

# ASSESSING OVERHEATING RISK

## EVIDENCE REVIEW





The Zero Carbon Hub was established in 2008, as a non-profit organisation, to take day-to-day operational responsibility for achieving the government's target of delivering zero carbon homes in England from 2016. The Hub reports directly to the 2016 Taskforce.

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# 01 INTRODUCTION



The purpose of this Evidence Review is to describe the types of methodologies and tools currently available to industry and the public sector for the prediction of overheating risk in residential properties in England and Wales. The methods are described in a neutral way to help readers understand the purpose and capacity of each and to highlight any gaps or issues with their use in the domestic sector.

This Review links and overlaps with others in the Zero Carbon Hub's overheating series, and in particular, the Defining Overheating Evidence Review.

This Review summarises:

- The existing methodologies for predicting overheating risk in domestic and non-domestic buildings;
- The tools available to carry out these assessments;
- The data required for assessments particularly focusing on internal gains and occupancy profiles;
- Weather files including future climate data; and
- Key observations regarding current practice in overheating risk assessment.

**i** This Evidence Review forms part of a wider evidence gathering exercise being conducted by the Zero Carbon Hub for our *Tackling Overheating in Homes* project. It provides a summary of relevant evidence and concepts relevant to the theme: assessing overheating risk.

Figure 1. The tools and methodologies covered

	Housing	Both Dwellings and Commercial buildings	Commercial buildings
<b>Methodology</b>	○ SAP Appendix P	○ CIBSE Guide A ○ CIBSE TM52 (adaptive thermal comfort) ○ PHPP overheating assessment	○ Building regulations Part L2A Criterion 3 ○ BB101 (2006) (schools only)
<b>Possible tools</b>	○ Accredited SAP tools	○ Dynamic Simulation Modelling (DSM) tools ○ PHPP spreadsheet	○ Accredited DSM tools

## Key points

- The results obtained from modelling overheating risk are very much a product of their user's level of experience and the information inputted. Consistency and robustness of results for any type of analysis is generally improved when a methodology is followed prescribing, for example, how the analysis should be undertaken, what internal gain profiles and weather files should be used; and what the pass/fail thresholds should be. Such methodologies eliminate some of the user discretion which can influence or bias the outcome.
- Lifestyles and occupancy preferences vary enormously, and as homes are rarely built bespoke for one set of occupants, guidance is needed for designers on what internal occupancy profiles and gains to accommodate, including an upper limit on 'reasonable' gains that should be utilised when predicting overheating risk. These should be designed specifically for the purpose of testing overheating as opposed to predicting annual energy consumption (for example) and may need to be adjusted according to unit size.
- There are other crucial user inputs. Assumptions made regarding areas such as window opening, ventilation, shading and thermal mass are likely to affect the thermal comfort results achieved. A methodology should ideally offer clear guidance on which situations demand which inputs.
- Gul et al (2012) studied current building practices and concluded that the domestic and non-domestic sectors take a significantly different approach to design. Dynamic Simulation Modelling (DSM) is currently rare for domestic developments but it plays a key role in the design of non-domestic buildings. The reasons for this are largely linked to cost and skills availability, so the domestic industry will need to decide whether these tools offer sufficient improvements in design stage predictions to overcome the barriers.
- Methodologies such as the Standard Assessment Procedure (SAP) and Passive House Planning Package (PHPP) are usually quicker and simpler to apply than using DSM tools do not capture the dynamic relationship between the internal and external environment. We need to understand better the reliability of all these tools and methodologies by comparing predicted results to in-use performance. Such analysis could then inform how to strike a balance between the complexity (and cost to projects) of a methodology and the accuracy of the prediction.
- Future methodologies should take into account work that was done when developing CIBSE TM52 and other existing methodologies, and consider the limitations set out in this Review to develop a flexible, cost-effective and reliable approach to designing for future homes.

**i** Building physicists consider there is a strong case for developing a new overheating prediction methodology aimed specifically at informing the design of domestic buildings.

### Box 1. Key terms

It should be noted that there is scope for misinterpretation of some of the terms used in this Review, as they may be used by the sector to describe both a tool and a methodology. This is illustrated by reference to the Standard Assessment Procedure (SAP) which is a methodology describing how to calculate compliance with the requirements of Building Regulations Approved Document Part L1A (Conservation of fuel and power for new dwellings) but is also commonly used to describe the software tools which have been developed to implement the SAP methodology.

This report uses the term 'methodology' to describe a protocol to be followed when performing an overheating assessment. This is independent to the tool or software utilised when following the methodology.

A methodology has various elements and definitions. For example, methodologies are likely to include guidance on how to set up the assessment, the software or type of software to be used and some of the key parameters or inputs to use; for example the type of weather file, the internal heat gains for different room types, and the hours of occupancy to assume.

A methodology may be more, or less, prescriptive depending on its purpose. For example, whether it is being used to demonstrate mandatory compliance or as voluntary guidance.

Critically, an overheating methodology should prescribe the pass/fail criteria, or quantify the relative overheating risk, specifying whether the result is within an acceptable range.

## 02 METHODOLOGIES AND OVERHEATING CRITERIA



This section covers the main methodologies and overheating criteria currently used in England and Wales.

- [SAP Methodology](#)
- [CIBSE Guide A \(2006\)](#)
- [CIBSE Guide A \(2015\)](#)
- [CIBSE TM52 \(2013\)](#)
- [BB101 \(2006\)](#)
- [Part L2A 2013 Criterion 3](#)

### SAP methodology

The Standard Assessment Procedure (SAP) is the methodology used by the Government to assess and compare the energy and environmental performance of dwellings. Its purpose is to provide accurate and reliable assessments of dwelling energy performance which underpin energy and environmental policy initiatives.

SAP was developed by the Building Research Establishment (BRE) for the former Department of the Environment in 1992. The methodology is based on the BRE Domestic Energy Model (BREDEM), which provides a framework for calculating the energy consumption of dwellings.

SAP (DECC 2013) is used to assess compliance with English Building Regulations Approved Document Part L1A 2013: Conservation of Fuel and Power in new dwellings. There are five key criteria included within Part L1A. Overheating risk is covered in Criterion 3: Limiting the effects of heat gains in summer. Similar requirements are in place in Scotland, Northern Ireland and Wales.

However, buildings must demonstrate compliance with Building Regulations when they are completed. It is usual for Part L checks to be done at several points during the design process.

It is a requirement that Criterion 3 should be satisfied even if the dwelling is air-conditioned. This requirement for 'appropriate passive control measures to limit the effect of heat gains on indoor temperature in summer' (HM Government 2013) is assumed to reduce the requirement for, or installed capacity of, air conditioning systems.

Appendix P consists of a single calculation for each month of June, July and August using monthly average weather data for the month in question and produces a single predicted average internal temperature for the property for each. This temperature is then compared to a 'threshold temperature' in order to determine the risk of overheating for each month. The overheating risk is categorised as either 'high', 'medium', 'slight' or 'low'.

Where the resulting mean internal temperature is greater than 23.5°C, a high risk of overheating is predicted, where the temperature is between 22°C and 23.5°C, a medium risk is predicted and for a temperature between 20.5°C and 22.0°C, a slight risk is predicted.

