MODELLING CLIMATE CHANGE ADAPTATION MEASURES TO REDUCE OVERHEATING RISK IN EXISTING DWELLINGS

Rachel Capon and Jake Hacker
Arup, 13 Fitzroy Street, London W1T 4BQ

ABSTRACT

Overheating during hot summers is a major risk which will increase under climate change. Thermal dynamic modelling is used to compare the current overheating risk of typical residential properties in the UK with the future overheating risk for the middle decades of this century, i.e. the period 2040-2069. A wide range of passive and low-energy climate change adaptation measures - which could be retrofitted to existing dwellings to alleviate overheating - have been modelled and a package of adaptation measures recommended and costed.
For comparison purposes, the mal-adaptation option of installing air-conditioning is also examined.

INTRODUCTION

Overheating as a local impact of climate change is not well understood. Projections suggest that by 2050, a hot summer - like that of 2003, when temperatures exceeded 38°C - will occur every other year. During prolonged periods of high temperatures, heat stress becomes a major cause of increased morbidity and mortality of vulnerable populations, especially the elderly, the very young and those in poor health. In London, around 600 excess deaths were attributed to the 2003 heat wave, with 2000 deaths across the UK.

This work formed part of a research study, undertaken for a consortium of Regional Climate Change Partnerships in London and the South-East of England (Three Regions Climate Change Group, 2008), which examined the effect of three key Climate Change impacts – flooding, water stress and overheating - on existing residential dwellings. Suitable adaptation measures which could be retrofitted to deal with these risks were proposed. Two prevalent types of existing dwellings were considered; semi-detached owner-occupied houses and rented medium-rise flats. In the latter case, two scenarios were considered: that of a tenant, who would have limited scope and means for adaptation of their own flat and that of a landlord, who would undertake refurbishment of the whole block.

Thermal dynamic modelling was used to compare the current overheating risk of these properties with the future overheating risk for the middle decades of this century, i.e. the period 2040-2069. Building overheating could be ameliorated by the widespread installation of air-conditioning systems. However, this should be considered a mal-adaptation to climate change, as the associated energy use will generate CO_2 emissions which will further exacerbate global warming. The main focus of this study was to consider a wide range of passive and low-energy climate change adaptation measures, as an alternative to air-conditioning.

The simulations carried out illustrate that a combination of passive and low-energy methods can provide very effective protection against future overheating risk. Indicative costings have been provided. Using the model results, the initial capital costs for passive adaptation can be compared to the life-cycle costs of air-conditioning (installation, running and maintenance and carbon emissions).

BUILDING TYPES MODELLED

House

The house is a typical two-storey semi-detached property of the 1930s or 1950s, with brick masonry construction and external cavity walls. The ground floor is suspended and has wooden floorboards. (This is typical of the 1930s; by the 1950s, solid concrete floors were more widespread). The ceilings are constructed using timber joists, with wooden floorboards on the first floor. All floors are carpeted. The roof space has 100 mm of glass-fibre quilt loft insulation; the roof is clay tiles.The original windows are still intact with single glazing and timber frames. In order to represent the worst-case scenario, the house has a south-west orientation, with both the main living room and master bedroom at the front of the house.

It is assumed that the house is occupied by a family of two adults and three young children. It is fully occupied at night and partly occupied during the day. It is therefore assumed that the bedroom is occupied at night, from 10 p.m. to 7 a.m., whereas the living room is at least partly occupied throughout the day, from 9 a.m. until 10 p.m.

Flat/Block of Flats

The flats are part of a typical medium-rise block, constructed in the 1960s or 1970s, with a masonry construction of medium-weight concrete blocks. The external walls have an outer brick skin and a 50 mm cavity The walls internal to each flat are lightweight stud partitions. The ground floor is solid heavyweight cast concrete, whereas the ceilings are constructed using timber joists, with chipboard on the higher floors. All floors are carpeted. The block has an asphalt-covered flat roof; a “cold roof” construction with only 50 mm glass fibre quilt insulation below a ventilated cavity. There is single glazing throughout. The living room and kitchen face south-west. Both bedrooms are on the opposite side of the building and face north-east.

