the risk of subsidence that might be caused or exacerbated by new planting removing moisture from load-bearing soils. The foundation construction and condition of existing structures, especially on shrinkable clay soils, should be a determining factor when taking decisions on species and location for new plantings, to minimize subsidence risks and to seek compatibility between structures and trees.

3.2. Timescales

In terms of implementation timescales, it is essential that the priority measures which are fundamental to the design and layout of the development are integrated from the outset, as the cost and practical implications of retrofitting them are prohibitive. For Oakham North these include:

- Resilient foundation designs
- Surface water drainage systems
- Green infrastructure

To ensure that green infrastructure is sufficiently mature to provide tangible benefits to the development from the time of the first occupation, advanced planting of trees in relevant parts of the site has been recommended to Larkfleet.

A number of other measures are practical to implement from the outset, provide an immediate benefit to residents, and have been recommended for immediate installation in the new homes at Oakham North (Figure 6). Alongside these we have listed measures which are not necessary under the short term climate projections and are not currently considered viable for this development, but may be retrofitted in future as and when the need is demonstrated. The 2030 and 2050 timeframes

are realistic, as it is likely that most mechanical equipment and water fittings will be replaced every 20 years or more frequently. It was felt that that there is insufficient confidence about long term climate projections or knowledge about the technologies that could be available in future to be able to advise on what adaptation measures should be retrofitted in the 2080s.

	Recommended adaptation measures
Now	**New-build homes** *Designing for comfort* • Locate high heat gain spaces such as kitchens on north or eastern elevations • Use open plan spaces to enhance cross ventilation • Use thermal mass with night cooling where feasible • Fit simple shading devices, especially west and south orientations and rooms where heat gains and occupancy levels are high, such as living rooms and kitchens. External shuttering preferred to simple internal blinds if viable • Fit mechanical ventilation with heat recovery or ensure sufficient space for future installation, including an allowance for larger ventilation ducts • Educational material on climate change and how behaviour affects thermal comfort *Construction* • Design-in resilient foundations *Managing water* • Install good practice low water-use fittings and water meters • Provide rainwater butts for outdoor irrigation • SUDS *Green infrastructure* • Green infrastructure for individual buildings (e.g. green roofs, green garden space) and communal areas, including trees **Retrofit to existing homes** • N/A as this is a new site.

	Recommended adaptation measures
2030s	**New-build homes** • Re-assess dwellings under improved/updated climate predictions for 2050 to validate or revise impact of adaptation measures *Designing for comfort* • Include phase change materials in specification of dwellings as financial viability increases • External blinds or shuttering on west and south orientations • Earth tubes or evaporative cooling *Managing water* • Install best practice very low water use fittings • Provide rainwater harvesting or greywater recycling **Retrofit to existing homes** *Designing for comfort* • Install more advanced shading devices eg external shutters if not already in place • Retrofit phase change materials in rooms where overheating a problem • Retrofit improved mechanical ventilation, with evaporative cooling and/or mechanical cooling to kitchen/living areas where needed *Managing water* • Retrofit best practice very low water use fittings
2050s	**New-build homes** *Designing for comfort* • Significant levels of solar shading and mechanical ventilation • Mechanical cooling for vulnerable house types and homes in higher density urban areas **Retrofit to existing homes** *Designing for comfort* • Retrofit mechanical cooling for living spaces and kitchens *Managing water* • Retrofit rainwater harvesting or greywater recycling

Figure 6: Recommended timescales for adaptation strategy

3.4. Cost benefit analysis

Larkfleet Homes have advised that the base construction cost for the homes in Phase 1 of the Oakham North development is around £1,000 per sq. m. including prelims (site overheads), general overheads, profit, professional fees, plot drainage, fencing and an allowance for communal areas. This base construction cost assumes that the homes are built to achieve Code for Sustainable Homes level 3 and compliance with the Building Regulations Part L (2010), before the adaptation strategy is taken into account. It is comparable to the base construction costs considered in the published analysis of the costs of achieving the various levels of the Code for Sustainable Homes.[xviii]

The additional cost of implementing the measures recommended in the adaptation strategy has been estimated by quantity surveyors at Capita Symonds. Their detailed report is provided as a separate document alongside this report (see Appendix 3.5). The conclusions of their analysis are as presented in Figure 7 for each of the house types considered.

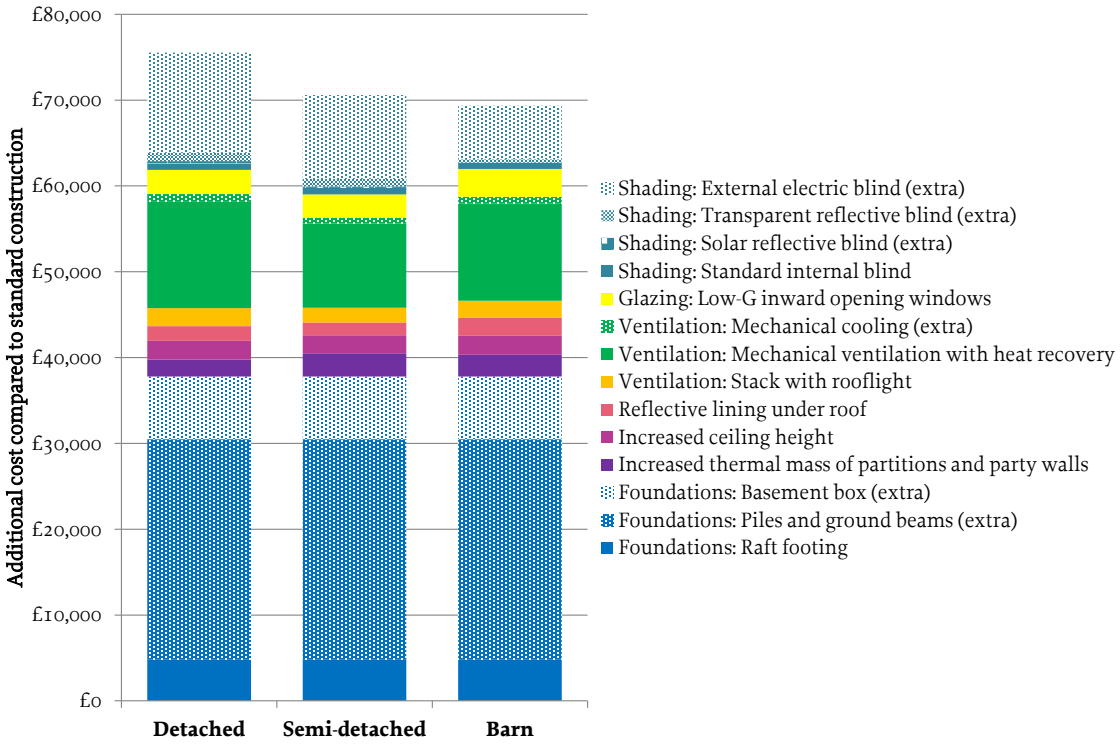


Figure 7: Range of additional costs for adaptation strategy compared to base construction cost

Where more than one option is available for adaptation, including foundation design and shading, the incremental additional cost for each enhanced option has been indicated by a shaded area in Figure 7. For example, the additional cost of the raft footing foundations option compared to the base construction case is estimated at £4,800 for the detached home whereas the full cost of the basement box foundation for the same house type is estimated at £37,800.

Taking into account the optional items in the adaptation strategy, the minimum additional cost per dwelling of installing the adaptation measures outlined in Figure 7 would be £16,365 for the detached dwelling, which represents an increase of around 16% compared to the base construction cost of achieving Code 3 and Building Regulations Part L (2010) compliance. This would provide for the basic raft footing foundations, increased thermal mass, increased ceiling heights, stack ventilation, reflective lining under roof, low-G glazing and standard internal blinds.

If the highest specification options were implemented from the above list the maximum over-cost per detached home would be £73,500 based on the cost analysis, or an increase of 68% compared to base construction costs. This would provide for the basement box foundations, increased thermal mass, increased ceiling heights, stack ventilation, mechanical ventilation and heat recovery with cooling, reflective lining under roof, low-G glazing and electronically controlled external blinds. The impact on construction costs is similar for the other house types.

The most significant elements of the above costs are the enhanced foundation options, the mechanical ventilation and cooling, and the external shading devices. While these are the most expensive items, they also provide the greatest benefits in terms of ensuring that the homes are resilient and well adapted to the long term impacts of climate change. Of these, the mechanical ventilation and cooling systems, and the external blinds are not considered to be essential in today's climate and they can be retrofitted at a later date when the need becomes more apparent, provided sufficient space is provided and the structural design of the property allows for future retrofit. This is therefore the recommended strategy for Oakham North.

The advantage of providing for the most expensive foundation option, the basement box, would be the provision of additional living or storage space in the basement which could add to the value of the properties. However, it has not been possible to quantify the value uplift which could be realised in this way and a basement box would not be feasible for a number of homes on the site due to groundwater levels and ground conditions. If the piled foundations are used this would reduce the additional cost to £64,150, but without the benefit of the additional space. Both of these foundation options have the potential to ensure that major repair or remedial works are not required in future, which could in turn have a beneficial impact on insurance costs in the short to medium term, although it has not been possible to quantify this.

Foundations can be modified to some extent in future, but some options may be infeasible or unviable due to the extent of the works required, and remedial works such as underpinning could be prohibitive. On the positive side, some of the foundation options outlined here would only be recommended on parts of the site where there are clay soils, which does not apply to the whole of Phase 1 at Oakham North.

Site-wide infrastructure and external adaptation measures including the SUDS strategy and green infrastructure were already incorporated into the masterplan for Oakham North, and are not considered to be additional cost items compared to the base construction case. In addition, the installation of low-flow water efficient fittings has not been included in these costs as it would be necessary with or without the adaptation strategy to enable the Code for Sustainable Homes target to be achieved for the site.

While there are expected to be tangible benefits to future occupants as a result of implementing the above measures, there are not expected to be any direct revenue streams associated with any of the additional cost items described above. In addition, there is no evidence currently available to suggest that housebuyers will be willing to pay more for the homes as a result of implementing the adaptation strategy. The main drivers for buyers of new homes are often ability to buy, price, ability to secure an attractive mortgage deal and location, so adaptation is not a sufficient priority at present to influence values. It is therefore not possible to calculate a payback for any of these items, or to demonstrate a positive cost-benefit analysis in monetary terms from the perspective of the developer, unless the measures implemented today are cost neutral, such as private outdoor green space and trees which add clear value to the development, or unless they are an essential part of the basic infrastructure and construction specification for the site which is necessary to obtain regulatory compliance or planning approval, such as appropriately designed SUDs.

The case for designing for future climate is strong. Buildings and infrastructure have a long lifespan and homes built today will, in many cases still be around in 50 years or more. They are built to suit

the current climate and do not take account of the way in which a different climate might affect its performance. As a result, the impacts of climate change can make buildings uncomfortable, unsafe or even commercially unviable to maintain. Alternative approaches to construction are often more expensive and, particularly with current pressures on development viability, are not pursued where they can be avoided. In light of this, we have prioritised adaptation measures that are either economically viable to install from the outset or cost effective to retrofit.

Adaptation measures can avoid significant costs in future. This must be reconciled with the commercial realities of development, where there is pressure to keep build costs down. This requires a creative approach to developing adaptation strategies, focusing on measures which improve the overall quality of new development through the multiple social, environmental and economic benefits which can provide. For example, increasing the amount of urban greenery, particularly trees, can help absorb floodwater and can help make buildings and public spaces more comfortable in hot weather. They can help improve air and water quality, and encourage use of public spaces, all while adding to the value of nearby homes[xix]. A growing evidence base indicates that trees are a cost effective way of bringing benefits to the environment, to individual people and to society as a whole. Current research is exploring methods for quantifying the value of trees in terms of additional gains such as human health, well-being and crime reduction, but it is not yet at a stage where it is possible to identify a specific monetary value to use in cost benefit analysis for Oakham North.

One of the weaknesses of cost-benefit analysis is that it does not prioritise the non-monetary benefits of climate change adaptation or those which are more difficult to quantify. These are sometimes more important to the occupants of the development and other stakeholders but do not accrue to the developer, such as improved health and well-being. Related to this, there may be a difference between who incurs the costs of adaptation and who reaps the benefits, or vice versa, depending on when adaptation measures are implemented during construction or retrofitted at a later date. If all of the benefits of adaptation accrue to future residents of the site and other stakeholders such as the local authority or water company, and these do not result in higher demand for the properties or higher sales values, there is little incentive for the developer to invest unless compelled to do so by planning policy or regulation.

To illustrate this point, the following table provides a broad overview of some of the monetary and non-monetary costs and benefits of the different adaptation options and identifies, where possible, who pays and who benefits.

