Thermal comfort and control

Overall demand for space heating as a service has grown over the past three decades. Improved efficiency compensated for higher internal temperatures, higher levels of central heating and the heating of a larger part of the home, so that energy consumption per household remained more or less stable; but growth in household numbers meant that total energy demand for space heating rose by 36% between 1970 and 2001 (DTI 2004c). This chapter sets out some key considerations related to comfort and energy, in the present and for the future, setting the context for the discussion of the building fabric and low carbon heating options in later chapters.

4.1 Comfort, health and climate

In physiological terms, thermal comfort is what we experience when the body functions well, with a core temperature of around 37°C and skin temperature of 32-33°C. There are many ways of maintaining these body temperatures in a wide range of climates and this has been the case for centuries. If it were not so, large parts of the globe would be uninhabited. In the UK climate, comfort is a major consideration when considering the future demand for space heating and cooling, and the ways in which this can be met. There are interactions between climate, behaviour, building design and heating, cooling and insulation technologies.

The immediate challenge is to raise the level of energy efficiency in housing so that indoor warmth is sufficient for health and well-being in winter – ensuring that all households are adequately and affordably heated is a priority of current UK energy policy. As well as raising comfort levels, improving the energy efficiency of the housing stock provides cost, health and environmental benefits, both for individuals and society at large. The significant improvements required in the UK housing stock represent an opportunity to maximise these benefits for all. Once a safe level of thermal comfort for health has been reached, personal preferences will affect the extent to which improvements in residential energy efficiency are realised as energy savings, or lost because people live in larger homes, heat a larger proportion of their homes, and/or turn up their thermostats. Personal comfort preferences, and the technologies available for meeting them, will also determine how much the demand for artificial cooling is likely to grow between now and 2050, particularly given rising temperatures due to climate change.

4.1.1 Climate change

The United Kingdom Climate Impacts Programme has modelled four scenarios for future climate change (UKCIP 2002). A study of the potential impacts of climate change on human health notes the trend towards higher temperatures in all four scenarios and calculates that, without adaptation, there could be a rise to 2,800 heat-related deaths per year by the 2050s under a medium-high climate change scenario (Donaldson et al 2001). These would be accompanied by a fall in cold-related deaths in milder winters (assuming no disruption of the Gulf Stream), but are clearly a cause for concern. During the 2003 heat wave, it is estimated that approximately 2,000 excess deaths were caused in the UK (NS 2003b). Deaths peaked on the day after the highest temperatures were recorded. The elderly are most at risk from overheating, as from cold; and the highest risk is for those who live on their own (DEFRA 2004b, Rau 2004).

4.1.2 Policy approaches to comfort

Comfort is a complex issue which raises a number of policy considerations. Comfort conditions in general are socially influenced and may change with time as design, activity, technology and clothing fashions change (Shove 2003). However, the main question addressed here is the extent to which thermal comfort should be addressed by engineered solutions to the problem of maintaining a defined optimum temperature range in winter and summer (Fanger 1970, CIBSE 1999). This is a common approach in office buildings and could spread to homes.

The 2003 heatwave was good for some – but caused 2,000 excess deaths in the UK

The main alternative to this approach is to concentrate on getting the materials, design, location and shading of the building as suitable as possible for likely future climate conditions, while leaving it possible for residents to make themselves comfortable by adaptation that does not involve energy-intensive engineered solutions: shedding or adding clothes, altering thermostats, opening or closing doors and windows and being more or less active (Nicol and Humphreys 2002).

Decisions on the best course of action will depend on a number of factors, not least whether a building is being designed from scratch or adapted. Design of new buildings offers far more options for the use of natural ventilation, high quality insulation, high thermal mass and shading in order to avoid thermal discomfort.

4.2 Heating

People are normally sedentary for around two-thirds of their time at home (provided they are not immobile through disability), regardless of their age, or how much of each day they spend in the home (Boardman 1985). The World Health Organisation (WHO) recommends temperatures of 21°C for the main living area and 18°C for the rest of the home. The values recorded for living areas in the UK have so far been lower than this, although they are increasing. Winter conditions in 1986 and 1996 were comparable, and recorded temperatures in England show that living rooms were on average 0.9°C warmer in 1996, whilst hallways were 1.6°C warmer (DETR 2000).

4.2.1 Underheating

The 1996 English House Condition Survey (EHCS), using spot temperatures, found that 6.9 million homes (28%) had living rooms at or below 16°C, and 10.9 million (44%) had cold hallways (Table 4.1). Although around 80% of those interviewed claimed that they were satisfied with their home temperatures, the data show that many were

Table 4.1: Temperatures in homes and health effects, England. 1996

Indoor temperature (°C)	*Assumptions of physiological effect*	*Living rooms at these temperatures (million)*	*Halls/stairs at these temperatures (million)*
24+	Risk of strokes and heart attacks	0.4	0.3
21-24	Increasing discomfort	3.5	2.1
18-21	Comfortable temperatures	8.8	6.3
16-18	Discomfort, small health risk	4.1	4.6
12-16	Risk of respiratory diseases	2.5	4.7
9-12	Risk of strokes, heart attacks	0.2	0.9
< 9	Risk of hypothermia	0.1	0.7
Unhealthily cold (<12°C)		2.8	6.3
Total cold homes (<16°C)		6.9	10.9

Source: Richard Moore, pers. comm.   Note: Outside temperature 5°C or below living at temperatures that are associated with physiological discomfort and danger to health (DETR 2000). The national temperature survey has since been dropped from the EHCS, but it is important that this is reinstated if progress towards warmer, healthy homes is to be monitored and confirmed.