#### Box 2. The SAP Appendix P calculation

The SAP methodology takes account of:

- Solar gain depending on:
  - glazing orientation;
  - solar shading of glazing;
  - glazing solar transmission;
- The assumed ventilation rate (which can be either mechanical or natural);
- The construction thermal capacity (the thermal mass); and
- The mean summer temperature for the chosen location.

Weather inputs for each location consist of mean monthly values of:

- Monthly external temperature (degrees Celsius);
- Wind speed (m/s); and
- Solar radiation (W/m<sup>2</sup> on horizontal plane).

The ventilation, fabric heat loss and solar gains are calculated for each month and standard internal gains are applied depending on the floor area. For natural ventilation via openable windows, an effective air change rate is assumed depending on the type of ventilation opening (trickle vents, slightly open windows, windows open half the time or windows fully open) and the type of dwelling (single storey or two or more storeys) and whether cross ventilation is possible. The effective 'air change rates' value is a single value taken from a table. For mechanical ventilation, a design air change rate can be specified.

This method of determining overheating risk does not take into account the magnitude of peaks in external temperature or the duration of warm spells.

Although Appendix P is not integral to SAP and does not affect the SAP rating itself, Building Control routinely check the assessment has been completed as part of the SAP report. Therefore, it is considered to be part of the building compliance process. For compliance purposes, a medium or lower risk of high internal temperatures is normally deemed acceptable. A note is included in the methodology that designers may want to improve on the Building Regulations requirements in order to allow for future climate change.



Dwelling overheating risk is covered in SAP 'Appendix P': Assessment of internal temperature in summer. Appendix P provides a method for demonstrating compliance with Criterion 3.



The SAP methodology uses standard internal heat gains and profiles for occupancy, equipment and lighting which cannot be adjusted by the user.

Figure 2. An extract from a dummy SAP compliance report showing the Appendix P outputs

Regulations Compliance Report		
<b>5 Cylinder insulation</b>		
Hot water Storage:	Nominal cylinder loss: 1.27 kWh/day Permitted by DBSCG: 1.70 kWh/day	
Primary pipework insulated:	Yes	OK
<b>6 Controls</b>		
Space heating controls:	Programmer, TRVs and boiler energy manager	Fail
Hot water controls:	Cylinderstat Independent timer for DHW	OK OK
Boiler interlock:	Yes	OK
<b>7 Low energy lights</b>		
Percentage of fixed lights with low-energy fittings:	100.0%	
Minimum:	75.0%	OK
<b>8 Mechanical ventilation</b>		
Not applicable		
<b>9 Summertime temperature</b>		
Overheating risk (Thames valley):	High	Fail
Based on:		
Overshading:	Average or unknown	
Windows facing: South	5.5m <sup>2</sup> ,	
Windows facing: North	6m <sup>2</sup> ,	
Windows facing: South	6m <sup>2</sup> ,	
Roof windows facing: Horizontal	0.25m <sup>2</sup>	
Ventilation rate:	2.00	
Blinds/curtains:	None	
	Closed 15% of daylight hours	
<b>10 Key features</b>		
Air permeability	2.5m <sup>3</sup> /m <sup>2</sup> h	

## CIBSE Guide A (2006) – Environmental Design Guide overheating methodology (to be superseded in 2015)

CIBSE Guide A (2006) provides comprehensive guidance for designers regarding overheating risk in non-air conditioned buildings, and suggests criteria for limiting peak internal temperatures in some types of buildings.<sup>1</sup>

This guidance has now been largely superseded by the publication of CIBSE TM52 (CIBSE 2013), which will be incorporated into the forthcoming 2015 version of CIBSE Guide A. However, the CIBSE Guide A (2006) methodology is included in this Review for completeness, as recent residential developments may have made use of it.

The guide recommends using the of the CIBSE Design Summer Year (DSY) weather files for any overheating assessments (see Section 6).

Table 1.8 from Guide A (2006) is shown over the page. It provides a simple recommendation that the annual number of hours for which the internal operative\* temperatures in a building exceed certain thresholds (28°C for living areas and 26°C for bedrooms) are limited to no more than 1% of occupied hours.

1. See the Zero Carbon Hub's Defining Overheating review.

### Box 3. Operative Temperature

The Operative Temperature is also known as 'Dry Resultant Temperature' or 'Resultant Temperature'. It combines air temperature with radiant effects which means it gives a more realistic idea of the temperature that would be perceived by occupants within the space.

Table 1. Benchmark summer peak temperatures and overheating criteria, recreated from Table 1.8 CIBSE Guide A (2006)<sup>1</sup>

Building	Benchmark summer peak temp. / °C	Overheating criterion
Offices	28	1% annual occupied hours over operative temp. of 28°C
Schools	28	1% annual occupied hours over operative temp. of 28°C
Dwellings – living areas	28	1% annual occupied hours over operative temp. of 28°C
Dwellings – bedrooms	26	1% annual occupied hours over operative temp. of 26°C

This simple threshold is fairly straightforward to evaluate using DSM software. A model of a building can be simulated against a full year of DSY weather data, and then the results for each zone (room or space isolated within the model) post-processed to determine the number of hours for which the threshold temperature is predicted to be exceeded. If this is greater than 1% of the total annual occupied hours for that zone then the criteria is failed and designers should modify the design to reduce the overheating levels predicted.

The main complexity in this exercise, when considering dwellings, is determining the hours of occupancy to assume and the internal gains to specify. The following guidance on dwellings is included:

*"The individual has more freedom to adapt to conditions at home than at work. Bedroom temperatures are likely to be more critical than living area temperatures as most people find sleeping difficult in the heat...The use of shading to reduce solar gain during the day and of night time ventilation when feasible can reduce internal night time temperatures. Additional air movement from quiet fans can also help improve comfort. CIBSE TM36 (29) provides further discussion and relevant case studies." (CIBSE 2006)*

1. Guide A provides the following additional notes: 'It is reasonable to calculate the percentage of occupied hours over a year to reflect true hours of occupation, e.g. 08:00–18:00, and to allow for 5, 6 or 7-day working as appropriate. It is recommended that the overheating criteria be assessed against the CIBSE Design Summer Years (DSYs) using the calculation methods recommended in chapter 5, section 5.10.4.1. It is incumbent upon the designer to ensure that any software used for the purpose of predicting overheating risk is validated for that purpose and operated in accordance with quality assurance procedures described in chapter 5.'

CIBSE TM36 Climate change and the indoor environment: impacts and adaptation (Hacker et al. 2005) provides further guidance on overheating risk and its mitigation. It covers all building types including dwellings.

In summary, the strength of the Guide A (2006) overheating criteria is its simplicity, which makes it straightforward to understand and apply. However, it is not prescriptive about the internal gains and occupancy profiles to use within the analysis. Importantly, this test also requires the use of DSM software to determine whether the criteria are met.

## CIBSE Guide A (2015) – Environmental Design Guide

An update to CIBSE Guide A is due to be published early in 2015. It includes an extensive update to the section on thermal comfort incorporating the adaptive thermal comfort principles covered in length in CIBSE TM52 (see below).