Adaptation option	Costs	Benefits
Building fabric and services measures to reduce overheating	• Higher build cost for developer • Ongoing running costs for mechanical ventilation/ cooling • Maintenance costs for owner/occupier	• Improved thermal comfort for occupier • Reduction in heat-related deaths and illnesses
Sustainable drainage systems (SUDS)	• Higher build cost for developer • Maintenance costs for owner/occupier, developer may contribute to this as commuted sum up-front	• Reduced risk of flooding for owner/occupier • Potential savings in insurance premiums for owner/occupier, improves ability to insure property • Reduced impact on flood risk in wider catchment area
Water-efficient fittings and water metering	• Potential higher build cost for developer, could be cost-neutral • Ongoing running costs for owner/occupier of water recycling if used • Maintenance costs for owner/occupier	• Lower water bills for occupiers where supplies metered • Reduced risk of drought to owner/occupier and wider catchment area
Alternative foundation design	• Higher build cost for developer	• Higher property value for developer only if basement box option used • Improved long term structural resilience for owner/occupier • Potential savings in insurance premiums for owner/occupier
Green infrastructure, particularly trees	• Potential higher build cost for developer, could be cost-neutral • Maintenance costs for owner/occupier, developer may contribute to this as commuted sum up-front	If well designed/maintained offers following benefits to owner/occupiers and the environment: • Improved appearance of the development • Ecological benefits • Improved thermal comfort • Reduced surface water run-off • Climate resilient landscaping, with reduced maintenance and irrigation requirements • Potential increase in property values

Table 1: Overview of some costs and benefits of adaptation options

3.5. Recommendations implemented and barriers to implementation

It has not been possible to implement most of the measures recommended in the adaptation strategy for houses in Phase 1 of Oakham North due to the advanced stage in the planning, design and development process, although there is greater scope for adaptation in future phases. The following sections set out which of the measures recommended in the adaptation strategy will be implemented by Larkfleet, together with a summary of the barriers to implementation where applicable.

3.5.1. Designing for comfort

- **Locate high heat gain spaces such as kitchens on north or eastern elevations and use open plan spaces to enhance cross ventilation:** This will be achieved where feasible in future phases of Oakham North, within the constraints of fixed aspects of site layout and standard house form.
- **Use thermal mass with night cooling:** The standard specification for a timber framed superstructure will not be changed to increase structural thermal mass. Materials to increase the thermal mass of the property, such as phase change plasterboard panels, is not expected to be implemented in any of the phases of Oakham North as they are not considered viable or cost-effective yet, and they can be retrofitted at a later date.
- **Fit simple shading devices:** Internal blinds are not provided as standard with new homes, as these tend to be an element installed by the householders on the basis of their preferences. Larkfleet has confirmed that it will offer internal blinds to buyers as part of the package of fit-out options for houses in Oakham North Phase 1 and future phases of development.
- **Fit mechanical ventilation with heat recovery or ensure sufficient space for future installation:** This is not proposed for homes in Oakham North Phase 1 at present or future phases. Larkfleet has installed several hundred MVHR units in homes on other sites, but they have stopped installing it in new homes at present in light of poor householder feedback. This includes perceptions that the ventilation unit is not working due to a lack of a visible or audible sign that it is functioning and that it must cost more money than natural ventilation if it is switched on all the time, and an inability to dry clothes in some rooms because of the high air-tightness and low air change rates. Larkfleet have also had problems with some contractors not being experienced in installing MVHR, although no actual problems with the performance of the units once installed.

  MVHR is being proposed for the social housing in the next phase of Oakham North, as the role of the Housing Association in managing tenant relationships and providing maintenance services is helpful in managing risk. In the longer term the Building Regulations are expected to drive installation of MVHR as standard to meet energy efficiency and carbon targets. Until it becomes a requirement to achieve the regulatory standards, there are no plans to install MVHR in market housing at Oakham North. Ducting for ventilation will not be installed to enable retrofit of MVHR in future, as it is a dead cost if not used and air-tightness standards would be lower than if the house were designed to use MVHR from the outset.
- **Educational material on climate change and how behaviour affects thermal comfort:** Information about climate change impacts and adaptation will be provided as part of the homebuyers guide for all phases of Oakham North, including guidance on how to manage internal heat gains and maintain a comfortable indoor environment and a description of the water-efficiency features in the property.

3.5.2. Construction

- **Resilient foundations:** Standard foundations designed to meet the regulatory requirements in place at the time will be used for houses in all phases of Oakham North, due to the high cost associated with implementing the alternative options explored here.

3.5.3. Managing water

- **Install good practice low water-use fittings and water meters:** These will be installed as standard for the homes in all phases of Oakham North to enable them to achieve Code level 3 water targets.
- **Provide rainwater butts for outdoor irrigation:** Rainwater butts will be offered to housebuyers in all phases of Oakham North as an optional extra as part of the fit-out.
- **SUDS:** The SUDS system being implemented for all phases of development at Oakham North is expected to be sufficient to manage increased surface water run-off associated with more intense periods of rainfall projected to occur as a result of climate change. In addition, the masterplan for the development provides more green space than the area currently needed for surface water attenuation, so it should be possible to increase the attenuation volume further in future if needed. To ensure the strategy is effective in the long term, there is a need to make provision for the management of SUDS systems. Although the regime for SUDS and drainage system adoption is currently undergoing a period of change, it is expected that Rutland Council and Anglian Water will adopt SUDS at Oakham North and ensure their long term effectiveness, provided they are located in the public realm.

Green infrastructure

- **Green infrastructure** is an important element of the masterplan for Oakham North, including private gardens for individual buildings, communal areas with soft landscaping and tree planting across the site. The tree planting schedule for future phases of Oakham North is being changed to reflect recommendations from the adaptation strategy. Introducing more trees into the masterplan is considered to add to 'kerb appeal' of new homes, although Larkfleet will avoid some larger tree species which can cause problems such as blocking light and are not always desirable for potential residents. High quality landscape at the entrance to the site can also improve marketability. Good maintenance of green infrastructure is essential to ensure that this appeal is borne out in practice. In Oakham North, public open space will be adopted by a management company, to ensure that clear and affordable arrangements are in place for management, including trees in private gardens. This is intended to make the houses more attractive and give housebuyers the confidence that the site will be well looked after.

3.5.5. Barriers to implementation

To sum up, the barriers to implementing some of the adaptation options which would otherwise contribute on a practical level to adaptation and climate resilience at Oakham North are as follows:

- **Inability to influence some aspects of site design**: Some elements of site infrastructure have already been implemented or aspects of the design have been fixed, for example by planning conditions, including the layout of the site, the house types and built form, and the SUDS strategy.
- **Cost and development viability**: the development business model is already challenging in the current economic climate and even when this improves it is likely that land value expectations will also rise to reflect increasing house prices. This means that there is insufficient capacity in the development budget to cover the significant uplift in construction costs associated with some adaptation measures unless investing in these things can be shown to lead directly to a corresponding uplift in market values.
- **Construction complexity, supply chain and fit with traditional construction techniques:** Some of the adaptation measures create additional complexity in the construction process, rely on equipment or materials which are still in limited supply, or use construction techniques which not all contractors are able to offer. This can lead to problems with build quality, performance, maintenance and can act as an additional pressure on costs.
- **Lack of strong requirements for effective climate change adaptation in regulations and planning policy** acts as a disincentive for developers to build in climate change resilience. This is because there are limited resources, other pressures on construction budgets, and financial disadvantages for those developers who go further than the minimum requirements. Implementing regulations which require a more proactive approach to adaptation would create a level playing, and potentially encourage a downward pressure on land values to create space in the development budget for the necessary measures.
- **Market appeal** may be affected if housebuyers perceive a reduction in quality of living conditions or an increase in running costs associated with some of the adaptation measures, for example if homes are fitted with mechanical ventilation systems.
- **Lack of financial return for the developer**: in general, while the measures set out in the adaptation strategy provide clear long term benefits to future occupants, society and the environment, they do not directly benefit the developer. House valuations do not yet show an uplift to reflect the benefits of climate resilience, as housebuyers are generally not felt to have a sufficient appreciation of the advantages and are either not willing or able to pay such premiums for it. In addition, unlike renewable energy technologies for example, most of the measures set out here do not generate an ongoing source of income which developers could capitalise on or attract third parties to invest in. This inability to realise the monetary value of the long term, wider benefits of adaptation make it very difficult to justify the upfront expense for the developer when there is no regulatory requirement or strong policy incentive either.

The economic context remains challenging for development and construction progress at Oakham North has been slower than anticipated at the outset of this project as a result. To date, the show homes on Phase 1 have been built and 10 to 12 forward reservations have been taken. This has prevented occupant testing and feedback on the elements of the adaptation strategy that are to be implemented within the timescales of the D4FC project. In terms of the long term prospects for the scheme, some changes to the wider masterplan are anticipated for future phases of the development and some plots of land may be sold to other developers.

A more comprehensive range of adaptation measures will be implemented in future phases of the Oakham North development and on other Larkfleet Homes schemes, if some of the barriers described above can be overcome. Larkfleet will continue to monitor developments in the housing market and supply chain, and test new technologies and techniques. The factors Larkfleet will take into account when making decisions on the adaptation strategy for future phases of Oakham North and other development sites include:

- What their competitors are doing on adaptation
- Whether and when requirements are being introduced through regulations or planning policy
- Whether the housebuyer sees value in it and proof that adaptation will have an impact on house prices
- Monitoring what optional extras housebuyers are willing to pay for
- Testing some technologies on a trial basis in show homes and monitoring performance
- Feedback from housebuyers on the measures installed and the information provided in the homebuyers' guide
- Improvements in the technologies and products available on the market and reductions in cost, for example for phase change materials used to increase thermal mass

4.0 Learning from work on this contract

4.1. Summary of approach

Our approach was designed to identify the potential impacts of climate change on the Phase 1 development at Oakham North and assess the options for adaptation. We used the available published information on climate projections and the associated risks to identify and prioritise key risks for the site, then undertook more detailed modelling to design and validate adaptation measures based on their contribution to risk reduction. Throughout the project we worked with the client to review the results, discuss the options and agree the adaptation strategy, culminating in the conclusions presented in this report.

The approach can be broken down into the following stages:

- Climate change risk assessment
- Options appraisal
- Detailed testing
- Forming the strategy
- Dissemination

Each of these stages is described in further detail in the following sections.

4.1.1. Climate risk assessment

UKCP09 projections were used to understand the range of potential climate impacts relevant to Oakham and the surrounding area. A number of scenarios were selected to reflect the challenges facing the development, using the medium and high CO_2 emissions scenarios at the 50th and 90th percentile to represent 'average' and 'extreme' impacts in 2030 and 2050. In addition, information was collected about the development and the site context to enable vulnerabilities to be identified and the relevance of specific impacts to be understood.

The UK Climate Change Risk Assessment was then used to identify the potential risks to the development, with particular reference to the Climate Change Risk Assessment for the Built Environment Sector.[x] We used a risk matrix to assess the level of risk, taking into account the combination of likelihood of impact, vulnerability and consequences, and rank it as low, medium or high. This enabled us to draw conclusions and focus the options appraisal on the most important issues for the site.

4.1.2. Options appraisal

Working with Larkfleet, we set out a baseline design for each of three standard house types which were typical of what would be built at Oakham North. Using these house types, we assessed the baseline level of climate change impacts before any specific adaptation measures were incorporated, in terms of the three categories of thermal comfort, construction, and water management. The baseline constructions were defined using Larkfleet's standard practice, the requirements of the building regulations, and national and local planning policy.

We then set out a range of adaptation options for improving thermal comfort, construction and water management at the building and site level, drawing on the Design for Future Climate guidance, our own expertise and understanding gained from recent research. For each category we considered:

- Whether existing standards already require measures which successfully mitigate risk, eg building regulations thermal comfort standards or planning requirements for flood risk management and surface water drainage
- Whether there is the potential and the need to take these same measures further in order to reduce exposure to climate risk, e.g. specifying deeper strip footings at low additional cost
- Whether responding to climate change would require more innovative measures that go beyond current requirements and represent a more substantial change in dwelling design and construction, e.g. solar shading to meet more stringent overheating standards
- Other options which could contribute to adaptation, including options that require action across or beyond the site boundary, or provide multiple benefits, such as green and blue infrastructure

The above approach was based on the assumption that looking to expand on existing design features first would help in identifying options that are more likely to be lower cost, avoid unnecessary complexity and are likely to be more relevant to the wider industry.

4.1.3. **Detailed testing**

We tested the effectiveness and viability of the range of adaptation options on the three dwelling types. The options were tested for effectiveness in mitigating climate risk, cost, deliverability and the implications for the end user, such as maintenance or insurance. Where options were likely to be too expensive in the short term, options which could be retrofitted in future were considered.

Detailed analysis was undertaken by specialists in thermal comfort, construction, water management, green infrastructure, and quantity surveying. The approach was as follows:

- **Thermal comfort**: The adaptation options were assessed using IES dynamic thermal simulation software, which allows a detailed thermal comfort and overheating analysis to be carried out taking into account shading, thermal mass, ventilation effects and the impact of other innovative features. Weather data files created by Exeter University under the PROMETHEUS programme were used for building thermal analysis, to assess the performance of each of the three building types in future climate scenarios.

