# A Climate Change Adaptation Strategy for Octavia Housing

**Final Report**

**TSB Project Application No. 13839-86229**

**December 2013**

# TSB Final Report – Outline (KJ)

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**Executive Summary**

Climate change is affecting the ability of existing social housing to provide the quality environment expected by residents. Whilst mitigation to climate change is seen as a strategic challenge, supported by Government grants and initiatives, adaptation has to compete for its resources alongside other building maintenance and refurbishment issues. This poses a problem for many landlords; how do they prioritise adaptation for an uncertain future climate over solutions that improve the immediate quality of their housing stock today? This project developed a built asset management framework that would allow Landlord's to address this question.
Climate change will have a major impact on the performance of UK social housing. Increased storm intensity will result in more flooding and heat waves will increase the level of heat stress for many residents. Whilst technical solutions exist to address these issues, the legacy of building design; social capital associated with existing building; and the cost/disruption associated with retrofit solutions will require adaptation, in the form of maintenance or refurbishment, to be programmed over a long time scale. However, developing long term built asset management plans is complicated. Short term targets, political agendas and resident expectations all demand that decisions provide short term results. The resolution of this conflict lies at the heart of adaptation planning. This project developed an approach to strategic built asset management that addressed this conflict.

Unlike the majority of the Design for Future Climate Change 2 projects, this project did not involve the design of specific adaptations for specific buildings, but sought to develop a decision making framework that would allow built asset managers to integrate future climate change adaptation into their existing built asset management process. A 4 stage adaptation framework was developed to assess the impact that current and future climate change could have on Octavia Housing's domestic property portfolio and to identify generic adaptation solutions that could be integrated into their built asset management strategy. The project used current and future (UKCP09) climate projections to inform a range of weather scenarios (Section 2) and examined the potential impacts of these scenarios on the performance of Octavia's domestic building stock (Section 3.2). Generic adaptations to flooding and overheating were examined for a range of typical domestic buildings (Section 3) and typical triggers and thresholds (Section 3.2.8) were established to support the integration of future adaptations into Octavia's built asset management strategy (Section 3.3).
Octavia Housing is a Registered Social Landlord that owns and manages approximately 4000 homes, located mainly in inner London. Octavia's property portfolio is extremely diverse. It ranges from large modern purpose built blocks, to Victorian street properties, in between this there is a huge variety of property types some located on estates, some isolated purpose built blocks. A number of Octavia's properties are Listed Buildings and others are in Conservation Areas. Approximately 72% of the stock is located in the boroughs of Westminster and Kensington & Chelsea and many in very high value parts of those boroughs. Octavia also manage a number of specialist properties providing support for the elderly and other vulnerable groups. They own and manage 20 Charity shops which are run by the Octavia Foundation and have 42 commercial properties, mostly in Central London which generate income for the housing association.

The vulnerability and resilience of Octavia's housing stock was assessed using the adaptation framework (to provide strategic guidance) and the performance based built asset management

model (to identify potential vulnerabilities and generic adaption solutions) developed by the University of Greenwich (Section 3.2). An analysis of local flood risk assessments; past history's; future climate scenarios; and property surveys identified pluvial flooding (as a consequence of increased storm intensity) and overheating as the most critical climate related issues affecting the current and potential future performance of Octavia's stock. One hundred and sixty one (4.03%) of Octavia's properties are highly vulnerable to, and have a low coping capacity for a potential flood event. One thousand one hundred and sixteen (27.3%) of Octavia's properties are highly vulnerable to, and have a low coping capacity for, a potential overheating event.

The potential of a range of generic technical and operational adaptation solutions (Section 3.2) to address Octavia's most vulnerable property archetypes were examined. For flooding a combination of technical resistance and resilience measure were identified and a priority rating systems based on typical triggers and thresholds was developed to identify immediate (action to be taken in the next 5 years) and longer term (action to be taken between years 6-30) adaptation implementation plans. Adaptations to Octavia's operational processes were also developed and the majority of these will be implemented next year. For overheating, whilst a range of generic technical resistance measures were identified, the year in which the actions should be taken requires a more detailed analysis of individual building problems and the design of potential solutions. Obtaining the building level data required to develop specific adaptation solutions to Octavia's potential overheating problems will form part of the stock condition survey process over the next 5 years. Full details of the adaptation plans are given in Section 3.3.

Although no specific adaptation work was undertaken as part of this project the adaptation framework provides an exemplar of how any UK RSL could conduct an assessment of its climate change risks and adaptation needs and integrate these into a built asset management strategy. The framework (Section 2.4) provides a four phase approach to the development of an adaptation strategy. The first phase involves assessing the vulnerability and resilience of the building stock to existing climate threats. This will allow the organisation to establish a base understanding from which to assess the potential impact posed by future climate change. Future climate impact scenarios are introduced to the analysis through a combination of future weather risk assessments (phase 2) and building impact models (phase 3). The weather risk assessments can either be generated through the UKCP09 weather generator or by access to Environment Agency or Local Government assessments. Building impact assessments would tend to be generic at this stage of the assessment process (potential adaptations applied to building archetypes or organisational systems) and are intended to inform the need for more detailed analysis of specific buildings as part of the ongoing adaptation plan. The adaptation strategy also needs to provide a series of thresholds and triggers that will be used to prioritise adaptations alongside other building intentions in the built asset management strategy (phase 4). The thresholds and triggers are qualitative statements that express the organisation's expectations of the performance of a dwelling against each impact scenario. The triggers and thresholds also describe the management approach to adaptation planning and an indicative adaptation plan can be developed that identifies short term (years 1 to 5) and medium/long term (years 6-30) actions. Short term actions will include developing specific technical and organisational adaptations for highly vulnerable, low resilient buildings; medium/long term actions will focus on refining vulnerability/reliance assessments as future scenarios become more reliable. Finally, the adaptation strategy should include the provision of a feedback loop that quantifies the performance of any adaptations and informs the next iteration of the built asset management strategy.

In principle, the approach outlined above could be used by Social Landlords to assess the vulnerability and resilience of the approximately 4 million (England) socials housing units to climate change and develop generic adaptation solutions as part of short and long term built asset management planning. However, before this approach can be widely adopted, a number of practical issues will need to be addressed.

Whilst the underlying theory and the assessment tools developed in the project worked well, some of the underlying data required to support the tools was lacking or incomplete. As such, working assumptions had to be made that reduced the level of detail and confidence that built asset managers had in the final adaptation plans. At the time of this project there was no consistent UK wide data on the future impact that climate change could have on physical performance of the building stock. Most flood maps that were available to Octavia didn't accommodate climate change scenarios and, in the case of pluvial flooding, didn't map future rainfall predictions onto local drainage topology. As such the future flooding scenarios lack the currency associated with existing fluvial flood assessment. Where there are accepted climate change models, organisations asset management databases don't generally contain the level of building detail required to develop adaptation solutions. For example, whilst external temperature profiles can be generated to support building simulations, most RSL built asset management databases are unlikely to contain the level of detail to allow these assessments to be undertaken without substantial resurvey work. Whilst these issues do not undermine the development of the adaptation strategy, they will influence attitudes towards adaptation planning, resulting in a wait and see approach which is at odds with the needs to plan for the implications of climate change.

For the approach outlined in this project to be applied across the UK would require the development of national climate impact models that allow RSL's to map their property portfolios against a range of flood and heat wave scenarios and would involve the RSLs collecting more detailed building performance data to allow them to undertake initial vulnerability and reliance assessments of their properties.

Finally, a 10 step adaptation checklist is presented to guide other UK social housing built asset managers through the process of assessing the impact of current and future climate change on their stock. The checklist is supported by a range of toolkits (outlined throughout the body of this report) that allow climate risks to be translated into meaningful impact scenarios that are specific to any given building stock profile. The toolkits also provide guidelines for the development of qualitative risk thresholds and triggers that reflect the aspirations of the landlord and tenants. Links to external toolkits are also included in this report that allows an initial assessment of generic adaptations for flooding and, including indicative cost/benefit analyses. Guidance is also given on integrating these generic adaptations into short, medium and long term adaptation plans.

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## Appendix 5

# 1. Building Sock Portfolio Profile

## *1.1 Introduction*

This project did not address the impact of climate change on a single building but on a portfolio of 4088 housing units owned and operated by Octavia Housing. As such, the building profile outlined in this section represents the stock portfolio profile, presented as typical housing unit archetypes, and does not provide specific details about individual building units.

Octavia Housing recognises the challenges posed by climate change in the built environment, and as such are looking to establish generic 'typical' technical solutions for its housing stock to reduce any adverse impacts in the future.

The project explores the measures (technical and operational) which can be applied individually or collectively to its varied housing stock of 4088 owned and managed properties, and highlights the challenges faced in integrating adaptation solutions in to its 30 year business plan and Built Asset Management Strategy.

This section provides the contextual background to Octavia and its approach to built asset management.

## *1.2 Background*

*Figure 1.1 Octavia Hill (1838-1912)*

Octavia Housing is a Registered Social Landlord (RSL) operating as a non-profit making organisation providing a range of service covering: - below market rental property; sheltered accommodation; and shared ownership properties to people living in London.

Octavia Housing was founded by Octavia Hill, a Victorian philanthropist and social reformer, who began her work with the poor of London in the 1860's. She purchased her first properties in 1865 and became a pioneer of social housing. She was one of the first to understand the impact poor housing had on the health of occupants and the ability to get and make a valuable contribution to society.

One of Octavia's many passions was safeguarding the environment; she saw the importance of protecting our land and allowing people to enjoy open space. She was the joint founder of the National Trust and a lead campaigner for the introduction of a Clean Air Act. She believed that her purpose was to "make lives noble, homes happy and family life good", holding to the view that housing regeneration was as much about people as buildings.

Whilst the specific problems facing Octavia today are different from those 150 years ago, the challenge to support improved quality of life in the light of climate change is never the less as demanding. Octavia Housing prides itself on its pro-active and innovative approach to building sustainable communities and maintaining the quality of its homes.

It is important to understand the impact that climate change may have on Octavia's property portfolio over the next 30 years and utilise the information gained in developing its solutions for the future, and look at how these solutions can focus the business plan and asset management strategy going forward.

Whilst developing the climate change solutions, consideration needs to be given to the economic, environmental and physical performance of each property within the portfolio and to identifying performance improvement triggers/thresholds for measures to be implemented as part of routine maintenance or refurbishment. The impact of this will be evidenced in showing that the right climate change solution is undertaken at the right time to ensure continued performance of each property as the climate changes.

### *1.3 Octavia's Building Portfolio*

Octavia Housing manages a stock of 4088[1] homes with a market value exceeding £1 billion. The use of these properties is made up of 81% are let at below market rents, 10% are provided on a shared ownership basis and the remainder through special projects such as extra care homes for the elderly.

Octavia's homes are distributed across 11 London boroughs (Table 1.1, Figures 1.2 and 1.3). Approximately 72% of the stock is located in the boroughs of Westminster and Kensington & Chelsea and many in very high value parts of those boroughs.

| | General Needs | Leasehold/Shared Ownership etc. | **Total** |
|---|---|---|---|
| BARNET | 12 | | **12** |
| BRENT | 341 | 138 | **479** |
| CAMDEN | 38 | 8 | **46** |
| HARROW | | 31 | **31** |
| HILLINGDON | 1 | | **1** |
| HOUNSLOW | 53 | 31 | **84** |
| HAMMERSMITH & FULHAM | 318 | 36 | **369** |
| ROYAL BOROUGH KENSINGTON & CHELSEA | 1192 | 71 | **1263** |
| SOUTHWARK | 64 | | **64** |
| WANDWORTH | 45 | 7 | **52** |
| WESTMINSTER | 1621 | 66 | **1687** |
| **Total** | **3685** | **403** | **4088** |

*Table 1.1 Stock numbers: January 2013 (QLX)*

Octavia own few whole houses, more than 86% of its stock is made up of maisonettes and flats (the majority the result of the conversion of houses rather than purpose built blocks).

Forty six percent of the General Needs stock is made up of bedsits or one bedroom properties, 33% of two bedroom properties and 18% of three bedroom properties and the remaining 3% of 4 and 5 bedroom properties. Forty nine percent of the stock was built before 1919, 8% between 1919 and

[1] Note: This figure varied throughout the duration of the project as Octavia acquired and disposed of properties.

1944, 22% between 1945 and 1980 and 21% post 1980, having a high percentage of pre 1919 homes set Octavia apart from other housing providers as can be seen in Figure 1.4.

The portfolio is extremely diverse ranging from large modern purpose built blocks, to Victorian street properties in various locations. A number of Octavia's properties are Listed Buildings and many others are located in Conservation Areas which means that a large proportion of the stock is 'difficult to treat' in terms of climate change adaptation.

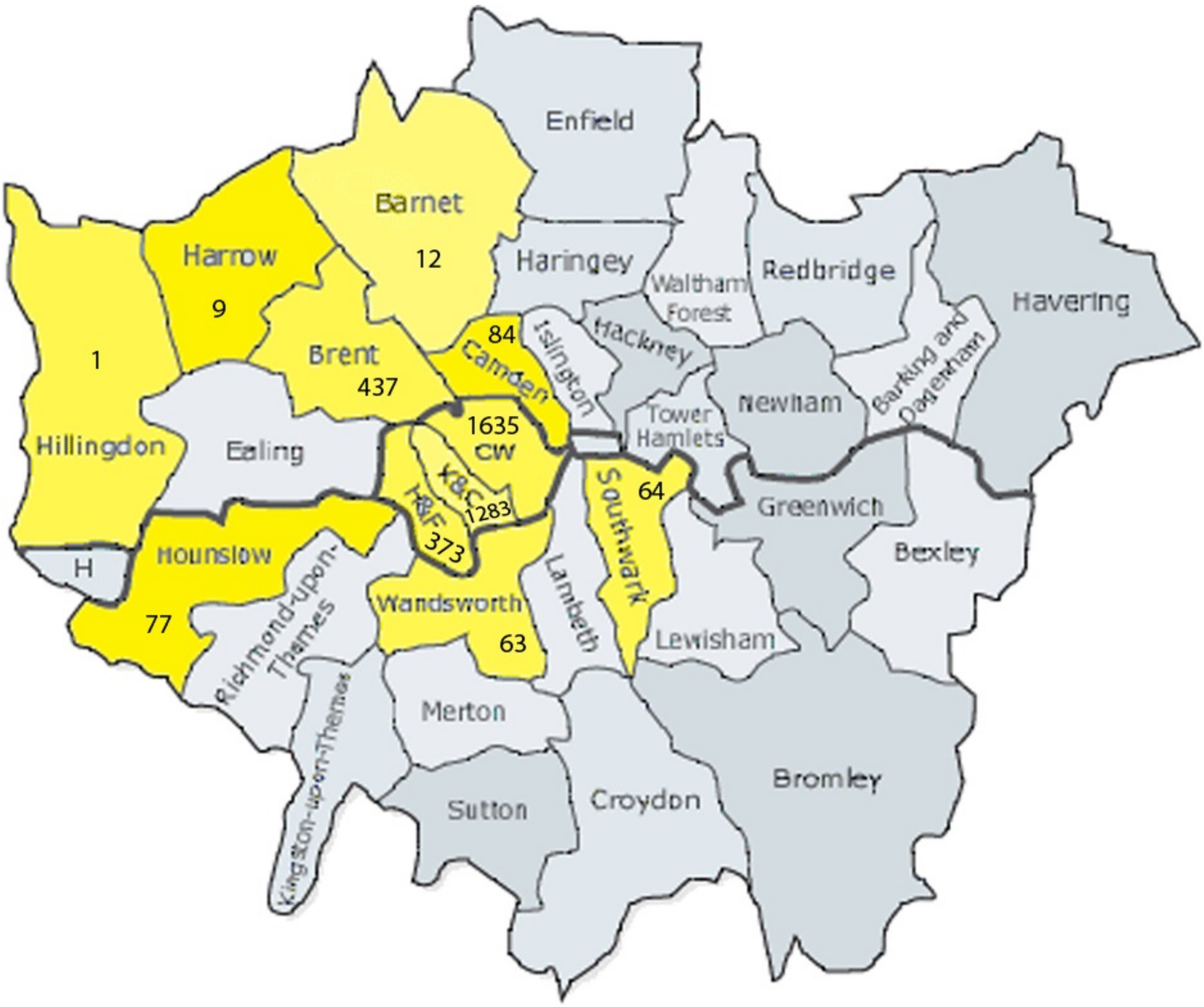


*Figure 1.2 Distribution of Octavia's housing stock (2011)*

*Figure 1.3 A bird's eye view of Octavia's properties*

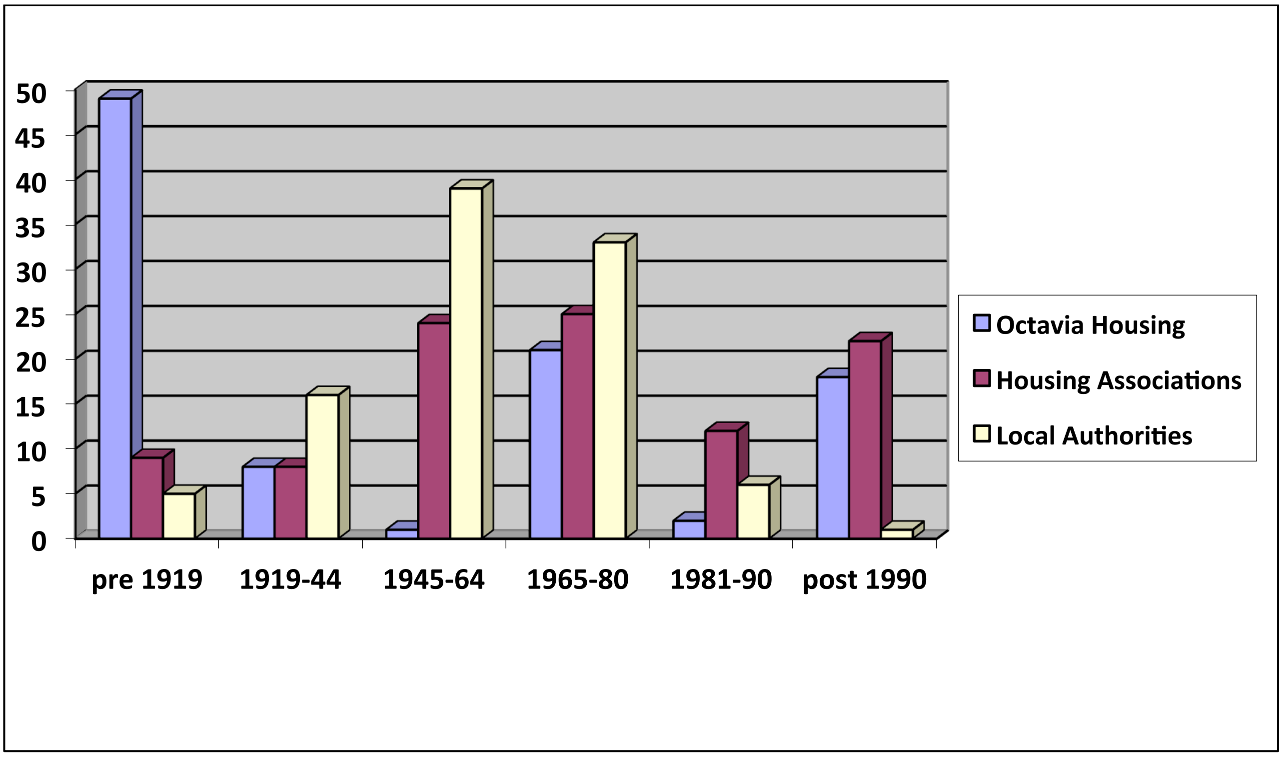


*Figure 1.4 Comparison of Octavia's property by age compared to other UK social housing (English Housing Survey 2011-12 and Octavia QLX data January 2011)*

In this project a combination of property age, construction and accommodation type was used to define archetype examples against which the impacts that climate change could have on their performance could be assessed. Detailed internal surveys of 26 typical archetype properties were undertaken to identify the impact that a flood and/or overheating would have on such properties. The archetype properties covered the range of property types owned by Octavia and included converted upper/ground floor and basement flats built before 1900; modern blocks of flats built since the 1970's and a small number of houses built between 1900 and 2008. Details of each property surveyed, including construction type, are given in Appendix 5.2.

### *1.4 Octavia's Asset Management Strategy*

Octavia's Asset Management Strategy is founded on the Octavia Standard (See Appendix 1.1) which goes beyond the national minimum standard for Social Housing set out in the Decent Homes Standard. The Decent Homes Standard comprises a set of performance criteria against which the quality of social housing is judged[2]. Where properties do not meet the Octavia Standard, the failure is addressed through an urgent repair or included in the planned work programmes. The standard is constantly under review to reflect changes in national housing policies, Octavia's aspirations and feedback from residents.

Octavia assess the performance of their housing stock against their Housing Standard through a combination of a Stock Condition Survey and resident satisfaction feedback. Octavia's last full independent stock condition survey was undertaken in 2007 by Rand Associates. This was a detailed survey accessing 83% of the stock and formed the basis for Octavia's medium term investment plans. The survey showed that 27% of the General Needs stock failed to meet the Decent Homes Standard. These failures triggered a 5 years reinvestment programme (Table 1.2) and today the stock is generally in good condition with approximately 3% of the stock currently estimated to be 'non decent'. This compares well with the 15% of non decent homes in the wider English Housing Associations stock[3].