## CIBSE TM52 (2013) – The limits of thermal comfort: avoiding overheating in European buildings

### Box 4. Adaptive Thermal Comfort

Overheating in buildings has historically been quantified by the number of occupied hours per year that the indoor temperature exceeds a particular temperature, irrespective of external temperatures. However, research (de Dear, Richard & Brager, G. S 1998) has shown that comfortable room temperatures vary with the external air temperature: occupants are 'comfortable' with higher room temperatures during prolonged warm weather. This is known as Adaptive Thermal Comfort.

TM52 (2013) provides a methodology to assess Adaptive Thermal Comfort. The TM52 assessment is based on comparison of the predicted room temperature with a maximum acceptable room temperature calculated from the 'running mean' of the outdoor temperature. The running mean places greater weight on the temperature for days closer to the present as these have more influence on a person's comfort levels. This means that the overheating threshold is dynamic and is based on the weather file utilised.<sup>1</sup>

TM52 sets out three criteria, with a 'pass' dependent on meeting two out of the three criteria. These are:

- Threshold temperature exceeded  $\nrightarrow$  3% of occupied hours per year
- Daily weighted exceedance (degree hours)  $\nrightarrow$  6
- Temperature  $\nrightarrow$  upper limit

The guidance is for this test to be run using CIBSE DSY weather files, but it would also be valid to run against future weather files to test for future viability of designs.

1. For more information on 'comfort bands' see the Zero Carbon Hub's Defining Overheating Evidence Review.

## BB101 (2006) methodology

Building Bulletin 101 (Education Funding Agency 2006) is a document produced by the Education Funding Agency which specifies ventilation performance for the design of school buildings. The current version was published in 2006, and it is currently being revised and due for publication early in 2015.

As BB101 is specifically targeted at schools, it is not directly relevant to the domestic sector except in the context of looking at methodologies for predicting overheating risk and setting acceptable targets for limiting overheating. An important difference between schools and dwellings is the fact that dwellings are occupied during the night, meaning that thermal comfort during night time hours must also be considered. This is likely to lead to a divergence in feasible overheating mitigation strategies for schools and dwellings.

The BB101 methodology assesses three different criteria and requires at least two of these to be met in order to pass the test. In the 2006 version these are relatively simple:

- A.** There should be no more than 120 hours when the air temperature in the classroom rises above 28°C;
- B.** The average internal to external temperature difference should not exceed 5°C (i.e. the internal air temperature should be no more than 5°C above the external air temperature on average);
- C.** The internal air temperature when the space is occupied should not exceed 32°C.

It is understood that the update to BB101 will be based closely on CIBSE TM52 (2013).

An alternative route to satisfying the requirements of BB101 (2006) is via the Classcool tool (Education Funding Agency 2014). This is spreadsheet based, and therefore requires less software expense and know-how than using DSM tools, but can take fewer design options into account.

## Part L2A 2013 Criterion 3

English Building Regulations Approved Document Part L2A 2013: Conservation of Fuel and Power in new buildings other than dwellings (HM Government 2014) includes requirements on limiting solar heat gains in summer. This section of the Building Regulations covers largely non-domestic buildings, but does include some provision for domestic buildings which fall outside Part L1A. For example, it applies to 'rooms for residential purposes' such as care homes and student accommodation, and also to corridors and public spaces in communal living accommodation or mixed use developments. It has been included as another example of how overheating risk is assessed in practice.

The relevant section is Criterion 3: 'Limiting the effects of heat gains in summer'. The guidance is applied to any applicable building including those with air conditioning. Again, it is assumed that the intention is to reduce the need for air conditioning or to reduce the capacity of any installed air conditioning system.

It should be noted that this methodology places a limit on solar gain only – it does not assess the temperature in a space or consider gains other than solar gains. It is therefore not strictly an overheating methodology.

**i**  
A number of commercial tools are available that implement the non-domestic Part L2A 2013 Criterion 3 methodology. In order for tools to be used for Building Regulation compliance, they must be approved by government.

The solar gains in each zone of the thermal model created are compared to the 'limiting gains' for that zone. The limiting gains are the solar gains through benchmark glazing, defined by the methodology. The benchmark glazing used depends on whether the activity in the zone is classified as being side-lit (e.g. offices), top-lit (e.g. warehouses) or unlit (e.g. auditoria).

Building Regulations Parts L1B and L2B refer to domestic and non-domestic refurbishments. These do not include any form of overheating or solar gain check.

## Passive House Planning Package (PHPP)

The PHPP methodology predicts a building's level of thermal performance from the frequency which temperatures are calculated to rise above an established comfort limit (Tmax), expressed as a percentage of the total hours of the year. The default Tmax used in PHPP is 25°C, however different temperatures may be used for comparison.

### Box 5. PHPP thresholds

The Passivhaus guidelines recommend that when the frequency of temperatures in excess of the comfort limit exceeds 10% of annual occupied hours, additional summer heat protection measures will be necessary.

It is mandatory to meet the 10% target to achieved Passivhaus certification. The guidelines also recommend that the frequency of temperatures in excess of the comfort limit does not exceed 5% of annual occupied hours in order to guarantee high summer comfort. If the percentage of hours in excess of the comfort limit is in the range of 0-2%, this is considered 'Excellent' and results in the range 2-5% are 'Good'.

For the purposes of dwelling calculations, all hours of the year are assumed to be 'occupied hours'. The method of calculating the frequency of overheating is a monthly calculation similar to SAP. It is based on a dynamic single zone building model. The key difference between SAP and PHPP is that PHPP is able to use actual data for internal gains (occupancy, lighting and equipment gains) in the overheating calculation, rather than assumptions based on floor area.

## 03 TOOLS



This section covers the main tools currently used for overheating analysis in the UK. These are grouped into the categories of 'tools used for Building Regulations compliance', 'other commercial tools' and 'research tools'.

The first category includes SAP and DSM tools. Dynamic modelling tools have a wide range of applications, and where regulations require an accredited tool, dynamic modelling tools should only be used to assess compliance with regulations for which they are accredited.

'Other commercial tools' include the following:

- Passive House Planning Package (PHPP);
- Passive Design Assistant;
- Computational fluid dynamics (CFD);
- Urban models;
- City scale models;
- Neighbourhood scale models; and
- Building and street scale urban climate models.

Two Research tools are covered:

- Low Carbon Futures overheating tool; and
- Community resilience to extreme weather (CREW) – Retrofit advice tool.

### Tools used for Building Regulations compliance

#### SAP tools

A number of commercial tools are available which implement the SAP methodology. In order for tools to be used for Building Regulation compliance, they must be approved by government. These tools use the same methodology so should theoretically produce



Except for the urban models, none of the tools covered in the Review are currently able to include the effects of Urban Heat Island (UHI) except by using weather files adapted to include this (See CIBSE TM49). Nor do they take into account any 'greening' effects due to strategic planting or water features. These can be effective at mitigating UHI effects, but are difficult to model accurately.

identical results for identical inputs, but may vary in their user interface and cost.

Tools meeting these requirements are listed on the BRE website for SAP 2012 (BRE 2014a) and for SAP 2009 (BRE 2014b). Each tool will produce a compliance report which states the results for each of the four criteria included in the SAP methodology, including Criterion 3 which covers the requirement to limit solar gains.