  We assessed internal options including changes to the thermal mass, fenestration, glazing and internal layout. We also assessed the impact of external options on internal comfort, particularly building and landscape based shading features.
- **Construction**: The impact of climate change on soil stability was assessed by geotechnical and structural engineers and suitable alternative design measures were identified, including deeper foundations, piling and construction options that allow for some movement in foundations without compromising the superstructure of the building. Reference was made to best practice for foundation design in other locations around the world where climate variability and extremes in soil moisture are more common and soil types are similar, including Australia.
- **Water management:** The existing drainage strategy for the site was assessed to determine whether it would be sufficient to meet the necessary surface water run-off targets for the site and prevent surface water flooding during projected extreme rainfall events. This was conducted using hydraulic modelling software and rainfall data derived from UKCP09's weather generator. This analysis took into account the role of dedicated SUDS features and the multifunctional role of the public realm, including the use of car parking areas or the site's allotments for water storage. Water efficiency measures were also assessed in terms of their potential to contribute to demand management and their appropriateness for the development.

- **Green infrastructure:** We tested a selection of trees for their ability to improve comfort, development value, and cope with the potential impacts of climate change. The relationship between tree planting near buildings and potential impacts on construction and sub-surface stability was also be explored. Recommendations were provided for a tree planting strategy for the site.
- **Commercial valuation:** The additional over cost of the range of adaptation options compared to the baseline design of the three building types was assessed by a quantity surveyor. The potential for these measures to add value to the development either directly or indirectly was considered, for example through an increase in market valuation, or social or environmental benefits. Where options were considered to be too expensive to implement in Phase 1 of the development, we looked at the potential to introduce them over time.

Details of the approach taken to analysis in each of these areas are provided in the technical reports provided alongside this document.

4.1.4. Forming the strategy

The strategy set out in this document was formed through a process of ongoing dialogue between the client and the consultant team, to understand the risks, identify the options for adaptation and consider their suitability, applicability and viability for the development in light of the analysis undertaken.

Central to this dialogue was a series of workshops with the client and the project team. These workshops considered:

- Climate risks and options for adaptation
- Approach to designing for thermal comfort, construction and water management and initial findings
- The adaptation strategy and how it would be implemented at Oakham North Phase 1, future phases of development and applicability to other schemes

Throughout the development of the strategy, the focus was on identifying options which could increase resilience to each of the key impacts without compromising the marketability of homes on the development.

4.1.5. Dissemination

A range of activities have already been undertaken to disseminate the findings of this study, and these will continue beyond completion of the Design for Future Climate project.

Dissemination activities completed to date include the following:

- Project highlighted as an example of our ongoing work on climate change adaptation during training on climate change skills for local planning policy officers, at 6 sub-regional sessions delivered across the East of England, during December 2011 – January 2012, including reference to TSB and DFFC funding
- Presentation by Rob Shaw on climate change adaptation at Ecobuild, 21 March 2012, focusing on our work at Oakham North and presenting early findings to development and construction professionals (provided in Appendix 4.3)
- Interim report, submitted to TSB June 2012

- Presentation by Rob Shaw and Raphael Sibille to Defra's Adapting to Climate Change team, which included a case study on the Oakham North DFFC project and a discussion of findings (12 October 2012, see Appendix 4.4)
- Findings used to inform advice provided to our clients on a range of projects, including using Oakham North as a case study for an eco-opportunities study completed for the new community north of Fareham, on behalf of Fareham Borough Council
- Reference to Oakham North adaptation strategy work in a presentation on 14 June 2012 by Helen Pearce to the Eco Development Group, which brings together local authority leads for each of the Eco-town projects
- Project used as an example of good practice in a CPD presentation on climate change mitigation and adaptation to design, planning and development professionals across LDA Design (December 2012)
- Project has informed ongoing TCPA-led climate change training for Councillors in Yorkshire and Humber, for which Rob Shaw is one of the trainers
- Completion of the final project report (August 2013)
- Completion of a case study on the project (August 2013, see Appendix 4.5)

Future dissemination activities will include:

- Preparation of a joint press release by LDA Design, Capita Symonds and Larkfleet Homes, which will be promoted to various publications including Building Magazine, the Landscape Journal, and Capita Symonds' client publication. Press release to be prepared late summer 2013 following completion of the case study. Publication date subject to sign-off from the various parties and acceptance by the publications.
- The project will continue to inform LDA Design's input on adaptation to the Town and Country Planning Association (TCPA) led Planning and Climate Change Coalition (PCCC), which comprises representatives from a range of organisations with an interest in climate change, spatial planning and planning policy including practitioners, policy makers and relevant NGOs. The coalition regularly briefs MPs and government ministers in relation to development of national policy and regulation. In particular, we will look to use the project findings where relevant in our input to the PCCC's new adaptation working group, which launched in May 2013

Our ability to present at major conferences is limited by the general requirement to pay (sometimes substantial) sponsorship fees in order to secure a speaker slot, which are not covered by the D4FC dissemination budget. However, we will continue to look for suitable opportunities to present the project at conferences.

4.2. Project team

The development of the adaptation strategy for Oakham North was led by LDA Design, which has a longstanding relationship with the client and prepared the Outline and Reserved Matters applications for the development as part of the core design team.

LDA Design was supported in the development of the climate change adaptation strategy by four sub-consultants with specialist knowledge of building design and climate change adaptation:

- rCOH – architects in the core design team for Oakham North, contributing intimate knowledge of the development and design of adaptation measures to the adaptation strategy

- Wormald Burrows – drainage engineers in the core design team for Oakham North, also responsible for reviewing the drainage and water management design proposals against climate change projections for the adaptation strategy
- Buro Happold – experts in building physic and climate change adaptation, conducted analysis of thermal comfort for the adaptation strategy (not part of the core design team for Oakham North)
- Capita Symonds – geotechnical and subsurface foundations experts responsible for advising on structural design and other construction issues, specialist sustainability quantity surveyors who assessed the cost and benefits of the recommended adaptation measures (not part of the core design team for Oakham North)

LDA Design, rCOH and Wormald Burrows were all involved in the core design team for Oakham North as well as providing specialist input to the development of the climate change adaptation strategy. Buro Happold and Capita Symonds were not involved in the core design team, but were engaged by LDA Design to provide specialist input to the climate change adaptation strategy.

Our client, Larkfleet Homes, participated in the development of the strategy by providing information about the development, feedback on the feasibility and viability of implementing the various adaptation options, and confirmation of which elements of the adaptation strategy would be implemented at Oakham North.

A team organogram is provided in Appendix 4.1 along with a short biography for each of the key team members (Appendix 4.2).

4.3. Project plan

In terms of the programme for the Oakham North development, the proposal at the outset of the D4FC project was for the entire scheme to include approximately 1,200 homes and a number of other uses to be built over 7 years. Phase 1, which includes 135 homes, was intended to commence construction with around six show homes in June 2012. This was intended to be used as an opportunity to test adaptation measures prior to any further roll out. The project plan for the D4FC project was designed to fit within this overall development programme. It is shown in the chart on the following page.

Unfortunately, the adaptation strategy was completed after construction of show homes on the site commenced, which has made it difficult to incorporate and test measures in practice within the programme for this project. Larkfleet will continue to monitor developments in the housing market and supply chain, and test new technologies and techniques beyond the end of the D4FC project, prior to any larger roll out or change in their standard practice in future. This testing will include monitoring performance of items installed in show homes or market homes on a trial basis, obtaining housebuyer feedback, and monitoring which optional extras housebuyers are willing to pay for.

Project programme

Milestone	Task	Invoicing period
1.1	Project inception	
1.2	Climate risk assessment	
2.1	Options appraisal - comfort, construction and water	
2.2	Workshop on climate risks and options with the client	
3.1	Work package 1: designing for comfort	
3.2	Work package 2: Construction	
3.3	Work package 3: Managing water	
3.4	Work package 4: Commercial valuation	
4.1	Preparation of strategy	
4.1	Workshop on preparation of the strategy with client	
4.1	Show home with in-built adaptation measures completed	
4.1	Client testing, monitoring and feedback of show home	
4.2	Comparison of on-site construction costs with QS costs and client/contractor feedback	
4.3	Workshop to agree an implementation strategy and how to take measures forward with client	
4.4	Project dissemination	
4.4	TSB dissemination event	
4.4	Draft and final report issued to TSB	

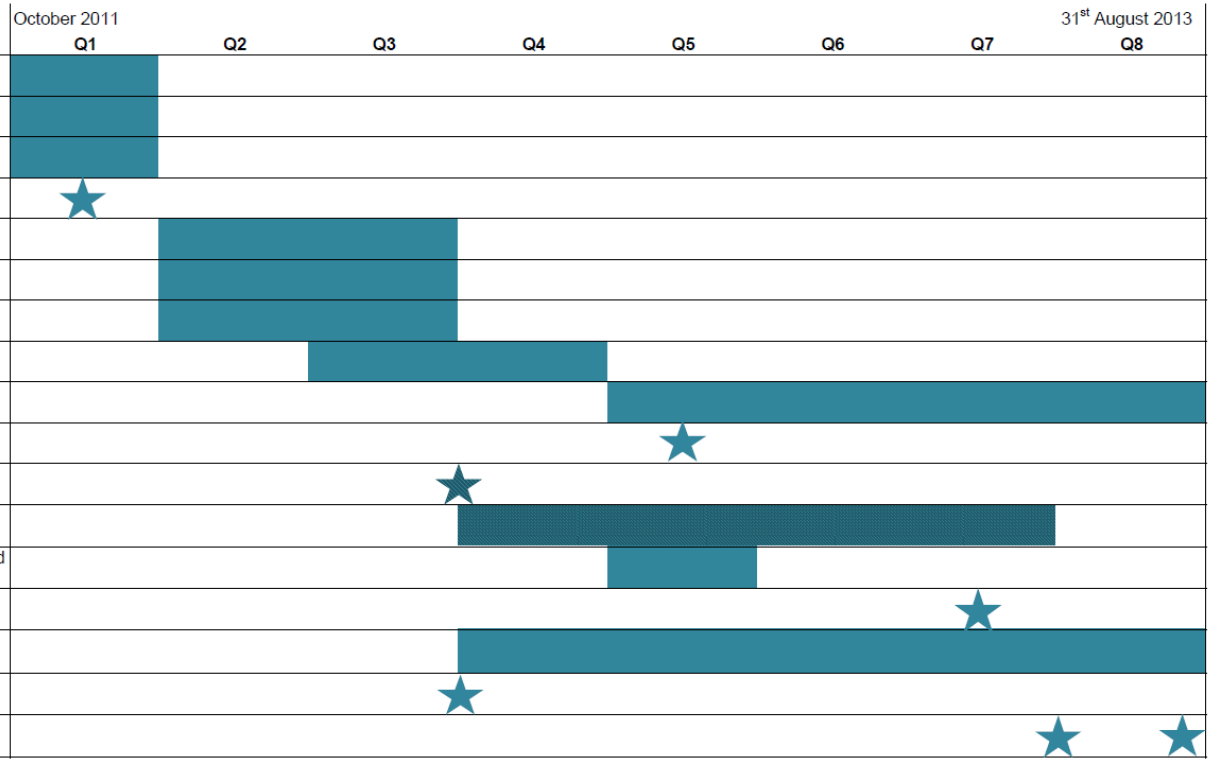


Figure 8: Project plan

4.4. Strengths and limitations of resources and recommended resources

Below are key issues that have been encountered while attempting to gather information and which have, to a lesser or greater extent, limited the quality or extent of our analysis.

- Met Office[xxiii] projections of extreme rainfall events are provided for selected cities and only for the medium emissions scenario. Data related to the high emissions scenarios would have been more consistent with the rest of our analysis.
- Improved evidence of new extremes in rainfall events (beyond the 1 in 100 year event) would have contributed to our assessment of the credibility of the Environment Agency's current flood guidance. The difficulty of providing this type of information is recognised.
- Thermal modelling has been conducted using IES and the Prometheus weather tapes produced by Exeter University. It is not possible to accurately represent shading from trees and the impact of green infrastructure on internal temperatures using this software. No suitable alternative was identified.
- The Prometheus weather files tapes are available up to the 2050s only. An assumption has been made that the 2050s 90th percentile is equivalent to the 2080s 50th percentile.
- UKCP09 have acknowledged that projections of changes in wind speeds are unreliable. A lack Information on wind speeds and storms has limited our ability to model some potential construction issues and its potential contribution to increasing soil moisture deficits.