[2] For further details see:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/7812/138355.pdf

[3] DCLG (2013) 'English Housing Survey 2011-12: Headline Report' available at:
https://www.gov.uk/government/publications/english-housing-survey-2011-to-2012-headline-report

| | Actual 2008-9 | Actual 2009-10 | Actual 2010-11 | Actual 2011-12 | Forecast 2012-13 | Average |
|---|---|---|---|---|---|---|
| | | | | | | |
| **Revenue costs** | | | | | | |
| Responsive works | 2,656 | 1,972 | 2,138 | 2,433 | 2,060 | 2,252 |
| Major repairs | 0 | 0 | 0 | 298 | 300 | 299 |
| Gas contract | 655 | 384 | 755 | 630 | 650 | 615 |
| Void works | | 688 | 787 | 338 | 626 | 488 |
| Planned maintenance | 361 | 126 | 148 | 128 | 175 | 188 |
| Cyclical maintenance | 1,067 | 1,295 | 1,170 | 1,311 | 2,191 | 1,407 |
| **Total revenue costs** | 4,739 | 4,465 | 4,998 | 5,138 | 6,002 | 4,835 |
| | | | | | | |
| **Capital expenditure** | | | | | | |
| Bathrooms | 1,051 | 558 | 506 | 992 | 472 | 895 |
| Boilers | 2,186 | 1,847 | 559 | 255 | 278 | 1,282 |
| Common areas (incl Fire Safety works) | 29 | 416 | 816 | 1,358 | 1,333 | 988 |
| Electrical | 249 | 546 | 1,040 | 344 | 0 | 545 |
| Kitchen | 1,665 | 539 | 1,260 | 1,030 | 708 | 1,301 |
| Lifts | 0 | 0 | 0 | 74 | 156 | 57 |
| Roofs | 109 | 776 | 264 | 111 | 56 | 329 |
| Structure | 144 | 121 | 369 | 90 | 241 | 241 |
| TV Aerials | 23 | 2 | 302 | 499 | 0 | 207 |
| Windows & doors | 191 | 316 | 34 | 31 | 457 | 257 |
| Energy efficiency works | 0 | 0 | 0 | 0 | 0 | 0 |
| Princedale Road | 0 | 0 | 256 | 0 | 11 | 67 |
| Others | 78 | 165 | 208 | 121 | 65 | 159 |
| **Capitalised costs** | 5,726 | 5,286 | 5,614 | 4,905 | 3,777 | 5,062 |
| | | | | | | |
| **Total direct costs** | 10,465 | 9,751 | 10,612 | 10,043 | 9,779 | 10,218 |

*Table 1.2 Octavia's spend profile for the last 5 years*

In addition to improving the general condition of its stock, Octavia also aspires to improve the sustainability of its stock. In 2007 Octavia's stock had an average SAP[4] Rating of 61. Through a major boiler replacement programme (over 1/3rd of the stock has had new high efficiency condensing boilers installed) and a new build programme (Octavia build approximately 150 new houses per year to very high environmental standards) this had risen to 69 in 2011. Whilst this figure compares well with other UK rented housing providers (Figure 1.5), Octavia have recently set a new threshold target whereby no property will having a SAP rating of less than 75 by 2023. This is an ambitious target given the profile of the stock and it will require significant reinvestment over the next few years. Octavia is currently undertaking a pilot project to deliver 200 properties to

[4] For further details see: https://www.gov.uk/standard-assessment-procedure

the new standard by the end of March 2014. The data collected from the study will be used in developing the strategy to ensure all properties meet the new standard.

Octavia strive to be innovative in their approach to building refurbishment and in 2011 Octavia was responsible for the first retrofit Passivhaus in the UK as part of a TSB sponsored project following this they have just completed the largest a new build Passivhaus project in London.

Octavia recognise that climate change needs to be reflected in its asset management strategy as this historically has been shown to be the least developed element. In 2010 Octavia took part in the Community Resilience to Extreme Weather[5] (CREW) project funded by the Engineering and Physical Sciences Research Council[6]. As part of this work a group of researchers from the University of Greenwich examined the generic vulnerabilities and resilience of a small number of Octavia's properties to flooding and heat waves as well as the adaptive capacity of Octavia as an organisation to recover from such events (see Appendix 2.1 for the summary report). The study found that Octavia's properties were potentially vulnerable to flooding (particularly pluvial flooding) and heat waves and that the existing stock had very little inherent resilience to such events. Furthermore, whilst Octavia did possess many of the attributes associated with good adaptive capacity, their disaster recovery and business continuity plans were predicated on the assumption that fluvial flooding (from the River Thames and its tributaries) would be the major threat and as such they would be largely ineffectual should pluvial flooding occur.

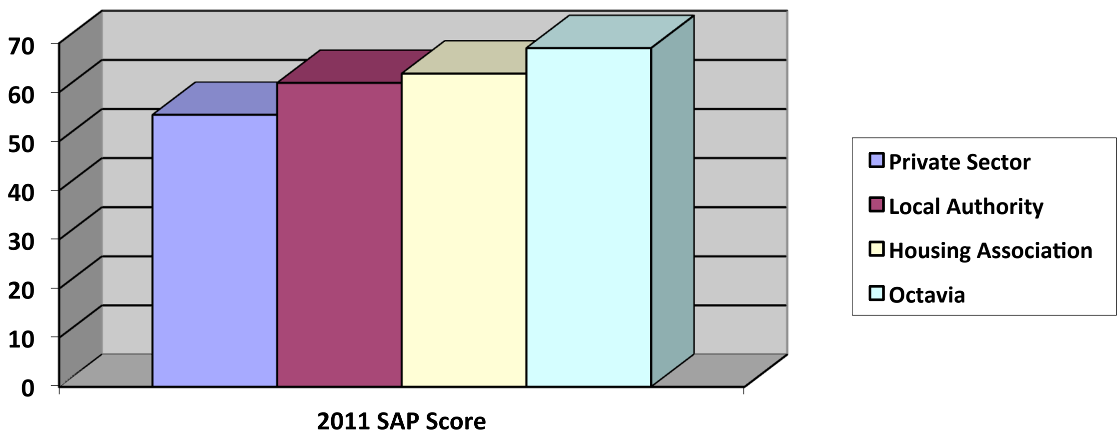


*Figure 1.5 Mean SAP rating by tenure 2011 (English Housing Survey)*

The study recommended a full examination of the risks to Octavia's stock portfolio and the development of an adaptation strategy to reduce vulnerability and improve the resilience of their building stock. The current project is a direct response to these issues.

Going forward, the priority for the built asset management strategy over the next five years is to develop operational plans that continues to deliver the Octavia Standard; improves the general energy efficiency of the stock; and reduces the vulnerability and improves the resilience of the stock through appropriate adaptation. To support this activity Octavia have forecast the need for an outline budget of £4.5 million annually over the next 5 years. This forecast includes an estimated

[5] For further details see: http://www.arcc-cn.org.uk/wp-content/pdfs/CREW_Final_Report.pdf
[6] For further details see http://www.epsrc.ac.uk

budget of £1.5 million for energy efficiency retro fit works. This work will also address some climate change issues, for example, they propose to external insulate a number of it solid wall properties, which as well as improving the thermal properties of their homes is a measure identified in this report as helping to keep homes cool. Although the level of funding for adaptation to address future climate change is yet to be addressed, a small budget has been set aside to undertake some pilot projects, this together with works contained in the actions contained in the Adaptation Strategy (section 3.2) will enable estimated budgets to be produced and presented to Octavia Board for approval.

### *1.5 Further Information*

Further details of Octavia Housing can be found at http://www.octaviahousing.org.uk/

# 2. Climate Change Risks

### *2.1 Introduction*

Climate change affects both new and existing building. Whilst for new buildings preparation for future climate change can be considered as part of the original design process, the same approach cannot as easily be applied to existing building. Future adaptation options for existing buildings are often limited by design legacy or by the high costs associated with changing the structural form. In addition, many existing buildings have a community legacy that makes adaptation not only technically demanding, but also socially challenging. This section explores the impact climate change may have on Octavia's existing building portfolio and in particular assesses the impact that flooding and overheating may pose to its residents. As these assessments were made against a portfolio of properties no single building was examined in detail but archetypes were used to represent Octavia's 4088 homes located in 11 inner London boroughs. As such the climate impacts described in this section should be considered as typical impacts for a range of property types and locations. Further, as the aim of this project was to develop an approach by which adaptation could be integrated into a built asset management strategy; fundamental changes to the structural form (construction type) of Octavia's properties were not considered appropriate. Should future detailed analysis of any particular building identify the need for such a radical approach then it is very likely that Octavia's asset management strategy would be to disinvest in this property rather than to instigate such a fundamental refurbishment. Changes to non-structural elements were examined to improve resilience to flooding and overheating.

### *2.2 Assessing Climate Change Risks*

In order to assess the impact of climate change on Octavia's property portfolio required the development of current and future climate impact scenarios across a wide spatial scale. However, generating scenarios across a spatial scale requires a different approach than for a single building location. In addition to generating weather files, the scenarios have to take account of local topology and infrastructure. In the case of flooding, the rainfall scenarios have to be superimposed on both the physical location of the building stock and any catchment area that affects the potential flood zone. In the case of overheating, the temperature profiles need to take account of any urban heat island affect as well as localised urban density. Taking account of both these situations requires significant computing and modelling resources which were beyond the scope of this project. However, the impact of future climate change on London has been examined through the EPSRC CREW project; Drain London Project; and forms the evidence base in the Mayor's Adaptation Strategy. Where applicable these external sources have been used to generate the future climate impact scenarios used in this project. Current climate impact scenarios have been generated from existing Strategic Flood Risk Assessment plans.

The CREW project that preceded this project was undertaken by a consortium of 14 universities, supported by the GLA and 5 London Boroughs. The CREW project sought to identify the potential impact of climate change on the vulnerability, resilience and adaptive capacity of the SE London Resilience Zone. Although the majority of Octavia's stock is located outside this zone the impacts identified by the CREW project are considered indicative of, and applicable to, the wider London region. As such the CREW findings provided the basis for the climate change risks used in this project.

The aim of the CREW project was to investigate the socio economic impacts of current and future climate hazards at a spatial scale. The project involved a research consortia working together to map the impacts of climate change on the weather patterns across London and interpret these as a series of hazards for the local community. Potential weather scenarios were generated using the UKCP09 weather generator and these were applied to the local geographical topology to produce a series of hazard models for flooding, heat waves, subsidence, water resources and wind. The hazard models were developed for the year 2020 and 2050.

Researchers at Newcastle University led by Dr S Blenkinsop used the latest probabilistic climate model outputs and climate downscaling tools to project the frequency and severity of future extreme weather events for London. Whilst the UKCP09 provides climate model baseline simulations and future projections of climate at a resolution of 25 km, this is not sufficient to reproduce the local scale variations in climate that are important to the hazards shown in Figure 2.1. SWERVE enhanced the functionality of the UKCP09 weather generator to provide downscaled weather simulations at a resolution of 5 km to generate the high resolution climate information required for hazard modelling. For example, rainfall simulations were generated at 2 km and 15 minute resolutions to provide the detail required for realistic simulations of urban flooding. All the models used the medium greenhouse gas emission assumptions and the UKCP09 weather generator. More details of the modelling assumptions can be found in Appendix 2.3.

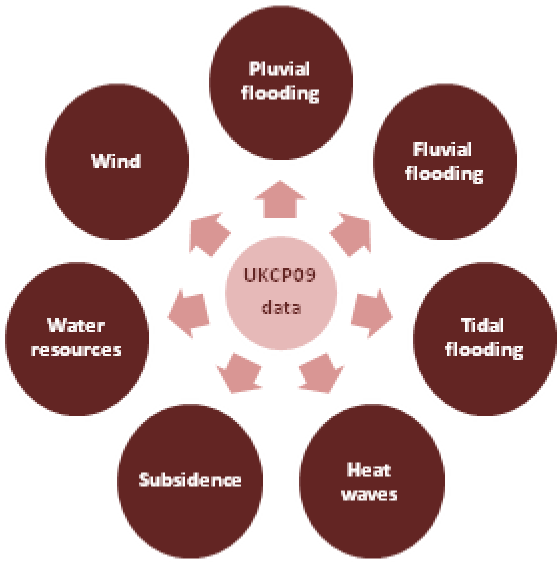


*Figure 2.1 SWERVE hazard model*
Source: CREW Final Report

The UKCP09 reflects the uncertainty in climate modelling by providing thousands of probabilistic projections of climate change. SWERVE developed a statistical sampling method to select a subset of the possible projections and then used these to model each hazard. (Figure 2.2 shows an example of this approach applied to pluvial flood modelling (Burton et al., 2010)). Each SWERVE hazard model provided decision makers with ‘low’ (very unlikely to be less than), ‘medium’ (central estimate) and ‘high’ (very unlikely to be more than) projections of the future hazard (Blenkinsop et al., 2010). The projections corresponded to the 10th, 50th and 90th percentiles derived from UKCP09 projections.

Based on the above approach the team at Newcastle University examined the following impacts:

- Temperature/heat
    - summer maximum temperature
    - heat wave frequency based on London specific temperature thresholds

- Flooding
    - flood depth and frequency for fluvial and pluvial flood events
    - maximum and average flood depths
- Water resources
    - disruption to water supply including hosepipe bans and rationing
- Subsidence
    - clay related soil substitutes
- Wind
    - damage to buildings-maximum gust speeds of at least 35 m/s
    - danger to pedestrians comfort or safety-maximum gust speeds of at least 20 m/s

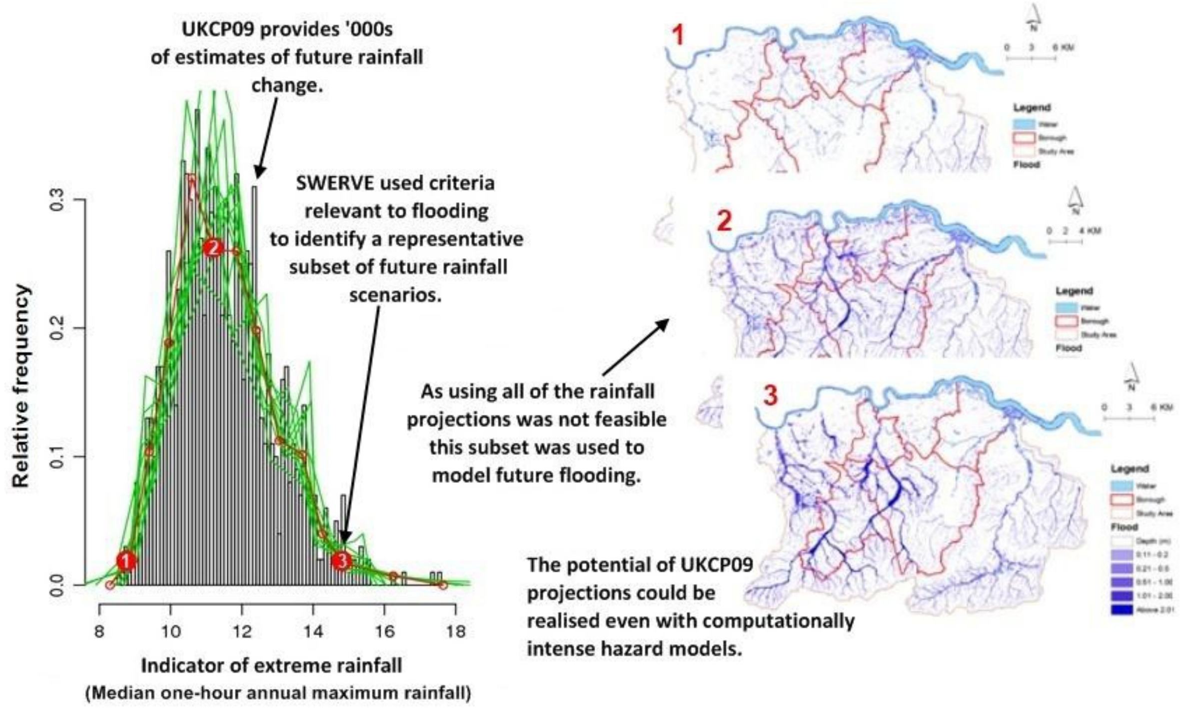


*Figure 2.2 A simplified scheme for sampling UKCP09 projections for application in the urban inundation model.*
Source: The CREW Final Report

The impacts were presented as low (very unlikely to be less than), medium (central estimates) and high (very unlikely to be more than) projections of future hazards against the current baseline (1961-90 climatological baseline). The main findings from the SWERVE models were:

**Temperature**: - potentially large increases in average maximum summertime temperatures are projected across the whole of London by 2050 (up to 3.5°C by 2020 and 5.8°C by 2050). The temperature projections were considered in terms of heat wave thresholds (temperatures in excess of 32°C - 18°C - 32°C for sequences of daily maximum, minimum and next day maximum temperatures) defined by the NHS Heat Wave Plan for England[7]. The detailed future temperature

[7] For further details see:: http://www.england.nhs.uk/2013/05/23/heatwave-plan-2013/

projections were then combined with population estimates to identify areas of London where future heat wave risks were greatest. From this analysis residential areas of inner London were identified as the most high risk areas in need of future adaptation planning (Figure 2.3)

**Flooding**:- increased storm intensity and duration will create a flooding risk for London. This risk is more likely to be associated with pluvial flooding (arising directly from rainfall accumulating on the surface) rather than fluvial (arising when rivers overtop their blanks) flooding. The River Thames, the main watercourse running through London, has defences designed to contain a tidal surge with a 0.1% probability of exceeding the defences in any given thousand year period. Additionally, when defences were constructed, considerable extra height was added and it is generally believed that the defences provide a standard of protection in the region of one in 2000 year event. Thus, the primary flooding risk for London is from pluvial flooding.

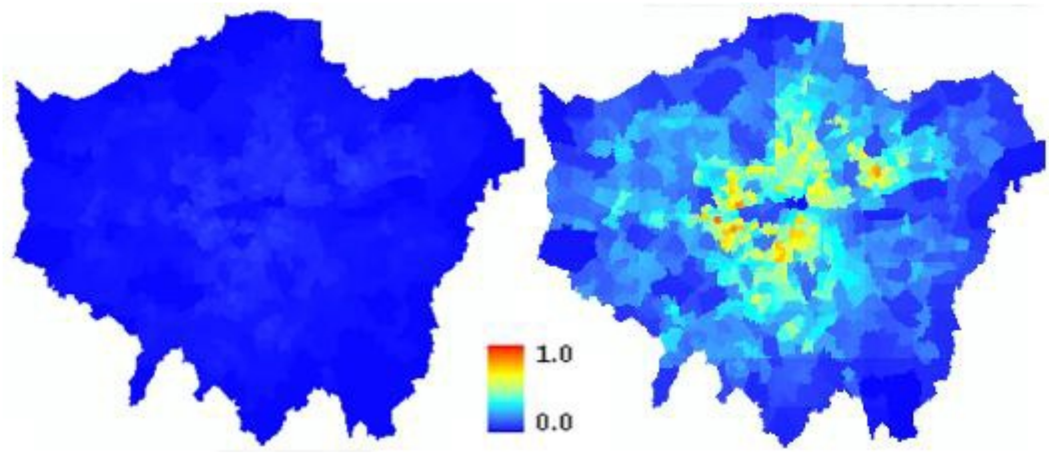


*Figure 2.3 Heat wave risk for the baseline (left map) and 2050s high projection (90th percentile, right map).*
Source: The CREW Final Report

**Water resources**: - the demand for water is largely driven by population increases confounded by climate change. Even assuming no effect from climate change, by the 2020s total demand saving days (Figure 2.4) are projected to increase by approximately 50% (compared to the baseline period). Note: The assessment of future drought occurrence used combined the UKCP09 climate projections with a rainfall model capable of simulating spatial rainfall patterns. The resulting rainfall projections were used within a hydrological model and the Environment Agency's water resource model for London (AQUATOR)[8].

**Subsidence**:- clay-related soil subsidence projections were calculated using a combination of climate and soil characteristics data and were presented to users via a 9-point vulnerability score ranging from "Extremely Low" to "Extremely High" (Blenkinsop et al., 2010). The risk of clay related subsidence across SE London is likely to remain unchanged by the 2020s and increase slightly by the 2050s. Inner London is likely to be less affected than outer London. This finding has been assumed to apply across the Greater London area (Figure 2.5).

[8] For further details see: http://www.hydro-logic.co.uk/HL/aquator

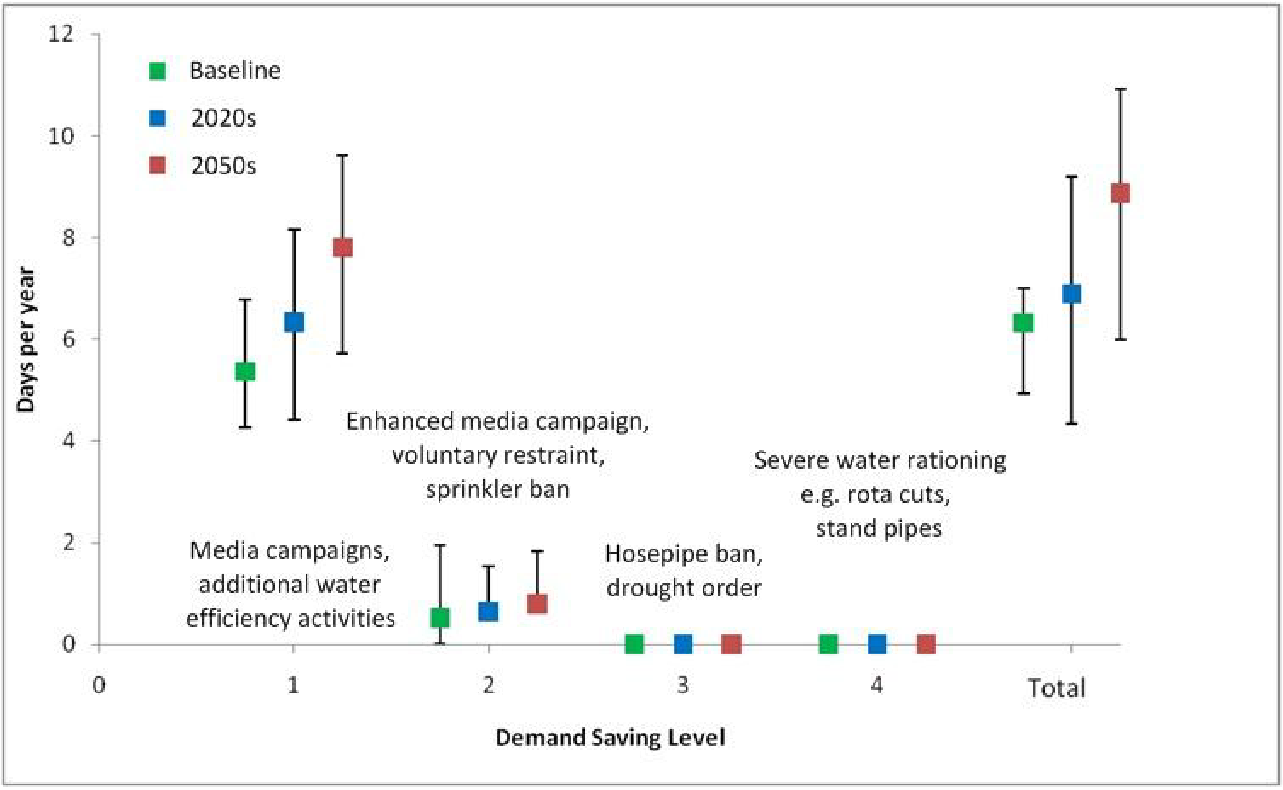


*Figure 2.4* *Annual demand saving days for the baseline and future scenarios based on current demand.*
Source: The CREW Final Report

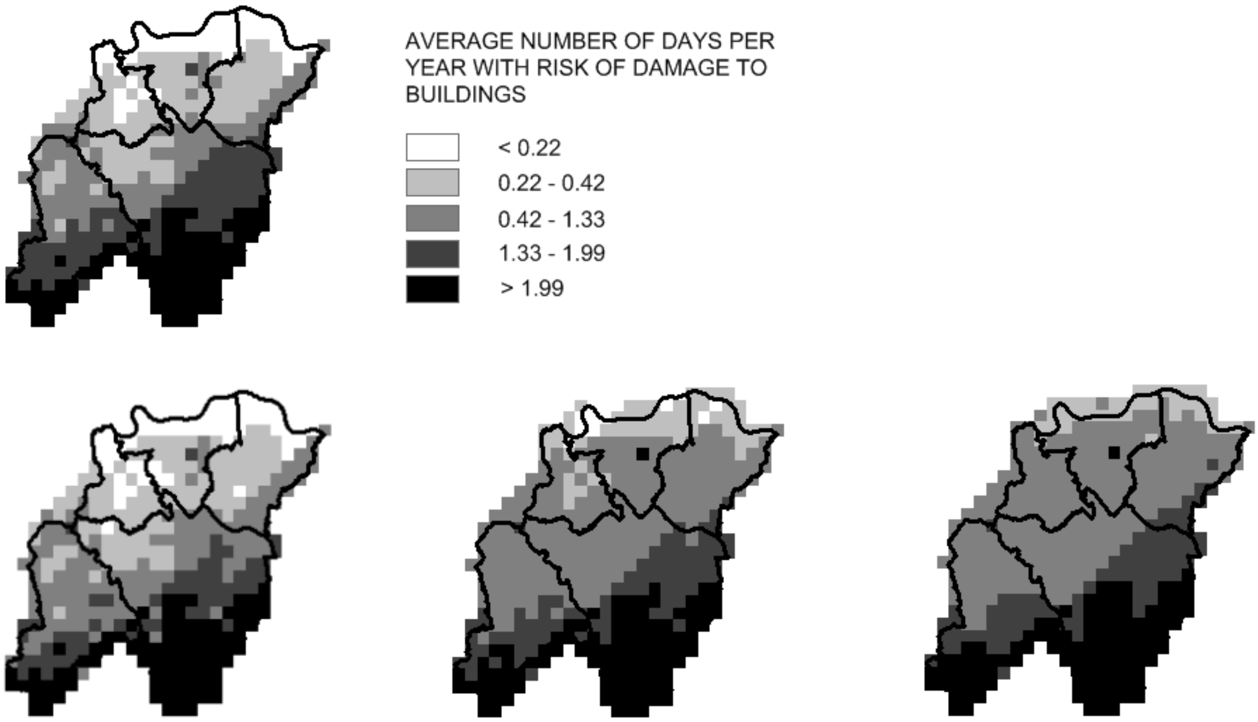


*Figure 2.5* *Simulated current (baseline) and projected future (2050s; low, central and high) projections of average annual frequencies of wind gusts which provide a risk of damage to buildings.*
Source: The CREW Final Report

**Wind**: - average daily wind speed information is provided from UKCP09 climate modelling experiments but this is relatively coarse, at a resolution of 25 km. SWERVE used a method which has previously been used in the engineering community to estimate structural loading on new buildings to statistically derive hourly maximum wind speeds and gust speeds at a resolution of 1 km (Blenkinsop et al., 2012). SWERVE concluded that changes in mean daily wind speed are likely to be small and not significantly different from the baseline period by 2050.