#### Dynamic Simulation Modelling tools (DSM)

Dynamic simulation modelling<sup>1</sup> is a term applied to software packages that model energy interactions in a building against external weather data. They predict a wide number of parameters from internal space and surface temperatures to the energy consumed by HVAC (Heating, Cooling and Ventilation) plants.

In principle, the process for using DSM tools for predicting overheating risk is that a model of the building is created, then the overheating 'standard' you are trying to meet is applied. This gives you a pass or fail against it. The modeller can then make changes to the design of the building until a pass is achieved. See figures 3 and 4.

#### Box 6. Creating DSM models

A DSM model needs to be constructed using a significant amount of design data including:

- **Building geometry** – this can be imported from a geometrical modelling or BIM tool (such as Sketchup or Revit), or more commonly built within the package by the user from imported plans and elevations.
- **Internal layout** – the model is zoned to reflect the internal layout and usages of each space within the building. Results are calculated for each zone. Some rooms will be divided into several zones to take into account stratification in double or triple height spaces, and different uses within an open-plan space or perimeter effects – isolating the areas closest to the windows.
- **Location and orientation.**
- **Construction details** – the material each element is constructed from their thermal properties (U-value, g-value, thermal mass etc).
- **Internal heat gains for each internal zone** – including occupancy, lighting and equipment gains (and the sensible and latent components of each), and the daily profiles that these will follow. For example, occupants in a home may only be present from 8pm to 6am on weekdays if they work long hours; or they may be at home for much more of the day if they are retired, have young children or work from home.
- **Ventilation details:**
  - Natural ventilation – type (e.g windows, louvres or doors), opening sizes and opening schedules/triggers;
  - Mechanical ventilation – supply and extract volumes and any conditioning applied to incoming air – including heat recovery; and
  - Infiltration estimated for the building – usually based on the required air pressure test result.
- **Weather data** – a weather file is selected based on the location of the site and the type of analysis. This can include future weather or data that takes into account UHI effects such as the CIBSE TM49 (CIBSE 2014b) datasets.



The tools are termed 'dynamic' as they calculate results for regular time steps, typically hourly, thus building a set of results which tracks each zone in the building model though a day, week or often a full year. Such tools are used to perform a wide variety of assessments, predicting overheating risk being one of these.

1. Also referred to as dynamic thermal modelling or Building Energy and Environmental Modelling.



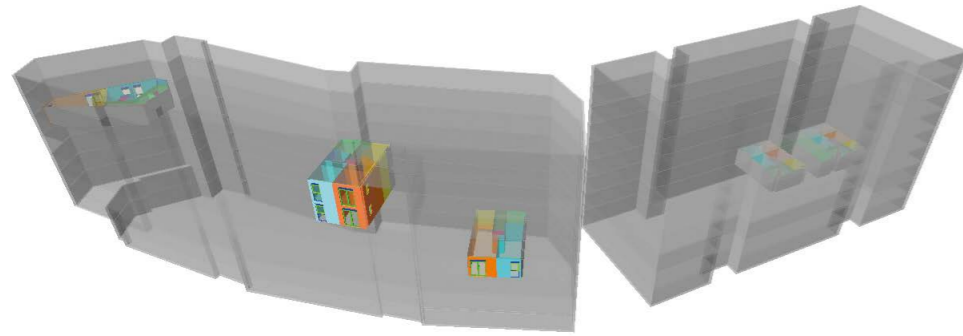


Figure 3. Example model of units in an apartment block

There are many DSM tools available for modelling buildings with different applications including, evaluating energy performance and checking Building Regulations (Part L2A) compliance, as well as predicting overheating risk.

DSM tools can be independently validated by testing against CIBSE TM33 Tests for Software Accreditation & Verification. TM33 validates the algorithmic performance of the software against published standards and covers aspects such as heat transfer, solar shading, and HVAC.

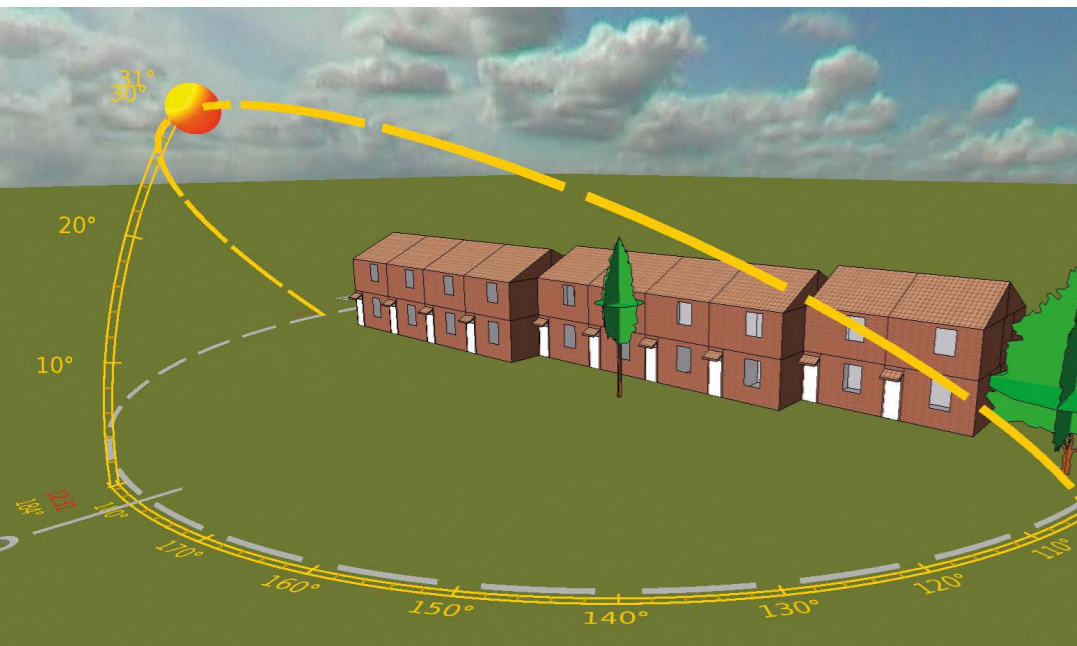


Figure 4. Example terraced houses modelled in DSM software

Given their sophistication and flexibility, the results obtained from DSM tools are very much a product of their user's level of experience and the information inputted. Consistency and robustness of results for any type of analysis is generally improved when a methodology is followed prescribing how the analysis should be undertaken and what the pass/fail thresholds should be. Such methodologies eliminate some of the user discretion which can influence or bias the outcome. For overheating there are several methodologies currently established for different building types in the UK – these include BB101 (for schools) and CIBSE TM52 (CIBSE 2013, 5).

Unless there is guidance to follow, a modeller has discretion to allocate model parameters as they consider appropriate, and as they are advised by the design team. Such parameters include internal gains, profiles and the weather file used. Ensuring that these parameters are suitable and reasonable is critical in ensuring that the model gives realistic results.