Two adults share each flat. It is unoccupied during the day, except at the weekends. The bedrooms may be used for part of the evening for personal entertainment or use of a home PC, as well as being used for sleeping at night.

MODELLING METHODOLOGY FOR OVERHEATING

Thermal Comfort and Overheating

Heat may enter into a dwelling via several mechanisms. Internal heat gains originate from people, lights and other electrical appliances. Typical appliances and usage profiles, e.g. for a TV in the living room, are included in the overheating model. The main external source of heat gain is solar radiation incident on the external surfaces of the dwelling. This may either transmitted through the window glass or absorbed by and conducted through the building fabric. No building is completely airtight; there will be a background rate of external air infiltration. Ventilation with fresh air is also essential. Nonetheless, if the external temperature exceeds the internal air temperature, air infiltration and ventilation will heat up the space.

Thermal Modelling

Simulating these thermal processes is a complex problem. The combined effect of different adaptation measures is not necessarily equal to the sum of their individual impacts. Hence - in addition to the base cases - the proposed adaptation measures were modelled both individually and in combination. The use of air-conditioning for comfort cooling and to prevent overheating was also simulated.

The modelling was carried out using the OASYS ROOM suite of software. This is a single cell dynamic thermal model, which calculates the unsteady heat flows within the building fabric for a single room. The model is forced using CIBSE weather year data, which includes external temperatures, winds and incident solar radiation. The long-wave radiant heat flows are calculated separately from short-wave radiation. Solar gains are calculated using standard optical theory and distributed over the room surfaces according to the relative positions of sun, surface and windows. Natural ventilation, both buoyancy and wind-driven, is also calculated within the program.

Current and Future Weather Data

The assessment has been carried out using the current CIBSE Design Summer Year (DSY) for London (1989) and a CIBSE future weather year for the 2050s, i.e. a version of the DSY adjusted in line with the UKCIP02 climate change projections for London under the Medium-High emissions scenario for the 2050s timeslice (CIBSE, 2009). It has peak temperatures similar to those experienced in south-east England in summer 2003 (Figure 1). The London DSY data is from Heathrow airport which has a peak urban heat island intensity of around half that of central London. In the present study, only the hottest month, July has been modelled.

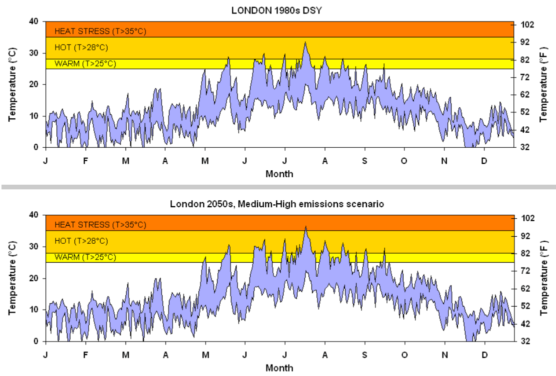

Figure 1 Temperature ranges for London for current DSY (1989) and future DSY for the 2050s under the Medium-High emissions scenario

Quantifying Overheating

Three different measures of quantifying overheating have been used, two of which are presented in the individual case studies below. The first is the percentage of occupied hours for which the comfort and overheating threshold temperatures are exceeded during the month of July. This enables comparison with the CIBSE criteria. The second measure is the cooling degree hours (CDH) above the CIBSE comfort temperature for July. The final measure is the peak occupied temperature during the month.

ADAPTATION MEASURES MODELLED

Solar Control

All solar control measures work by reducing the solar heat gain transmitted into a dwelling through the windows. In general, external measures are more effective than internal ones, as they block the solar radiation before it is transmitted through the window glass. The following measures were modelled.

- Internal reflecting blind/curtains – ventilated by open window. If internal blinds are used, the amount of sunlight transmitted through the glass is not reduced. Heat therefore builds up between the window and the blind. A considerable portion of this heat will penetrate into the room, especially if the window is closed. Opening or ventilating the window allows some of this heat gain to be removed to the exterior.