Resources which were found to be particularly useful during the course of this project and area recommended for use in future work include:

- The UK CP09 climate projections and the weather generator
- Changes in the frequency of extreme rainfall events for selected towns and cities, Met Office (2010)
- Climate Change Risk Assessment for the Built Environment Sector, Defra (2012)
- Climate Change Risk Assessment, Annex A: Scenarios of climate variability and change, Defra (2012)
- UK Climate Projections Briefing Report, Defra (2009)
- Regionalised Impacts of Climate Change on Flood Flows, Defra and Environment Agency (2009)
- Design for Future Climate, an Adaptation Agenda for the Built Environment, Bill Gething (2010)

4.5. Strengths and weaknesses of approach and recommended methodology

In general, we found the approach taken to develop the adaptation strategy to be effective within the current context, particularly the current pressures on development viability, uncertainty in the climate projections, and the lack of a strong regulatory driver for climate change adaptation. We would recommend the methodology set out above to others, with the following caveats.

The preparation of an adaptation strategy should start as early as possible in the development process, at the feasibility stage when a site is being considered if not before this during site selection. Our ability to influence the proposals for Oakham North Phase 1 was significantly limited as key decisions had already been made prior to our involvement. Fortunately some of the critical elements of site infrastructure, particularly the drainage strategy and green infrastructure proposals, were subsequently found to be sufficient to provide resilience to future climate based on the projections used in this study.

Related to this, we also found limitations as a result of working with standard house types which had already been fixed for the development. An adaptation strategy is likely to be more successful and affordable if there is flexibility to modify built form and fabric.

A further challenge to our approach was the length and variability of the development programme for large sites. Although our D4FC project had a duration of almost two years, it was still found to be insufficient to be able to see the adaptation strategy through to practical on-site testing, implementation and occupant feedback, which would be instrumental in refining and delivering a successful adaptation strategy.

Although it is important to recognise the wider benefits of adaptation and find a way to incentivise building in resilience from the outset of built development where possible, cost benefit analysis was found to be of limited use in the development of the adaptation strategy. This is because:

- It is difficult to quantify many of the benefits of adaptation
- They accrue to future occupants and other stakeholders potentially some years beyond the construction of the homes
- These beneficiaries do not yet recognise the importance of climate change adaptation and are not willing to pay for it
- As a result the developer has no way of recovering the costs of their investment

4.6. Influencing client decision-making

The Larkfleet Group, our client and the developer of Oakham North, sees the business value in taking a lead in responding to the energy and climate change challenges. Through Lark Energy, another company within the Larkfleet Group, opportunities for supplying low carbon energy to the site are being explored, including the use of CHP and small-scale anaerobic digestion plants which generate biogas as a feedstock.

Larkfleet expressed their commitment from the outset to the project and their willingness to be involved in developing the adaptation strategy and consider implementing its recommendations. They contributed to the design process in two principal ways. They participated in a series of workshops, which covered a presentation of the climate risks and adaptation response options to inform Larkfleet and help us confirm priorities, development of the adaptation strategy, agreeing how it would be taken forwards.

In spite of the developer's track record of being innovative and forward thinking, and their early engagement in the project, it has been challenging to provide a sufficiently convincing business case for investment in adaptation, and with good reason. The benefits of some adaptation measures will not be realised for some years, long after today's new homes have been sold. Many homebuyers will not be aware of the long term implications of climate change and the importance of adaptation, and indeed may have moved on to other homes long before the effects really take hold.

It is therefore unlikely that the costs of building more climate resilient homes will be recovered through an uplift in property values in the short term, unless the adaptation measures that are implemented provide tangible, wider benefits that are immediately obvious such as more attractive landscaping, more comfortable living spaces or demonstrably lower maintenance or insurance costs. In addition, unlike renewable energy technologies, most adaptation options do not provide an ongoing income stream which can be captured by the developer or a third party investor and used to offset upfront costs. This inability to recover the potentially significant additional development and construction costs associated with adaptation presents a significant challenge in encouraging developers to invest.

Regulation could drive more general application of these measures, as it creates a level playing field, and land values could be expected to go down to compensate, creating space within the development budget for adaptation. For this purpose, regulation would be a preferable mechanism to planning policy which can vary from one place to another. In addition, increasing recognition of the risks by insurance and mortgage brokers would help to influence developers – and housebuyers – to take climate resilience into account more substantively in their decision-making.

4.6.1. **Decision making under uncertainty**

An effective climate change adaptation strategy needs to take account of the uncertainty implicit in projections of climate change and its consequences. The use of scenarios to illustrate a range of potential outcomes is well established as a way of making informed decisions in situations where there are multiple variables to take into account, long timeframes to consider, and uncertainty over the outcomes. To inform the adaptation strategy for Oakham North we have selected scenarios which set out a broad range of possible climate outcomes over a realistic timescale compared to the lifetime of the project, and which are based on credible and peer-reviewed research.

Even with the use of scenarios however, considerable uncertainty remains regarding how climate change will play out and the actual range of impacts that will be encountered, due to the multiple interactions in the climate, ecosystems, society and the economy. This uncertainty, combined with scepticism and resistance from some stakeholders, makes effective decision-making challenging, particularly where decisions relate to the investment of substantial amounts of money and the construction of buildings and other infrastructure which will be in place for many years to come.

A framework for decision making under uncertainty, used by the Committee on Climate Change Adaptation Sub-Committee, has been used as a guide. This led to the following principles being applied in determining the adaptation strategy for the development and agreeing the timescales set out above for implementation:

1) A resilient design should take advantage of no and low-regrets adaptation measures which provide a range of additional benefits or where they help to manage existing vulnerabilities, such as designing in water-efficient fittings which will reduce water bills and help to manage existing supply and demand constraints during periods of drought
2) Robustness measures should be incorporated which are effective under a range of possible climate outcomes, such as planting a diverse mix of tree species to increase resilience
3) Measures which increase flexibility create opportunities to respond to new information and increasing certainty in future, for example ensuring that there is space within dwellings for mechanical cooling to be fitted at a later date
4) Where flexibility is limited and potential risks high, adaptation measures should be designed in from the outset, for example in the case of surface water drainage strategy for the site

In developing the adaptation strategy we have also been careful to avoid mal-adaptation, which could result where measures implemented now in the hope of reducing exposure to climate risk turn out to be unnecessary, ineffectual or even counterproductive.

5.0 Extending adaptation to other buildings

The learning points from the adaptation strategy for Phase 1 of Oakham North should be relevant to future phases of development at Oakham North, similar projects undertaken by the client Larkfleet Homes and throughout the housebuilding sector – both at the building and urban development scale, provided the barriers raised in the sections above can be addressed. In addition, the lessons learnt will be carried forwards in the professional advice given on future projects by the consultant team engaged in this study.

5.1. Application of the strategy to other buildings

5.1.1. Future phases at Oakham North and other Larkfleet developments

Larkfleet have committed to using the findings from the study to inform the landscape, public realm and buildings at Oakham North. The form and construction of houses built in later construction phases will be similar to those in Phase 1 and therefore could benefit from the lessons learned throughout this study. A number of the recommendations, especially those related to communal infrastructure, are unlikely to be suitable for incorporation into proposals for Phase 1 as the development is too far advanced, but it is hoped that it may be feasible to incorporate them where appropriate in later phases of development, which will comprise 1,065 additional homes.

5.1.2. Other housing development across the UK

Oakham North is similar to other greenfield housing developments across the UK in terms of housing density, mix and size of the dwellings proposed, with the exception that homes are of timber frame construction rather than the more common masonry brick and block construction.

Larkfleet specialises in timber frame buildings, and the homes at Oakham North are primarily designed using timber frame construction with brick cladding. According to the UK Timber Frame Association, over 25% of new homes in the UK use timber frame construction.[xx] Based on the latest government statistics, there were 146,500 new homes completed in the UK in the 2011-12 financial year,[xxi] which translates to around 36,625 new timber framed homes. There remains a gap between housing demand and supply of approximately 100,000 units per annum and supply is anticipated to increase as the market recovers. A growing proportion of this growth is expected to be of timber framed construction, due to its increasing use in delivering high energy efficiency, low-embodied carbon buildings.

The foundation design options developed for Oakham North are likely to be applicable to other residential building projects where shrinkable clay foundation or stable rock is expected and detached homes are being constructed. The solutions may not be appropriate for terraces or blocks of residential flats without detailed assessment of the precise foundation conditions. Minor changes will be required for different geographic location in the United Kingdom as current guidance on climate change suggests that regional variations in climate may be more extreme in future than at present.

To support and encourage uptake of the findings across the wider industry, each of the project partners will use their respective communications teams to support dissemination, as described in the section on our approach to dissemination, above.

5.1.3. Other projects involving the project team

The study findings will influence the future working practices of the partners, helping each of the consultant teams to provide more effective advice to their clients and develop new areas of business. Each of the companies involved in the project is at the forefront of sustainable

masterplanning, landscape, public realm, engineering and development and we are increasingly being asked by clients for advice on how to reduce the risks associated with climate change. This project has been instrumental in raising our level of knowledge such that we can provide a confidence and comprehensive response to these requests.

5.2. Resources, tools and materials developed through this contract

The tools and materials used in this project are listed in Section 4.4 of this report, which are all published resources developed by others. No specific resources, tools or materials have been developed by us through the course of this project which could be used directly in future work. The most significant resource developed through this contract has been the improvement in the level of knowledge, skills and understanding amongst the team involved in developing the adaptation strategy.

5.3. Further needs to be able to provide adaptation services

No further needs have been identified to enable the consultants in the project team to provide adaptation services. The project team is already applying the lessons learned through this project in work that is being undertaken for other clients and sites. These projects include developing advice on climate change adaptation options for a major new development of over 7,500 homes and commercial uses north of Fareham, setting out the implications of climate change for communities across the Clwydian Range Area of Outstanding Natural Beauty in North Wales, and working with communities in the Lower Ouse Valley in Sussex to help them develop a vision and action plan for adaptation to the long term impacts of climate change.

We are also using the project findings to help influence and shape government policy and regulation. This includes working with the Town and Country Planning Association's influential Planning and Climate Change Coalition to establish a new adaptation working group.

Appendix 0: Checklists

Appendix 0.1: Checklist 1: Report structure

Has the report been structured to answer the following questions (taken from the specification from Section 7):	
1. What is your building profile?	✓
2. What is the risk exposure for your buildings/s to the projected future climate?	✓
3. What is the adaptation strategy for your building/s over their lifetime to improve resistance and resilience to climate change and thus extend the commercial viability?	✓
4. What is the best way to conduct adaptation work?	✓
5. How can this work be used to extend adaptation of other buildings?	✓

Appendix 0.2: Checklist 2: Report contents

Does Executive Summary contain summaries of Sections 1-5	✓
Section 1: Building profile	
A description of the building/s associated with the adaptation project, including projected usage, type, location and special features or aspects which will affect the resistance and resilience to climate change.	✓
If your study proposal covers building/s within a larger development, please describe the whole development.	✓
Appendix 1 should include further comment, photographs/images of the building and drawings of the building project.	✓
Section 2: Climate change risks for this project	
An assessment of the risk exposure of the building to the projected future climate considering the design challenges around water, comfort and construction as listed in table 1 below.	✓
Identification of the climate scenarios and climate data used in the design of this building in terms of UKCP09 data. An explanation, including a discussion of risk exposure, of why these scenarios were selected.	✓
Other features significant to the adaptation strategy developed.	✓
Appendix 2 should include relevant subsets of UKCP09 data, data relating to risk exposure and the building project.	✓
Section 3: Adaptation strategy	
This should be the largest section of the report including	
The adaptation strategy	✓
Timescales for your recommendations to implement relevant measures over the lifetime of the building, including those listed in table 1. Triggers to invest in adaptation measures should be related to maintenance intervals, changes in regulations, cost effectiveness or environmental metrics.	✓
Cost benefit analysis and risk mitigation of implementing these adaptation measures.	✓
Details of which recommendations are being implemented on this building and any barriers to implementation.	✓
Appendix 3 should include full quantity surveyor costs, redrafted drawings, building control changes and valuations of the building incorporating the	✓ (see supplementary

recommended changes. It can also include further analyses and comment, future-forecasting, drawings/images, specification of what products will be needed and data.	reports attached)
Section 4: Learning from work on this contract	
A summary of your approach to the adaptation design work	✓
Who was involved in the work and what they brought to the project	✓
The initial project plan and how this changed through the course of the project.	✓
List the resources and tools you used and review their strengths and limitations	✓
Describe what worked well and what worked badly in your approach, and the methodology you recommend others to use.	✓
Decision making processes by the client on implementing recommendations and what were the best ways to influence them?	✓
List the resources you recommend others to use	✓
Appendix 4 should include a biography of each member of the project team who was involved in the project and references for the recommended resources.	✓
Section 5: Extending adaptation to other buildings	
This short section should include:	
An assessment of how this strategy, recommendations and analyses might be applied to other buildings and building projects.	✓
A description of the limitations of applying this strategy to other buildings.	✓
An analysis of which buildings across the UK might be suitable for similar recommendations.	✓
Resources, tools and materials you developed through this contract for providing future adaptation services.	N/A – covered in other sections of the report where relevant
Further needs you have in order to provide adaptation services.	✓
Appendix 5 should include further analyses and comment, the sources of data and calculations used to analyse the building stock relevant to this building project.	N/A – references provided within main body of text – no further detail to provide