Based on the above CREW models the most relevant climate risks to Octavia's housing would appear to be overheating and pluvial flooding. These findings are further reinforced by the London Climate Change Adaptation Strategy[9]. With regard to overheating, the Strategy predicts that the average summer day will be 2.7°C warmer, and a very hot summer day 6.5°C warmer, than the baseline average. With regard to flooding, the Strategy confirms the protection provided to London by the Thames Barrier and current River defence systems (albeit at lower return period than those predicted by the CREW project) and acknowledges that pluvial flooding as a consequence of increased storm intensity, whilst much more difficult to predict, is likely to pose the greatest risk. Indeed, predictions based upon a 1:100 year rainfall event suggest that significant pockets of London could flood up to a depth of 0.5m with those areas lying along valleys or inland waters could flood to a depth of 1.0m. The London boroughs of Southwark, Hammersmith and Fulham, Newham, Wandsworth, Tower Hamlets, Westminster and Greenwich are considered those at potentially most at risk of pluvial flooding.

### *2.3 Impacts of climate change on domestic buildings - Overheating*

The general impact of overheating on domestic buildings was examined in both the Beating the Heat and CREW projects.

The Beating the Heat project examined the impact of future overheating on the performance of five UK building archetypes[10]. The project applied climate change scenarios to a range a building types, and used the UKCIP decision-making framework to develop adaptation measures; and assess their impact against a range of performance targets. The performance target for discomfort was set at 25°C (warm) and 28°C (hot) for offices, schools and living areas in homes; and 21°C (warm) and 25°C (hot) for bedrooms in homes. Heat stress risk was deemed to be high when indoor temperatures rose above 35°C. The project examined the performance of two house types, a 19th-century house and a new build house that are relevant to this project.

The 19th-century house was found to be prone to overheating during the summer months, exceeding the hot threshold 13% (estimated) of the time by the 2050s. Whilst solar shading: in the form of external blinds or shuttering; and secure ventilation could theoretically reduce overheating, internal temperatures would still peak at 34°C in the living room and 33°C in the bedroom in the 2050s. As an alternative, forced air conditioning could cool the house below the discomfort thresholds but this would be at the expense of increased energy consumption. For the new build house, while similar overheating characteristics exist, the passive adaptations would be more

[9] For further details see: http://www.london.gov.uk/priorities/environment/publications/managing-risks-and-increasing-resilience-the-mayor-s-climate

[10] For further details see: http://www.arup.com/_assets/_download/download396.pdf

successful in reducing indoor temperatures but again a forced air conditioning solution would be needed to cool the house below the discomfort threshold.

The effect of overheating was also examined in the CREW project by a team of researchers from De Montfort University (led by Dr S Poritt). Four typical archetypes (19th-century terraced house, 1930s semi-detached house, 1960s low-rise flats and modern detached properties) were examined (Note: these were chosen in part to be consistent with the Octavia pilot study which was also undertaken as part of the CREW project). The thermal performance of each archetype was measured, and the impact that the adaptations had on the number of degree hours that each property exceeded 28°C was calculated. Dr Poritt used dynamic thermal simulation computer modelling (Energy Plus[11]) to assess and rank the effectiveness of single and combined passive adaptations or interventions in reducing overheating during a heat wave period. Three options were used for providing simulation weather data: future weather data, developed using a morphing methodology described in CIBSE TM36[12]; European weather data, to approximate the predicted future UK climate; and real UK heat wave periods from 1976, 1995 and 2003. Dr Poritt's analysis identified two 'Tiers' of building types in terms of overheating exposure. Tier 1 included the 1930s semi-detached house, the 1960s ground floor flat, and the Victorian (19th century) end and mid-terraced houses. Tier 1 buildings typically experience less than half the overheating exposure of Tier 2 buildings (Figure 2.6), which included the 1960s top floor flat and the modern detached house, constructed to 2006 Building Regulations. Note: 'Degree hours' is a commonly-used building design measure indicating the number of hours at which the temperature exceeds a stated threshold temperature multiplied by the degrees that the threshold is exceeded.

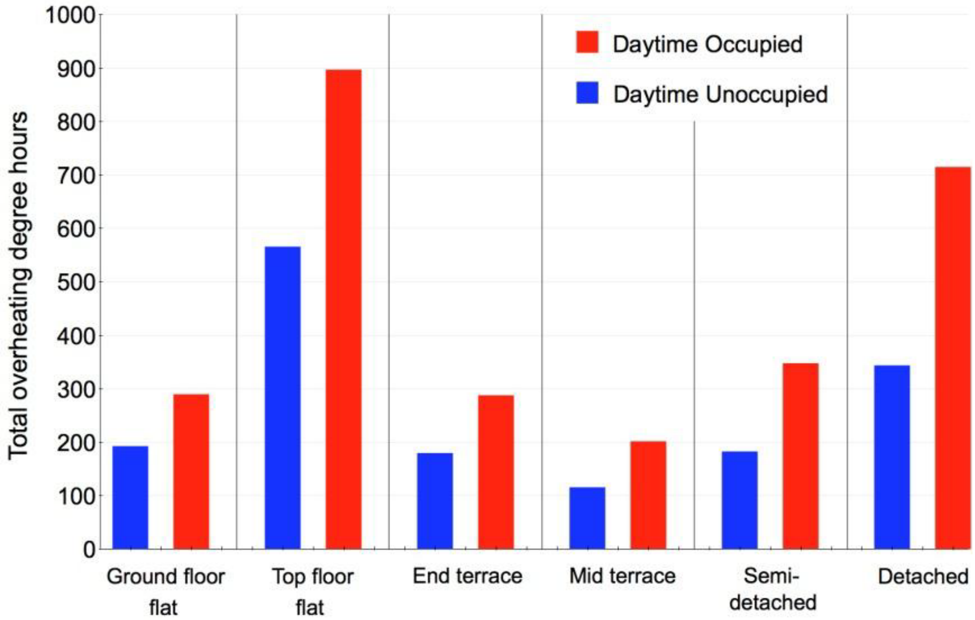


*Figure 2.6 Overheating exposure of modelled house types*
Source: The CREW Final Report

[11] For further details see: http://apps1.eere.energy.gov/buildings/energyplus/energyplus_about.cfm
[12] For further details see: https://www.cibseknowledgeportal.co.uk/component/dynamicdatabase/?layout=publication&revision_id=793

Dr Poritt also examined the effectiveness of a range of behavioural and technical adaptations in reducing overheating. Dr Poritt showed that implementing window rules, whereby the building users refrain from opening windows when the outside temperature is higher than the indoor temperature, could result in a 30% reduction in overheating exposure for dwellings occupied during the daytime. Other behaviour related adaptations included closing internal blinds or curtains and using night ventilation. The typical effectiveness (against the base case) of individual technical interventions (for an end terrace house) is shown in Figure 2.7. External insulation consistently outperformed internal insulation in all of the considered dwelling types, occupancies and building orientations for total overheating exposure (adding together the time spent in the living room and bedroom). Furthermore, internal insulation could lead to worse overheating, in some cases, than if no adaptation is implemented. External shutters were shown to be the single most effective adaptation, typically resulting in a 50% reduction in overheating for all house archetypes (except a Victorian terraced house). For Victorian terraced houses having solid walls, light-coloured external walls were shown to be marginally more effective than external shutters.

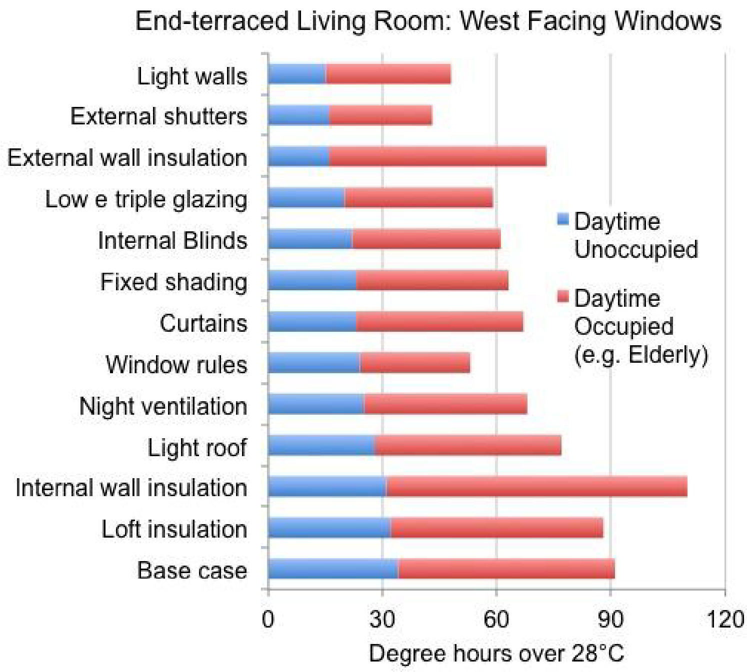


*Figure 2.7 Sample graph showing effectiveness of single adaptations for the end-terraced house*
Source: CREW Final Report

Dr Poritt concluded that no single adaptation measure could eliminate future overheating exposure and he suggested that combinations of measures would be needed to maximise overheating exposure reduction. Dr Poritt ran approximately 100,000 computer simulations of the effectiveness of combined interventions in reducing overheating against the base case. The results of these are publically available through the retrofit advice web toolkit[13]. The simulations showed that a range

[13]For further details see: http://www.extreme-weather-impacts.net/twiki/bin/view/Main/PublicTools

of adaptation combinations could eliminate overheating for Tier 1 type dwellings (semi-detached, terraced and ground floor flats). For typical Tier 1 building types combined adaptations costing approximately £3k could result in an 85% reduction of overheating whilst more expensive adaptations (£10k) could result in a 95% reduction of overheating. Reducing overheating in Tier 2 building types is much more difficult (no combination of adaptations could eliminate overheating) and expensive (£23k to achieve the sample performance reduction as £3k for Tier 1). More details of the modelling assumption can be found in Appendix 2.3.

### *2.4 Impacts of climate change on domestic buildings - Flooding*

The impact of flooding on domestic buildings is well known. The Building Research Establishment (BRE) in their: Six steps to flood resilience[14] provide guidance to local authorities and professionals on preparing for, and recovering from, a flood risk event. At an individual building level the technology can be used to either prevent floodwater from entering the property (improving resistance) or to speed up recovery following a flooding event (improving resilience). Resistance measures are best used when flood duration is short and flood depth is shallow. Resilience measures are best used when water penetration into a property cannot reasonably be prevented. Taken together, resistance and resilience measures retrospectively applied as part of an adaptation strategy aligned with disaster recovery planning could prevent the worst impacts of flooding on both building fabric and residents.

Flood water can enter the domestic building in a number of ways including: from doors and windows, through permeable brickwork and air bricks, through the floor, through gaps in the wall for appliances etc., back flow through the foul water system, and through party walls. As such, it is important when assessing the vulnerability of individual buildings to ensure that all possible points of water entry are identified and the potential of adaptation solutions to improve resistance should be examined. Adaptation solutions include:

- Pre-installed; demountable; or temporary aperture technologies designed to fit over openings in the building envelop.
- Demountable; self-closing; free-standing; or building skirt perimeter technologies designed to protect the entire building from water ingress.
- Building technologies such as non-return values, sealants and warning systems.

Where water ingress cannot reasonably be prevented, adaptations to improve resilience should be considered. Adaptation solutions include:

- Replacing construction materials with water resilient materials;
- Replacing fixtures and fittings with water resilient fixtures and fittings;
- Providing facilities to quickly remove water after a flood event;
- Raising services to above anticipated flood level.

[14] For further details see: http://www.preventionweb.net/english/professional/publications/v.php?id=33841

As part of the CREW project a team of researchers from the University of Greenwich developed a four phase adaptation assessment framework to measure the vulnerability and resilience of existing domestic buildings to flood risk events[15] (Figure 2.8).

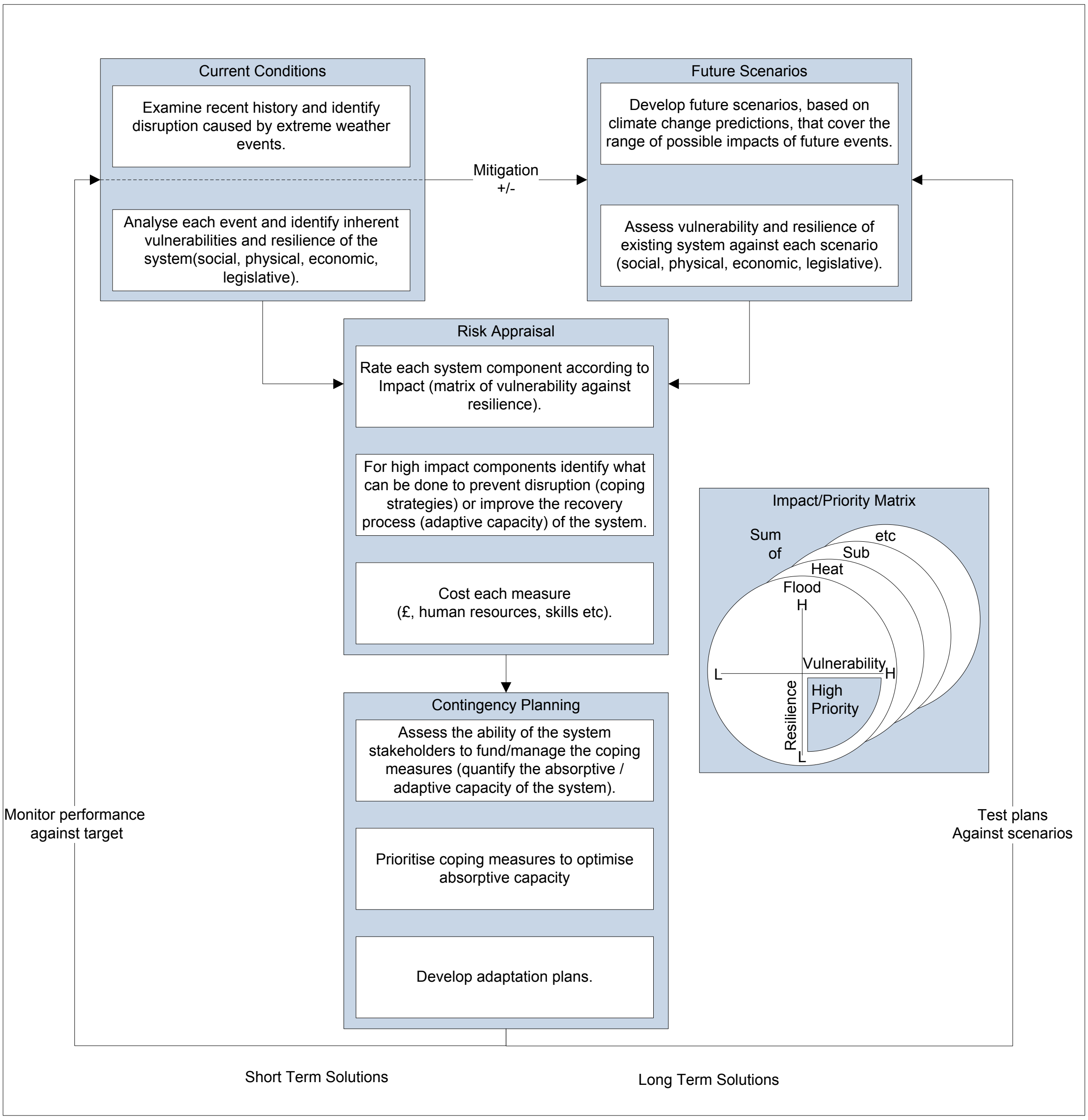


*Figure 2.8 Adaptation assessment framework model*
Source: The CREW Final Report

The first phase of the assessment framework involves establishing the system boundaries; the focus of the study; and any inherent vulnerability and resilience that the system has to extreme weather events. This analysis should be undertaken by examining local history and current weather impact assessments that may affect the system. The model then extends the range of current weather impacts to take into account potential future climate change. At this stage a number of future weather scenarios (e.g. UKCP09 climate projections) can be superimposed onto the system

[15] Jones (2012) 'Preparing for extreme weather events: a risk assessment approach' in Booth et al 'Solutions to climate change challenges in the built environment', Wiley-Blackwell

topology and the impact of specific weather hazards can be evaluated at the system and component level. Adaptations can then be developed to either reduce vulnerability or improve the resilience of each component or system. The adaption's can then be costed and prioritised with a view to compiling a short term action plan that address current weather impacts and a long term action plan that prepares for future climate change impacts. This model has been used as the theoretical basis for the current project.

## *2.5 Impact of Climate Change on Octavia's Housing Stock*

The assessment of the impact of climate change on Octavia's housing stock was done in two parts. In 2011 a pilot study was undertaken by the University of Greenwich as part of the development of the adaptation assessment framework outlined in the previous section. The pilot study (full report in Appendix 2.1) used a small sample of dwellings to develop a theoretical approach to measuring the vulnerability and resilience of Octavia stock. The main conclusion from the pilot study was that Octavia's housing stock was vulnerable to flooding. The report also concluded that the housing stock had very little inherent resilience should a flood occur; that there was apparent mismatch between perceived and actual risks to Octavia's stock; and that Octavia demonstrated limited organisational capacity to respond to a flood event. The report recommended a more comprehensive assessment of flooding risks across Octavia's housing stock. This project was undertaken in response to this recommendation. The four phase risk assessment framework outline above was applied to Octavia's stock portfolio.

*Phase 1: Assessing current risks*

Octavia's homes are located in some of the most densely built areas of London and their stock is potentially vulnerable to both fluvial (river) and pluvial (storm) flooding. Environment Agency Preliminary Flood Risk Assessments (PFRA), local authority strategic flood risk assessments and historic flood risk records were used to identify the extent of current flood risk across the 11 boroughs in which Octavia's stock is located. Pluvial flooding was assessed using Drain London maps supplemented with local strategic pluvial flood assessments where they existed (note: Drain London data was not available for all London boroughs in which Octavia's stock is located). Where pluvial flood assessments were not available, the generic London pluvial flood risk assessment was combined with local flood risk maps to identify the scope of flood risk that Octavia's properties faced. The geographical location (Longitude and Latitude) of Octavia's individual properties were superimposed onto the flood risk maps (using a Geographical Information System) and each property that was located in a potential flood risk zone was identified. In this way the flood risk of 94.2% of Octavia's properties were assessed. The remaining 5.8% could not be assessed as flood data was not accessible at the time of the study. Table 2.1 shows the flood maps used and the location by Borough of the 1024 Octavia properties at potential risk from flooding.

*Phase 2: Future climate change scenarios*

Whilst Drain London did make allowance for the impact of future climate change on flood, the PFRA's available generally did not. As such, working assumptions had to be made in the development of the futures scenarios.

| Borough | No of Octavia Properties | Flood Maps Used | No of properties at risk from flooding | % of Octavia's stock at risk of flooding |
|---|---|---|---|---|
| Barnet | 12 | NONE | N/A | N/A |
| Brent | 516 | PFRA | 194 | 4.86 |
| Camden | 15 | DRAIN LONDON | 0 | N/A |
| Hammersmith & Fulham | 370 | PFRA | 73 | 1.83 |
| Harrow | 22 | NONE | N/A | N/A |
| Hillingdon | 1 | NONE | N/A | N/A |
| Hounslow | 83 | NONE | N/A | N/A |
| Kensington & Chelsea | 1255 | PFRA | 392 | 9.82 |
| Southwark | 64 | NONE | N/A | N/A |
| Wandsworth | 52 | NONE | N/A | N/A |
| Westminster | 1599 | PFRA | 383 | 9.60 |
| TOTAL | 3989 | | 1024 | 25.67 |

*Table 2.1 Location of Octavia's properties considered to be potentially 'at risk' of flooding: Numbers as of 2011*

The impact of climate change of fluvial flooding from the Thames has been examined (see CREW report) and, whilst the ability of existing defenses is reduced it is not significantly diminished. As such future fluvial flooding was assumed to pose the same risk as current fluvial flooding.