An advantage offered by DSM tools is that they usually build in functionality to post-process the model results in line with standard methodologies. For example, the CIBSE TM52 overheating criteria involve several algorithms; it would take some time for the average user to build a spreadsheet to perform these and there would be a risk that they are misapplied. Being able to run these calculations easily is a significant time-saver and ensures that the calculations are consistently correct.

It is possible that the sophistication of this type of modelling may be perceived as excessive for small units where the commonly used tools are simpler and less training is required. Cost is also likely to be a factor in deciding which tool to use, as is the training required to become competent with the tools.

Gul et al (2012) studied current building practices and concluded that the domestic and non-domestic sectors take a significantly different approach to design. DSM is still relatively rare for domestic developments, but plays a key role in the design of non-domestic buildings.



DSM tools in particular have the capacity to model more of the complex features of buildings, including most HVAC options, external shading devices, different thermal mass options, and some newer technologies such as Phase Change Materials.

## Other commercial tools

### Passive House Planning Package (PHPP) Spreadsheet

To demonstrate compliance with the Passivhaus criteria, buildings are modelled in the Passive House Planning Package (PHPP). The PHPP is a complex spreadsheet developed by the Passivhaus Institut (PHI) in Germany to predict the annual heating and primary energy demand of a building and summer comfort levels.

#### Box 7. PHPP inputs

The following list summarises the input data required for the summer comfort calculation in PHPP:

- Thermal transmittance of building fabric ( $W/(m^2.K)$ );
- Summer ventilation (air changes per hour);
- Glazing total solar transmission;
- Glazing area ( $m^2$ );
- Glazing orientation;
- Extent of shading;
- Specific capacity (thermal mass) ( $Wh/(m^2K)$ );
- Treated floor area ( $m^2$ );
- Local monthly climate data either from embedded database or entered by user; and
- Designer input for internal gains: it is strongly advised by the PHI that actual data is inputted for internal gains.

### Passive Design Assistant

Passive Design Assistant (PDA) (ARUP 2014) is a free software tool<sup>1</sup> that demonstrates the principles of passive thermal design. This includes factors such as insulation, solar gain, thermal mass, ventilation and climate.

PDA enables an assessment to be made of temperatures within a building operating in 'free running' (non-mechanical) mode, or the demand for heating and cooling when the building is being operated in mechanical mode. The tool was developed to have a simple and intuitive user interface. The software models a single room or space and uses an industry-standard calculation method (CIBSE's Simple Dynamic Model). Results respond to parameter changes instantly, and the user can construct material build-ups from a library of material types and input site-specific climate data.

It is intended that the software is simple enough to be used by all those involved with or interested in the design of buildings, however, it is recommended by ARUP that more complex calculation methods are used for detailed design development. There had been approximately 4,000 downloads of the PDA software up to November 2014.

1. See [http://www.arup.com/Publications/Passive\\_Design\\_Assistant](http://www.arup.com/Publications/Passive_Design_Assistant)

### Computational fluid dynamics (CFD)

CFD uses numerical methods to solve fluid flow and heat transfer problems. The area being studied is divided into many cells and the governing heat and fluid transfer equations are solved for each of the cells. A single CFD model may contain millions of cells if such a resolution is required. This scale is in contrast to DSM tools which assume that the air in each thermal zone is perfectly mixed and therefore the temperature is the same throughout the zone.

#### Box 8. Using CFD

CFD can be used in building design for a variety of purposes including for:

- Natural ventilation analysis (e.g. assessment of the stack effect);
- Testing the efficacy of mechanical ventilation strategies (e.g. mixing of introduced air with the room air);
- Assessment of pollutant concentration from internal or external pollution sources; and
- External wind pedestrian comfort analysis.

In relation to overheating, CFD can be used to model air movement and temperature within spaces under either buoyant or forced flow (i.e. driven by fans) conditions. As thermal comfort is affected by radiant as well as air temperature, a CFD package used for the assessment of thermal comfort must include radiant heat transfer.

CFD models may be either steady-state (not varying with time) or transient (varying with time). Generally where CFD is used for building thermal comfort assessments, the simulation will be steady state. CFD is therefore most efficiently used where a specific situation needs to be tested, for example to study the distribution of air temperature throughout a naturally ventilated space on a hot summer day under a specified ventilation regime.

### Urban models

In order to factor in the impact urban climate has on the level of overheating within a building, the air temperature at a point in a city is needed, and depends on two main factors:

- **Macroclimatic effect** – the relative position of a building's location between the urban centre and the rural surroundings (its radial distance); and
- **Microclimatic effect** – the effect of its immediate environment.

There is a good correlation between the radial distance of a site from an urban centre and its air temperature: as the radial distance decreases, the temperature rises. However, overlaid upon this general pattern is the effect of the local surroundings, e.g. areas near to parks will tend to have lower temperatures and streets with darker surfaces will tend to be warmer. There are many other factors that affect local temperature and this makes modelling for microclimatic effects highly complex.

Research projects have attempted to quantify and describe the local effects of urban warming, such as The LUCID ('The Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities') project. The project established practical methods to assess and quantify these effects in London (Mavrogianni et al. 2011). The crucial variables to any model are the temporal and spatial scales and the complexity of inputs. Urban climate models range spatially from building/street, neighbourhood and city scales. What follows is a description of some of the urban climate models available at these three spatial scales.



Building simulation software use weather files such as the CIBSE Design Summer Year to vary the boundary conditions of a building model.

The CIBSE TM49 Design Summer Year (CIBSE 2014b, 49) weather files usefully represent the macroclimatic urban heat island effect in London.

Urban models dynamically simulate how variations in the land use and topography of urban environments impact the local climate.

### City scale models

City scale models can model the evolution of local meteorological conditions over cities. Examples include regional climate models that can be used as numerical weather prediction (NWP) models, of which some can output climate data at increasingly fine resolutions of down to 1-2 km<sup>2</sup>. However, their accessibility is often limited and they require a high level of technical knowledge and computing capabilities. Examples include the Met Office Unified Model (Met Office Unified Model 2014) and the Weather Research and Forecasting Model (Skamarock and Klemp 2008).

To be used in an urban context effectively, NWP models can be coupled to urban surface energy balance models. Examples include the widely used Town Energy Balance (TEB) scheme (Masson 2000) and the Met Office Reading Urban Surface Exchange Scheme (MORUSES) parameterisation scheme (Bohnenstengel et al. 2011) (Porson et al. 2010a; Porson et al. 2010b).

The latter of these was developed as part of the LUCID project and was implemented into the wider Met Office Unified Model. The output was a variety of urban climate data, which covered the whole of London, at a resolution of 1km<sup>2</sup> over a 100km x 100km domain. The outputs included air temperatures as gridded screen level temperatures at a height of 1.5m.