Appendix 1: Further information on the building profile

Appendix 1.1: Elevations

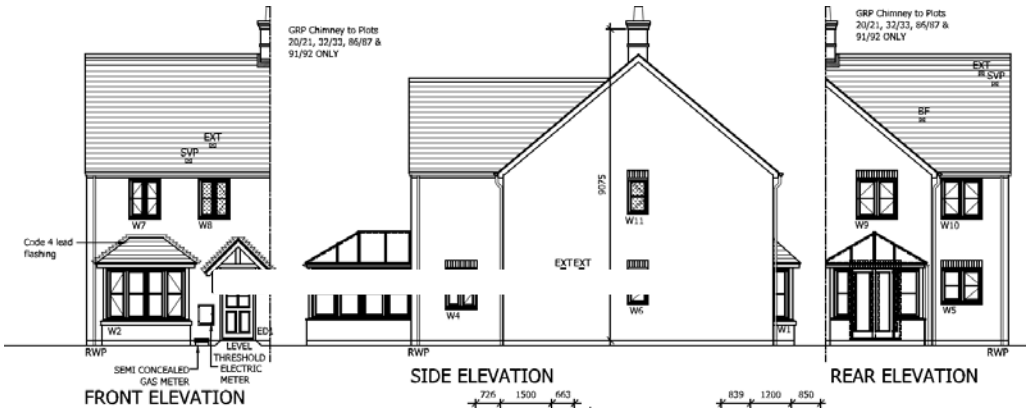


Figure 9: Elevations for semi-detached house, type 2308

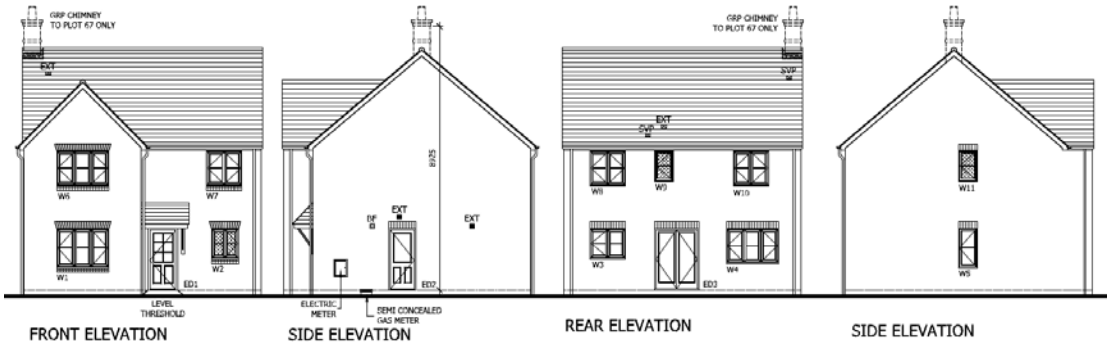


Figure 10: Elevations for detached house, type 2422

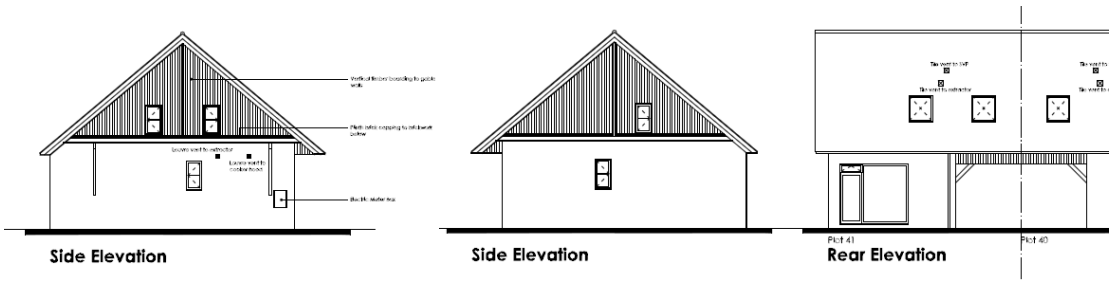


Figure 11: Elevations for barn-type terraced homes

Appendix 1.2: Building fabric thermal performance assumptions

Element	u-value
Roof	0.13
Walls	0.25
Ground floor	0.2
Windows	1.20, g=0.50
Doors	1
y-value	0.04
Airtightness $m^3/(hr.m^2)$	3
Mechanical Ventilation	MVHR 85% efficiency 1W /(l.s) specific fan power

Figure 12: U-values and technical performance standards by building element

Appendix 2: Further information on climate change risks

Appendix 2.1: Selection of climate change scenarios

Projections of mean annual change in temperature from the latest regional climate in Figure 13 show relatively little difference (less than 1°C) between the highest 'business as usual' (A1F1 or UKCP09 high scenario) and the lowest 'aggressive mitigation' (E1 which is below UKCP09 low scenario) projections in the 2050s. Temperature change in the 2080s is much more dependent on the emissions trajectory, with a difference of 3.2°C between 'business as usual' and 'aggressive mitigation'.

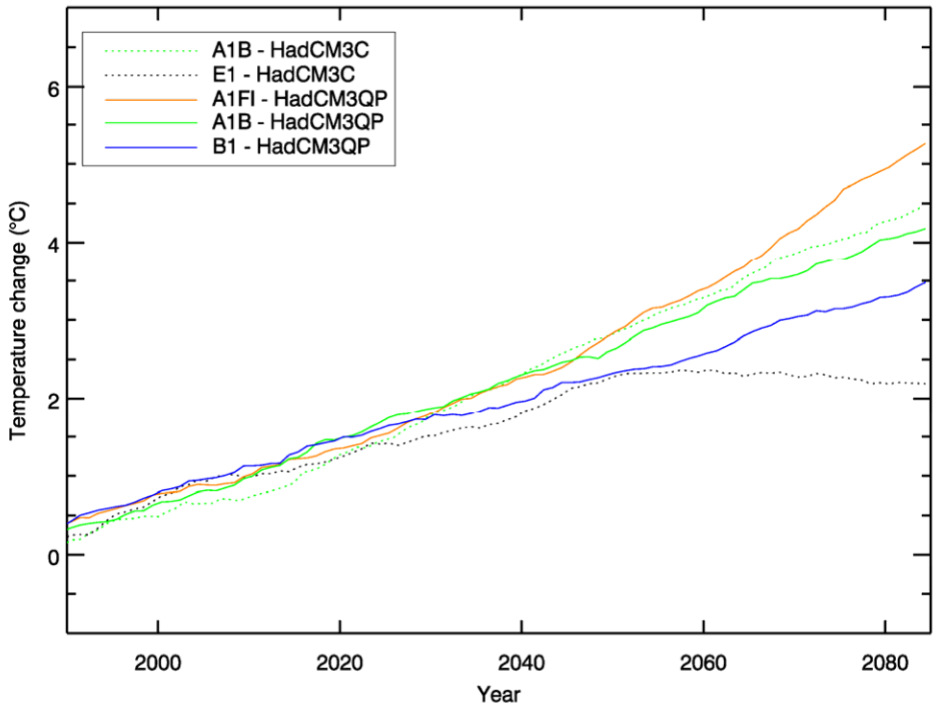


Figure 13: UK-scale comparison of the mean annual change in UK temperature in the HadCM3QP and HadCM3C models, Annex A: Scenarios of climate variability and change of the Climate Change Risk Assessment

The implication is that temperature rises are not strongly influenced by the emissions trajectory up to the 2050s. The adaptation strategy should aim to make the development resilient to any of these outcomes to avoid the risk of maladaptation. The range in possible temperatures in the 2080s means it is unlikely that a single strategy could be optimized to match all the projected outcomes. The strategy should include measures which facilitate retrofit options which could accommodate a wide range of temperature changes in the 2080s.

This argument is supported by Figure 14 which shows a comparison between the likely temperature increases in 3 emissions scenarios. The temperature range within a single scenario is often greater than the difference between them. Because of the uncertainties in future projections the strategy should demonstrate sufficient flexibility to the range of possible futures and that the projections should not necessarily be used to 'predict and provide' standards to be met[xxii].

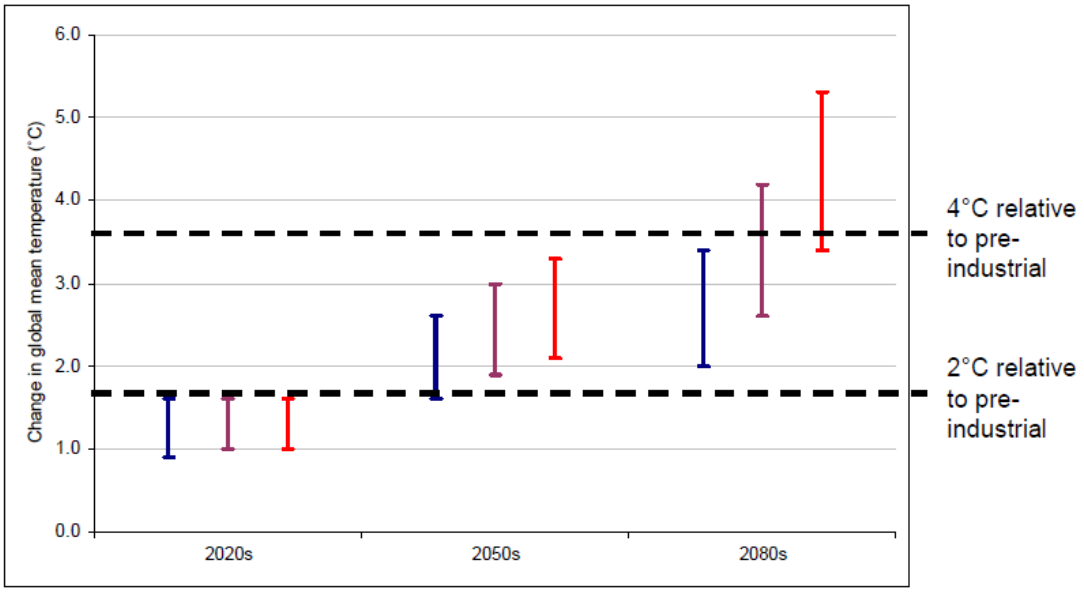


Figure 14: Projected changes in global mean temperature (°C) relative to the for all three UKCP09 emissions scenarios and the three UKCP09 future time periods (blue=low, purple=medium, red=high, Annex A: Scenarios of climate variability and change of the Climate Change Risk Assessment

Appendix 2.2: Climate change projections

Figure 15 and Figure 18 show the underlying climate around Oakham (based on measurements from 1961–1990) alongside projections of the expected change over the century under the high emissions scenario (based on the IPCC A1F1 scenario).

Temperature projections

The temperature is likely to increase throughout the year in future, with an increasing likelihood of prolonged hot periods and higher peak temperatures:

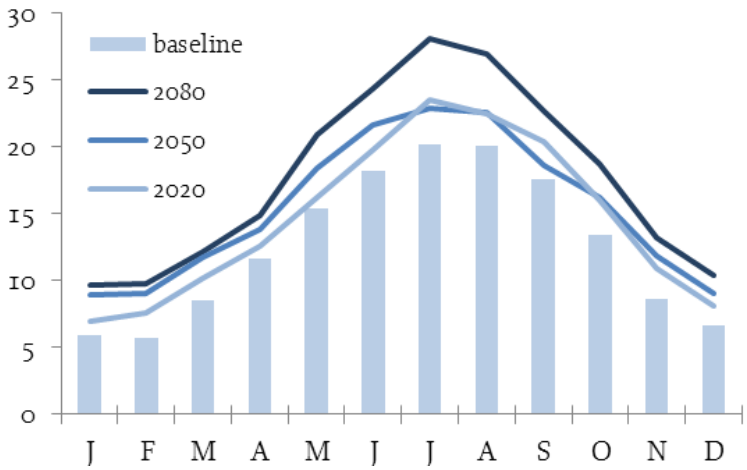


Figure 15 Average monthly maximum temperatures (°C) in Oakham over the century, under a high emissions scenario, compared to baseline period, using UKCP09 data

The Weather Generator has been used in conjunction with a threshold detector to predict changes in likelihood of heatwaves in future.