The impact of climate change on pluvial flooding is difficult to assess but is more likely to affect Octavia's properties in the future. The lack of access to Drain London data[16], and the limitations of the current project (the project assumed Drain London data would be publically available and as such did not have the resources to model pluvial flooding) meant that the potential increased flood risk area in 10 of the 11 London Boroughs in which Octavia's stock is located could not be established. As such no increase in potential flood area has been used in the assessments. This shortcoming in the data is a significant issue and will result in the current assessments being an

[16] Note: Access to DRAIN London mapping was requested from all local authorities, however they were reticent to share, and reluctant to even authorise the DRAIN maps in their present state. Reasons of scale validity and refinement were cited.

underestimate of the potential future risks. As such, the pluvial flood risk assessments should be repeated when the data becomes available[17].

*Phase 3: Assessing Risks - Flooding*

The risk posed by a flood event on an individual property is a combination of the likelihood of the flood occurring; the ease of water ingress into the property or critical infrastructure (e.g. electricity supply/distribution) servicing the property (the property's vulnerability) and the impact that any water that enters the property/critical infrastructure would have on the performance of the property (the property's coping capacity).

To assess the potential impact of a flood on Octavia's property portfolio, flood impact surveys were undertaken. These comprised an interrogation of Octavia's built asset information system (to obtain floor level – basement, ground, upper floors etc.); and external surveys of the properties using Google Map Street View combined with street level surveys to identify potential means of water ingress from the street for the 1042 'at risk' properties identified through the flood mapping exercise (Table 2.2). The vulnerability of each 'at risk' property was assessed by combining the risk of a flood event with the impact that a flood would have on the property (impact thresholds: high impact for properties where there was a high risk of direct water ingress from the street; medium impact where there was a medium risk of direct water ingress from the street; and low risk where there was no risk of direct water ingress from the street BUT where access to the property or where interruption to services was likely). It is estimated that approximately 4% of Octavia's stock could be vulnerable to direct water ingress as a consequence of flooding with a further 19.3% vulnerable to disruption to access or services, most notably electricity supply (Table 2.2). A further 2.8% of properties require further investigation before a vulnerability category can be assigned.

| Vulnerability | No. of properties | %age of flood risk stock | %age of total stock |
|---|---|---|---|
| High | 161 | 15.7 | 4.03 |
| Medium | 0 | 0 | 0 |
| Low | 769 | 73.7 | 19.3 |
| Unknown[18] | 112 | 10.6 | 2.8 |

*Table 2.2 Estimated number of properties at risk of direct water ingress or disruption to operation as a consequence of flooding.*

Internal surveys of 26 properties were undertaken to identify the impact that a flood would have on a typical 'at risk' properties. The archetype properties covered the range of property types owned by Octavia and included converted ground floor and basement flats built before 1900; modern blocks of flats built since the 1970's and a small number of houses built between 1900 and 2008. More details of each property surveyed, including construction type, vulnerability, coping capacity and

[17] Surface water flood maps for the whole of the UK became available from the Environment Agency on the 12th December 2013. These maps allow postcode mapping of buildings against pluvial flood risk maps.

[18] Note: Unknown are those 'at risk' properties where the floor level was not recorded in the built asset information system and where this data was not apparent from the external street level survey.

adaptation options are given in Appendix 3. For each property it was assumed that a flood had occurred in the street immediately adjacent to the property that had resulted in water ingress into the property.

For basement flats it was assumed that up to 1.0m of water would enter the property and would remain in the property for a period of up to 48 hours depending upon the ease at which flood water could be removed once external flooding had receded.

For ground floor flats it was assumed that up to 0.5m of water would enter the property and remain in the property for a period of up to 24-hours depending upon ease at which flood water could be removed once external flooding had receded.

For houses it was assumed that up to 0.5m of water would enter the ground floor the property and remain in the property for a period of up to 24 hours depending upon ease at which flood water could be removed once external flooding had receded.

The impact that these scenarios would have on each of the properties surveyed are given in Appendix 3.

In summary, the findings from the surveys were:

Whilst all the basement flats surveyed had adequate drainage protection for normal (current) rain fall conditions, it was unlikely that any could be adequately protected from the presence of flooding in the street immediately adjacent to the flat. Once water had entered the property it would cause damage to internal walls, doors, floor coverings (all basement floors surveyed were solid), electricity supply, kitchen and bathroom fittings. One unexpected finding from the surveys was the apparent ease with which much of the flood water could be removed from the flats once the flood had receded. A number of flats had rear gardens that were lower than the rear door which would enable trapped water to flow out of the flat once the external flood waters had receded. As such the initial assumption of 48 hours inundation is probably an overestimate. This said, all the flats would need to cleaned and dried before repairs could be carried out and this would require the tenants to be relocated for a significant period of time. As such the coping capacity of all basement flats against flooding was rated as LOW.

Again all the ground floor flats had adequate drainage protection for normal (current) rain fall conditions. Should water enter the property the impacts would be similar to those for basement flats. Although the severity of impacts is likely to be less than for basement flats it would still require the tenant to be relocated whilst the flat was dried, cleaned and repaired. As such the coping capacity of all ground floor flats against flooding was again rated as LOW. One interesting issue to arise from these surveys is the inconsistency in information contained in Octavia's asset database. One of the blocks of flats surveyed was catagorised as ground floor (because access was from the ground floor) but all the habitable areas were on the first floor or above. This type of inconsistency could prove problematic if the survey results are extrapolated across the whole of Octavia's stock.

For upper floor flats there is no risk of water ingress but access would be limited whilst there was flood water in the street and services into the flats could be affected depending on power routing (it was not possible to identify detailed power routings in the surveys). It probably wouldn't be necessary to evacuate residents (unless on advice from the emergency services) and any residents that were evacuated could return to the flats once the flood water had receded and critical services had been restored. As such the coping capacity of upper floor flats against flooding was rated as HIGH/MEDIUM.

All the houses surveyed had adequate drainage protection for normal (current) rain fall conditions. Should water enter the property the impacts would be similar as for ground floor flats. Depending on the severity of the flood and impact on critical services it would be necessary to move the resident out of the property whilst the ground floor level is dried, cleaned and repaired. However, once critical services had been restored it might be possible for residents to return to their homes whilst decorative repairs are ongoing. The coping capacity of Houses against flooding was rated as MEDIUM/LOW.

*Phase 3: Assessing risk - Overheating*

The risk posed by a heat wave event on an individual property is a combination of the likelihood of the heat wave occurring and the impact that this would have on the performance of the property (the property's coping capacity). An assessment of the impact of a heat wave event in London was considered by combining the outputs from the Beating the Heat and the CREW projects. Both these projects identified inner London as being particularly vulnerable to heat waves with, by the 2050's, average maximum summer temperatures increasing by 3.7$^{o}$C. The impact of such a temperature rise was modeled in the CREW project for 4 typical house archetypes (19$^{th}$ Century Terraced; 1930's Semi-Detached; 1960's Flats and Modern Detached houses). Using computer based simulations the CREW project classified buildings as either Tier 1 (which included:19$^{th}$ Century Terraces; Ground Floor Flats and 1930's Semi Detached houses) which would be the least affected by heat waves or Tier 2 (which included: Modern Detached houses; and Top Floor Flats) which would be the most affected by heat waves (Table 2.3). Based on these categories Octavia have approximately 1760 Tier 1 properties (assumed to exhibit Medium/Low vulnerability for the purpose of this study) and 2229 Tier 2 properties which were divided into Top Floor Flats (assumed to exhibit High vulnerability for the purpose of this study) and other Modern Houses (assumed to exhibit Medium/High vulnerability for the purpose of this study). The coping capacity of Octavia's Flats is generally LOW with very little external shading or internal circulation (many of the flats do not have through aspects to support natural ventilation or ceiling fans to assist air movement). Octavia's houses do have the capacity for natural ventilation but location makes street noise a problem in many areas. Anecdotal evidence provided by Octavia's asset management staff suggest that some of their worst performing accommodation (in terms of overheating) are their modern sheltered accommodation blocks (see later example). The coping capacity for Octavia's modern housing and blocks (excluding top floor flats) ranges from Low/Medium to Medium/High.

*Phase 3: Assessing Risk – Other factors*

Other climate change factors that could potentially affect the future performance of Octavia's housing stock include: subsidence, drought and wind.

Octavia assessed the impact of subsidence on their stock in 2007 and identified 1088 potentially at risk properties and a contingency to deal with these is already part of Octavia's built asset management strategy. Given that the CREW project identified only a small potential increase in risk as a consequence of climate change by 2050 Octavia will continue with its existing strategy.

| Vulnerability | Property Types | No. of Properties | %age of Total Stock |
|---|---|---|---|
| Medium/Low | Tier 1 including<br>19th Century Terraces Ground Floor Flats 1930's Semi Detached Houses | 1760 | 44% |
| Medium/High | Tier 2 including<br>Other Modern Houses | 1113 | 28% |
| High | Tier 2 including<br>Top Floor Flats | 1116 | 28% |

*Table 2.3 Estimated number of properties at potential risk of overheating.*

The impact of increased wind speed as a consequence of storm activity by 2050 has also been predicted to be small. Again, Octavia's current strategies for dealing with storm damage through insurance cover should prove adequate to deal with any increased risk.

The incidence of drought in London is expected to increase by approximately 50% by 2020. Whilst the immediate impact of this increase on Octavia's residents is beyond Octavia's control, improvements in water efficiency of Octavia's stock as part of their involvement of a London wide initiative could help mitigate these issues.

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# 3. ADAPTATION STRATEGY

## *3.1 Introduction*

Built asset management strategies and plans are used by facilities managers to ensure that their buildings continue to perform at a level appropriate to their organisation's needs. Throughout the building's life cycle its ability to meet its user's needs diminishes, either through the physical decay of the buildings components or as a result of increased demands bought about by changes in use or external circumstances (e.g. climate change). The resulting performance gap is known as the obsolescence gap. Built asset management strategies seek to minimise the obsolescence gap through routine maintenance which seeks to repair the physical decay and periodic refurbishment which seeks to address changes in user demand or external circumstances. However, given that most asset managers have limited finance for maintenance and refurbishment, the obsolescence gap can never be eliminated and will continue to grow over time. Once the obsolescence gap becomes too wide to close through cost-effective refurbishment the building is either sold or demolished.

In social housing, most asset management strategies seek to ensure that sufficient funds are available to avoid their assets becoming obsolete and requiring demolition. However, if not addressed in a timely fashion, climate change could potentially change this delicate balance.

A changing climate will place increased demands on the performance of Octavia's stock. Increased flooding will require flood resistance and resilience measures to be incorporated into vulnerable properties. Overheating will require cooling measures to be applied to the majority of their stock. Both these activities could prove very expensive and beyond the capacity of Octavia to fund if they have to be delivered over a shorter time period. However, if steps could be taken now to integrate adaptation into Octavia's 30 year built asset management strategy then these costs could be spread and the threats of large-scale obsolescence to their stock reduced.

This section of the report will outline an adaptation strategy to complement Octavia's existing built asset management and climate change mitigation strategies. The adaptation strategy will provide generic solutions and indicative timescales for the retrofit of flood resistance and resilience measures and cooling strategies over the next 30 years. The adaptation strategy will also outline indicative costs associated with the adaptation solutions. Finally, a short-term built asset management plan will be proposed that identifies those adaptation solutions that should be undertaken over the next five years. The potential impacts of future climate change on subsidence, drought and wind are likely to be less pronounced than flooding and overheating and, should such events occur, they will be dealt with through Octavia's existing responsive mode maintenance and repair programmes.

## *3.2 The Asset Management Strategy*

Octavia's Asset Management Strategy was based on a modified version of the performance model developed by Professor Jones[19] (2007) through his work on sustainable maintenance and

[19] Jones, K. & Sharp, M. 'Performance based model for built asset maintenance', Facilities, Vol 25, No 13/14, 2007, pp 525-535.Vol 25, No 13/14, 2007, pp 525-535.

refurbishment of social housing (Figure 3.1). The performance model involves identifying the critical success factors (CSF's) against which maintenance and refurbishment (including climate change adaptation) will be judged. Once the CSF's are established a series of performance toolkits are developed that measure the performance-in-use of each property against key performance indicators and benchmarks. Failure of a property (or properties) to satisfy a benchmark target triggers a more detailed analysis to identify the underlying cause of the problem and the potential for improvement. These potential improvements are expressed in the form of project briefs against which potential solutions (adaptations) can be evaluated. Solution scenarios are used to evaluate priorities against Octavia's CSF's and impact models used to evaluate the consequence of deferring an adaptation intervention on the performance of the house-in-use. Finally a set of post occupancy evaluation forms are used to report on the success of the adaptations and provide feedback to Octavia's climate change adaptation policy and strategies.

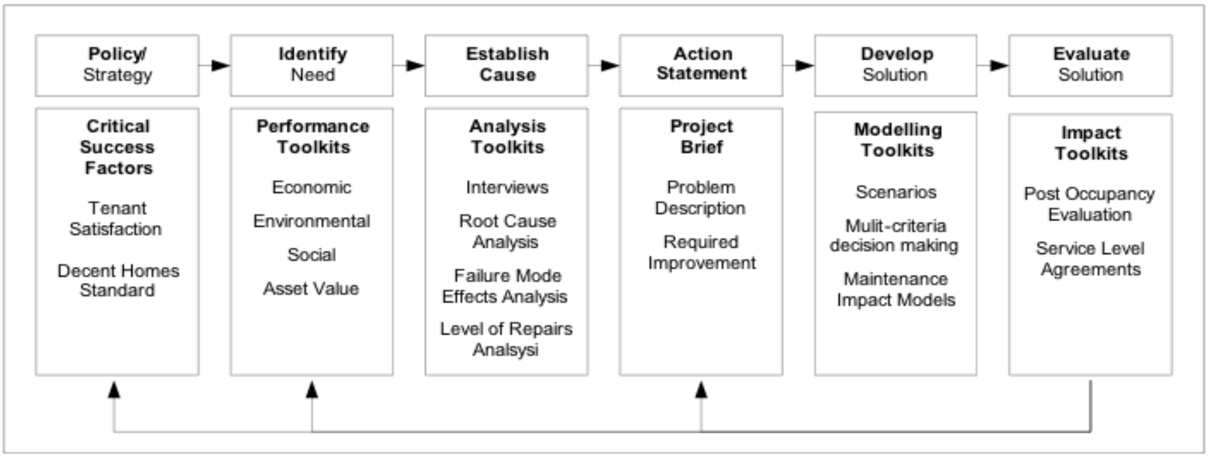


*Figure 3.1 Performance based Built Asset Management Model*

For this study, maintenance and refurbishment interventions were limited to those associated with adaptations required to address the potential impact of climate change.

### *3.2.1 Policy and Strategy: CSF's*

The first task was to establish a strategic view of climate change adaptation and develop a series of key principles that would guide Octavia's decision making process. Octavia's approach to the quality of their housing is governed by the 'Octavia Standard' (Appendix 1.1). This is a document that sets out expectations for the quality of Octavia's stock and describes the processes that are instigated should a property fall below expectations. Although the Standard doesn't explicitly address the impact that climate change could have on the house it does establish that:

> *"Your home should be in good working order and fit for purpose - it should meet a certain set of standards, both inside and outside and in shared and private areas to make it a safe and healthy environment to live in."*

The Standard also implies that Octavia will adopt a proactive approach to ensuring that its homes meet the Standard.

In the context of this project the Standard provides the basis from which CSF's have been derived and which the success of adaptation to climate change will be measured. These are:

1) Maintaining a healthy and safe internal environment by minimizing overheating in accordance with the Housing Health and Safety Rating System[20] and the NHS Heat Wave Plan for England[21]. Performance threshold to relate to peak day and night temperature and duration of heat wave event
2) Reduce disruption to tenants from flooding events. Performance thresholds to relate to the degree of disruption that a flood event would cause to tenants.
3) To continue to maintain tenant confidence and trust in Octavia's ability to deal with climate change issues. Performance threshold to be measured through the tenant satisfaction survey.
4) To maintain a watching brief on other possible climate change impacts (e.g. subsidence, drought, wind etc.). Performance threshold to be measured through increased occurrence of such events.

### *3.2.2 Identify Need: Performance toolkits*

Four Performance Toolkits were developed for this project.

One Toolkit sought to identify those properties that were located in a potential (current and future) flood zone AND were vulnerable to water ingress. This toolkit involved superimposing Octavia's properties onto flood maps using geo-referenced data and a geographical information system to identify those properties are potential risk of flooding (for example see Figure 3.2). Each of these properties were then examined in more detail (using Octavia's asset management database, Google Street View, and external street surveys) to identify the potential for water ingress assuming a 0.5 m flood in the street immediately adjacent to each property. A combination of the potential flood risk and likelihood of water ingress into the property was used to determine each properties level of vulnerability (Figure 3.3.)

A second toolkit sought to quantify the impact that exposure to a flood would have on the performance-in-use of those properties at risk of such an event. Assessments of the potential impact of flooding events on a sample of those properties identified as highly vulnerable to such an event was used to identify their coping capacity (Figure 3.4). A combination of the potential damage that a flood event would cause and the recovery time it would take to return the property to its pre-flood performance level was used to categorise the properties coping capacity threshold as Low Medium or High.

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[20] The Housing Health and Safety Rating System available at:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/15810/142631.pdf

[21] NHS Heatwave Plan for England available at:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/201039/Heatwave-Main_Plan-2013.pdf

A third toolkit sought to identify those properties that were potentially at risk from (current and future) heat waves. Due to lack of detailed stock wide data on building construction; building orientation; percentage glazing; ventilation; and airtightness, potential vulnerability was assessed by assimilating heat wave data from the Mayor's Climate Change Adaptation Strategy, Beating the Heat and the CREW report and mapping the archetype properties examined in these reports to Octavia's stock. Whilst this approach provided thresholds to identify potential vulnerability, further detailed assessments on a building by building basis would be needed to substantiate the overheating threats and examine potential adaptation solutions.

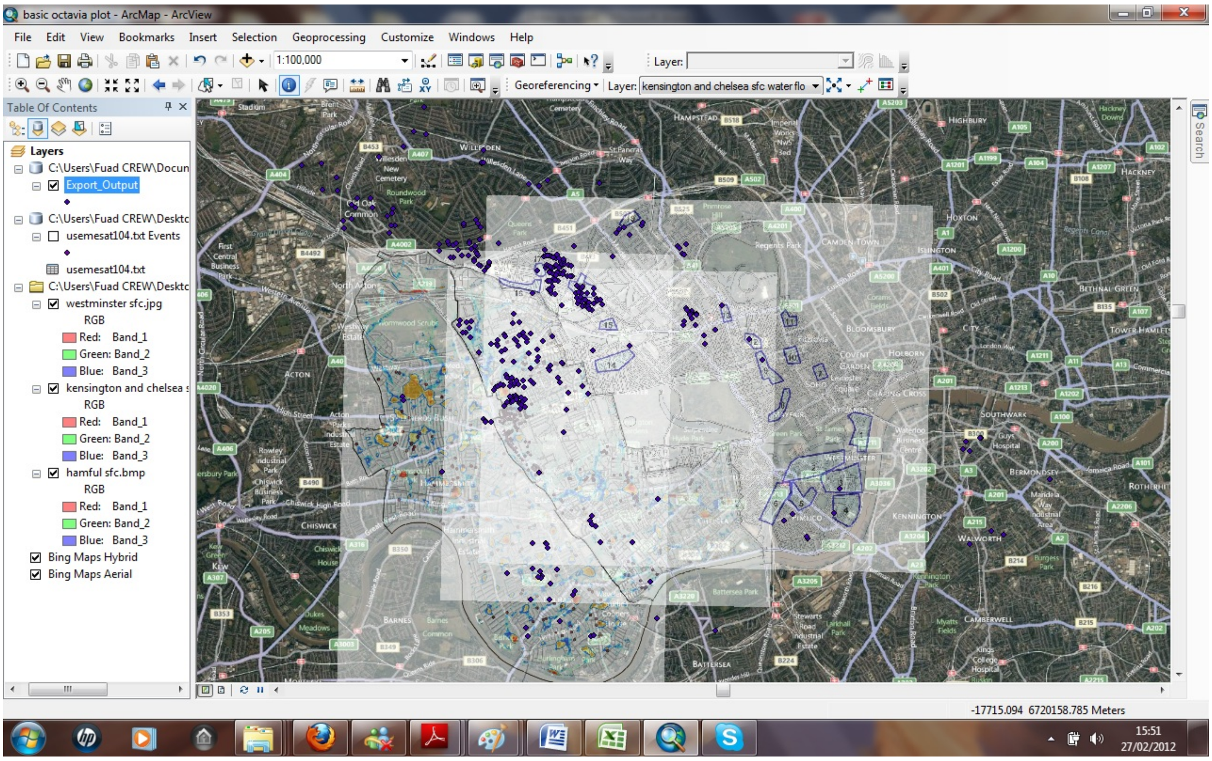



*Figure 3.2 Overlaying Octavia property plot onto the flood risk data of three boroughs*

| | | Likelihood of a flood event | | | |
|---|---|---|---|---|---|
| | | No likelihood | Low | Medium | High |
| Likelihood of water ingress to the property / damage to critical infrastructure | No likelihood | Not vulnerable | Not vulnerable | Not vulnerable | Not vulnerable |
| | Low | Not vulnerable | Low vulnerability | Low vulnerability | Low vulnerability |
| | Medium | Not vulnerable | Low vulnerability | Medium vulnerability | Medium vulnerability |
| | High | Not vulnerable | Low vulnerability | Medium vulnerability | High vulnerability |