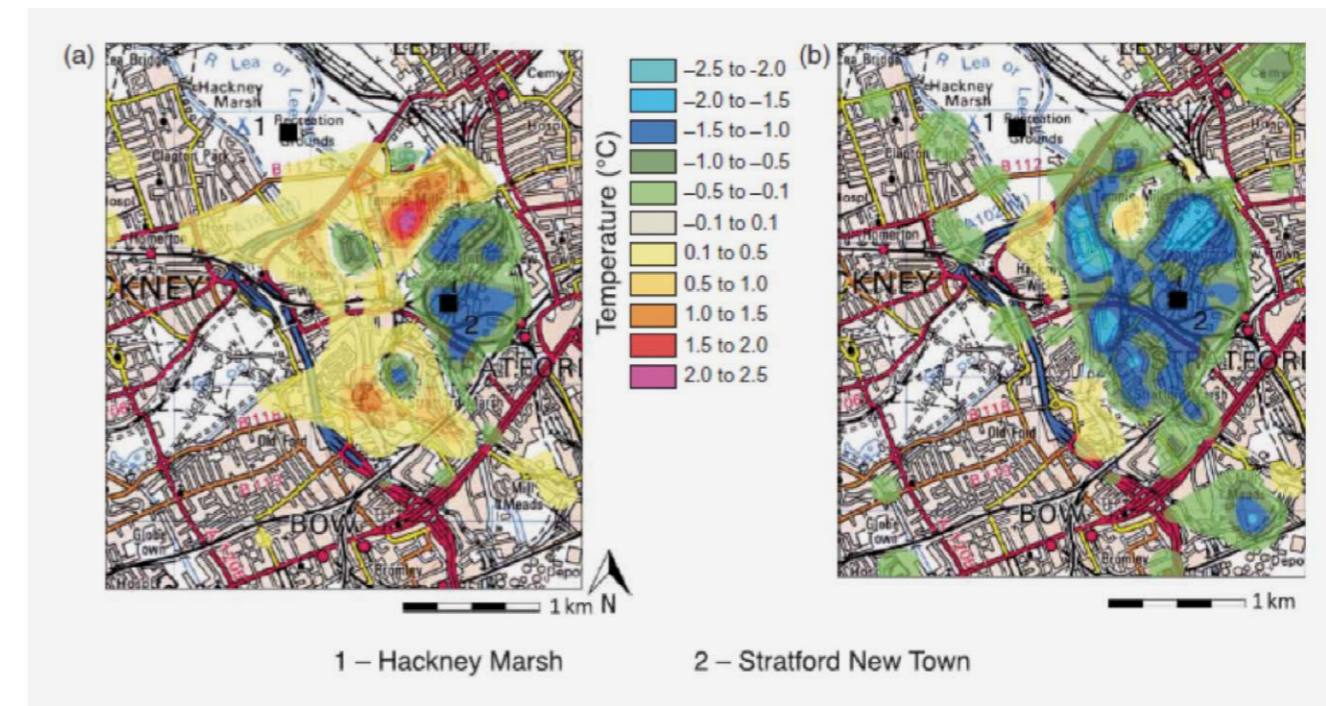
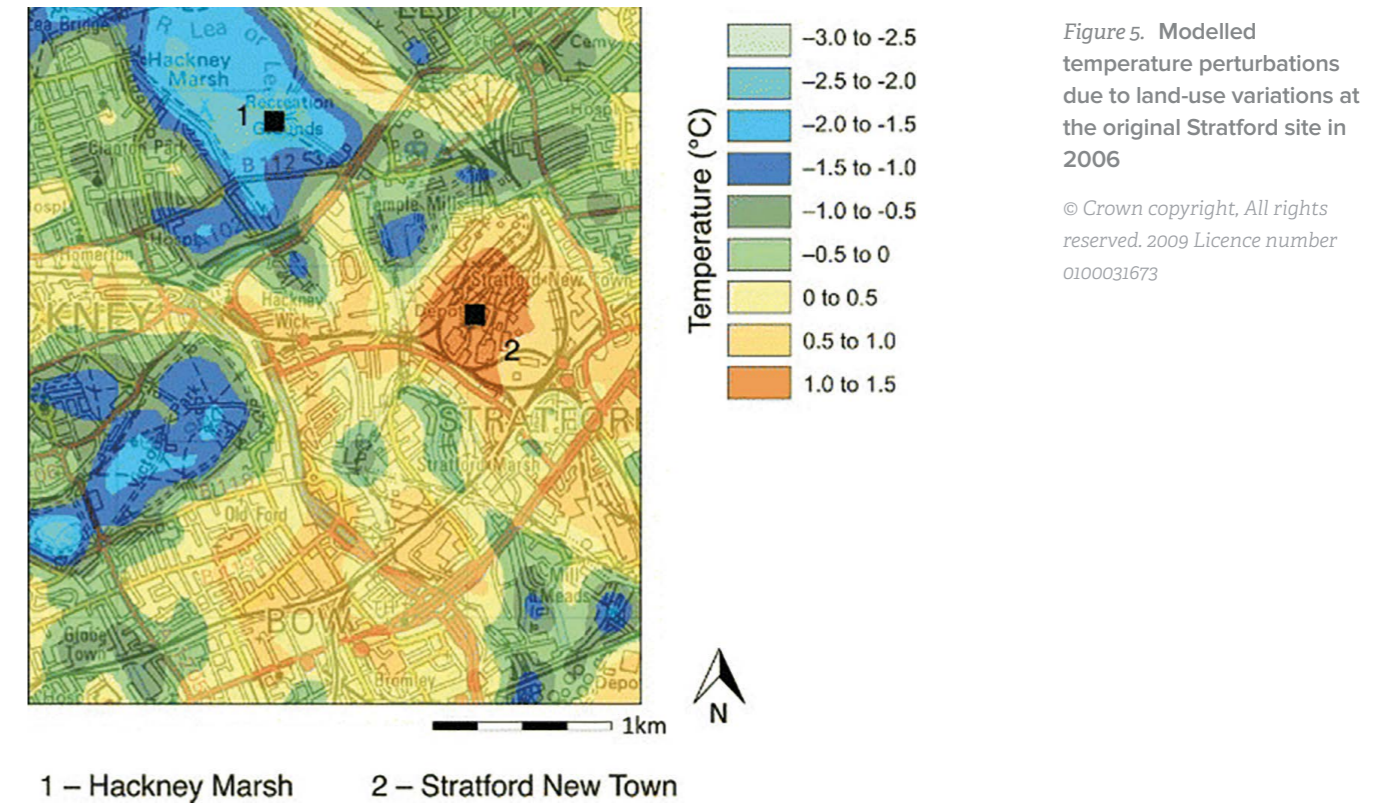
The major advantage of using modelled data is the spatial range available. As the data can be outputted as a city-wide grid, the macroscopic UHI effect and the manner in which it varies through different transects can be analysed.

### Neighbourhood scale models

Neighbourhood scale models operate over smaller spatial domains, typically of up to 10km<sup>2</sup> and models can output data at resolutions of 1m<sup>2</sup>. Many surface energy balance schemes can be used as neighbourhood scale urban climate models. They take into consideration the morphology of a city and the consequent energy and water exchanges, and airflows between a city and the atmosphere.

The models require meteorological boundary conditions inputs such as background weather data, which are simplified compared to city scale models. The models consider local factors such as detailed urban geometry, street layout and building heights, vegetation and moisture in the form of trees, parks and rivers, types of urban surfaces and materials, and anthropogenic heat emissions. They can output temperature, humidity, wind speed, surface temperatures and heat fluxes depending on the complexity of the model.

**i** One advantage of urban models are that the impact of a large land use change, such as a mixed use developments or a greening strategies can be analysed at high resolutions.