- External Awning – An awning provides complete shading of the window when the sun is directly overhead. A Dutch awning has been modelled. In this design, the enclosed sides of the awning also provide additional shading when the sun is incident at other angles. An advantage of an awning is that the view out of the dwelling is only partially obscured and ventilation through the windows is not obstructed.
- External Shutters – These are a very effective means of solar control, although they obscure the external view for the occupants and can restrict ventilation through the windows. These considerations may be less relevant, if the building is unoccupied during the day. As an added benefit, the shutters could be constructed so that they provide increased security to a residential building.

Both Awnings and Shutters have the advantage that they can be retracted when not required, for example in winter or overnight.

Natural Ventilation

Natural ventilation is an important mechanism for reducing overheating. It is particularly beneficial to provide night purge ventilation in order to expunge internal air which has heated up during the day and replace it with cooler external air. Night purge ventilation also removes stored heat from any exposed thermal mass. During the day, if the external air temperature exceeds the internal temperature, it is better to close the windows.

Natural ventilation can be driven by two mechanisms: external wind and/or air buoyancy. In the latter case, hot air rises and is expelled at high level with cooler air being drawn in at low level. Meteorologically, overheating is usually associated with calm anticyclonic conditions. Therefore only buoyancy-driven ventilation has been considered in this study.

Occupants frequently open windows for ventilation before internal temperatures exceed comfort levels. For the base case, it is assumed that the existing side-hung casements are maximally opened during occupied hours once the internal temperature exceeds a threshold of three degrees below the CIBSE comfort temperature, i.e. 20 °C and 22 °C for bedrooms and living areas respectively. In the adapted house, the windows are opened in the same manner, but they are closed again by the occupants whenever the external air temperature exceeds the internal temperature.

Where windows are replaced with double glazing as part of a retrofit adaptation, these should be designed to maximise buoyancy-driven natural ventilation. The ventilation rate depends upon both the effective area of the openings and their separation. Higher ventilation rates are achieved by using vertically separated lower and upper openings, rather than a single opening. Consequently, in all replacement windows, a vertical sash design - for which the effective area of the openings is 25% of the window area and the separation distance 75% of the window height - has been used.

In practice, security concerns may prevent the optimum use of the windows for natural ventilation, e.g. at night. Additional window security measures may be needed or desired, but these lie outside the scope of this study and have not been costed.

Enhanced Air Movement

Ceiling or desk fans may be used to provide relief from overheating. Rather than reducing the actual heat gains and temperature inside a room, they have a physiological “wind-chill” effect. This effect is equivalent to around a 2°C drop in operative temperature inside the room (CIBSE Guide A). The effect of fans is not simulated by the model, but the 2°C temperature difference has been subtracted a posteriori from the model output.

Floor Coverings

On the ground floor, the temperature of the floor fabric depends upon the temperature of the underlying soil, which is considerably lower than the external air temperature during the summer months. In addition, a solid, e.g. concrete, floor has considerable thermal mass which is capable of absorbing excess heat from the room. Carpet insulates the room from these combined cooling effects of the floor, unlike other floor coverings such as wood or wooden laminates.

Roof: Improve Roof Insulation Standard

The house has a pitched roof. Increasing the amount of insulation in the loft reduces the heat transmission through the roof. Consequently the first-floor bedroom is marginally cooler during the day, but also stays marginally warmer at night.

The block of flats has a flat roof with very poor thermal performance, leading to serious overheating in the top-floor dwellings. In order to improve its performance, a complete upgrade of the roof is required. Here, the upgrade considered is a “warm roof” construction consisting of a 25 mm unventilated cavity, 200 mm of polyurethane board to provide improved insulation, a layer of roofing felt and a layer of asphalt painted in a light colour to improve the reflectivity of the roof surface.

Façade Upgrade: Reflectivity of External Walls

The reflectivity of the external walls can be increased by painting the brickwork in a light colour or applying a light-coloured render, reducing the amount of solar radiation absorbed by the walls. This may increase solar glare in the exterior space, although this could be mitigated by planting of trees or other vegetation, (which have additional benefits for reducing overheating).

Façade Upgrade: Improve Wall Insulation

Where wall cavities are present, cavity wall insulation is possible. For maximum benefit, it should be combined with natural ventilation to purge heat from the building at night. Otherwise, heat may be retained in the building for longer, making it warmer rather than cooler.