*Figure 3.3 Vulnerability threshold matrix for flooding*

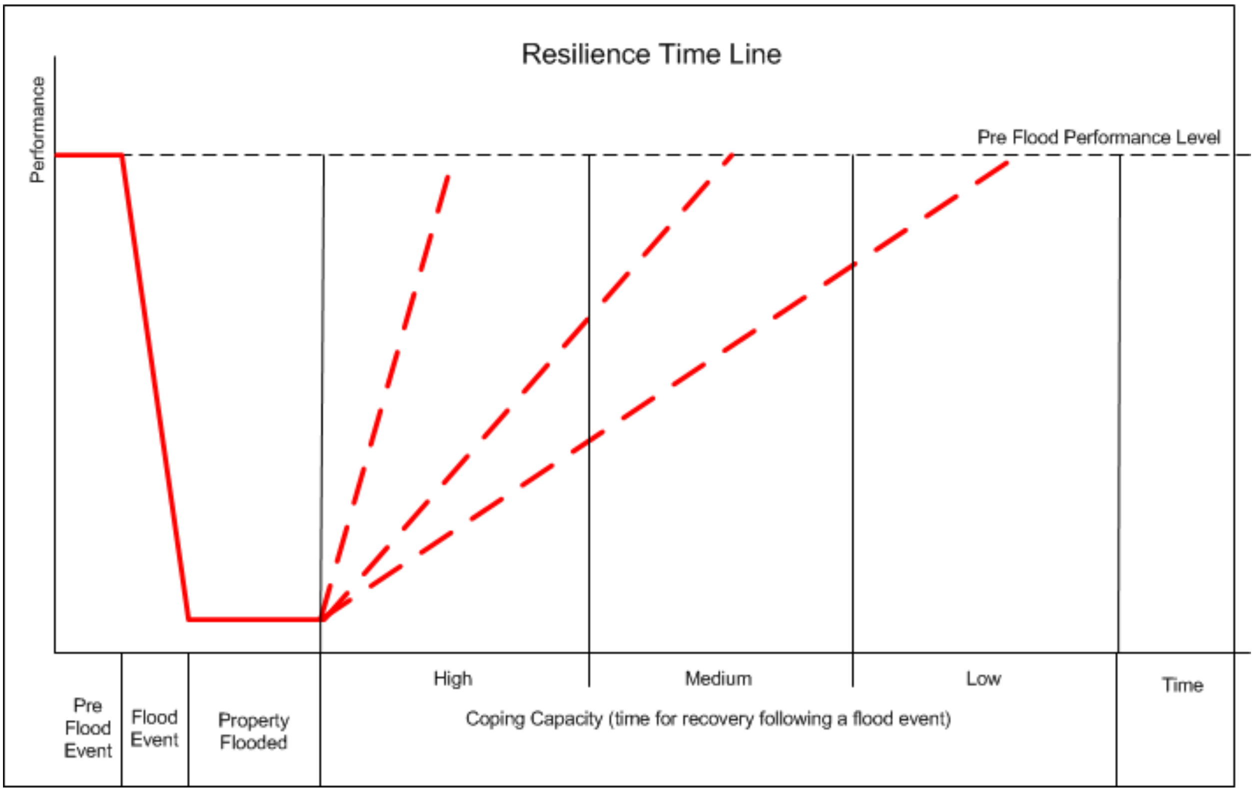



*Figure 3.4 Coping capacity against time following a flood event*

| Potential Vulnerability | Property Archetypes |
|---|---|
| Low | Air conditioned homes |
| Medium/Low | 19$^{th}$ Century Terraces; Ground Floor Flats |
| Medium | 1930's Semi Detached Houses |
| Medium/High | Modern Houses |
| High | Top Floor Flats |

*Figure 3.5 Vulnerability threshold for overheating based on property archetypes*

A fourth toolkit examined a sample of 'typical' Octavia properties to assess their coping capacity in a heat wave scenario. Assessing the impact of heat stress on individuals is a complex problem that involves the temperature profiles; time of exposure to these profiles; the inherent vulnerability of the individual to heat stress; and the capacity for individuals to adapt to higher temperatures. The London Climate Change Partnership (LCCP) Heat Threshold Project[22] identified a range of housing thresholds that were applicable to London. The report identified 25$^{o}$C as the 'warm' temperature threshold and 28$^{o}$C at the 'hot' temperature threshold for living rooms (thresholds for bedrooms are typically 2-3$^{o}$C lower) and 35$^{o}$C (at 50% humidity) as a 'danger' level for healthy adults. The LCCP report recommended the inclusion of heat risk on the London Community Risk Register. They

[22] For further details see:
http://climatelondon.org.uk/wp-content/uploads/2013/01/LCCP_HeatThresholds_final-report-PUBLIC.pdf

suggested that a daily maximum temperature of 32$^o$C and minimum of 15$^o$C over 5 consecutive days would result in approximately 1000 fatalities and 5000 casualties, mainly amongst the elderly. NHS England and the Met Office suggest temperature/temporal thresholds of 32$^o$C – 18$^o$C – 32$^o$C over 2 consecutive days. Given the lack of building specific data available to evaluate the impact of heat on internal temperature (discussed previously) this project chose to apply the external temperature/temporal threshold suggested by the NHS/Met Office to Octavia's property archetypes. Subjective assessments were made of the impact that a of 32°C - 18°C - 32°C day-night-day heat wave for 2 consecutive days would have on the performance of the property (its coping capacity). A building's coping capacity was rated as High, Medium or Low (Figure 3.6). With the exception of sheltered accommodation no account was taken of the type of resident in the property or of any predisposition that the resident may have to heat stress.

| Coping Capacity | Subjective Judgment Threshold Criteria |
|---|---|
| Low | No through ventilation; Single south facing aspect; high level of glazing; limited ability for shading; limited ability for overnight purging; low thermal mass; limited ability to cool any room (e.g. bed/sit flat); no access to external shaded space (e.g. garden). |
| Medium | Some opportunity for cross ventilation; multiple facing aspects; medium level of glazing; some ability for shading some ability for overnight purging; medium thermal mass; some ability to cool at least one room; some access to external shaded space (e.g. garden). |
| High | Good opportunity for cross ventilation; north facing aspects; medium level of glazing; high ability for overnight purging; high thermal mass; good ability to cool at least one room; good access to external shaded space (e.g. garden). |

*Figure 3.6 Coping capacity during a heat wave*

The vulnerability and coping capacity of each 'at risk' property for flooding was plotted onto an impact grid (Figure 3.7). From this figure it would appear that 43 properties are highly vulnerable and have low coping capacity for a flooding event and these should be prioritized for early action in the asset management plan. Those 118 properties that are highly vulnerable but have a Medium/Low coping capacity for a flooding event should be prioritized as short-medium term action in the asset management plan. The 769 properties that have a low vulnerability and high coping capacity should be reviewed at regular intervals as more climate change data becomes available.

The vulnerability and coping capacity of each 'at risk' property to overheating was also plotted onto an impact grid (Figure 3.8). From this figure it would appear that 1116 properties are highly vulnerable and have low coping capacity and these should be prioritized for early action in the asset management plan. Those 1113 properties that are highly vulnerability and have a Medium coping capacity should be prioritized as short-medium term action in the asset management strategy. The 1760 properties that have a low vulnerability and high coping capacity should be reviewed at regular intervals as more climate change data becomes available.

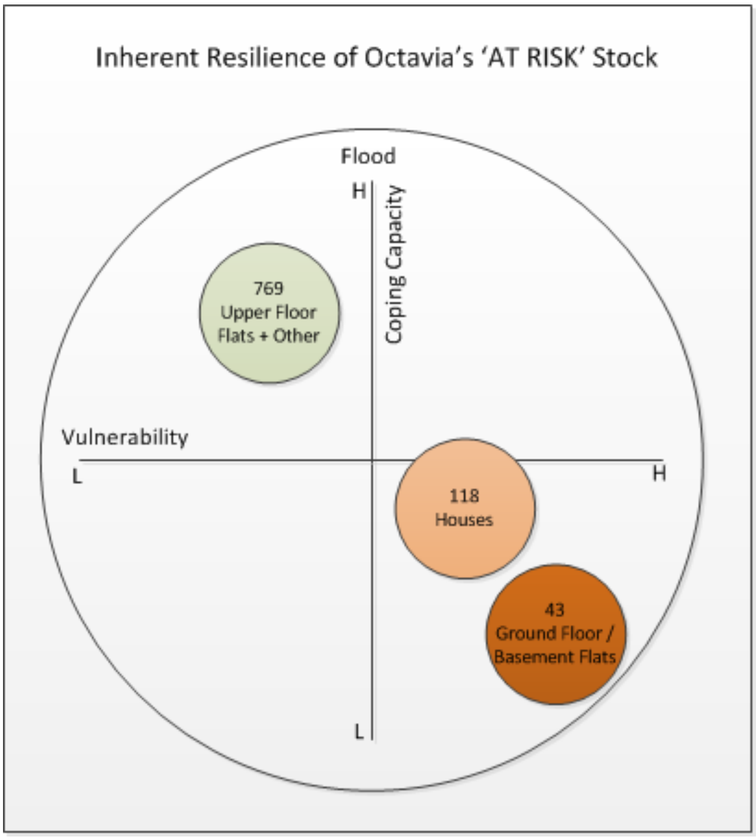



*Figure 3.7  Vulnerability and coping capacity of properties at risk of flooding*

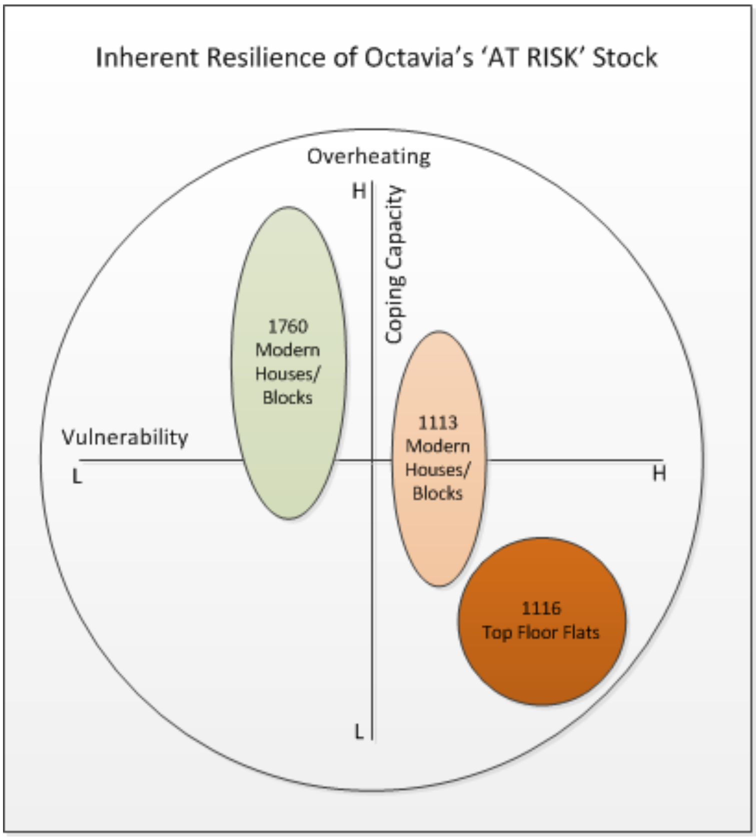



*Figure 3.8  Vulnerability and coping capacity of properties at risk of overheating*

### *3.2.3 Establish Cause: Analysis Toolkits*

Internal surveys (see Appendix 5.1 and 5.2) of 26 typical properties were undertaken to establish the root cause of both overheating and flooding and to identify potential adaptation solutions. In all cases these solutions were affected by legacy design decisions made when the buildings were newly constructed or underwent major refurbishments.

Adaptation options in the form of resistance (preventing water entering the property) and resilience (increasing speed of recovery once the property has flooded) measures were considered for those properties potentially at risk from flooding.

From the surveys it was clear that it would be very difficult (if not impossible) to prevent water entering basement flats or basements floors of individual houses. Further, once water had entered the property it was likely to cause significant damage to both building components and fixtures & fittings that significant work would require in order to return the property to a habitable condition. Thus the adaptation strategy for this type of property is to let it flood but to improve the resilience of building components (nonstructural) and fixtures & fittings to shorten the time it would take to return the property to a habitable condition.

For all ground floor flats it should be possible to prevent water entering the property through the use of temporary resistance measures (e.g. door dams, air brick seals etc) for all but the most severe flood scenarios. If water does enter the property then similar damage to that which would affect basement flats would occur, although flood depths will probably be less and any damage less extensive. The adaptation strategy for this type of property would be to prevent water ingress wherever possible through the use of temporary resistance measures and include resilience measures to shorten the time it would take to return the property to a habitable condition. The balance between resistance and resilience should be made on a property by property basis.

For houses and upper floor flats potentially at risk of flooding it should again be possible to prevent water entering the property (except for basements) through the use of temporary resistance measures. The adaptation for this type of property would be to prevent water ingress whenever possible through the use of temporary resistance measures and include resilience measures, particularly in communal entrance ways and to the ground floor and basements of houses, to shorten the time it would take to return the property to a habitable condition. Again the balance between resistance and resilience measures should be made on a property by property basis.

All Octavia's properties that are vulnerable to flooding should be covered by a flood action plan. Octavia should work with their residents to develop individual flood action plans (see EA[23] web site). These plans should provide practical guidance on preparing for a flood and guidance on what to whilst a flood is in progress (see Appendix 5.3 for an example of a personal flood plan[24]).

All Octavia's properties are vulnerable (to a greater or lesser extent) to the impacts of heat waves. Although modeling the impacts on individual properties was beyond the scope of this project (although an initial model of a sheltered flat is included as an example of the type of modelling that could be carried out) it was clear from the internal surveys that there was limited opportunity to

[23] For further details see: http://www.environment-agency.gov.uk/homeandleisure/floods/38329.aspx
[24] For further details see http://thefpa.org.uk/

reconfigure the internal layout of the properties to address overheating. The adaptation strategy for these types of properties should be to reduce internal temperature through the use of ventilation and circulation systems where possible and to explore the possibility of external shading to reduce solar gain. Where residents are particularly vulnerable to heat stress the provision of a 'cool room' should be examined. For modern houses the use of passive circulation should be examined alongside external shading. Upper floors could also potentially be suitable to night purging although this would depend on location (e.g. noise, pollution levels etc.). All sheltered accommodation should have a cool room for vulnerable residents.

In December 2012 a 2 hour long workshop was conducted amongst staff and tenants of Octavia Housing. Participants were invited though Octavia Staff, although more expressed interest, only two tenants were able to attend, which made our findings indicative, not representative of the diversities present amongst the tenants of Octavia, who are likely to number over 10 000. Five members of Octavia staff attended, covering different roles in the Asset Management department, their interest in issues of sustainability and environment also encouraged them to attend.

The intention of the workshop was to understand, 1) previous experiences with overheating and flooding and coping; 2) the distribution of responsibility between landlords, tenants and government; 3) Octavia's organisational resilience and 4) tenant perceptions of adaptation measures. Insights confirmed earlier findings from CREW about the need to take a bottom up approach to adaptation alongside technical adjustments and a general empowerment of tenants.

Although tenant engagement is a long way off for Octavia, this exercise was useful to highlight the differential levels of engagements and existing organisational channels between tenants and Octavia. There is no single 'ideal' tenant. Although both tenants attending were prepared to fix flood guards to their doors if provided and warned, they were not prepared to pay an additional fee for them. When asked about their informational needs, 'Social tenant experiences of extreme weather elsewhere in the UK' was flagged. The workshop also identified the potential role that behaviour change adaptations could play in improving the resilience of Octavia's tenants to the impact of climate change and this informed the development of non-technical adaptations as part of Octavia's adaptation strategy. The format of the workshop is described in Appendix 5.5.

Although the workshop was poorly attended it was useful to raise awareness of climate change impacts and practically think though the role of technical and non-technical adaptation solutions.

### *3.2.4 Action Statement:*

The following principles should be applied by Octavia when developing and evaluating adaptation solutions.

Flooding:

- If it is economically feasible to prevent flood water entering a property then this approach should be adopted.
- Water resilient components, fixtures and fittings should be installed when flood water is likely to enter a property.

- Ensure all essential services are resistant to a flooding event.
- Work with residents to prepare personal flood action plans.

Overheating

- Ensure properties do not over heat.
- Provide cool rooms in sheltered properties for vulnerable residents.

### *3.2.5 Develop Solutions: Modeling Toolkits*

Developing individual building level adaptions was beyond the scope of this study. Instead, the study examined generic adaptations against the range of climate change impacts that Octavia's stock is expected to face. These assessments were made against a series of future scenarios. For flooding it was assumed that a flood had occurred in the street immediately adjacent to the property that had resulted in water ingress into the property. For basement flats it was assumed that up to 1.0m of water would enter the property and would remain in the property for a period of up to 48 hours depending upon the ease at which flood water could be removed once external flooding had receded. For ground floor flats it was assumed that up to 0.5m of water would enter the property and remain in the property for a period of up to 24 hours depending upon ease at which flood water could be removed once external flooding had receded. For street level houses it was assumed that up to 0.5m of water would enter the ground floor of the property and remain in the property for a period of up to 24 hours depending upon ease at which flood water could be removed once external flooding had receded (if the house had a basement then the basement flood scenario was used). The potential for a range of flood resistance and resilience measures to address these flooding scenarios was assessed for archetype properties using the 26 internal surveys (See Appendix 5.1 for Survey Details). Assessment were not made at the property level but were generic for the property archetype. The heat wave scenario assumed an external temperature profile of $32^{o}C$ – $18^{o}C$ – $32^{o}C$ for two consecutive days. Tables 3.1 - 3.5 show the range of technical, resident and management adaptions examined during this project and comments on their appropriateness to Octavia's stock.

| Vulnerable Element | Technological Adaptation | Potentially Applicable to Octavia |
|---|---|---|
| Airbricks | Use airbrick covers or raise airbricks/vents to above expected flood level and duct down to floor void. | All vulnerable properties that have air bricks. |
| Basement / Ground Floor properties | Install a building skirt systems / house wrapping; install external flood doors; Provide temporary barriers to doors; waterproof external walls; | It is technically feasible to prevent water ingress into vulnerable properties but it is likely to be too expensive. Should consider for protection of vulnerable services (i.e. where services are located in the basement of large blocks of flats. |
| Block work - comparatively porous | Coat exterior wall with microporous spray coating every 5 years | All vulnerable properties that have external block work. |
| Concrete - large areas | Use porous materials on driveways; provide drainage channels in front of doors. | To external communal areas surrounding vulnerable properties (although would be of little use in most flood scenarios) |
| External Doors | Survey & plug gaps around door frames; use door guards; raise door thresholds; install external flood doors; install letterbox covers | Applicable to all vulnerable ground floor flats and houses. |
| Drainage pipes & Sewage System | Install one way valves in drainage pipes | Applicable to all vulnerable properties |
| French Windows | Replace patio doors with conventional windows with brickwork underneath | Applicable to all vulnerable properties that have French Windows. |
| Service entry points | Seal pipe entry points | Applicable to all vulnerable properties. |
| Windows | Plug gaps around window frames | Applicable to all vulnerable properties |

*Table 3.1 Flood Resistance Adaptation Measures*

| Vulnerable Element | Technological Adaptation | Potentially Applicable to Octavia |
|---|---|---|
| Basement / Single storey dwelling | Install a sump and pump; Install additional weep holes at base of walls; provide furniture bags. | Potentially applicable to all vulnerable ground floor and basement properties although individual assessments of basements need to be made given the lower rear aspect of many basement flats. |
| Bathroom - chipboard stiffening panel (on bath) | Install cast iron/pressed steel baths (where on ground floors and have chipboard stiffening panel) | Applicable to all vulnerable ground floor and basement properties. |
| Boiler - low | Mount boilers on the wall above the likely flood water level | Applicable to all vulnerable properties. |
| Cavity insulation (when mineral fibre or blown-in expanded mica) | Install closed cell insulation | Applicable to all vulnerable properties with cavity walls (although this type of construction is not common in Octavia's stock). |
| Chipboard flooring - porous | Replace chipboard flooring and carpets with treated timber | Applicable to all vulnerable properties that have chipboard flooring. |
| Cooker - low | Raise cooker to eye level; install brick/concrete plinths for low-level appliances | Applicable to all vulnerable properties. |
| Door/Door frames - wooden; Window/Window frames - wooden | Install fibreglass (grp)/plastic/PVC-U doors and door frames; Paint doors/ frames with oil based / waterproof paint; Install lightweight doors with rising butt hinges; Install fibreglass (grp)/plastic/PVC-U window frames | Applicable to all vulnerable properties. |
| Electrics / Gas / Water Services | Raise distribution board / fuse box >1m above floor level or predicted flood level; raise service meters (electric) to >1m above floor level or predicted flood level; Place service meters in plastic housings; Raise electric sockets >1m above floor level or predicted flood level; Move electric cabling to >1m above floor level or predicted flood level; Route cables for power outlets down from upper floors. | Applicable to all vulnerable properties. |
| Ground floor -untreated floor boards | Replace floor boards and joists with treated timber | Applicable to all vulnerable properties with this type of construction. |

| | | |
|---|---|---|
| Ground floor - Sand cement screed | Replace sand cement screeds with a denser proprietary concrete screed | Applicable to all vulnerable properties with this type of construction |
| Gypsum plasterboard | Install silicon/mineral board (in place of plasterboard); Fix plasterboard horizontally rather than vertically. Consider use of membrane to isolate brickwork from wall finish. E.g. Twistfix | Applicable to all vulnerable properties with this type of construction. |
| Kitchen - Chipboard cupboards / low level cupboards | Place kitchens on first floor level (where possible); Fit kitchen units with extendable plastic/stainless steel feet; Install plastic kitchen/bathroom units; install eye level cookers; fit water resistant plinths. | Applicable to all vulnerable properties although the acceptance to tenants of flood damaged units (which have been subject to foul water damage) is questionable. |
| Party Walls / Gypsum plaster / plasterboard | Install lime plaster or cement render on walls (in place of gypsum plaster); fix plasterboard horizontally not vertically. | Applicable to all vulnerable properties with this type of construction. |
| Phone socket – low & TV socket - low | Raise phone points >1m above floor level or predicted flood level | Applicable to all vulnerable properties. |
| Skirting - wooden | Install fibreglass (grp)/plastic/PVC-U skirting boards; Install solid timber skirting boards with wooden paint on both sides | Applicable to all vulnerable properties. |
| Staircase - timber base | Make bottom part of staircase from concrete instead of timber | Possibly suitable for modern houses and communal areas in converted flats but have timber staircase's. |
| Suspended ground floor - underfloor cavity | Install access hatches in suspended floors; Clear/repair air bricks/vents to suspended timber ground floors; Replace timber floor with solid concrete with waterproof membrane and tiles and falls for draining; | Applicable to all vulnerable properties having this type of construction. |
| Timber (exposed end grain of built in timber joist) | Replace timber wall plates and joists on sleeper walls with corrosion resistant steel alternatives; Install a damp proof membrane around ends of floor joists where built into walls | Applicable to all vulnerable properties having this type of construction. |
| Wall finishes | Use water resistant finishes | Applicable to all vulnerable properties. |
| Washing machine - low | Washing machine on first floor level | Applicable to vulnerable houses but not flats. |