#### Box 9. ADMS Model

ADMS 4 Temperature and Humidity (ADMS) is an example of a two-dimensional neighbourhood scale temperature and humidity model, developed as part of the LUCID project (ADMS Temperature and Humidity User Guide 2010). The model calculates perturbations of temperature and humidity due to local land use changes. The model is still only available for research purposes, but it has been applied to case studies in London. The model was recently used to model the impact of land use changes to local air temperatures in the London Olympic Parkland (Hamilton et al. 2014). Some of the outputs from that study are shown in Figures 5 and 6. Figure 5 shows how modelled land use variations impact local air temperature perturbations. Figure 6 shows simulation results of how the development of site from 2006 to the legacy site would impact local air temperatures.

ADMS has also been used to model the impact of green and cool roofs around the Victoria station area in London (Jansz 2012). Virk et al. (2014) used the outputs from this modelling by editing the weather file input into a dynamic thermal simulation model. They assessed how green and cool roofs can impact overheating within an office.

### Building and street scale urban climate models

Building and street scale urban climate models operate at very detailed spatial scales. These are able to model the airflow and radiative exchanges in street canyons and the buildings within them.

Many of the more complex neighbourhood scale models will factor street canyon and building parameterisation. However, the airflow and energy balances will be simplified to reduce computational costs and increase the temporal scale of simulations.

CFD is increasingly being used to model airflow, surface and air temperatures in streets. These can then be coupled to dynamic thermal simulations for real-time results. The advantage of using such detailed models is that specific scenarios can be tested, such as how a façade or building orientation will impact the immediate surrounding environment. As mentioned previously, the temporal scale of CFD simulations will be limited by computational constraints.

## Research tools

Over the past few years research has increasingly focused on the risk of overheating as one of the impacts of climate change. EPSRC funded a series of projects under the Adaptation and Resilience in the Context of Change (ARCC) umbrella to look at the use of the UKCP09 projections (UKCP09 Data, 09) in building design, the impact higher temperatures would have in buildings, and what are the adaptation measures to be considered to increase their resilience. Various guidance documents and tools emerged as a result.

### Low Carbon Futures (LCF) overheating tool

The Low Carbon Futures project team at Heriot-Watt aimed to provide the industry with a simplified way to extend the building simulation work to consider multiple climate projections but without adding significant resources and cost to the analysis. They achieved this by creating an emulator that correlates a range of climate variables with the outputs of dynamic building simulation (e.g. internal temperatures, heating/cooling demand, etc.).

The tool is an add-on to what a designer would normally do, i.e. run a dynamic simulation for a single weather file, and it can be applied to any design that is using dynamic simulation processes, domestic or commercial.

The tool analyses the statistical relationship between the climate variables and the building performance, as a result of the single simulation, and uses it to demonstrate how a defined failure risk changes within multiple climates, in this case the probability of the building exceeding a pre-determined overheating threshold.

Figure 7 is an example of the format in which outputs of the LCF tool are presented. The cumulative frequency graph shows the likelihood that a specific building exceeding the threshold of 1% of occupied hours above 28°C. In this case the building has a 7% chance of failing under the current climate. By the 2080s the risk increases to 97%. A similar output can then be produced for the same building with various adaptation options. The adapted building would have to be simulated again using a single weather file followed by the application of the LCF tool (Low Carbon Futures Project 2014).

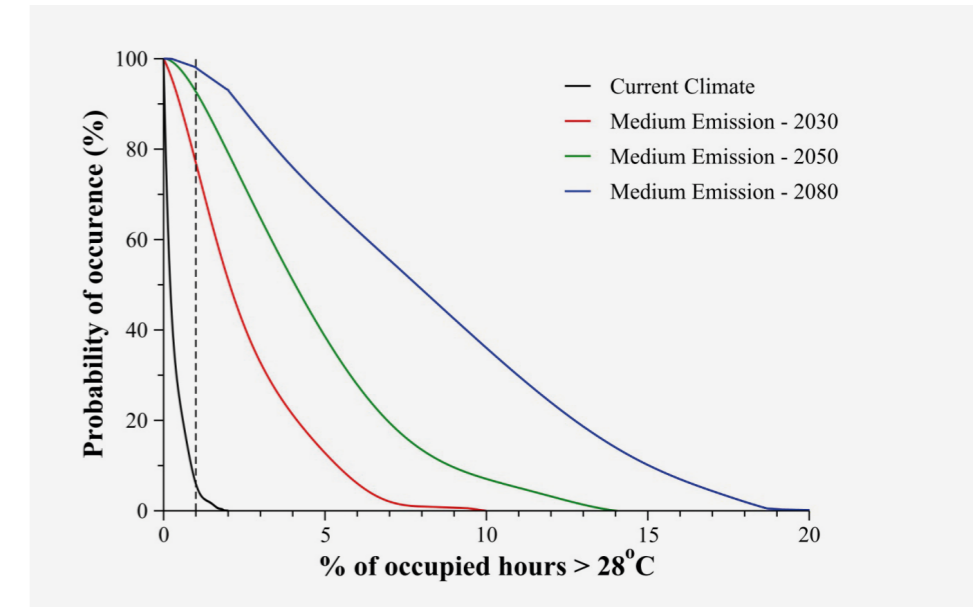


Figure 7. Example of LCF outputs

### Community resilience to extreme weather (CREW) – Retrofit advice tool

The CREW project used multiple dynamic simulations to analyse the thermal performance of typical UK housing types and assess the effectiveness of adaptation options in reducing overheating risk. Figure 8 shows the housing types assessed and figure 9 shows outputs for an end terrace. The tool can present the effectiveness of single adaptations for a selected room, orientation and occupancy pattern, and combined adaptations for the same selections. The tool can also provide an estimate of the cost of the combined adaptations and their effectiveness in reducing winter heating costs.