Fenestration Upgrade: Double Glazing with low e coatings

Replacing the existing single glazing with double glazing improves the thermal insulation of the windows. Low-emissivity coatings on the inside pane also help prevent internal heat from being lost through the glass. In general, replacement double glazing will also be more air-tight than the original single glazing.

Hence, installing replacement double glazing has an insulating effect. Without a natural ventilation strategy it is not necessarily beneficial in combating overheating.

If replacement double glazing is combined with natural ventilation through open windows – as in the base case and assuming the effective area for ventilation is unchanged - the overall effect is beneficial. Night ventilation allows the room to cool as much overnight as with the original glazing. The improved insulation of the replacement double glazing then keeps the room cooler during the day. If suitably designed, replacement double glazing can also offer an improvement in natural ventilation rates. This allows a greater degree of cooling by night purge ventilation, thus further reducing the peak day time temperature.

It is essential that if replacement double glazing is fitted, the potential natural ventilation rates are not decreased. Rather, the new windows should be designed to maximise the potential for natural ventilation and night purging.

Fenestration Upgrade: Secondary Double Glazing

If the existing windows have a deep reveal, double glazing can be installed set back behind the existing single glazing. A reflective blind is positioned between the existing single glazing and the new double glazing and ventilated by opening the single glazing (Figure 2). The blind reduces the amount of sunlight transmitted through the secondary double glazing. Ventilating the blind also reduces the heat gain in the space between the existing glazing and the secondary glazing. The secondary double glazing also has an insulating effect.

This is the most effective fenestration upgrade mechanism, offering greater improvement than either double glazing or an internal ventilated blind alone, (not taking into account the possibility of improved natural ventilation with replacement double glazing). It is still less effective than external shading measures.

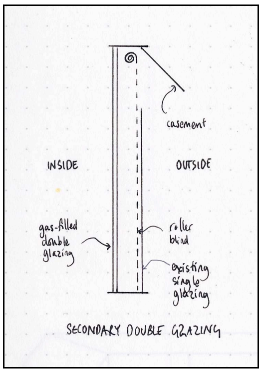

Figure 2 Secondary Double Glazing

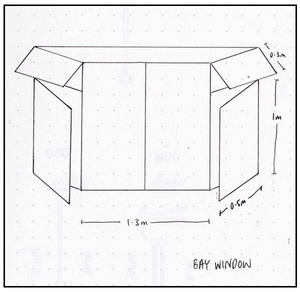

Figure 3 Existing house casements

Other Measures

Other measures could be considered appropriate for climate change adaptation, for example, the use of trees to provide shading and increase the moisture content of the air, mechanical systems to increase the rate of night-purge ventilation and the use of solar control coatings on replacement glazing. However these are outside the scope of this study.

HOUSE SIMULATION RESULTS

For the house, the ground floor reception room and the master bedroom on the first floor were modelled. Both these rooms are orientated to the South-West and thus at greatest risk of overheating.

Individual and Combined Adaptation Measures

Figure 4 shows July CDH for natural ventilation, double glazing and solar control options for the house living room. The Basic Nat Vent option ventilates the room through the existing casements, (shown in *Figure 3*), but without closing the windows if the external temperature exceeds the internal temperature. This reduces the number of cooling degree hours by ca 55%. If used in combination with solar control measures, e.g. an external awning, a greater reduction in cooling degree hours is obtained than by using either measure alone.