*Table 3.2 Flood Resilience Adaptation Measures*

| Technological Adaptation | Potentially Applicable to Octavia |
|---|---|
| Air conditioning | Fixed air conditioning could be used to cool the most difficult to treat properties and sheltered accommodation (subject to planning constraints). Portable air conditioning could be used to create cool rooms for vulnerable tenants. |
| External /Cavity/Internal wall insulation | Wall insulation acts in two ways: it reduces the transfer of heat from outside to inside during the day (desirable during a heatwave); and reduces the transfer of heat from inside to outside during the night (and desirable during a heatwave. It can also have a detrimental effect on overheating if a property is occupied for long periods of time (it e.g. by an elderly tenant). External insulation as a better overall effect than internal insulation. Could be applicable to all properties (subject to planning constraints) if used in conjunction with night-time purging. |
| Circulation fans | Applicable to all vulnerable properties but most suited to converted flats with high (> 2.4 m) ceiling heights. |
| Cross ventilation | Difficult to create cross ventilation in single aspect flats. Should be applicable to multi-aspect properties providing window openings are present. |
| Fixed shading | Applicable to all vulnerable properties (subject to planning constraints). |
| Ice/cold water supply | Applicable to sheltered accommodation or purpose-built flats. |
| Increased thermal mass | Potentially applicable to properties with lightweight construction (subject to planning constraints). |
| Increased vegetation | Applicable to external areas, particularly associated with sheltered accommodation. |
| Internal blinds | Applicable to all vulnerable properties. Could be incorporated within triple glazed units. |
| Light coloured walls/roof | Applicable to all vulnerable properties (subject to planning constraints). |
| Loft insulation | Applicable to all pitched roof spaces that have access points. |
| Low e triple glazing | Applicable to all vulnerable properties (subject to planning constraints). |
| Night ventilation | Applicable to first and upper floor properties (subject to security, noise and pollution levels). |
| Passive ventilation | It may be possible to create passive ventilation through reversed airflow in existing chimneys. Applicable to properties with existing chimneys. |
| Solar reflective coatings | Applicable to all vulnerable properties (subject to planning constraints). |

*Table 3.3 Reducing Overheating - Technical Adaptation Measures*

| Tenant Measure | Potentially Applicable to Octavia |
|---|---|
| Personal Flood Plans | Engage with tenants living in vulnerable properties and assist them to develop personal flood plans (see appendix Dfor advice from the Flood protection Association - http://thefpa.org.uk/). Provide generic flood guidance on Octavia's website. Ensure that tenants in vulnerable properties are signed up to the environment agency flood alert system. |
| Insurance Cover | Engage with tenants to ensure they are aware of the limitations of Octavia's insurance cover for flooding and assist them where possible in obtaining personal building contents insurance cover. |
| Home usage | Develop guidance for tenants on how to use their home during a heat wave. Guidance should include the use of curtains/blinds/Windows during the day to reduce solar gain and ignited to wage night-time purging. Guidance should also include advice on how to stay healthy during heat waves and on the personal equipment that tenants could obtain to assist the cooling/circulation of air within their home[25]. |

*Table 3.4 Reducing Flooding and/or Overheating – Resident Adaptation Measures*

| Landlord Measure | Potentially Applicable to Octavia |
|---|---|
| Vulnerable Tenants | Different types of tenants exhibit different vulnerabilities to flooding and heat waves. Where ever possible avoid placing highly vulnerable tenants in highly vulnerable properties. Where existing vulnerable tenants are living in vulnerable properties place a high priority on adapting these properties to address the vulnerability on mobility. |
| Disaster Recover/Contingency Planning | Test disaster recovery and contingency plans. For flooding: assess the vulnerability of Octavia's supply chain; identify potential suppliers of critical equipment (e.g. dehumidifiers etc) and replacement goods (e.g. kitchen units etc); identify potential alternative temporary accommodation for those tenants living in vulnerable properties; assess the level of insurance cover. For overheating: identify those tenants vulnerable to heat stress and develop support mechanism to assist these tenants during a heatwave period. For both flooding and overheating: assess the suitability of Octavia's current built asset management system to reports on flooding and overheating risks; modify data collection associated with the stock condition survey to capture data necessary to plan for future flooding and heatwave events. |

*Table3.5 Landlord Adaptation Measures*

[25] For further details see: http://www.nhs.uk/Livewell/Summerhealth/Documents/heatwave-plan-for-england-2013.pdf

Although Octavia had an up to date stock condition survey it did not contain the level of detail to allow an assessment of the applicability of the technical adaptations at an individual building level. For flooding, a lack of detail of fixtures and fittings; location and state of repair of openings in external walls; service routes; door rebates; and finishes did not allow detailed adaptation solutions to be evaluated. For Overheating, a lack of detail of aspect (single or multiple); glazing area; floor level; insulation level; ceiling heights; and orientation did not allow detailed modelling of adaptation solutions. This gap in data should be filled at the earliest opportunity or at the very latest as part of the next stock condition survey.

### *3.2.6 Develop Solutions: Cost/Benefit Analysis for Flooding*

The cost benefit analysis was done in two parts: firstly an assessment of generic costs and benefits applicable to this project was compiled from UK Government reports; secondly, a more detailed assessment of the specific cost/benefit issues related to Octavia (including where applicable exemplar cost/benefit assessments) were done for typical Octavia properties.

Table 3.6 shows an estimate of the cost of the flood resistance and resilience measures applicable to Octavia's stock derived from the DEFRA/Environment Agency Technical Report on the Evidence Base[26] and the Flood Resistance and Resilience Scoping Study[27]. Typical costs for the range technical adaptations examined in this study are shown in Table 3.6.

| Archetype | Flooding Adaptation Measures | Typical Cost (adjusted for inflation) |
|---|---|---|
| Basement Flat | Allow flat to flood and increase internal resilience. | £13k for a 2 bedroom flat |
| Ground Floor Flat | Fit temporary resistance measures and increase internal resilience. | £18k for a 2 bedroom flat |
| Upper Floor Flat | Fit temporary resistance measures to communal areas. | £5k for a typical communal area |
| House | Fit temporary resistance measures and increase internal resilience of ground floor. | £18k for a 2 bedroom house |

*Table 3.6 Typical costs for a range of technical flooding adaptations*

The cost/benefit ratio for flood resistance and resilience measures fitted to a typical residential property[21] ranges from 0.1 (for resilience measures in a property with 1% chance of flooding) to 10.6 (for temporary resistance measures in a property with 20% chance of flooding). However, given that Octavia's properties are most vulnerable to pluvial flooding, and at the time of this project published current data didn't provide an estimate of the annual chance of flooding, it is recommended that Octavia look beyond a simplistic cost/benefit analysis, to a qualitative assessment for the potential impact of a flood event on the quality of life of their tenants (in line with the Octavia Standard) to support their adaptation strategy. The DEFRA/EA Report[21] also concludes that resistance measures are generally more cost beneficial than resilience measure and suggests that retrofitting full resilience measures is only really beneficial following a flood event or

[26] For further details see: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=14738

[27] For further details see: http://archive.defra.gov.uk/environment/flooding/documents/manage/frrs-scope.pdf

when the property is next due for a major refurbishment. As such the cost benefit analysis of flood resistance and resilience should take account of potential disruption to Octavia's tenants should a flood occur before the adaptation measures are in place.

The Octavia stock comprised of a diversity of property types, construction forms, locations (through North and West London in generally an urban context) and occupancy, and this project has sought to identify appropriate interventions of simple and cost effective measures that can be incorporated where identified trigger point thresholds have been flagged up, but where such measures can be cost effectively integrated within current asset management programs.

It is clear that where the landlord has a statutory obligation to provide homes that continue to support the wellbeing and needs of residents, at affordable rents, any Climate Change Scenarios will have a major impact on the availability of properties to rent, the comfort conditions within them, and the structural stability, and viability of the structures to provide a good standard of accommodation for residents over the life of the buildings.

The Climate Change study was to review scenarios and impacts as a forward look to 2080, but clearly much of the stock would have exceeded its original design life, and will have undertaken a number of investment cycles to continue to perform both as an asset and as a home. A summary of the appropriateness of the TSB checklist no 3 is included as a frame of reference, to the extent at which Design opportunities can be taken on board (Appendix 2.2).

Clearly the assessment of Cost v Benefit for an intervention for a flood event, ought to be viable where the cost is offset by the savings incurred upon a single flood event occurring, which could typically be, dependant on the nature and duration of the flood event be between £12,000 - £20,000 for a decant and minor rectifications to non-structural elements of a single home, and simple tables are included to highlight both possible measures, and when they could be integrated within the asset management plan.

Consideration of building and construction detailing, as well as the ability of existing buildings and materials to perform outside of the original design parameters, the enhancement of existing maintenance regimes to keep drains and gutters free running, and the increasing availability of new products at competitive cost, does present asset managers with the opportunity to use the tool kits as a road map to raise climate change awareness.

Making the right 'choices' and selecting the suitably accredited products can avoid unnecessary works being undertaken, and money being wasted where an over emphasis on flood resistance, rather than flood resilience (the ability to recover after a flood event) may not be the most appropriate strategy.

There is much guidance available from the 'Environmental and Flood Protection Sector' aimed at residential owners. The on-going development of the 'Blue Book' by the National Flood Forum[28] listing specialist suppliers and manufacturers, ought to assist asset managers in setting up

[28] For further details see: http://www.bluepages.org.uk/

comprehensive guidance documents for the enhancement of specifications and design checklists to accompany voids works, and planned and programmed capital works programmes.

With a large stock holding, making a single property 'Climate Change Resilient' where it may sit within a terrace of properties that remain untreated, or where other flats are in leasehold ownership, does suggest that a layered approach has to be adopted that looks at the home, the block, the street and then the neighbourhood. Community flood planning and climate change resilience can then become an area based objective of a range of stakeholders.

Taking the aforementioned points into consideration, The trigger points at which the benefit, justifies the costs of the intervention, over the building life cycle have been appraised as follows:-

*Loss of Rental Income - Decanting Properties*
Table 3.7 sets out average rent of Octavia's properties. These rents are on average 30% of current Market Rent levels; however, in some boroughs the figure could be as low as 10%.

| Type House/Flat/Maisonette | Controlled Rent | | Market Rent | |
|---|---|---|---|---|
| Bed Size | £ Per Week | £ Per Annum | £Per Week | £ Per Annum |
| 1 Bed | 118.88 | 6181.76 | 356.64 | 18545.28 |
| 2 Bed | 136.42 | 7093.48 | 409.26 | 21281.52 |
| 3 Bed | 154.28 | 8022.56 | 462.84 | 24067.68 |
| 4 Bed | 154.71 | 8044.92 | 490.12 | 25486.24 |
| 5 Bed | 171.83 | 8935.16 | 515.49 | 26805.48 |

*Table 3.7 Octavia rent levels as December 2013*

*Decanting Properties and Relocating Tenants*
Apart from the social costs and trauma of a post flood event, clearly mitigating the decanting of a property and the potential loss of income, whilst manageable for single property events, where void properties may be available, could have a major impact if at a street or neighbourhood level. Any associated loss of infrastructure, (Mains services supplies), loss of heating, contamination of water supplies etc., beyond the curtilage of individual dwellings may also result in the need for a property decant, though of a much reduced period. The decision to decant the property will also need to reflect the individual circumstances of the resident, any vulnerability issues, and clearly suggest the development of a robust action plan to mobilise decanting options at short notice.

It is difficult to quantify the social costs of a short term, medium or long term (disruption to life and loss of personnel possessions etc.) relocation. Actual financial costs are easier to estimate, temporary accommodation can be established over a typical 6 month period to for a post flood event. However, there are a number of variables which make establishing an accurate figure difficult. In the case of Octavia the cost can vary significantly from borough to borough. The Royal Borough of Kensington and Chelsea have some of the highest rent levels in England. Finding an equivalent 4 bedroom house in the borough as a temporary decant could cost Octavia £600 a week, more than 10 times the weekly rent. That assumes there is a supply of housing available, however, demand for housing in London is always going to be high. Local Authorities where Octavia's homes are located are already heavily reliant on Temporary Accommodation to meet current housing needs. The chance of finding a supply of affordable temporary housing in any significant number within Central London is fairly small. This means decanting to the out skirts of London.

Moving residents a long way from their homes for any length of time would cause further problems for those who work locally and have children who attend schools in the borough. The cost of travelling would all form part of disturbance claims made by residents.

Many social housing residents do not have contents insurance. Social Landlords such as Octavia could face Civil claims from their residents. Resident might argue that Landlords had awareness of the hazards and did not take reasonable steps to protect their homes from extreme weather. Landlords would defend such claims on the grounds of 'reasonably practicable'; however, many Social Landlords may feel they have a moral obligation to financially support their most vulnerable residents.

Added to this is the cost of reinstatement which is dependent on the extent of damage and the size of the property. A typical 1 bedroom basement flat which has been flooded could have a reinstatement cost £20,000. The drying out and remedial works could take 6 months. If decant, loss of rent and additional temporary rent costs are included, the cost is likely to be over £30,000. This is not including any hardship payments to uninsured residents.

If the excess on Building Insurance is £10,000 (Octavia's current level per single claim) then immediate cost to the landlord would make it harder to justify undertaking adaptation works as an immediate priority. If the flooding impacted more than one home costs would increase but as long as the claim was accepted as a single incident the excess would remain at £10,000. Again it makes it difficult to argue for undertaking adaptation works.

Consideration needs to be given to damage to the Landlords reputation as well as the cost of any non-recoverable hardship payments made to residents.

The other factors that will need to be considered is the impact on insurance premiums following sizeable claims and the possible withdrawal of insurance cover. Such changes could force Landlords into undertaking these works but could also force some to consider disposal options given the cost of adaptation.

*Extra Care/Sheltered Accommodation*

Within the risk assessment process, the review of the occupancy profile is of paramount importance to establish both the need for resilience measures to be adopted, and whilst these change over time, where specialist accommodation is provided additional requirements may need to be satisfied to ensure important infrastructure is protected from flood. The loss of a lift, communal heating, meal facilities, contaminated water supplies etc., may result in the need for a whole block to be decanted.

Whilst Octavia has considered the likely impact that a major incident could have on its Specialist Accommodation and has robust plans in place should decant be required on a short term basis. This would include moving residents to alternative, some of which have spare accommodation for family visitors. For more major incidents involving long term disruption to buildings, Octavia would seek the cooperation of the Local Authority and Health Departments.

*Leasehold Accommodation and obligations*

With leasehold accommodation, the Occupier is responsible for insuring the building, and therefore at this stage, we have excluded any costs associated with the decant of leaseholders.

*Property Restitution (Post Flood)*

The benefit of avoiding a flood event and the associated remedial works, will define the 'payback period' for the intervention and adaptation measures adopted. Typically, based on Octavia's stock profile, the works are more about flood resilience than flood resistance and a simple package of measures to be introduced within the future asset management cycle is the best approach to those properties identified as high risk.

*Asset Disposals and Loss of Asset Value*

Where the climate change risk identifies the cost of a longer term solution outweighs the benefit achieved, developing an asset strategy that is inclusive of such measures can enable the on-going development of property to maximise both the value of the land, and develop more sustainable solutions. This is clearly an advantage where properties can be demolished or redeveloped.

Conversely, 'high risk' properties could be blighted and additional funding may need to be sought to ensure they remain in use, and asset value is not lost, where demolition is not an option. This is a complex dynamic, but one which has not been quantified within the current report.

### Case Study of Cost/Benefit Analysis

*Figure 3.9 Photo showing a typical basement flat used in the case study*

This case study examines the cost/benefit of retrofitting flood resistance and resilient measures converted London W9 Victorian property with a basement located in an area at high risk of pluvial flooding. Full details of the analysis are given in Appendix 3.1.

When considering what type of works to do to Octavia homes one consideration was should they concentrate on resistant measures or improved resilience. A major factor in this decision was the type of property. In the case study, the fact that the property is in a terrace means that trying to make the property fully resistant to flooding would be extremely expensive and would require works not only to prevent ingress from the street front but also from the adjacent properties which are not owned by Octavia and our unlikely to have carried out similar measures. As such it was felt that whilst there were some resistant measures which could be carried out in the short term which would not require the residents to move out of their home and would minimise the impact of short period flash floods, the longer-term solution would be to improve resilience of the property.

Resilience measures are aimed at minimising the extent of damage and the speed at which remedial works can be carried out to return the property to habitable use. Our case study property based on the risk profile has assumed a one metre high flood level in a basement property for a period of 24 hours. In considering the cost/benefit to Octavia the current insurance excess of £10,000 per claim was a consideration. Octavia also considered the psychological impact that a flood can have on residents. Octavia's demographic shows that it has a high percentage of older households; their ability to react quickly in the event of a flood is a factor that needs consideration when considering works to be done in homes. This also reinforces the need to do further work with residents in high risk areas and have recognised the need for Personal Flood Plans in its Action Plan.

Based on the analysis presented in Appendix 3.1 installing resilient measures was considered to be the best long term solution, works to walls and floors could also include thermal efficiency improvements which make the works more cost effective. These works would, however, be extremely disruptive to the residents and would require them to move out while the works where carried out, this would add to costs. Therefore, this is not an option we would propose until the property is vacated by the current residents.

In the short term it is proposed to undertake some resistant measures, these will be carried out as part of future cyclical maintenance measure in order to minimise costs.

Therefore the following approach is proposed.

Short term 'Resistant Measures' within the next 5 years

- Fit air brick covers: £250
- Install external flood door: £1500
- Seal service pipe entry points: £100
- Plug gaps around window frame: £150

**Total Estimated Cost: £2000**

Long term 'Resilient Measures' when property next becomes vacant

- Rewire property, raising power sockets and dropping supply from upper floor:£2000
- Replacing timber floor with solid concrete: £5000
- Water proof floor finish: £1200
- Replacing plasterboard to wall: £6000
- Replace Skirting boards: £500
- Treat base of staircase: £100

**Total Estimated Cost: £13600**

Based on data provided by the Association of British Insurers and the National Flood Forum (see Appendix 3.1), the above Resilient Measures will save an estimated £11,000 compared with a property where no measures have been carried out. Although this does not cover the full cost of the measures from a one off event, one of the additional benefits is the reduction in the disruption to the lives of residents which has not been quantified.

The decision not to do these works immediately is made because the additional cost incurred by having to move the resident out and the fact that they have access to habitable space on the upper floor was also a factor.

Based on this strategy the need to consult with the residents and assisting them in preparing Personal Protection Plans is something that needs to be carried out by Octavia.

### *3.2.7 Develop Solutions: Cost/Benefit Analysis for Overheating*

As for flooding, the cost benefit analysis for overheating was done in two parts: firstly an assessment of generic costs and benefits applicable to this project was compiled from publically available data set; secondly, a more detailed assessment of the specific cost/benefit issues related to Octavia (including where applicable exemplar cost/benefit assessments) were done for typical Octavia properties.

The CREW project website provides Retrofit Advice Toolkit[29] that RSL's can use free of charge to assess the potential impacts of a range of adaptations on the overheating performance of a range of domestic property archetypes. The following analysis was extracted directly from the on-line toolkit and assumes that the adaption combinations make no change to the heating energy that is required over a 12 month period.

For top floor flats a 50% reduction in overheating hours can be achieved through a combination of external shutters and night ventilation at a cost of approximately £3000. A 90% reduction in overheating hours (to approximately 90 degree hours overheating) would require external shutters; fixed external shading above windows; night ventilation; window rules; upgraded roof; and light walls at a cost of approximately £8000. Similar adaptation combinations could be applied to ground and mid floor flats (without the roof upgrade) but the percentage reduction in overheating hours would be less. The typical cost of a 50% reduction in overheating hours would be £6.500; and an 84% reduction (the maximum that could be achieved) would be £9.500.

For modern housing (built to 2005 building regulations) a 50% reduction in overheating hours can be achieved through a combination of night ventilation and curtains at a cost of approximately £500. A 90% reduction in overheating hours (to approximately 30 degree hours overheating) would require external shutters; night ventilation; triple e-glazing; light roof; extra roof insulation and window rules; at a cost of approximately £6000.

For 1930's 1950's housing a 50% reduction in overheating hours can be achieved through a combination of night ventilation and internal blinds at a cost of approximately £2000. A 90% reduction in overheating hours (to approximately 30 degree hours overheating) would require external shutters; night ventilation; and window rules; at a cost of approximately £16000.

For a 19th Century mid-terrace housing a 50% reduction in overheating hours can be achieved through a combination of night ventilation and curtains at a cost of approximately £200. A 90%

[29] For further details see: http://www.iesd.dmu.ac.uk/crew/

reduction in overheating hours (to approximately 10 degree hours overheating) would require external shutters; night ventilation; and window rules; at a cost of approximately £10000.

An alternative way of viewing the output from the Retrofit Advice Toolkit is to estimate the cost range of adaptations required to ensure that a property does not pass an overheating threshold. Table 3.8 shows the range of adaptations and costs that would be needed to ensure that Octavia's properties do not overheat for more than 100 degree hours per year in an extreme heat wave event.

To examine the effect of potential climate change on overheating, a thermal simulation and outline cost/benefit analysis was undertaken for a typical modern block of flats that were believed to be susceptible to overheating (Appendix 3).

| Archetype | Adaptations Needed | Estimated Costs |
|---|---|---|
| Upper Floor Flat | External shutters; fixed external shading above windows; night ventilation; window rules; and light roof. | £8000 |
| Mid floor flat | External shutters; low e triple glazing; night ventilation; window rules; and light roof. | £9.500 |
| Modern House | External shutters and night ventilation | £6000 |
| 1930-50's house | Internal blinds and night ventilation | £2000 |
| Mid Terrace house | None required | No cost |

*Table 3.8 Estimated costs of reducing overheating to 100 degree hours in any year.*

James Hill is a modern block of flats built in 2006 that operates as an Extra Care Home; it is linked to Octavia Head Office Emily House. James Hills has 29 self-contained flats located off a central corridor. The property includes a communal kitchen, day room and laundry. Works are currently in progress to convert the ground floor to a day care centre.

Sixteen flats are south facing: they have large glazed windows; little shading; and because they are single aspect they have no through ventilation. In recent years residents have complained of overheating during extended hot periods, with, on the hottest days, temperatures of over 40 degrees centigrade have been recorded. As the block is used to house frail elderly people this is regarded as major hazard.

A thermal simulation model of the overheating issue was undertaken as part of this project. The model used the Ecotec[30] software package to model the annual temperature distribution in the bedroom and living room for both the current and future climate projections (Appendix 3.3).

Table 3.9 shows the typical overheating profile for the base year (current); 2030 and 2050 climate change scenarios (from UKCP09). The future climate change analyses use both the medium and high emissions scenario to produce Design Summer Year (DSY) temperature profiles at the 50 percentile (50%ile) and 90 percentile (90%ile) level. Percentage overheat hours are given as the percentage of total year hours that the room is above 24°C.