Mortality in the UK rises on either side of an outdoor temperature of approximately 16-19°C (Donaldson et al 2001). Low temperatures are the most hazardous to health, with England and Wales having excess mortality of 23,500 during the winter of December 2003 – March 2004 (NS 2004c). This was a relatively low figure: the average for the previous eight years was 35,220. The UK has one of the highest levels of excess winter mortality in northern Europe and housing conditions are a contributory factor (Boardman 1991, Wilkinson et al 2001). Elderly people spend a higher proportion of their lives at home, so they need to be able to afford to heat it for longer hours. They are more likely to suffer from 'cold strain' than the young, so that even short periods of cold stress may damage their cardiovascular and respiratory systems (Healy and Clinch 2002).

An evaluation of the Warm Front/HEES programme, the main initiative to lessen fuel poverty in vulnerable households for owner-occupied and privately rented housing, shows that temperatures in the homes of the fuel poor are now rising, although those in extreme fuel poverty are not gaining much as yet (Sefton 2004). There is therefore still a large hidden demand for heating and many people are still at risk of death or disease, as well as enduring discomfort and distress from cold homes in winter.

4.2.2 Comfort factors

The percentage of potential energy savings that are taken as improved comfort is known as the 'comfort factor'. This has to be taken into account when estimating the effect of improvements to the housing stock. 'Warm Front' allows for up to 75% of theoretical savings to be taken as comfort. The comfort factor in the Energy Efficiency Standards of Performance (EESoP) programme of efficiency improvements was found to be 55% for 'disadvantaged' customers (Henderson et al 2003). The best general estimate available is that 80% of potential energy savings from efficiency improvements in housing will be taken as savings, once the average temperature has risen above 19°C, with only 20% of the potential savings taken in the form of further energy consumption or 'takeback' (Milne and Boardman 2000).

4.2.3 Model assumptions – heating

Under the 40% House scenario it is assumed that there will be adequate, affordable heating for all in line with the Government's legal obligation to eliminate fuel poverty by 2016. In the short term, there may be a further increase in emissions if the fuel poor become able to achieve higher indoor temperatures through higher incomes or benefits. This will be more easily achieved, with less of an energy penalty, as homes become more efficient and better at retaining heat.

Whilst the requirement to meet basic physiological needs and to do away with fuel poverty can be addressed in a relatively straightforward way, it remains difficult to describe, evaluate and prescribe for thermal comfort, or to predict the temperature beyond which all efficiency gains will be taken as energy savings. The 40% House scenario assumes 24-hour averages of 21°C for the living room and 18°C for the rest of the dwelling in line with WHO recommendations. These are on the high side for all-day averages, but allow for higher living room temperatures than 21°C for the elderly during the daytime, along with factors such as the use of bedrooms for homework.

4.3 Cooling

Adequate heating is the main issue in the short term, but cooling is likely to become an increasingly important issue over the coming years with rising global temperatures. Therefore, at the same time as improving the energy

Shading over windows could reduce the need for energy intensive air-conditioning units

efficiency of the housing stock, it is essential that cooling needs are taken into account in design, construction and refurbishment to avoid intensive energy demand for cooling in the future. Some of the solutions will overlap – for example, improved insulation is also important for keeping homes cooler in summer, especially in attic rooms.

It is estimated that 70-90% of energy decisions are made at the 'concept' stage of a building, which will go on to affect the behaviour of the people who use it (Chappells and Shove 2004). The commercial pressure to design for air-conditioning can be powerful, bringing more energy-intensive behavioural change in its wake: during the 1950s, the USA summer 'comfort zone' became cooler than the winter comfort zone of 20.5-26.7°C, as people became able to control indoor temperatures and wanted to achieve a contrast with the weather outside (Ackermann 2002). Eighty-three percent of US homes are now air-conditioned (Ackermann 2002) and sales of air conditioning are rising in the UK, especially during heat waves. Cooling existing buildings during heat waves, especially in dense urban developments, is likely to pose a challenge without air-conditioning, although there is scope for retrofitting with shading and shutters. This could be grant-aided, just as heating efficiency measures are now.

Although the use of air-conditioning in the UK is modest at present, ownership could rise steeply if temperatures were a few degrees higher and if people were to be in a position to switch on air-conditioning rather than using other methods to keep cool. Outdoor summer temperatures in the south of the UK are now occasionally close to the American threshold for air-conditioning (Levermore et al 2004), although European householders show less inclination to purchase air-conditioning at a given outdoor temperature than those in the USA. This is partly because of the higher average thermal mass of dwellings and differences in humidity. Southern European housing designs are therefore likely to provide better models for housing in a warmer UK than those from America.