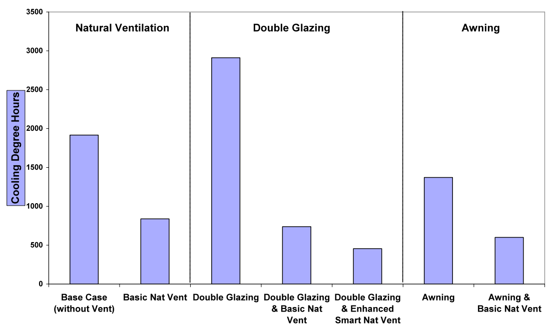

Figure 4 July CDH for house living room

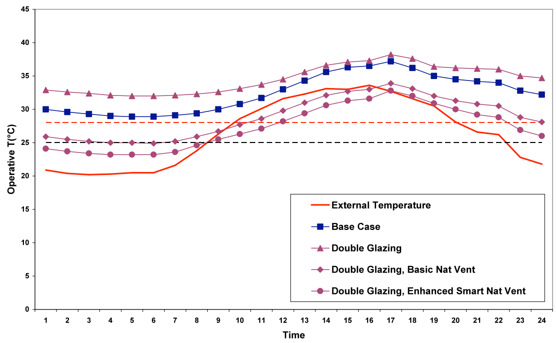

Figure 5 Operative Temperature profiles for the hottest day for house living room

By contrast, insulation measures – such as double glazing - used in isolation appear to make the situation worse; more heat is retained within the building at night. However, used in combination with natural ventilation strategies, they do provide protection against overheating. As hot air and heat stored in the thermal mass are expunged from the building overnight, the interior temperature is lower at the beginning of the day. (Figure 5 shows the operative Temperature profile in the house living room for the hottest day of the year). The insulation then prevents the building from heating up as much during the course of the day. If replacement low-e double glazing is fitted without any ventilation strategy, the July CDH increase by 50% over the base case. When double glazing is combined with the Basic Nat Vent strategy, July CDH are reduced by 60%. If, in addition, the replacement windows are designed to increase ventilation rates (Enhanced Nat Vent) *and* the windows are closed if it gets hotter outside than inside (Smart Nat Vent), the reduction in July CDH rises to 75%.

Recommended Retrofitting Adaptations

The combination of retrofitting adaptations recommended for the house is given in Table 1 together with indicative costs. (For the roof insulation, it is assumed that adequate loft access, e.g. through a hatch, already exists.)

Air Conditioning

The installations costs for a split system serving the whole house are £2500.

The air-conditioning was set to cool whenever the operative temperature in the room exceeded the CIBSE comfort temperatures (25 °C for the living room, 23 °C for the bedroom) during occupied hours. The total power consumption (calculated from the model cooling load output assuming a system Coefficient of Performance of 2.5) for the month of July is shown in Figure 7. This is converted into annual electricity costs at current prices (BERR 2008, London Direct Debit) and into CO_2 emissions (DEFRA, 2008) in Table 2. No adjustment has been made for future changes in electricity prices.

Table 1 Indicative Costs of Adaptation Measures recommended for the house

MEASURE	COST
External Solar Control: Awnings on SW facade.	**£1700**
Natural Ventilation Basic, Enhanced (improved window design).	**NO COST** for existing windows Cost included in fenestration upgrade.
Enhance air movement: install ceiling fans (DIY installation).	**£300**
Floor coverings: replace carpets with wooden floor on ground floor.	**£2100**
Roof: improve roof insulation standard.	**£2700**
Façade upgrade: Increase reflectivity through wall painting/coatings.	**£3700**
Façade upgrade: cavity insulation where wall cavities are present.	**£5000**
Fenestration upgrade: replace single glazing with double glazing, with low-e coatings.	**£5000**
GRAND TOTAL	**£20500**

Table 2 Annual Electricity Costs and CO_2 Emissions for Air-Conditioned House

Annual	ELECTRICITY	CO_2 kg
NOW	£81	385
2050s	£125	591

The actual power consumption depends on the efficiency of the air conditioning equipment. Furthermore, in practice, many occupants may choose a lower set-point for their air-conditioning systems, which would result in increased power consumption compared to the figures shown.

Benefits of Adaptation

Figure 6 shows the percentage of occupied hours for which the CIBSE comfort and overheating temperatures are exceeded for the month of July for the living room. All figures show the control or base case, the adapted house and the house adapted using air-conditioning, for both the present day and the 2050s. Figure 7 shows the number of cooling degree hours for July in the living room. The total power consumption for cooling by means of air-conditioning is also shown. This should be regarded as a minimum value; in practice occupants may choose a lower cooling set-point resulting in higher power consumption.