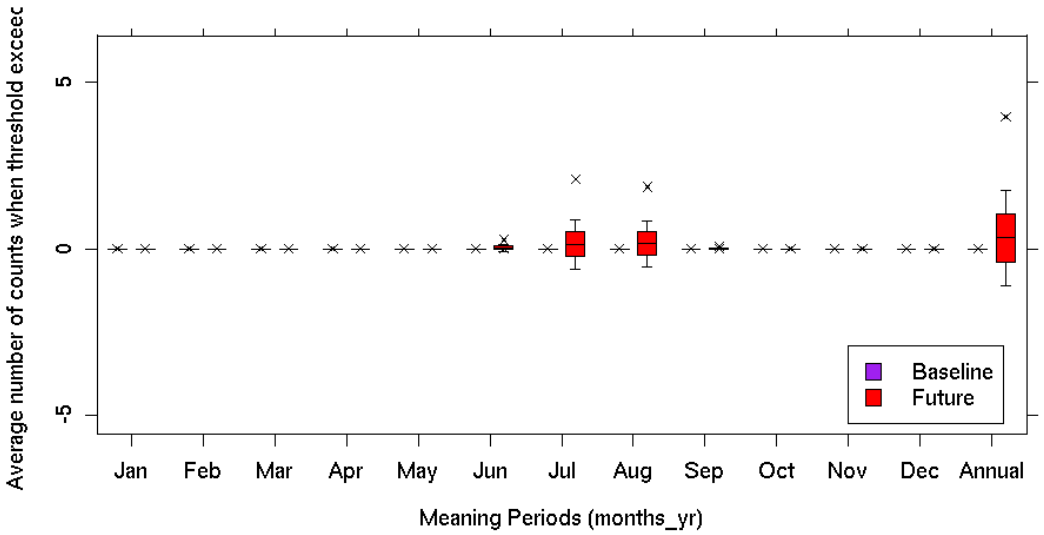


Figure 16: Likelihood of heatwaves (maximum temperature is above 30°C and night temperature is above15°C for a at least 3 days) occurring in the 2050s, high scenario, output from UKCP09 threshold detector

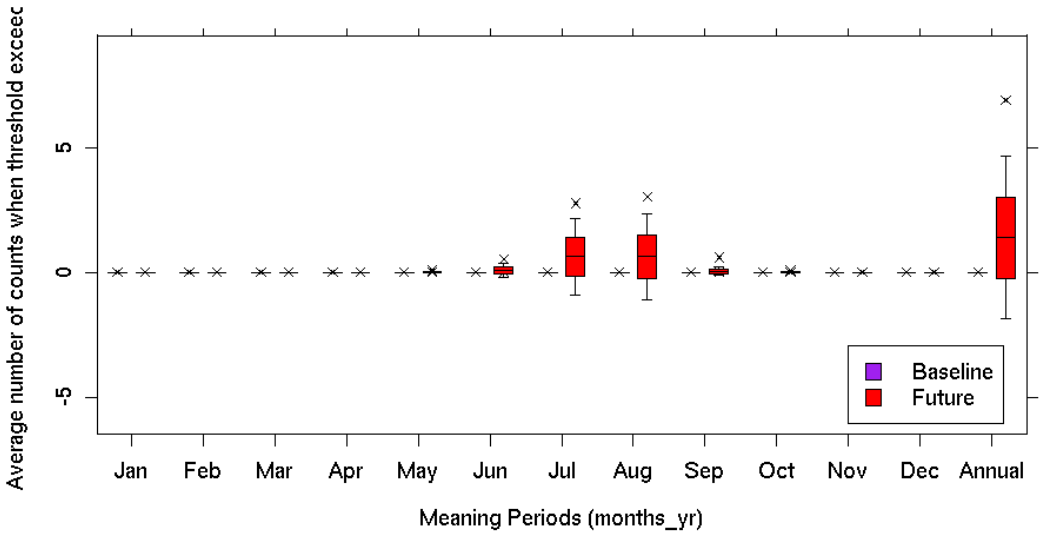


Figure 17: Likelihood of heatwaves (maximum temperature is above 30°C and night temperature is above15°C for a at least 3 days) occurring in the 2080s, high scenario, output from UKCP09 threshold detector

Figure 16 and Figure 17 show that heatwaves have a low to zero likelihood in current (baseline) climate. In the 2050s the likelihood of a heatwave increases in July and August. The mean average number of annual events increases to 0.4, which suggests that heatwaves will occur every 2-3 years. In the 2080s the mean average number of annual events increases to 1.4, suggesting that heatwaves could become a regular annual occurrence. The likelihood of prolonged events lasting 2 weeks or more is also greatly increased.

Rainfall projections

The amount of annual rainfall is not expected to change significantly but changes to hydrological patterns make it likely that a greater proportion of all rainfall will fall in winter. The uncertainty in summer rainfall projections is larger than for winter, suggesting lower confidence in the scale of changes that are expected.

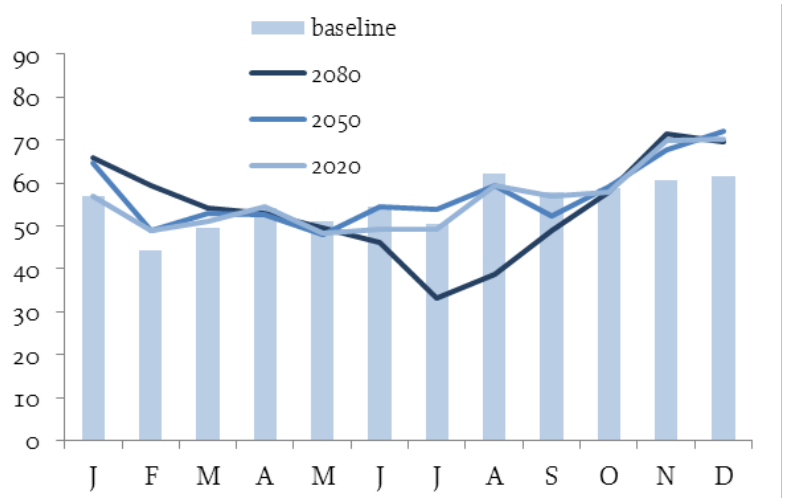
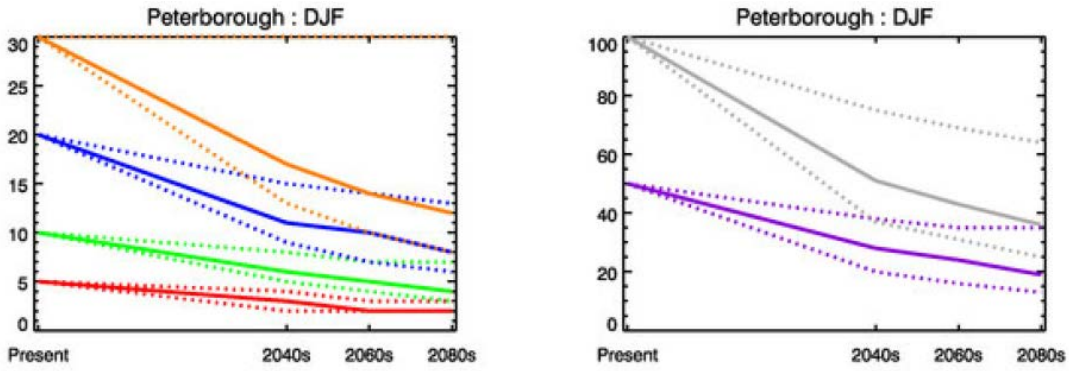


Figure 18 Average monthly rainfall (mm of rainfall per month) in Oakham over the century, under a high emissions scenario, compared to baseline period, using UKCP09 data

A warmer atmosphere has a greater capacity for holding water which leads to a greater proportion of rainfall falling in in heavy downpours. This is supported by recent climate records showing a disproportionate increase in heavy rainfall events. The estimates developed suggest an increase in frequency and magnitude for both short and longer duration rainfall events, and increases of up to 30% in the magnitude of shorter one day events. For longer 10-day events there is a smaller projected increase of 10%. Some variation is expected in the trends between regions.

It is not possible to use the Weather Generator to assess whether intense rainfall will become a more common occurrence in future because of the acknowledged inaccuracy of Weather Generator outputs over periods shorter than 1 day. Analysis by the Met Office[xxiii] has used an alternative technique to estimate changes in the frequency of extreme rainfall events due to climate change. Peterborough was the nearest town to Oakham assessed in the study. Its proximity means that the projected changes will be similar.

Winter



Summer

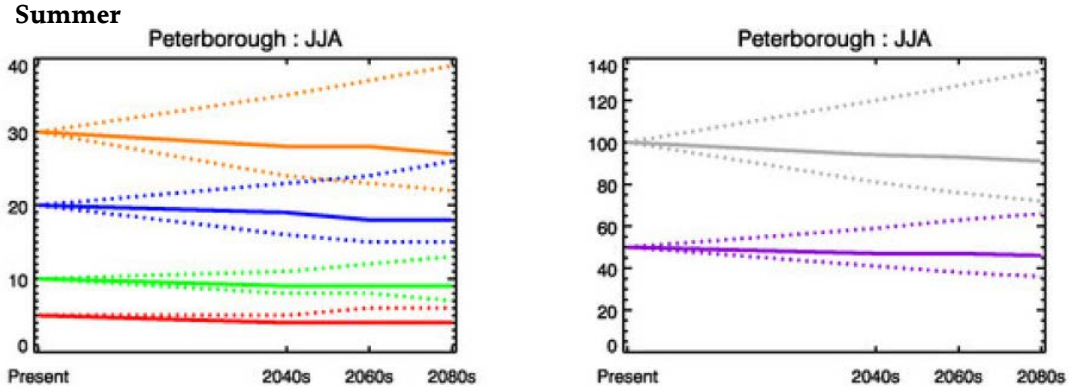


Figure 19: Projected changes in the likelihood of selected rainfall events in Winter (DJF) and summer (JJA) -The central estimate (50th percentile) is indicated by a solid line, and the 10th and 90th percentiles, illustrate the possible range of return periods and are shown by dotted lines. Note that Peterborough has been used as it's the closest town to Oakham North assessed in the study. Met Office, 2010, Changes in the frequency of extreme rainfall events for selected towns and cities

Figure 19 shows how the return period for a range of different rainfall events is projected to change. For instance, a winter (DJF) rainfall event that is expected at present to occur 1 in 30 years (the solid orange line) is projected to become more than twice as frequent; a17 year return period in the 2040s and a 12 year return period in the 2080s.The dotted orange line represents the range of probable return periods implying that the 1 in 30 year event is unlikely to have the same probability in the 2080s and is also unlikely to occur more than every 1 in 8 years. Note that Figure 19 is based on the medium emissions scenario. The Met Office has not provided any analysis using other emissions scenarios.

Wind speed projections

Changes in wind speeds were included in the 2002 edition of the UK Climate Projections. In the 2009 edition they were assigned a very low level of confidence and were therefore not reported. While Association of British Insurers note that the potential impact of increasing wind speeds and storms is considerable, the uncertainty in the projections of windstorms in UKCP09 means that there can only be limited value in taking precautionary measures at this point.

Appendix 3: Further information on adaptation strategy

The following reports are provided alongside this report, which provide further detail on the research and technical analysis undertaken to inform the adaptation strategy.

Appendix 3.1: Thermal Comfort Analysis and Recommendations, Buro Happold (2012)

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix3.1_ThermalComfortReport.pdf

Appendix 3.2: Technical Report on Construction Standards, Capita Symonds (2012)

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix3.2_ConstructionReport.pdf

Appendix 3.3: Managing Water Technical Report, Wormald Burrows (2013)

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix3.3_WaterReport.pdf

Appendix 3.4: Review of Existing Research on Trees and Climate Change, LDA Design (2012)

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix3.4_TreesReport.pdf

Appendix 3.5: Cost Feasibility Appraisals, Capita Symonds (2012)

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix3.5_CostAnalysisReport.pdf

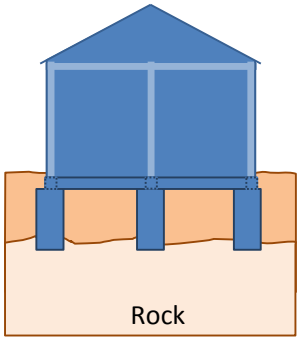
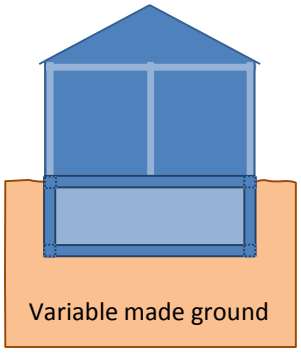
Appendix 3.6: Thermal comfort adaptation options and assumptions