[30] For further details see: http://usa.autodesk.com/ecotect-analysis/

| | Living Room | | Bedroom | |
|---|---|---|---|---|
| Scenario | %hrs overheating | Peak temperature | % hrs overheating | Peak temperature |
| Base case | 4.1 | 28-30 | 5.0 | 28-30 |
| 2030 (medium/50%ile) | 13.3 | 32-34 | 13.3 | 34-36 |
| 2030 (medium/90%ile) | 22.9 | 34-36 | 25.9 | 32-34 |
| 2030 (high/50%ile) | 14.1 | 32-34 | 16.2 | 32-34 |
| 2030 (high/90%ile) | 20.8 | 36-38 | 23.6 | 36-38 |
| 2050 (medium/50%ile) | 17.5 | 32-34 | 19.6 | 32-34 |
| 2050 (medium/90%ile) | 26.8 | 34-36 | 29.3 | 34-36 |
| 2050 (high/50%ile) | 17.2 | 34-36 | 19.9 | 34-36 |
| 2050 (high/90%ile) | 28.2 | 38-40 | 31.2 | 38-40 |

*Table 3.9 Percentage overheating and peak temperature range expected for James Hill House.*

In addition to overheating hours, an analysis was also done of the hourly internal temperature of the bedroom/living room for each day of a simulated year. Based on the base case (current case) the rooms become uncomfortable at an average daily temperature of approximately 18°C (Table 3.10).

Octavia is currently proposing works to address the overheating issue and although the design of the block is a key factor in the overheating problem, the design is not untypical off many developments built since 2000. Predicted rising air temperatures will increase the problem within this block unless remedial measures are undertaken.

Whilst Octavia do not consider mechanical air conditioning as a long term solution to its potential overheating problems (estimated at £5000 per flat), given the nature of accommodation that James Hill House offers, and the inherent vulnerability of its elderly, frail residents, a more viable short-term solution is required during extreme hot weather. In the short term Octavia will invest in the use of mobile air condition systems (estimated at £500/unit). This solution is not ideal in the long term from a cost and environmental impact viewpoint.

In addition to portable air conditioning Octavia will trial two window treatments. Reflective film and internal blinds will be used on all external glazed areas. Octavia have limited confidence in the performance of either of these types of system but need time to undertake more detailed long-term assessments of potential building level solutions that was beyond the scope of this project. Details of the cost/benefit analysis shown above are given in Appendix 3.2.

| Wednesday 8th August (220) | | | |
|---|---|---|---|
| Avg. Temperature: 17.9 C (Ground 11.4 C) | | | |
| HOUR | INSIDE (C) | OUTSIDE (C) | TEMP.DIF (C) |
| 0 | 21.9 | 17.3 | 4.6 |
| 1 | 21.3 | 17 | 4.3 |
| 2 | 21.2 | 16.6 | 4.6 |
| 3 | 21.5 | 16.6 | 4.9 |
| 4 | 21.8 | 16.4 | 5.4 |
| 5 | 21.8 | 16.2 | 5.6 |
| 6 | 21.8 | 17.1 | 4.7 |
| 7 | 21.9 | 18 | 3.9 |
| 8 | 22 | 20 | 2 |
| 9 | 22.1 | 21.2 | 0.9 |
| 10 | 22.4 | 21.4 | 1 |
| 11 | 23.2 | 23.4 | -0.2 |
| 12 | 24.4 | 24.8 | -0.4 |
| 13 | 25.2 | 24.8 | 0.4 |
| 14 | 25.6 | 25.1 | 0.5 |
| 15 | 26.3 | 24.8 | 1.5 |
| 16 | 26.6 | 25.3 | 1.3 |
| 17 | 26 | 24.7 | 1.3 |
| 18 | 25.5 | 24 | 1.5 |
| 19 | 25 | 22.8 | 2.2 |
| 20 | 24.8 | 21.3 | 3.5 |
| 21 | 24.2 | 19.2 | 5 |
| 22 | 23.9 | 18.5 | 5.4 |
| 23 | 23.6 | 18.5 | 5.1 |

*Table 3.10 Typical internal / external temperature profiles for simulated DSY.*

In considering ten long-term solutions Octavia should re-run the temperature analyses presented above and confirm their output through formal monitoring (current monitoring is anecdotal and not controlled) against known external temperature profiles and assess the performance of the range of technical adaptation measures identified by the Technology Strategy Board project to address the overheating profile. The adaptations should be examined as combinations using a similar methodology to that used in the CREW project.

### *3.2.8 Develop Solutions: Triggers and Thresholds*

Although detailed analysis of adaptations for a single property were not part of this project, the identification of strategic priorities that will inform future detailed adaptation plans was. Establishing when an adaptation should take place requires the development of triggers and thresholds against which priorities can be assigned. At the strategic level these triggers and thresholds tend to be statements of intent or desire, rather than quantified metrics that instigate an action. Such statements of intent provide an expectation of how a building should perform against any given situation and allow the implications of delaying an action (maintenance impact assessments) to be evaluated. For Octavia these thresholds relate directly to their Housing Standard (The Octavia Standard – discussed earlier) and are expressed as commitments for each quadrant of the Impact/Priority Matrix shown in Figure 3.10 and summarized in Table 3.11 and 3.12.

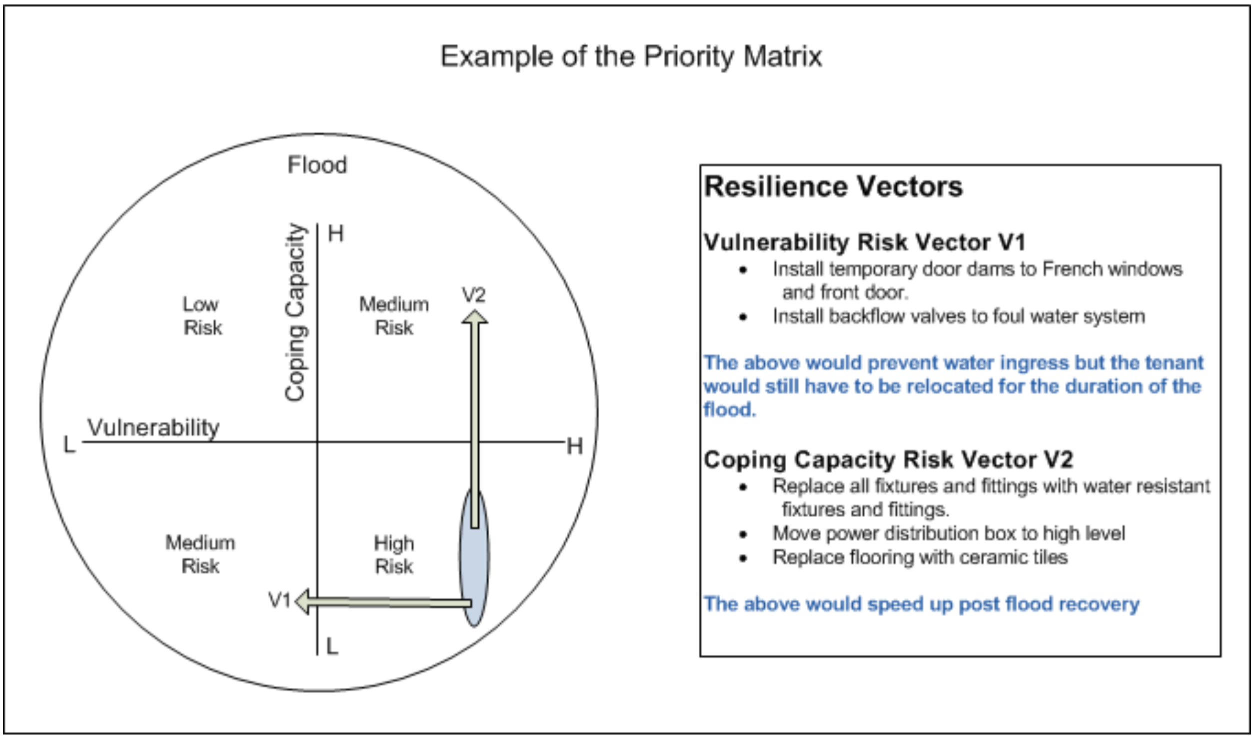



*Figure 3.10 Example of a priority matrix for flooding*

| Impact/Priority Quadrant | Action Trigger/Threshold |
|---|---|
| High Vulnerability / Low Coping Capacity | Take action to improve resistance and/or resilience over the next 5 years. |
| High Vulnerability / High Coping Capacity | Take action to improve resistance and/or resilience between years 6 and 10. |
| Low Vulnerability / Low Coping Capacity | Take action to improve resistance and/or resilience between years 11 and 30. |
| Low Vulnerability / High Coping Capacity | Take no action. |

*Table 3.11 Action trigger/thresholds for flooding adaptations*

In all cases the vulnerability and coping capacity of Octavia's stock should be re-assessed on a regular basis (e.g. every 5 years) as part of the rolling stock condition survey process. For flooding this should include reviewing the vulnerability of the stock against updated (to take account of climate change) Environment Agency and Local Authority Flood Risk Assessments and collecting data that will allow more detailed assessments of the coping capacity of the stock. For overheating this should involve monitoring tenant experiences of overheating through the annual tenant satisfaction survey. Where properties are perceived to be overheating detailed modeling, supported by sample monitoring should be used to substantiate the scale of the problem and evaluate potential solutions. Action triggers and thresholds should also be reviewed on a regular (e.g. every 5 years) basis.

| Impact/Priority Quadrant | Action Trigger/Threshold |
|---|---|
| High Vulnerability / Low Coping Capacity | Take action to improve performance over the next 5 years. |

| | |
|---|---|
| High Vulnerability / High Coping Capacity | Take action to improve performance between years 6 and 10. |
| Low Vulnerability / Low Coping Capacity | Take action to improve performance between years 11 and 30. |
| Low Vulnerability / High Coping Capacity | Take no action. |

*Table 3.12 Action trigger/thresholds for overheating adaptations*

In addition to the generic triggers and thresholds outlined above, specific action should be taken in Year 1 of the adaptation plan to address known, current problems. Where the problems are known, but the scale is unknown, action should be taken in the first 5 years of the adaptation plan to quantify the scale of the problem. Where there is uncertainty about the potential problem or a solution the situation should be regularly monitored. These thresholds and triggers are summarized in Table 3.13.

| *Year to Action* | *Threshold* | *Trigger* |
|---|---|---|
| *1* | *Know scale of problem and solution* | *Known level of risk is high* |
| *2-5* | *Know problem exists but don't know scale or solution* | *Establish level of risk* |
| *6-30* | *Unsure if problem exists. Don't have a solution* | *Continue to monitor risk* |

*Table 3.13 Thresholds and triggers for action in an adaptation plan.*

### *3.2.9 Evaluate Solution: Impact Toolkits*

Although it is difficult to measure the impact of adaptations before the future event occurs, assessments of the level of vulnerability and the associated resilience of Octavia's properties should be regularly reassessed. In particular, flood risk assessments, similar to those undertaken for this project, should be repeated as better future flood information becomes available. Updated flood maps that assess pluvial flooding (but not yet climate change) were released by the Environment Agency[31] on the 12th December 2013. Octavia should rerun the postcode mapping exercise undertaken in this project and reassess the vulnerability of its building stock now that this data is available. For overheating, Octavia should monitor the performance of its existing stock (through the tenant satisfaction survey) to identify those properties that are potentially overheating (using the guidance given by NHS England) and undertake thermal modeling of these properties (supported by real time monitoring where feasible) to assess the impact that adaptations could have on reducing overheating levels. Octavia should also examine its contractual arrangements with its supply chain to ensure that its disaster recovery/contingency planning is robust and can deal with the consequences of a major flooding or overheating event.

[31] For further details see: http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?topic=ufmfsw#x=523989&y=180530&scale=11

### 3.3 Adaptation Strategy

The following Adaptation Strategy summaries the recommended to address issues of flooding and overheating associated with climate change.

| Property Type | Vulnerability - FLOODING | Timescale for Action |
|---|---|---|
| Vulnerable Basement Flats | Threshold: Unfortunately it is unrealistic to assume that floodwater can be prevented from entering Octavia's vulnerable basement Flats. Thus the most appropriate adaptation strategy would be to accept that flooding will take place and then manage the recovery to ensure that the flat can be returned to a habitable condition in the shortest period of time. This would involve: | |
| | Undertake detailed surveys of the vulnerable properties identified in this report to identify flooding impact and develop post-flood recovery plans. These plans should include a detailed assessment of post-flood building works and an estimate of the time to return the flat to a habitable condition. | Year 1 |
| | Assess the potential of resilience measures to reduce the estimated time to return the flat to a habitable condition. Undertake a more detailed cost/benefit analysis of these measures and implement those that are appropriate. | Year 1 |
| | Ensure that Octavia is signed up to the environment agency early warning service and develop a communications strategy that informs its tenants of an impending flood events and keeps them informed of progress through the cleanup and repair phase. | Year 1 |
| | Engage with the residents living in these flats to ensure that they are as prepared as possible for potential flooding events. Consider providing secure temporary storage for personal belongings and treasured items (either within Octavia's present property portfolio or through third-party storage centres), including the provision of transport and labour to assist tenants in the removal of these items. | Year 1 |
| | Ensure that Octavia has arrangements with alternative landlords to provide temporary accommodation for those residents displaced by a flood. | Year 1 |

| Property Type | Vulnerability - FLOODING | Timescale for Action |
|---|---|---|
| Vulnerable Ground Floor Flats | Where ever possible floodwater should be prevented from entering ground floor Flats. Depending on the depth of any water entering the flat (will depend on floor level above the street) Resilient fixtures and fittings should be used to ensure that the flat can be returned to a habitable condition in the shortest period of time. This would involve: | |
| | Undertake detailed surveys of the vulnerable properties identified in this report to identify the flood resistant actions required to prevent water entering the property (including the sealing of air bricks, appropriateness of door dams, non-return valves on drainage and foul water systems etc.). Identify the impact that any floodwater entering the property would have on the post-flood recovery period. These plans should include a detailed assessment of post-flood building works and an estimate of the time to return the flat to a habitable condition. | Year 1 |
| | Assess the potential of resilience measures to reduce the estimated time to return the flat to a habitable condition. Undertake a more detailed cost/benefit analysis of these measures and implement those that are appropriate when next refurbishment is planned. | Year 1 |
| | Ensure that Octavia is signed up to the environment agency early warning service and develop a communications strategy that informs its tenants of an impending flood events and keeps them informed of progress through the cleanup and repair phase. | Year 1 |
| | Engage with the residents living in these flats to ensure that they are as prepared as possible for potential flooding events. Consider providing secure temporary storage for personal belongings and treasured items (either within Octavia's present property portfolio or through third-party storage centres), including the provision of transport and labour to assist residents in the removal of these items. | Year 1 |
| | Ensure that Octavia has arrangements with alternative landlords to provide temporary accommodation for those residents displaced by a flood. | Year 1 |

| Property Type | Vulnerability - FLOODING | Timescale for Action |
|---|---|---|
| Vulnerable Street Houses | Where ever possible floodwater should be prevented from entering the house. Depending on the depth of any water entering the house (will depend on floor level above the street, existence of a basement etc.) resilient fixtures and fittings should be used to ensure that the house can be returned to a habitable condition in the shortest period of time. This would involve: | |
| | Undertake detailed surveys of the vulnerable properties identified in this report to identify the flood resistant actions required to prevent water entering the property (including the sealing of air bricks, appropriateness of door dams, non-return valves on drainage and foul water systems etc.). Identify the impact that any floodwater entering the property would have on the post-flood recovery period. These plans should include a detailed assessment of post-flood building works and an estimate of the time to return the house to a habitable (or part habitable) condition. | Year 2-5 |
| | Assess the potential of resilience measures to reduce the estimated time to return the house to a habitable (or part habitable) condition. In particular examine measures that improve the resilience of essential services, kitchen and bathroom areas. Undertake a more detailed cost/benefit analysis of these measures and implement those that are appropriate when next refurbishment is planned. | Year 2-5 |
| | Ensure that Octavia is signed up to the environment agency early warning service and develop a communications strategy that informs its residents of an impending flood events and keeps them informed of progress through the cleanup and repair phase. | Year 1 |
| | Engage with the residents living in these houses to ensure that they are as prepared as possible for potential flooding events. Consider providing labour to assist residents in the removal of personal and treasured items to the upper floors of the houses. | Year 1 |
| | Ensure that Octavia has arrangements with alternative landlords to provide temporary accommodation for those residents displaced by a flood. | Year 1 |

| Property Type | Vulnerability - FLOODING | Timescale for Action |
|---|---|---|
| ALL properties located in a flood risk area irrespective of vulnerability | All properties located in a flood risk area are potentially vulnerable to disruption from flood events. Even upper story flats could be affected by flood damage to essential services (e.g. electricity supply, gas supply, communal heating etc.) that would require tenants to evacuate the property until the services restored. Where ever possible disruption to supply should be prevented. This would involve: | |
| | Undertake detailed surveys of the service routes from the points at which Octavia becomes responsible (normally from the point at which the services enter the property) and any communal services (e.g. heating provision etc.) Provided to the properties. | During the next stock condition survey |
| | Assess the potential of resilience measures to prevent disruption to service supply including: relocating service routes; protecting key components; preventing water ingress into service areas; compartmentalising supply (e.g. alternative routes to each flat/floor etc.); etc. | Year 2-5 |
| | Arrange access to temporary service provision solutions in case damage cannot be prevented (e.g. alternate heating sources should communal supply be unusable). | Year 1 |

| Property Type | Vulnerability - FLOODING | Timescale for Action |
|---|---|---|
| ALL other properties irrespective of vulnerability | The potential risk of flooding to or Octavia's properties could not be fully assessed in the current project. Lack of detailed flooding information across all of Octavia stock combined with inadequate or missing data in Octavia's asset management database could results further properties being at risk. At the next opportunity these gaps in data should be addressed. | |
| | Redo the flood risk assessment now that pluvial flooding information is publicly available. | Year 1 |
| | Collect a wider range of flood resistance/resilient information as part of the next stock condition survey. | Years 2-5 |
| | Integrate flood risk assessments into the stock condition survey process | Years 2-5 |
| | Testing disaster recovery and contingency plans, including assessing the vulnerability of the supply chain, to respond to a flooding event. | Every five years |

| Management | Vulnerability – OVERHEATING | Timescale for Action |
|---|---|---|
| Top Floor Flats, Modern Houses and Sheltered Accommodation | Where ever possible prevent vulnerable properties overheating to the point at which it becomes a danger to health of the resident. This would include: | |
| | Monitor properties to establish the extent to which overheating is currently a problem (through tenant satisfaction surveys and physical monitoring where appropriate). | Years 1 |
| | Undertake detailed surveys for the most vulnerable properties to assess the potential of adaptation measures to reduce overheating and/or heat stress (including thermal modelling where appropriate). Undertake detailed surveys of the remaining on properties as part of the next condition survey. | Year 2-30 |
| | Install adaptation measures as appropriate. | Year 2-30 |
| | Develop an approach to assess the vulnerability of individual residents to heat stress. | Year 2-5 |
| | Where residents are particularly vulnerable to heat stress, consider relocating them or providing a 'cool room', either in the flat or in the block. | Ongoing |
| | In sheltered accommodation provide a cool room for vulnerable residents. | Year 1-5 |
| | Develop guidance for residents on how to use their home during a heat wave. Guidance should include the use of curtains/blinds/Windows during the day to reduce solar gain and ignited to wage night-time purging. Guidance should also include advice on how to stay healthy during heat waves and on the personal equipment that tenants could obtain to assist the cooling/circulation of air within their home. Consult the NHS for England Heat Wave Plan. | Year 1 |

# 4. LEARNING FROM THE WORK

### *4. 1 Summary of approach to adaptation design work*

Unlike the majority of the Design for Future Climate Change 2 projects this project did not involve the design of specific adaptations for specific buildings. Instead it focused on developing a framework for integrating adaptation into the built asset management process that could be applied across a diverse property portfolio. The project used the Adaptation Framework Model developed as part of the EPSRC CREW project as a framework to:

- identify current flooding and overheating impacts on a range of Octavia's properties;
- develop future climate change impact scenarios for flooding and overheating;
- identify and evaluate current and future adaptations to alleviate climate change impacts;
- develop an adaptation strategy; and
- integrate this strategy into the built asset management strategy.

The development of the built asset management strategy used the theory of performance based built asset management developed by Prof Jones through the EPSRC IDCOP project to develop a range of assessment, analysis and review toolkits (detailed later) to identify the potential impact of climate change on Octavia Housing's 4088 unit property portfolio and develop an adaptation strategy as part of Octavia's overall built asset management strategy.

### *4.2 Who was involved and what they brought*

Three organisations were involved in the project.

Octavia Housing is a Residential Social Landlord based in inner London. It has a property portfolio of 4088 homes, the vast majority of which it provides at below market rents. Octavia provided the property portfolio for which the adaptation strategy was developed. The Octavia team was led by Noel Brosnan, the Director of Asset Management. Noel is a Chartered Building Surveyor; a Member of the Chartered Institute of Management; and a Technical member of the Institute of Occupational Safety and Health. Noel provided overall project management as well as guidance on Octavia's housing stock and management processes. Lewis Lowe is Octavia's Energy Manager and responsible for improving energy efficiency of their building stock. Lewis has 38 years of experience in Building Services and Energy related projects in the private and Public sector. Lewis coordinated team meetings, data collection and the tenants and staff focus groups and provided technical input on building performance issues.

The Sustainable Built Environment Research Group (SBERG) of The University of Greenwich is internationally renowned for its work in adaptation and mitigation of existing building to climate change. SBERG provided the academic input into the project, using adaptation and built asset management theory developed over the past 7 years from 2 EPSRC projects alongside fieldwork experience developing climate change scenarios and measuring their impact on social housing. The SBERG team was led by Prof Keith Jones, who is Chartered Member of the British Institute of Facilities Management; a member of the EPSRC Peer Review College and a member of the 2014 REF Panel C16: Architecture, Built Environment and Planning. Professor Jones developed the theoretical models used in this project; developed the adaptation options and strategy; and drafted the final report. Dr Fuad Ali is a post-doctoral researcher at SBERG, with expertise in climate adaptation modelling and socio-technical negotiations. Dr Ali developed the climate change scenarios and identified those properties that were at risk of flooding or overheating. Justine Cooper is a Research Fellow in SBERG and has industry experience in civil engineering; building surveying; subsidence; and project management. Justine provided technical input to the development of the adaptation and built asset management strategy.

Pellings are a chartered surveying company who undertook the field survey work, and advised on adaptation options, including the cost/benefit analyses. Pellings were represented by Nigel Goddard, a Chartered Surveyor with 35 years' experience in construction consultancy. Nigel's knowledge of professional surveying methods was integral to internal building surveys.