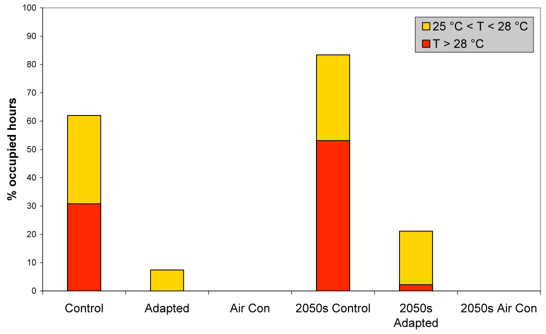

Figure 6 House Living Room: Percentage of July occupied hours exceeding CIBSE comfort temperature, 25 °C is shown by total size of bars. Hours during which the CIBSE overheating temperature, 28 °C, is exceeded are shown in red.

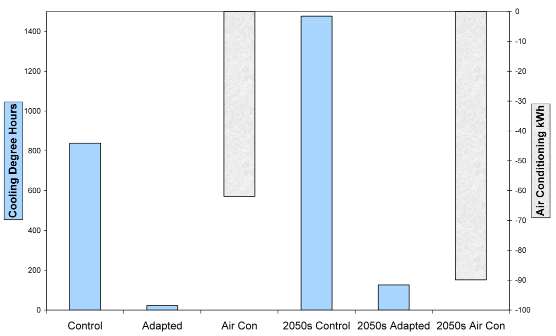

Figure 7 House Living Room: July CDH. The right hand axis shows air conditioning power consumption (in kWh) required to control overheating in the air conditioned cases.

In the control case, it has been assumed that the occupants open the windows once the internal temperature exceeds 20°C in the bedroom, 22°C in the living room. Nevertheless, during July, the CIBSE overheating temperature is exceeded for over 30% of occupied hours in the living room and over 6% of occupied hours in the bedroom. By the 2050s, the expected July exceedance is more than 50% of occupied hours in the living room and over 20% in the bedroom. The CIBSE *comfort* temperatures are exceeded for 62% of occupied hours in the living room, 28% in the bedroom, rising by the 2050s to 83% and 53% respectively. The corresponding July CDH are 839 for the living room, 161 for the bedroom, rising by the 2050s to 1477 and 405 respectively.

By retrofitting the recommended package of adaptations, the CIBSE overheating temperature is never exceeded in the current climate. In the 2050s, it is predicted that, during July, the overheating temperature will be exceeded for 2.2% of occupied hours in the living room and 1.1% of occupied hours in the bedroom. CIBSE recommend that the overheating temperatures should not be exceeded for more than 1% of *annual* occupied hours. Given that July is the hottest month of the design summer year and that overheating is not anticipated in the winter months, it is reasonable to assume that the adapted house satisfies the CIBSE overheating criteria and will continue to do so well into the current century.

Adapting the house causes a dramatic reduction in the number of cooling degree hours above the CIBSE comfort temperature, to 23 hours for the living room and less than 6 cooling degree hours for the bedroom in the current climate. This corresponds to a 97% reduction in cooling degree hours for both rooms. In the 2050s, 126 cooling degree hours are predicted for the living room, 42 cooling degree hours for the bedroom, i.e. a reduction in cooling hours of over 90% compared to the un-adapted house.

Many of the recommended measures improve the insulation of the house and thus are also beneficial in reducing electricity costs and CO_2 emissions in winter. This reduction should also be taken into account when calculating the benefit obtained from the adaptation measures.

FLAT / BLOCK OF FLATS

For the flat, the main Reception room on the South-West side and Bedroom 1 on the North-East side were modelled for different floors. The top floor flat is considerably more prone to overheating. This is due to a combination of two factors; the poor thermal insulation properties of the roof lead to severe overheating in the top floor flat, whereas the solid concrete floor in the ground floor flat has a significant cooling effect.

Retrofitting Adaptations

The combination of retrofitting adaptations recommended for the individual flat is shown in Table 3, together with indicative costs.

Table 4 gives the same information for a larger scale retrofitting programme for the whole block of flats. In this case, cost information is given both per flat and for the entire block.

Note that the fenestration upgrade on the individual flat is only suitable for situations where existing deep window reveals allow set back of secondary glazing from outer pane. For the whole block, the cost estimate for ceiling fans assumes they are connected to the lighting circuit using existing wiring. If additional wiring is required, the cost is increased by 60%.