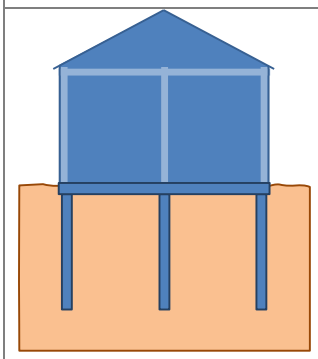
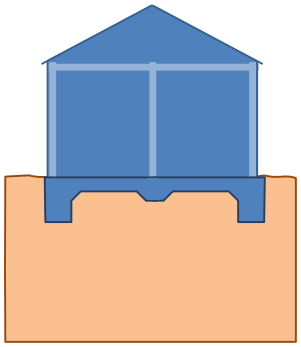
Measure	Description / key assumptions
Glazing solar performance	Improvement of g-value (solar transmittance) from 0.50 to 0.35 – equivalent to moving from low-E to solar control glazing
Thermal mass	Change of internal walls identified by architect from light-weight construction to heavy-weight construction
Thermal mass plus night-purge	Change of party walls identified by architect from light-weight construction to heavy-weight construction, with allowance for secure night-time window opening on upper and lower floors
Mechanical ventilation flow rate increase	Assumed whole house mechanical ventilation air change rate increase from 0.5 ac/h to 2 ac/h – this implies future improvements to MVHR products which may allow for increased ventilation without significant increase in fan energy, duct size, noise etc.
Pre-cooling of mechanical ventilation air	Use of earth-tubes (or similar) to reduce temperature of fresh air intake – assumed by circa 2 degrees C Typical configurations can include either Earth pipes/tubes – air drawn through buried pipes to capture heat from, or dissipate heat to, the ground Thermal labyrinths – similar to earth pipes but using larger volume (often concrete lined) spaces with increased air path for better heat transfer
Evaporative cooling	Use of evaporative cooling such as water spray as part of mechanical ventilation system to reduce supply air temperature to its wet bulb temperature
Stack ventilation	Where appropriate/feasible, this includes a central high level roof-light (typically above the dwelling stairs) and openings/louvres connecting living spaces to central stack – this is intended to drive warm/hot buoyant air upwards and away from the occupied space
External shading	Use of external shutters to reduce solar gains – user controlled
Internal shading	Use of roller blinds to reduce solar gains – user controlled
Green infrastructure	Use of grass, trees and planting in proximity to dwellings to reduce urban heat island effect through increased evapo-transpiration – reduction in average summertime dry bulb temperature by ~2 degrees C
Adaptive thermal comfort	Improved thermal comfort as a result of significantly increased occupant control over environment – based on guidance and adaptive comfort threshold criteria in BS EN 15251

Measures which were considered but have not been tested (or initial testing has determined negligible impacts) include:

- Adjustment of ceiling/floor heights to increase air volume within dwelling – height increase limited by architectural requirements (maximum ~300mm at ground floor, maximum ~75mm at first floor)
- Use of reflective foil lining under roof construction – limited application at domestic scale and requiring complex detailing

Appendix 3.7: Construction adaptation options and assumptions

Foundation options	**Description and implications**
Options 1 and 2: Mass concrete on ground beams 	Option 1 is a standard mass concrete foundation on ground beams, which is suitable for foundations on a stable rock bed where climate change is not expected to have any adverse effect on the foundations. Option 2 is for foundations on shrinkable clay or unstable gravels where the foundation is taken below the likely influence of future seasonal desiccation. It will not be suitable where the ground is affected by roots of trees and large shrubs. A conservative approach has been taken to the depth of the required foundation as a result of the uncertainty with regard to future seasonal desiccation depths. This option does require the excavations to be supported for health and safety reasons. This does add additional complication to the building works. In addition, as with Option 3, such a deep excavation will be open longer than usual and will be subject to a greater risk of flooding and softening of the base of the excavation in inclement weather.
Option 3: Basement box 	This option incorporates a basement to the residential building to make use of the need for deeper foundations due to climate change. Option 3 provides substantial additional living/storage space in the building and may have considerable advantages with space heating of the building. An access ramp may permit the use of part of the space for garaging of vehicles. The disadvantage is the additional cost of the option over Option 2 and 5 but this may well be outweighed by the possible deletion of a surface garage and a likely higher selling price given the greater usable square meterage of the building.
Option 4: Piles on ground beams	This uses the current BRE recommended pile and beam approach for building on ground with deep desiccation, and can be expected to remove all risk of ground movement if correctly designed and detailed. Common practice is to use small diameter (200 –300mm) bored concrete piles, with the option of including a slip membrane around the pile in desiccated clays to avoid uplift due to future heave. The primary advantage of

Foundation options	Description and implications
	bored piles is that they can be easily varied in depth from property to property to make allowance for variable depth of desiccation due to trees and large shrubs and for variable strength of the shrinkable clay. Costs for this solution are also dependent on the number of properties that are to be built as the mobilisation costs reduce per unit as the number of properties increases. It is more expensive than Option 5. Screw piling is an alternative steel pile option that is rotated into the ground to a set level. This form of piling is beginning to be used more extensively as it is rapid to install and can be an economic solution for residential buildings. In addition to being an economic option for installation there is minimal material displaced to the ground surface and thus minimal disposal costs. The primary disadvantage is where the ground contains hard layers, such as mudstone bands, which may prevent the screw pile reaching the required level. Such bands can be common in UK clays and site specific ground investigation should indicate if these bands are present in the ground. In highly variable ground bored pile are preferred as unlike screw piles as the actual ground encountered can be seen in arisings.
Option 5: Deep raft option 	This is an Australian practice of allowing some movement of the foundations but allowing the superstructure to be unaffected by the movement. This option reduces the excavation required and thus the amount of waste. It will require the additional skills of steel fixers to install the steel of the reinforced slab. The building will move with seasonal desiccation and on variable ground may lead to some local minor temporary tilting of the building. It is a cheap solution that is likely to be competitive with traditional shallow strip foundations. Some local authorities require this type of foundation to be underlain by an excavation filled with granular fill which we consider to be superfluous to requirements. The uncertainty of the precise effects of climate change on foundations on clay favours the adoption of a strengthened platform, which can allow buildings to accommodate greater foundation movements than currently adopted solutions.

The assessment of construction options has assumed that the climate may become similar to that of South Eastern Australia, leading to similar issues to those found in that area with shrinkable clays. Reference has therefore been made to 2011 Australian Standard AS 2870 – 2011 Residential slabs and footings in considering foundation options, particularly option 5.

The foundation options and pricing have assumed that there is no contaminated soil to be excavated or treated within the area of the foundations, made ground is not present to greater than 500mm depth, there is no required stabilisation of underground workings, the site for the foundations is essentially level and that no groundwater will be encountered within the excavations.

A two storey timber domestic structure can be constructed on piles designed to carry loads of 20kN/m run (2 tonnes a metre length of wall), a ground beam of 500mm width and 400mm depth (6 longitudinal reinforcing bars of 12mm' diameter (3H12 both top and bottom, R12 links at 250p) with some cross linking bars also of 12mm diameter every 250mm along the beam will then suffice to carry the loads. The beam can be supported at a maximum pile spacing of 4m with a 300mm pile of up to 10-15m in depth. On top of this, so as to ensure that damp does not affect the timber a nominal 300mm by 215mm brick dwarf wall may be constructed to carry the timber soleplate from which the timber panels are constructed, provide a damp course (dpc) and allow any under-floor ventilation as required.

The vertical timber studs used for the construction will be 38mm x 140mm to allow for the required insulation and pressure proofing and these will be attached to horizontal rails of a similar dimension that support the ply or board finish.

Appendix 3.8: Tree species considered resilient to projected climate change

Species	Size (approximate)	Notes
Acer campestre & cvs	Medium: 7x10 m after 25 years	
Acer platanoides & cvs.	Medium: 7x15 m after 25 years	
Acer rubrum & cvs.	Large: 9x6 m after 25 years	
Acer saccharinum & cvs.	Large: 8x15 m after 25 years	Needs open but sheltered location. Branches can be damaged by wind.
Alnus cordata	Medium: 12x3 m after 25 years	Good street tree
Alnus glutinosa	Medium: 10x5 m after 25 years	Fast growing. Naturally forms a good multi stem
Alnus x spaethii	Medium: 12x6 m after 25 years	Fast growing. Resistant to wind and frost.
Betula pendula	Medium: 10x5 m after 25 years	Open, elegant canopy
Betula utilis & cvs	Medium: 9x4 m after 25 years	Good white bark
Carpinus betulus	Large: 8x15 m after 25 years	Thrives on heavy soils
Castanea sativa	Large: 12x6 m after 25 years	Fast growing and drought tolerant
Catalpa spp.	Medium: 10x5 m after 25 years	Needs space for display of its form.
Cerecidiphyllum japonicum	Small: 5x4 m after 25 years	
Corylus colurna	Large: 8x3 m after 25 years	Very symmetrical, pyramidal form.
Crategus spp.	Small: 6x4 m after 25 years	Excellent in flower and many have showy berries in autumn.
Fagus sylvatica & cvs.	Large: 10x6 m after 25 years	Good Parkland tree
Ginkgo biloba	Medium to large: 5x10 m after 25 years	Conical habit
Gledistsia triacanthos & cvs.	Medium: 5x10 m after 25 years	Thorn less varieties preferred for public areas
Juglans nigra	Large: 15x8 m after 25 years	Fast growing. Round spreading head

Species	Size (approximate)	Notes
Juglans regia	Medium to large: 13x5 m after 25 years	Rounded broad head requires space to grow
Liquidambar spp.	Large: 10x5 m after 25 years	Straight trunk. Very good autumn colour
Malus cvs	Small: 7x3 m after 25 years	Good for spring flowers and autumn fruit
Platanus cvs	Large: 15x8 m after 25 years	Fast growing, good street tree
Prunus cerasifera cvs.	Small: 7x5 m after 25 years	Slow growing
Prunus padus & cvs	Medium: 12x8 m after 25 years	Vigorous
Pterocarya fraxinifolia	Large: 12x7 m after 25 years	Wide spreading and fast growing
Pyrus calleryana 'Chanticleer'	Medium: 8x3 m after 25 years	Upright street tree
Quercus castanaefolia	Large: 15x4 m after 25 years	Vigorous tree of columnar habit
Quercus ilex	Large: 10x7 m after 25 years	Only broad leaved evergreen in UK
Quercus robur & cvs.	Large: 12x8 m after 25 years	Native, fairly slow growing but long lived
Quercus rubra	Large: 12x8 m after 25 years	Fast growing. Strong autumn colour
Robinia spp. & cvs.	Medium to large: 14x8 m after 25 years	Fast growing. Can be brittle and unsuitable for exposed locations.
Sorbus aria spp. & cvs.	Small to medium: 6x4 m after 25 years	Round headed
Sorbus aucuparia	Small: 7x4 m after 25 years	Native and fast growing
Tilia cordata spp. & cvs.	Medium to large: 14x8 m after 25 years	Round headed native
Tilia x euchlora	Medium: 10x6 m after 25 years	Does not suffer from aphids. Robust in dry, hot summers.
Tilia tomentosa & cvs.	Large: 10x6 m after 25 years	Leaves are dark green above and silvery-white below.
Ulmus 'New Horizon'	4m x 10m after 25 years	Disease resistant strain

Appendix 3.9: Checklist 3: Design opportunities exploited

Adaptation design challenge	**Has this design opportunity been considered (C), recommended (R), implemented (I)**	
Keeping cool - internal	Shading -building form	N/A – building form already fixed
	Shading – manufactured	R
	Glass technologies	R
	Film technologies	N/A – new building
	Green roofs/ transpiration cooling	C
	Shading - planting	R
	Reflective materials	N/A, out of scope
	Conflict between maximising daylight and overheating (mitigation vs adaptation)	C
	Secure and bug free night ventilation	R
	Interrelationship with noise & air pollution	C
	Interrelationship with ceiling height	N/A, out of scope
	Role of thermal mass in significantly warmer climate	R
	Enhancing thermal mass in lightweight construction	R
	Energy efficient/ renewable powered cooling systems	R
	Groundwater cooling	R
	Enhanced control systems – peak lopping	N/A, out of scope
	Maximum temperature legislation	C

Adaptation design challenge	**Has this design opportunity been considered (C), recommended (R), implemented (I)**	
Keeping cool - spaces around buildings	Built form - building to building shading	N/A – building layout already fixed
	Access to external space -overheating relief	I
	Shade from planting	R
	Manufactured shading	R
	Interrelationship with renewables	N/A, out of scope
	Shading parking/ transport infrastructure	N/A, out of scope
	Role of water - landscape/ swimming pools	N/A, out of scope
Keeping warm at less cost	Building fabric insulation standards	C
	Relevance of heat reclaim systems	C
	Heating appliance design for minimal heating - hot water load as design driver	C
Structural stability -below ground	Foundation design - subsidence/ heave/ soils/ regions	C
	Underpinning	N/A
	Retaining wall and slope stability	N/A
Structural stability -above ground	Lateral stability - wind loading standards	N/A – insufficient information on wind speeds in climate projections
	Loading from ponding	C
Fixings and weatherproofing	Fixing standards - walls, roofs	N/A, out of scope
	Detail design for extremes - wind - 3 step approach	N/A, out of scope