There is a danger that climate change will contribute to continued growth of a market for air-conditioning, resulting in a destructive positive-feedback cycle of hot summers that increase a demand for fossil-fuel-based cooling systems. The cooling demand sub-model of the UKDCM looked at the possible effects of climate change on demand for air-cooling. Even under a low carbon emissions scenario, it showed a substantial rise in the number of 'cooling degree days' (CDD, that is, equivalent days above a base mean temperature of 18.3°C), rising to 193 CDDs for Heathrow in 2050, with comparable figures for Edinburgh and Manchester at 29 and 66. Such an increase in temperatures in the south of England could lead to 29% of homes there having some air-conditioning by 2050 – and as many as 42% under a high-emissions scenario – if other factors such as fuel prices, affluence, building construction type and sunlight intensity were comparable with the USA, and if policy operated on a World Markets-type scenario.

4.3.1 Model assumptions – cooling

The 40% House scenario does not include any air-conditioning but allows for some cooling, for example in hard-to-cool dwellings (mostly high-density, highly-glazed flats). This might be through absorption cooling from a district chilling network (using the heat from CHP), or heat pumps circulating cold water (or cold air) during the summer.

4.4 Water heating

Hot water demand has not been dealt with in detail in the UKDCM, but some basic assumptions have been made for modelling purposes. Although demand for hot water per household has risen in recent years, it is assumed to stabilise at the current level under the 40% House scenario. This is mainly due to a decrease in the use of water from the home's central water-heating system as more people adopt dishwashers and cold-fill washing machines, with the trend towards colder washes. This, along with the replacement of bathing by showering, is estimated to compensate for increased use of hot water for additional, or more high-powered, showers. Figures for water heating energy consumption are given in Chapter 5, while the energy required is covered in Chapter 7.

4.5 Other policy considerations

Other factors which influence energy demand for heating and cooling need to be taken into account when developing a policy approach to ensure that maximum savings are achieved.

4.5.1 Controls and consumption feedback

Predictions of energy use tend to suffer from over-reliance on an assumption that the public use control devices in the way that the designers intended. Eighty-eight percent of UK households had some form of programmed heating by the time of the 1996 EHCS, yet many householders still do not fully understand how to operate their controls, with many preferring to use them as on-off switches whether or not they are designed to be used in that way (Pett and Guertler 2004). There is a clear need for simpler, more user-friendly controls if householders are to be able to use timers and thermostats to best effect. Digital wall thermometers, which warn the householder when the temperature is too hot or cold for health, would also be useful as standard installations.

More accessible metering and informative bills can both help with user understanding and control of their heating: better direct feedback through meter-reading or direct displays can give savings of the order of 10%, while informative bills can produce savings of 5-10% or more, especially if feedback is incorporated into advice programmes (Darby 2001).

4.5.2 Training and infrastructure for comfort

Tightly controlled comfort conditions are more common in offices and public buildings than in homes, but conditions in the workplace are likely to affect what people do when they return home – for example, altering the thermostat in order to stay comfortable in the same clothes as they wear at work. It is going to be important to train designers, engineers, architects and building users in low-energy methods of controlling temperature in order to achieve comfort, whether in public or residential buildings.

Shading and thermal mass are going to become increasingly important considerations in building design and refurbishment, whilst air-conditioning and electrical fans are likely to become significant energy end-uses under 'business as usual' assumptions. Convergence on a high-energy controlled indoor environment is not inevitable, though. There is still plenty of scope to extend traditional, low-energy forms of cooling and to educate for an approach that concentrates on imaginative use of building design and low and zero carbon technologies to minimise heat gain during the summer and natural ventilation, along with the use of blinds, shutters and other forms of shading. Some of this expertise would then be usable in providing cool buildings through environmentally-sympathetic systems (Chappells and Shove 2004). Grants from schemes such as the Energy Efficiency Commitment could be used to provide summer shading and two-way heat pumps.

The 40% House scenario assumes adequate warmth for all, with an average living room temperature of 21°C

4.6 Conclusions

Comfort is a concept that goes beyond health needs to personal preferences. There is still considerable unmet need for warmth for the fuel poor in winter, while a warming climate poses the question of how best to achieve cooling in summer. Policy needs to be geared towards design for high thermal mass, high insulation values and the use of shading and natural ventilation wherever possible, rather than energy-intensive solutions; and better controls and use of feedback are advocated as a way of improving householders' control over their own comfort levels while reducing consumption. There is an urgent need for training in the use of techniques to minimise energy use for cooling during hot spells, which are likely to become increasingly important in the future. The approach and technologies for achieving improved comfort levels are discussed in detail in the following chapters.

In terms of the 40% House scenario, the following assumptions were made:

- There will be adequate, affordable heating for all in line with the Government's legal obligation to achieve affordable warmth by 2016.
- Beyond 2020, there will be average all-day temperatures of 21°C in the main living area and 18°C in the rest of the dwelling.
- Cooling demand is met by design for natural ventilation and shading and/or low and zero carbon technologies.
- The quantity of hot water per household remains stable.