Air Conditioning

For the individual flats, it is assumed that the tenants use portable air-conditioning units at a cost of approximately £200 per unit. Three units would be required.

For the block retrofit, window units are fitted in each of the bedrooms and the main reception room. The installation cost is £2600 per flat, i.e. £41600 for the entire block.

Table 3 Indicative Costs of Adaptation Measures recommended for an individual flat.

MEASURE	COST
Internal Solar Control: reflecting blind or curtains ventilated by open window. On SW-façade.	**NO COST** if existing blind or curtains suitably reflective. Replacement blind prices vary. Cost included in secondary double glazing.
Natural Ventilation through windows.	**NO COST** for existing windows.
Enhance air movement: desk fans.	**£60**
Floor coverings: replace carpets with wooden floor on ground floor.	**£2800**
Fenestration upgrade on SW-facade: install roller blind and secondary double glazing behind existing glazing.	**£4700**
GRAND TOTAL	**£7560**

Benefits of Adaptation

Figure 8 shows the percentage of occupied hours for which the CIBSE comfort and overheating temperatures are exceeded for the month of July for the flat living room. Figure 9 shows July CDH, as well as the total power required for cooling via air-conditioning. All figures show the base case (including use of existing windows for natural ventilation), the adapted flat/block of flats and the flat adapted using air-conditioning, for both the present day and the 2050s and both ground floor and top floor flats. The top floor flat is most prone to overheating due to the poor thermal insulation properties of the roof, whereas the ground floor flat is significantly cooler due to cooling effect of the solid concrete floor.

In the control case, it has been assumed that the occupants open the windows once the internal temperature exceeds 20°C in the bedroom, 22°C in the living room. In the ground floor flats, the CIBSE overheating temperature is exceeded during July for over 17% of occupied hours in the living room and over 8% of occupied hours in the bedroom By the 2050s, this rises to more than 55% of occupied hours in the living room and 39% in the bedroom.

In the flats on higher floors the situation is worse. The CIBSE overheating temperature is exceeded during July for 39% of occupied hours for the living room and 14% of occupied hours for the bedroom on the top floor. By the 2050s, the expected exceedances are 67% of occupied hours in the living room and 41% in the bedroom. The CIBSE *comfort* temperatures are exceeded for 67% of occupied hours in the living room, 41% in the bedroom in the current design summer year, rising to 85% and 65% respectively of occupied hours by the 2050s.

Table 4 Indicative Costs of Adaptation Measures recommended for the block of flats.

MEASURE	COST/FLAT	TOTAL COST
Internal Solar Control: reflecting blind or curtains ventilated by open window.	**NO COST** if existing blind or curtains suitably reflective. Replacement blind prices vary.	
External Solar Control: Shutters.	**£2445**	**£39100**
Basic Natural Ventilation Enhanced Nat Vent (improved window design).	**NO COST** for existing windows. Cost included in fenestration upgrade.	
Enhance air movement: install ceiling fans.	**£950**	**£15200**
Roof: improve roof insulation standard.	**£1850**	**£29600**
Façade upgrade: Increase reflectivity through wall painting/coatings.	**£1500**	**£24000**
Façade upgrade: cavity insulation where wall cavities are present.	**£1855**	**£29700**
Fenestration upgrade: replace single glazing with low-e double glazing.	**£2575**	**£41200**
GRAND TOTAL	**£11175**	**£178800**

Benefits of Retrofitting an Individual Flat

By retrofitting the recommended package of adaptations for an individual flat, the CIBSE overheating temperature is never exceeded in the ground floor flat. For the top floor flat, the exceedances for July of the current DSY are reduced to 11% for the living room and below 1% for the bedroom. In the 2050s, it is predicted that, during July, the overheating temperature will be exceeded for 0% of occupied hours in the living room and 3% of occupied hours in the bedroom in the ground floor flat and for 26% in the living room, 8% in the bedroom in the top floor flat.

The summer thermal comfort can be improved by making retrofitting adaptations. It is difficult to eliminate overheating, particularly in higher level flats, without making adaptations to the external fabric.