Adaptation design challenge	**Has this design opportunity been considered (C), recommended (R), implemented (I)**	
	Lightning strikes (storm intensity)	N/A, out of scope
	Tanking/ underground tanks in relation to water table- contamination, buoyancy, pressure	N/A, out of scope
	Detail design for extremes - rain - thresholds/ joints	N/A, out of scope
	Materials behaviour in high temperatures	N/A, out of scope
Construction -materials behaviour	Effect of extended wetting - permeability, rotting, weight	N/A, out of scope
	Effect of extended heat/ UV -drying out, shrinkage, expansion, de-lamination, softening, reflection, admittance, colour fastness	N/A, out of scope
	Performance in extremes - wind - air tightness, strength, suction/ pressure	N/A, out of scope
	Performance in extremes - rain	N/A, out of scope
Construction -work on site	Temperature limitations for building processes	N/A, out of scope
	Stability during construction	N/A, out of scope
	Inclement winter weather -rain (reduced freezing?)	N/A, out of scope
	Working conditions -Site accommodation	N/A, out of scope
	Working conditions - internal conditions in incomplete/ unserviced buildings (overlap with robustness in use)	N/A, out of scope
Water supply/ conservation	Low water use fittings	✓
	Grey water storage	✓

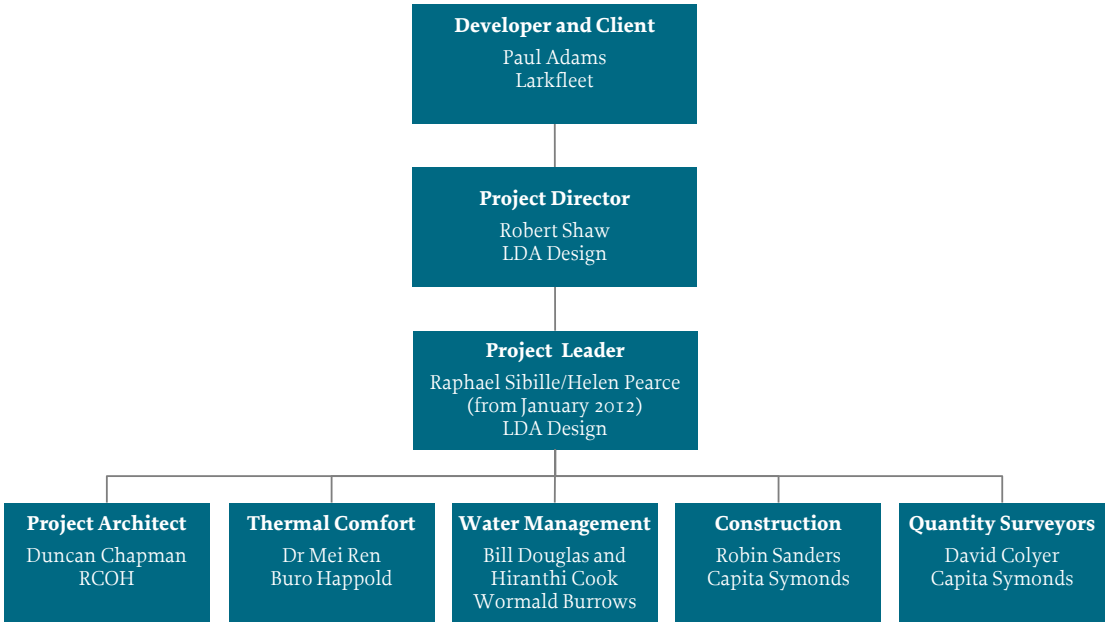
Adaptation design challenge	**Has this design opportunity been considered (C), recommended (R), implemented (I)**	
	Rain water storage	✓
	Alternatives to water based drainage	N/A, out of scope
	Pools as irrigation water storage	N/A, out of scope
	Limits to development	N/A, out of scope
	Water intensive construction processes	N/A, out of scope
Drainage - external	Drain design	R
	Soakaway design	R
	SUDS design	R
Drainage - building related	Gutter/ roof/ upstand design	N/A, out of scope
Flood - avoidance	Environment Agency guidance - location, infrastructure	C
	Combination effects -wind + rain + sea level rise	N/A
Flood - resistance/ resilience	Flood defence – permanent	N/A
	Flood defence - temporary -products etc	N/A
	Evacuation/ self sufficiency	N/A
	Flood tolerant construction	N/A
	Flood tolerant products and materials	N/A
	Post-flood recovery measures	N/A
Landscape	Plant selection - drought resistance vs cooling effect of transpiration	R
	Changes to ecology	N/A, out of scope
	Irrigation techniques	N/A, out of scope

Adaptation design challenge	Has this design opportunity been considered (C), recommended (R), implemented (I)	
	Limitations on use of water features - mosquitoes etc	N/A, out of scope
	Role of planting and paving in modifying micro climate & heat island effect	R
	Failsafe design for extremes -water	N/A, out of scope
	Firebreaks	N/A, out of scope
Building Management Operation	Review Handover, early occupation and policies in relation to the Soft Landings process and future legacy.	N/A, out of scope
Internal Gains	Review IT requirements and management systems in design and in use.	N/A, out of scope
Consumption	Ensure log book is in place, monitoring equipment commissioned and used.	N/A, out of scope
Activity	Engage with users through design.	N/A, out of scope
Maintenance	WOL building assessments as part of a usable O+M manual.	N/A, out of scope

Appendix 4: Further information on project learning

Appendix 4.1: Team structure

The team structure is set out in the following organogram, followed by short biographies on the key people involved.



Appendix 4.2: Biographies of team members

LDA Design: lead partner, knowledge of Oakham North, climate change adaptation specialists, architects, landscape architects, green infrastructure and design specialists, dissemination and case study material.

Rob Shaw, BSc (Hons), DipTP, MRTPI (Director of Sustainability and Climate Change, LDA Design) chaired the stakeholder panel for the ASCCUE climate change adaptation research, participated in a range of cutting edge projects including the current ARCADIA project and co-authored the TCPA's Climate Change Adaptation by Design guide. He developed the methodology and led work for the 2012 Olympics Legacy Scheme climate change adaptation strategy and was on the expert panel for the acclaimed European GrABS project. Rob is a regular speaker and communicator on adaptation, including for Design Council. He will direct the project. He will lead all stages and have an oversight of all work packages and contribute expertise to all project stages.

Raphael Sibille, MSc, BSc (Hons), AIEMA (Project Consultant, Energy and Climate Change, LDA Design) provides advice to public and private sector clients on climate change adaptation, energy efficient building design and renewable and low carbon energy technologies. Raphael co-authored the climate change adaptation strategy for the 2012 Olympics Legacy Scheme. He project managed a Local Climate Impacts Profiles for 10 local authorities in Yorkshire and contributed to a study for Climate East Midlands and DEFRA on the use of 'natural interventions' as adaptation measures. Raphael will be the project manager and will contribute expertise to all project elements.

Helen Pearce, MEng, MSc (Associate, Energy and Climate Change, LDA Design) specialises in advising public and private sector clients and communities on renewable and low carbon energy, climate change and sustainable design and construction. She has managed numerous projects,

many with challenging timescales, tight budgets and engagement with a range of stakeholders, including community consultation. She is responsible for the technical quality of our work in this area and maintains a rigorous, innovative and creative approach, ensuring it represents best industry practice.

rCOH: Project architects

Duncan Chapman, MA (Hons), Dip Arch, RIBA (Associate, Architect, LDA Design) brings specialist architectural expertise to bear to the interface between architecture, public realm, landscape and infrastructure design. Current projects include Oakham North Phase 1. Duncan will support the architecture, landscape and public realm work, contributing to all stages.

Buro Happold: Thermal comfort assessment

Dr. Mei Ren (Technical Director, Buro Happold) – Mei has a wide range of experience in building physics, low carbon consulting, planning, research and development and project management. Mei has delivered a major study on behalf of Partnership for Schools looking at school overheating risks across various projected climatic conditions. Mei is actively involved in research and development in the field of climate change adaptation. She participated and presented at the Climate Proof Cities programme funded by Dutch government. She also sits on CIBSE Climate Taskforce forum to review CIBSE recommendations of weather year data for building design.

Wormald Burrows: Water management

Bill Douglas (Partner, Wormald Douglas) and Hiranthi Cook (Associate Partner, Wormald Douglas) have respectively over 40 years and 18 years' experience in Civil Engineering. The team has been involved in the Oakham North project for 9 years, assisting in developing the overall drainage strategy (foul and surface water), Flood Risk Assessments and preparing drainage strategy modelling and reports. They have also assisted in the masterplan relating to all drainage matters.

Capita Symonds: Quantity surveyors and construction

Robin Sanders, BSc MSc DIC CEng MIMMM FCIHT FGS (Director, Forensic Services, Capita Symonds) has extensive experience in geotechnical design in relation to building foundations on soft or unstable ground including shrinkable clays. He pioneered the use of polystyrene as engineered fill for load-bearing structures. He has acted as an expert advisor and witness for most leading construction law practices, insurers and underwriters for the last 20 years on ground related disputes involving building foundations.

David Colyer (Associate Director, Capita Symonds) leads a team of specialist sustainability quantity surveyors (QS) and contributed to the government's 'Zero Carbon Task Force' advice on comparative suitability of various low-carbon retrofit measures for schools. David also provides commercial services for Capita's self-funded green retrofit solution for estates owners, which involves having a thorough understanding of latest technologies and also methods to evaluate investment options.

Larkfleet Homes: Developer and client

Paul Adams is Operations Director for Larkfleet Homes and our key client contact. He has responsibility for the development and marketing of homes in Phase 1 of Oakham North. His career in the housebuilding industry gives him expert insight into the supply chain, construction techniques and products, the housing market, housebuyer perceptions and issues affecting the viability of development.

Appendix 4.3: Presentation by Rob Shaw on climate change adaptation for Ecobuild, 21 March 2012

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix4.3_EcobuildPres.pdf

Appendix 4.4: Presentation by Rob Shaw and Raphael Sibille to Defra's Adapting to Climate Change team

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix4.4_DefraPres.pdf

Appendix 4.5: Case study

Uploaded as a separate document to the Connect portal:
400250_D4FC_OakhamNorth_LDADesign_FinalReport_Appendix4.5_CaseStudy.pdf

Appendix 5: Further information on extending adaptation to other buildings

See endnotes for references to resources and information used in the completion of this study which are recommended for use in future work.

Endnotes

[i] Design for Future Climate, an Adaptation Agenda for the Built Environment" 2010, by Bill Gething

[ii] CABE, 2005, Does money grow on trees?

[iii] Draft 2014 Water Resources Management Plan, Anglian Water (2013)
[iv] International Energy Agency, 2011, World Energy Outlook

[v] Policy Exchange, 2011, Climate Change Policy – Time for Plan B

[vi] IPCC, 2000, Special Report on Emission Scenarios

[vii] IPCC Working Group I and Working Group II, 2011, Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation

[viii] Stern, N, 2012, Climate change and the new industrial revolution, Lionel Robbins Memorial Lectures at London School of Economics

[ix] A projection of future change in climate (relative to a baseline period) that assigns probability levels to different climate change outcomes. This projection provides a change value for the future climate, expressed as the difference from the (modelled) 1961–1990 baseline climate (as opposed to the absolute value expressed in probabilistic climate projections). For more information refer to: www.ukclimateprojections.defra.gov.uk

[x] DEFRA, 2012, Climate Change Risk Assessment for the Built Environment Sector
[xi] 2009 – UK Climate Projections Briefing Report – DEFRA
2009 – UK Climate Change Projections – DEFRA
2010 – UK Wind Patterns and Climate Change – Does Anyone Know the Future? S. Jordan UK Conference of Wind Engineering
2010 – Challenges for the Assessment of Future Design Wind Wilkinson SM et al UK Conference of Wind Engineering

[xii] DEFRA & Environment Agency, 2009, Regionalised Impacts of Climate Change on Flood Flows

[xiii] Pittock, A. B. & Jones, R. N., 2000, Adaptation to what and why? Environ. Monit. Assess. 61, 9–35
[xiv] Design for Future Climate, an Adaptation Agenda for the Built Environment" 2010, by Bill Gething
[xv] Oakham North Environmental Statement, Hawksmead Ltd (2009)
[xvi] CLG, 2012, Technical Guidance to the National Planning Policy Framework
[xvii] Sewers for Adoption, 6th Edition
[xviii] Cost of building to the Code for Sustainable Homes: Updated Cost Review, Element Energy and Davis Langdon, CLG (2011)

[xix] CABE, 2005, Does money grow on trees?

[xx] Timber frame construction: Building towards a more sustainable future, UKTFA (2012)

[xxi] House building statistics statistical data set: Live tables on house building, Table 209: Permanent dwellings completed, by tenure and country, DCLG (last updated May 2013)

[xxii] DEFRA, 2012, Climate Change Risk Assessment, Annex A: Scenarios of climate variability and change

[xxiii] Met Office, 2010, Changes in the frequency of extreme rainfall events for selected towns and cities