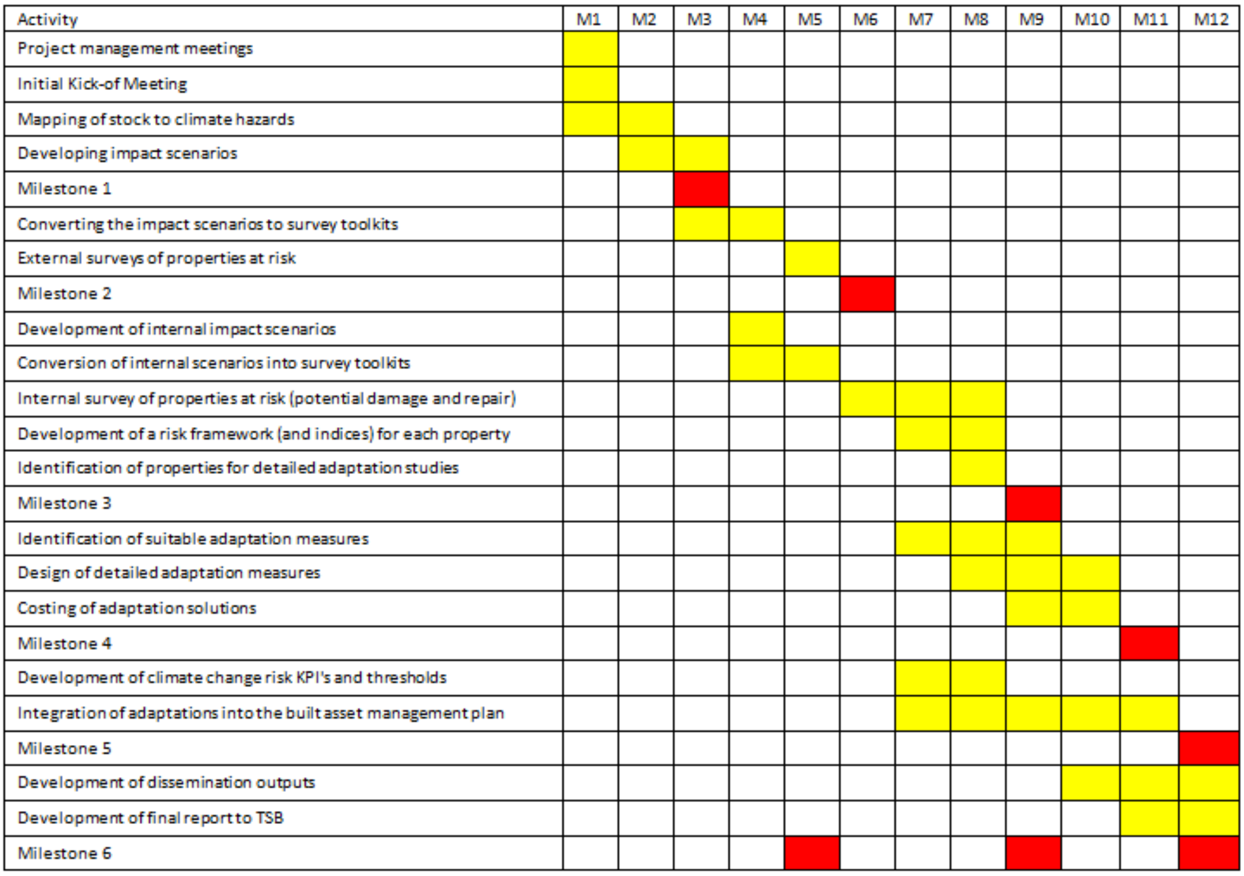
### *4.3 Initial plan and how it changed*

The original plan envisaged a 12 month project which would be delivered through 6 milestones. Whilst the sequence and content of the plan didn't change, the timescales did. Following the CREW project the team from SBERG were aware of the Drain London project which was developing a pluvial flood map for London. The SBERG team had already identified (through a pilot study undertaken as part of the CREW project) that this type of flooding was likely to be the most critical climate change impact that Octavia's properties would face and had assumed that the Drain London data would be available to this project. Unfortunately this was not the case. Issues of reliability meant that the Drain London data could not be released (except for one Borough) and the SBERG team had to find other ways of predicting flood impacts. The subsequent flood analyses took far longer than originally planned and put the whole project behind schedule. As a consequence, the internal building surveys had to be delayed until late 2012 and as such the development of the adaptation strategy didn't start until February 2013. This also proved more difficult than originally expected as the prototype toolkits developed from the original research undertaken by SBERG had to be modified to reflect the reality of Octavia's stock. The prototype data collection sheets used in the pilot study were developed for a limited range of building types and proved to generic in nature to collect the full range of data needed for this project. These issues were addressed through direct engagement with the TSB team.

### *4.4 Resources and tools used, strengths and limitations*

A wide range of data sources and tools were used in the project.

A review of existing literature on climate impacts in London (e.g. Beating the Heat, The London Climate Change Adaptation Strategy etc.) was supplemented with analysis of past and current research projects (e.g. CREW, LUCID etc.) to identify the range of climate projections and their impact on typical London domestic properties. Whilst this process took time it provided the theory integrating adaptation planning into built asset management and provided a sound base for the development of the specific climate impact scenarios used in the project.




Milestones

1. Report identifying properties potentially at risk:
2. Quantify risks
3. Report identifying technical and social implications of climate change to properties at risk and initial appraisal of adaptation measures
4. Detailed design and costing for adaptation solutions
5. Built asset management plan
6. Dissemination reports/case studies and final report

*Figure 4.1 Original project GANNT chart*

Flood mapping was done using DRAIN London mapping; Environment Agency Preliminary Flood Risk Assessments; local authority strategic flood risk assessments and historic flood risk records. These were generally available on the internet from Council and Environment Agency websites or through archives. The flood data was entered into a geographical information system and ArcGIS and GoogleEarth options were used to display and analyse building data. ArcGIS was a more complicated, costly but powerful tool offering significantly more options. Google Earth was more transportable between computers, but offered limited database integration. The geographical location (Longitude and Latitude) of Octavia's individual properties (extracted from their property database were superimposed to identify those properties at potential flood risk. The flood mapping and post code conversion was very time consuming and the costs could not have been justified in a normal stock condition survey. There was also inconsistency in the legends of flood maps between local authorities which made interpretation difficult.

The CREW Tool: Adapting Dwellings to Climate Change – Retrofit Advice Tool was used to analyse the potential of adaptations to reduce overheating. This was a simple web based tool that proved useful in evaluating adaptation options.

Octavia's building stock data was the most critical element of the risk analysis, and provided a reasonably accurate, intelligible profile of properties (typically 5-10% of the data was found to be erroneous). From the post code information we were able to derive locational data to plot on GIS software. In addition, assumptions about relative heat wave and subsidence risk could be made from floor level and building age information, roof type, and aspect. Where the data base was less useful was in the detail it held on the internal construction of properties. A lack of information on construction type, fixtures & fittings and service routes (amongst others) meant that it could not be used for flood risk assessment and full internal surveys had to be undertaken. Whilst this was both expensive and time consuming the required data could easily be collected during the stock condition survey process and this requirement should be programmed into future stock condition surveys.

All Survey forms, scenarios toolkits, adaptation designs and evaluation toolkits were developed within the project and worked as expected.

### *4.5 Methodological findings, challenges and recommendations*

The project used the theory underpinning the adaptation assessment framework and performance-based built asset management as the methodological basis for identifying climate related risks and developing and evaluating adaptation options. Both these theoretical models work well.

The risk assessment framework provided a four phase approach to the development of the short and long-term adaptation plans.

In phase 1, an assessment of published data (from major research projects, the environment agency, local authorities etc.) established pluvial flooding and overheating as the most significant current climate risks and a review of local history's, including interviews with key Octavia personnel, established the inherent vulnerabilities and resilience of Octavia's housing stock to these risks. This data was publicly available, easy to access and analyse, and robust. Other registered social landlords looking to undertake a similar study should access similar data for their area.

In phase 2, the impact of future climate change on the level of risk, vulnerability and resilience of Octavia's stock was assessed. The Drain London project should have provided the basic climate impact data for this part of the project. Unfortunately the data was only publically available for one of the London boroughs in which Octavia have properties. This lack of data caused major problems to the project. To overcome these problems the project developed a series of future scenarios based on possible climate futures, supported by the UKCP09 climate projections. Whilst these scenarios worked well when examining the generic vulnerability and resilience of Octavia's stock, they lacked currency when trying to prioritise adaptation actions. The lack of projected climate risk data must be addressed if real advances in adaptation planning are to be made.

In phase 3, a performance-based asset management approach was used as part of the risk appraisal process. The team developed a series of toolkits to assess the impact of pluvial flooding and overheating on a range of archetypal properties. Whilst the toolkits generally worked well, allowing 'potentially at risk' properties to be clearly identified and generic adaptation solutions to be evaluated, the level of data required by the toolkits was significantly greater than that which existed within Octavia's built asset management database. As such, internal and external surveys had to be undertaken to identify the potential impacts that flooding and overheating would have on the performance of a range of generic property archetypes to allow indicative adaptation solutions to be identified and evaluated. Whilst the survey approach worked well, the diverse nature of Octavia's housing stock and the costs associated with the survey work, limited the results to a small number of archetypes buildings. Going forward, Octavia will specify the information needed for adaptation to climate change as part of their routine stock condition survey process thus allowing the performance of all their properties against future climate risks to be assessed. Other registered social landlords should consider taking similar action.

In phase 4, indicative adaptation solutions for those properties at most risk from pluvial flooding and overheating were prioritised and integrated into short and long term adaptation plans. As indicated earlier, the lack of projected climate risk data did cause a problem when trying to set priority levels, particularly for longer term adaptation solutions. As such, Octavia's adaptation strategy can best be described as cautious. Properties that are currently at high risk from flooding, and properties that are currently known to be overheating, have been prioritised for early action (over the next five years). Properties that might be at risk from future flooding or overheating have not been prioritised for action (due to the level of uncertainty in the climate scenarios) but have been identified for further evaluation when more reliable climate impact data becomes available.

Whilst the project was deemed by Octavia to be successful, a number of lessons were learnt from the work which should be taken on board by other social landlords planning to undertake a similar project. These include:

1. **Don't start the process by talking about the threats posed by climate change; introduce climate change threats as a multiplier of current threats**. Although there is growing awareness of climate change and the impact that this could have on the housing stock, Octavia still found it difficult to translate this awareness into specific impacts that they could assess and programme into an adaptation strategy. The best way of introducing the threats to Octavia was by first establishing the current threat level against ACCEPTED risk criteria. In the

case of this project that was current flood risk. The impact of future climate change scenarios were then introduced as multipliers of current threats. This approach provided currency to the future impact scenarios and placed them on the same footing as other maintenance and refurbishment interventions.

2. **Modelling climate change threats on a spatial scale is far more complex than for a single building.** Using the UKCP09 projections as the basis for climate change impact assessments across a spatial scale requires augmenting climate datasets with those describing the physical topology and infrastructure of the area being considered (including for flooding any out of area catchment zones). The expertise and computing power required to perform such analyses would be beyond the scope of most social landlords. Instead, landlords will need to rely on publically available climate change risk assessments. However, the vast majority of currently available spatial flood and heatwave models don't take future climate change into account (Note: the exception is London where heatwave models have been developed through a number of projects). As such future climate impact scenarios have to use qualitative assessments of future impacts which again lack the currency of existing, probabilistic, based risk assessments. It is recommended that the UK Government develop future climate change impact models at a spatial scale to support social landlords in developing meaningful long term adaptation plans.

3. **Lack of detailed building level data to support the development and testing of adaptation solutions.** Octavia's built asset management and stock condition survey databases didn't contain the data necessary to support climate change impact evaluations. Inconsistency in location data (e.g. postcode and floor level etc.) and missing data (e.g. electrical service routes, details of fixtures and fittings etc.) meant that even when a property was identified at being of risk from flooding or overheating, the impact of the risk and ability of adaptations to reduce the risk couldn't be evaluated without a detailed property level survey being undertaken. Other social landlords should undertake a small pilot study to identify the types of climate change risks that they might face and the building level data that they might need to evaluate potential adaptations. This data should then be collected as part of their ongoing stock condition survey process.

4. **Setting strategic level thresholds and triggers is a sensitive issue.** Whilst Octavia had good guidance (through their Octavia Standard) on the performance levels that they expect from their housing stock, converting this guidance into strategic level thresholds that trigger inclusion of an adaptation into their built asset management plans was more difficult than had originally been considered. This was particular difficult for flooding. Octavia have a number of basement flats currently at risk from pluvial flooding. Whilst the initial approach to adaptation was to make these properties resistant to flooding, it became clear through the study that such adaptations would be uneconomical

to achieve (e.g. a number of basements flats are parts of tenements where Octavia doesn't own adjacent units). As such the threshold for these properties was to allow them to flood but improve their resilience to speed up recovery. Octavia are aware that they will have to work closely with tenants in the potentially at risk properties to explain how they will support tenants through a flooding event. This includes providing support to protect valuable items and having robust relocation plans in place.

5. **Don't ignore operational adaptation measures.** Not all adaptations to climate change are technical. Throughout this project it became apparent that a number of operational adaptations could be developed at little cost to Octavia that would help their tenants adapt to the impact of future climate change. Working with tenants to develop personal flood plans; providing guidance on how to stay safe during a heatwave; and exploring behaviour change interventions on the use of the home are all adaptations that should be integrated into an adaptation strategy

### *4.6 Decision making processes and best ways to implement adaptation recommendations*

This activity was fundamental to this project and has been presented throughout the report. Octavia have identified immediate actions that need to be addressed and will continue to monitor the performance of all their properties as part of their routine stock condition survey process.

Every year Octavia reviews its built Asset Management Strategy, the strategy review helps to inform the Business Plan financial forecasts, in the short term; the annual budget, medium term; the 5 year plan and long term; the 30 year Business Plan forecast. This project was able to influence the business plan, initialling a small budget which has been included in the 2013/14 Planned Work Programme for undertaking some adaptation work.

At an operational level, at the point at which a property becomes void an assessment will be made of its vulnerability and resilience to pluvial flooding and overheating and, if appropriate, adaptation options will be reviewed. If the adaptations are cost effective they will be programmed as part of general refurbishment.

The following points of future action have arisen as a consequence of this project.

Octavia will undertake a full stock risk evaluation against pluvial flooding now that London wide maps are publicly available.

For high risk properties, Octavia will undertake a full evaluation of the impacts of a flood on each property.

Octavia will evaluate the potential short-term accommodation (bed-and-breakfast) that would be available to them in the case of widespread flooding and integrate this into their business continuity planning.

Octavia will seek advice from their insurers as to the financial process (particularly timescales) that would be available to them should large-scale relocation of tenants be required.

Octavia will develop a mechanism to assess social vulnerability and to map socially vulnerable households against flood vulnerable properties.

Octavia will assess the preparedness of tenants to a flooding event in a way that does not imply that an event is imminent and that seeks to understand the level of insurance cover currently carried by tenants. This should be coupled to a tenant awareness campaign.

Octavia will seek to raise awareness of flooding amongst key managers to ensure a coordinated approach to climate change adaptation which crosses all departments and informs all maintenance, refurbishment and new build decisions. This involves internal training workshops.

Octavia will examine the impact of heat waves in more detail when reliable predictions become available.

Finally, the Adaptation Strategy has identified the fact that the likelihood of a flooding event happening to the 129 properties identified in the research is greater than the immediate likelihood of overheating in homes. This will be integrated in Octavia's 2014 Action Plan.

When the Asset Management Strategy is next produced the need for resources to undertake further detailed surveys as identified in the Action Plan can be prioritised. At the same time it will be possible to identify the funding required in the short and long term to address properties considered at risk.

The Octavia's Asset Management Team plan to undertake a pilot project to a high risk property which will enable a detailed cost/benefit analysis to be undertaken in order to determine the approach, and funding required to address 129 properties at high risk of flooding.

Resources required will include the need for a communication strategy with residents in high risk properties and assistance in preparing Personal Action Plans.

### *4.7 Recommended Resources*

The sources for all external toolkits and reference material used in this project are listed as footnotes. All the toolkits developed by this project are either described in detail in the body of the report or are given the Appendix 5.

# 5. EXTENDING ADAPTATION TO OTHER BUILDINGS

### *5.1 How this strategy may be applied to other buildings and projects*

This project did not examine the impact of climate change on a single domestic building, but on a portfolio of domestic buildings owned and managed by a UK RSL. As such the techniques, adaption solutions and approach to built asset management developed in this project should be applicable to all other UK RSL's. This said, the issues about reliable future climate risk data must be addressed, and an acceptable set of future climate impact scenarios (particularly for flood risk and overheating) must be developed before this work can realistically take place.

The project integrated a performance based built asset management model with a 4 phase adaptation framework to produce an approach by which a 30 year adaptation strategy could be developed. This approach could be applied to all 4 million social housing units in the UK. Table 5.1 provides a 10 step checklist for developing such an adaptation strategy. All the tools required to develop the adaptation strategy are explained earlier in this report.

| Step | | Actions (lessons from this study) |
|---|---|---|
| 1 | Identify current climate related threats to your stock | Identify known (current and past) climate impacts for your area.<br>Examine local histories for details of climate related impacts;<br>Review local flood risk assessments;<br>Review national flood risk assessments;<br>Review local heat wave assessments;<br>Review local authority adaptation plans;<br>Review incidence of extreme weather events. |
| 2 | Develop future climate impacts scenarios that are relevant to your circumstances | Identify future climate impacts change predictions for your area<br>Review Environment Agency climate change assessments<br>Review DEFRA climate change assessments;<br>Review UKCIP Scenarios;<br>Develop specific impact scenarios that are relevant to your building stock<br>Flood scenarios;<br>Heat wave scenarios;<br>Extreme weather events scenarios;<br>Supplement the above with future weather files using the UKCP09 Weather Generator (if appropriate). |
| 3 | Map current and future climate threats to your property portfolio | Examine known vulnerabilities of your stock to the key weather impacts<br>Map the location of each of your properties onto current and future flood risk maps;<br>Identify the numbers of properties at risk and the level of the risk (e.g. flood type, flood depth, flood duration etc.);<br>Map the location of each of your properties against current and future heat waves; |

| | | |
|---|---|---|
| 9 | | Identify the numbers of properties at risk and the level of the risk (e.g. external temperature profiles etc.);<br>Review the ability of existing disaster planning to cope with any increased incidence of extreme weather events. |
| 4 | Identify the coping capacity of your properties to current and future climate threats | Assess the impact that a climate related event would have on your property portfolio<br>Identify typical property archetypes for flood impact assessments<br>By access to existing building data, or through the use of building surveys, assess the likelihood of water ingress into a property and the coping capacity of the property to recover following a flood event;<br>Develop organisation specific vulnerability and coping capacity thresholds for each property archetype;<br>For those properties at risk of flooding, plot their vulnerability and coping capacity onto an Impact Grid.<br>Identify typical property archetypes for overheating impact assessments<br>By access to existing building data, or through the use of building surveys, assess the impact of a heat wave on the internal temperature profile of each archetype;<br>Develop organisation specific vulnerability and coping capacity thresholds for each property archetype;<br>For those properties at risk of overheating, plot their vulnerability and coping capacity onto an Impact Grid. |
| 5 | Identify possible adaptation solutions | Identify appropriate flood resistant and resilience measures;<br>Examine the technical feasibility of retrofitting such measures.<br>Identify appropriate overheating adaptations;<br>Examine the technical feasibility of retrofitting such measures;<br>Consider the use of thermal modelling of properties. |
| 6 | Articulate required improvements to the performance of your properties | Identify performance expectations for your properties against each climate change impact. For example,<br>Let properties flood and ensure rapid recovery; or<br>Prevent water ingress where ever possible; or<br>Ensure at least one room in every property does not over heat; etc. |
| 7 | Identify priorities | Develop priority thresholds based on the performance expectations identified in step 6<br>What types of adaptation should occur in years 1-5?<br>What types of adaptation should occur in years 6-10?<br>What types of adaptation should occur in year 11-30? |
| 8 | Develop adaptation strategy | Identify the actions to be taken for each vulnerable property archetype<br>Address known issues in year 1;<br>Gather missing data for high risk properties in year 1-5;<br>Monitor performance of medium risk properties in years 6-30;<br>Gather missing data for the rest of your stock as part of your next stock condition survey. |
| 9 | Prepare adaptation | Identify those properties requiring action in years 1-5. |

| | | |
|---|---|---|
| | plan | Undertake detailed (property level) assessments of the potential for different adaptation solutions to achieve the performance improvements identified in step 6<br>Cost each solution and select appropriate ones for inclusion in the adaptation plan.<br>Develop an adaptation programme for the works over a 5 year period. |
| 10 | Implement and test plan | Monitor effectiveness of interventions and close feedback loop<br>If you experience a climate related event how well did your plans work?<br>If you don't experience an event then test your plans against a simulation.<br>Review the effectiveness of your Disaster Management and Contingency Plans |

*Table 5.1 10 step check list to developing an adaptation strategy*

### *5.2 Limitations of cross application*

Risk profiling of an RSL's stock is dependent on building information as well as climate risk data. With the increasing production of local authority flood mapping (with or without climate change) we can expect qualified (with several layers of caveats) and climate risk information to be generally available to the RSL sector soon. It is less clear when heat wave data will be widely available across the UK. However, even with increasing access to climate related data, most RSLs will lack the building specific data associated with their stock to support effective management decision making. Specifically built asset management databases, do have not generally contain an appropriate level of data to support the identification of: properties at risk from climate impacts; the consequence of climate risks on the performance of properties; the development, costing and prioritising of adaptation solutions; or the programming of adaptations as part of the built asset management plans. RSL's should run a series of contingency planning scenarios against flooding and overheating to test the ability of their asset management databases to support adaption planning.

### *5.3 Analysis of the buildings that might be suitable for further application*

In 2011-12 there were approximately 4 million homes in the social rented sector, constituting 17% of all households and split roughly evenly between Local Authority's and the Registered Social Landlords. The outputs from this project should be applicable across the whole of the UK social housing sector.

### *5.4 Resources and tools developed for future adaptation services*

The project developed a number of tools which could be used to develop future adaptation services including:
A geo-referencing method using GIS software to identify 'at risk' properties;

A risk profiling method based on a Risk Assessment Framework and performance based built asset management planning;
A range of survey tools to assess the impact of climate change of building performance.

### *5.5 Further needs*

The most pressing need to emerge from this project is for UK wide climate change impact models to support organisations develop adaptations strategies for buildings located across a wide spatial scale. Translating the climate change models onto weather impacts that affect a portfolio of building is beyond the scope of most social landlords and as such needs to be addressed at a national level if realistic adaptation plans for the 4 million social housing units in the UK are to be developed.

UK social landlords need to identify the additional data they require to assess the impact of climate change on the performance of their properties and assess the suitability of adaptations to address any performance gap. Once identified, this data should be collected as part of their ongoing stock condition survey process.

Their development and application are described throughout this report. If you require further information of any of these please contact Mr Noel Brosnan (Noel.Brosnan@octavia.org.uk) or Professor Keith Jones (k.g.jones@gre.ac.uk)

### *References*

All references are given as footnotes throughout the report.