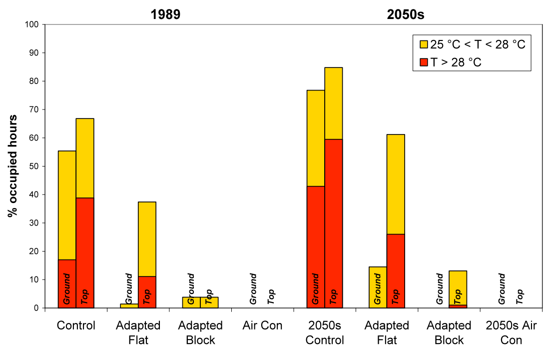

Figure 8 Living rooms in flats: Percentage of occupied hours exceeding CIBSE comfort temperature, 25 °C is shown by total size of bars. Hours during which the CIBSE overheating temperature, 28 °C, is exceeded, are shown in red.

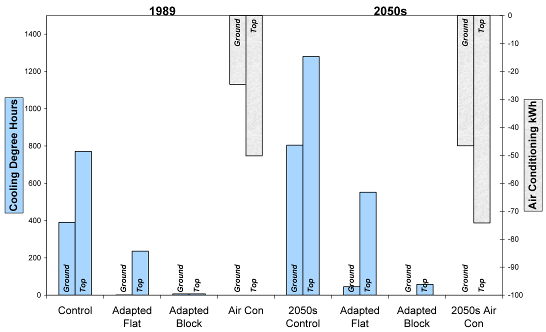

Figure 9 Flat Living Room: July CDH. The right hand axis shows air conditioning power consumption (in kWh) required to control overheating in the air-conditioned cases.

Benefits of Retrofitting the Block of Flats

By retrofitting the recommended package of adaptations for the whole block, the CIBSE overheating temperature is never exceeded in the current climate. In the 2050s, small exceedances of the overheating temperature are predicted for July; 0.4% for bedrooms in flats above the ground floor, 1% in the top floor living rooms. The CIBSE overheating criteria are fully satisfied for all properties in the adapted block, even in the warmer climate of the 2050s. Adapting the block of flats also decreases the number of cooling degree hours above the CIBSE comfort temperature by over 90% in all cases.

As for the house, many of the recommended measures are also beneficial in reducing electricity costs and CO_2 emissions in winter. This should be taken into account when considering the benefit obtained from the adaptation measures.

CONCLUSIONS

The response of three types of properties has been modelled for the hottest month of 1989, the CIBSE DSY and also for the morphed DSY, which represents a “hot” summer in the middle part of this century, the 2050s. For each property, various retrofitting adaptations were modelled. The combinations of adaptations recommended here were selected for their effectiveness, but subject also to the property type and the degree to which an owner or occupier might be prepared to invest in their property. The occupancy pattern also influences the choice of adaptations, e.g. awnings are recommended for the house as they do not restrict either the view or ventilations through windows to the same extent as external shutters would. For the flat only cheaper internal measures have been included in the case study, whereas for the house and the block of flats more comprehensive upgrades to the fabric of the building are recommended.

Using simple measures, such as natural ventilation for night purging, fans to increase air circulation and internal blinds, can be of considerable benefit. For the flat, they more than halve the number of cooling degree hours. Nevertheless, they alone are not sufficient. To eliminate overheating, adaptations must also be made to the fabric of the building. External shading in the form of awnings or shutters is essential, as is painting the exterior a light colour to reduce absorption of solar radiation, increasing the thermal insulation of the building and maximising the use of natural ventilation for night purging. The combination of measures recommended for the house or the block of flats is successful in eliminating overheating according the CIBSE criteria and reduces the July CDH by 90-100%, dramatically improving the internal comfort during the hottest months of the year.

REFERENCES

Three Regions Climate Change Group, 2008. Your Home in a Changing Climate: Retrofitting Existing Homes for Climate Change Impacts.

CIBSE, 2009. TM48: Use of Climate Change Scenarios for building simulation: The CIBSE future weather years.

BERR, 2008. Quarterly Energy Prices September 2008.

DEFRA, 2008. Act On CO_2 Calculator http://www.defra.gov.uk/environment/climatechange/uk/individual/actonco2/index.htm