Figure 8. CREW project housing types

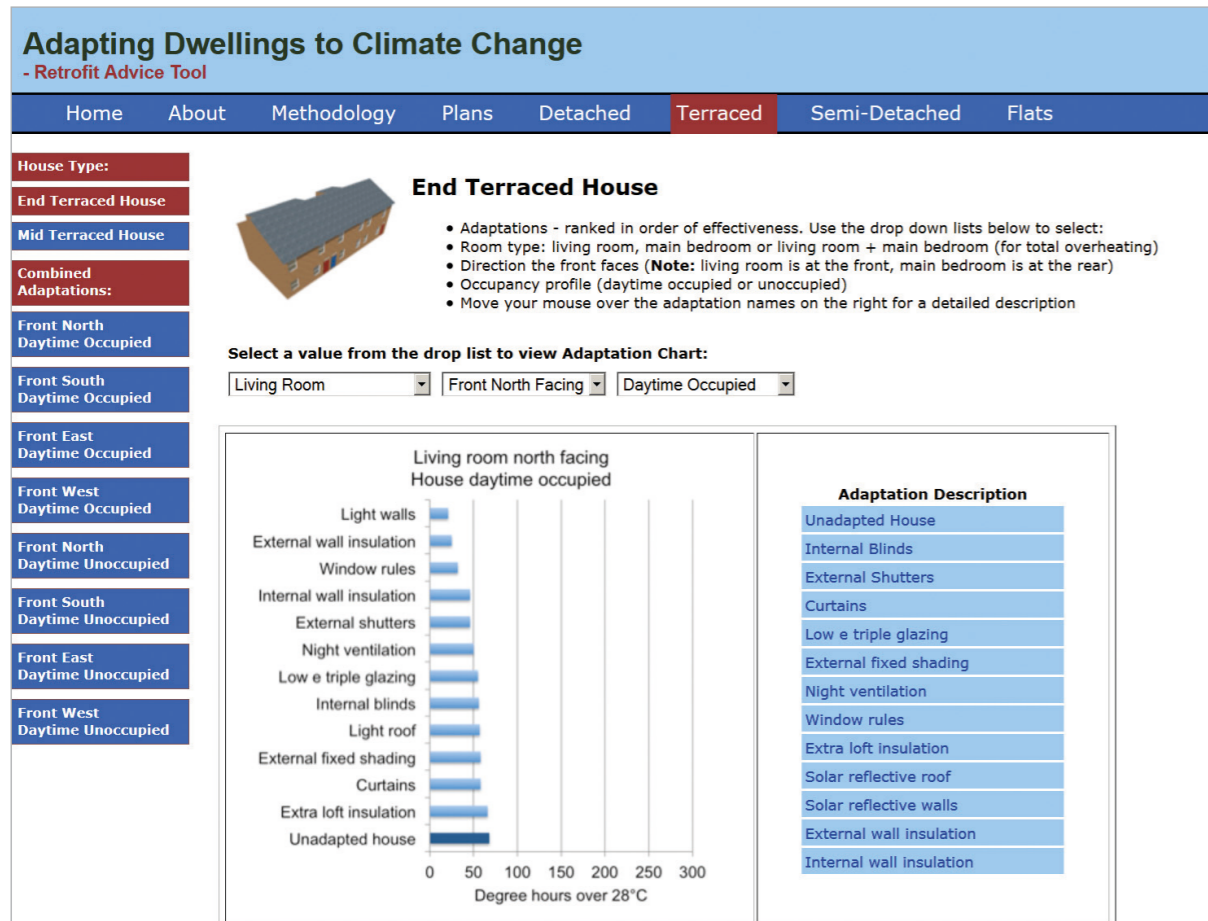


19<sup>TH</sup> CENTURY TERRACED

1930S SEMI-DETACHED

1960S FLATS

MODERN DETACHED



The simulations used observed weather data from the 2003 heatwave in London Heathrow, which could be considered an extreme scenario for the current climate. The houses were modelled for the London region and their performance might not be representative of other regions in the UK. Finally, the tool is not a design tool, i.e. it cannot replace the need for detailed analysis of the building's performance, but it provides an early indication of the effectiveness of adaptation options and their estimated cost which can inform early retrofit decisions (Community Resilience to Extreme Weather – the CREW Project: Final Report. 2013).

Figure 9. Example output from the CREW advice tool (screenshot)

## 04 MODEL INPUT DATA



### Occupancy profiles and internal gains benchmarks

#### SAP internal gains

SAP internal gains are calculated for each month and are based on the total floor area of the unit being assessed.

There are no explicit assumptions about hours of use for lights, appliances, or cooking made in SAP. It works at the level of monthly averages. Although there is some allowance made for gains not being coincident with heat demand in the gains utilisation factor equations.

Both the National Calculation Methodology (NCM) and SAP gain inputs were developed for use as a set of reasonable standard inputs to be used in both a baseline and 'as-designed' building, in order to rate the proposed building fabric and services in the absence of consideration of the building use. The two sets of gains have different formats and were developed independently for different methodologies; as such there is no reason why these should be consistent.

#### Box 10. Internal gains in SAP

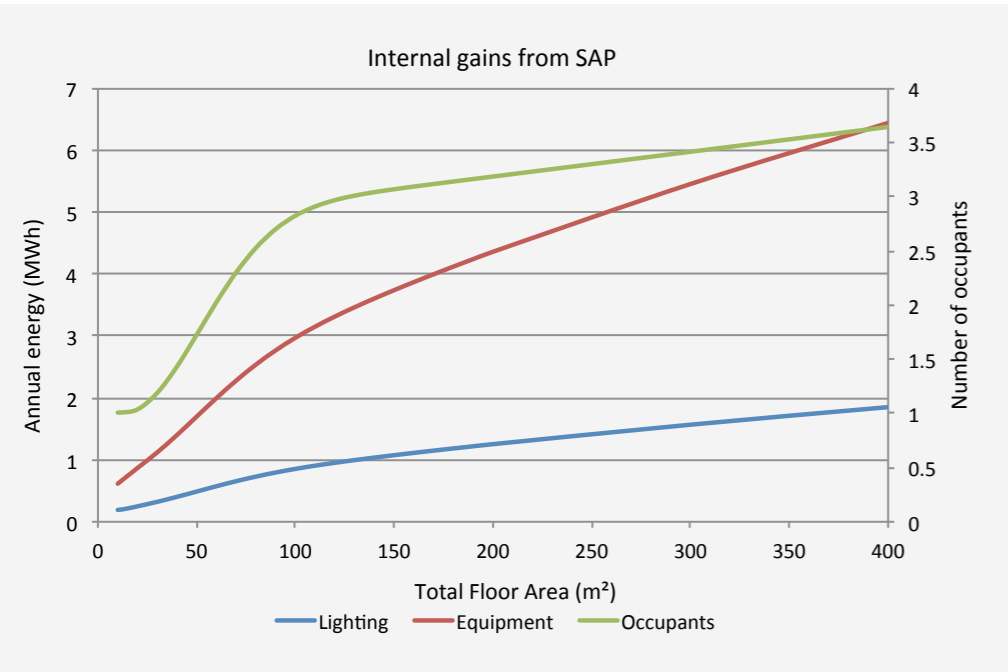
For a small apartment of 50m<sup>2</sup>, SAP calculates the number of occupants to be 1.7, the annual lighting energy consumption to be 488kWh (although 15% of this is assumed to be external lighting and therefore would not contribute to internal heat gains) and the annual equipment energy to be 1,700kWh.

For comparison, for the same one bedroom 50m<sup>2</sup> apartment, the annual internal gains calculated from the NCM dwelling profiles are 1,000kWh for lighting, and 766 kWh for equipment.

As the NCM uses varying hourly fractional occupancy schedules for each room type (e.g. bedroom or living room), rather than a total occupancy value for the whole dwelling, occupancy varies in a complex way with time and is not defined explicitly as a number of occupants.

Figure 10 below plots the annual energy consumption for lighting and equipment (and the number of occupants on the other vertical axis) used in SAP 2012 for increasing total floor area. It shows that these values follow a curve which starts to level off as the unit size increases into very large houses/apartments.

It is important to note that the values given in this graph are intended for use within an energy prediction calculation and have not been devised specifically to test overheating risk. Exactly how these gains should be set for a reasonable domestic overheating test is debatable and needs further research.



**i** When predicting overheating risk it is good practice to use a scenario with higher than average internal gains (without being excessive) since, statistically speaking, internal gains will be higher than average for much of the time.

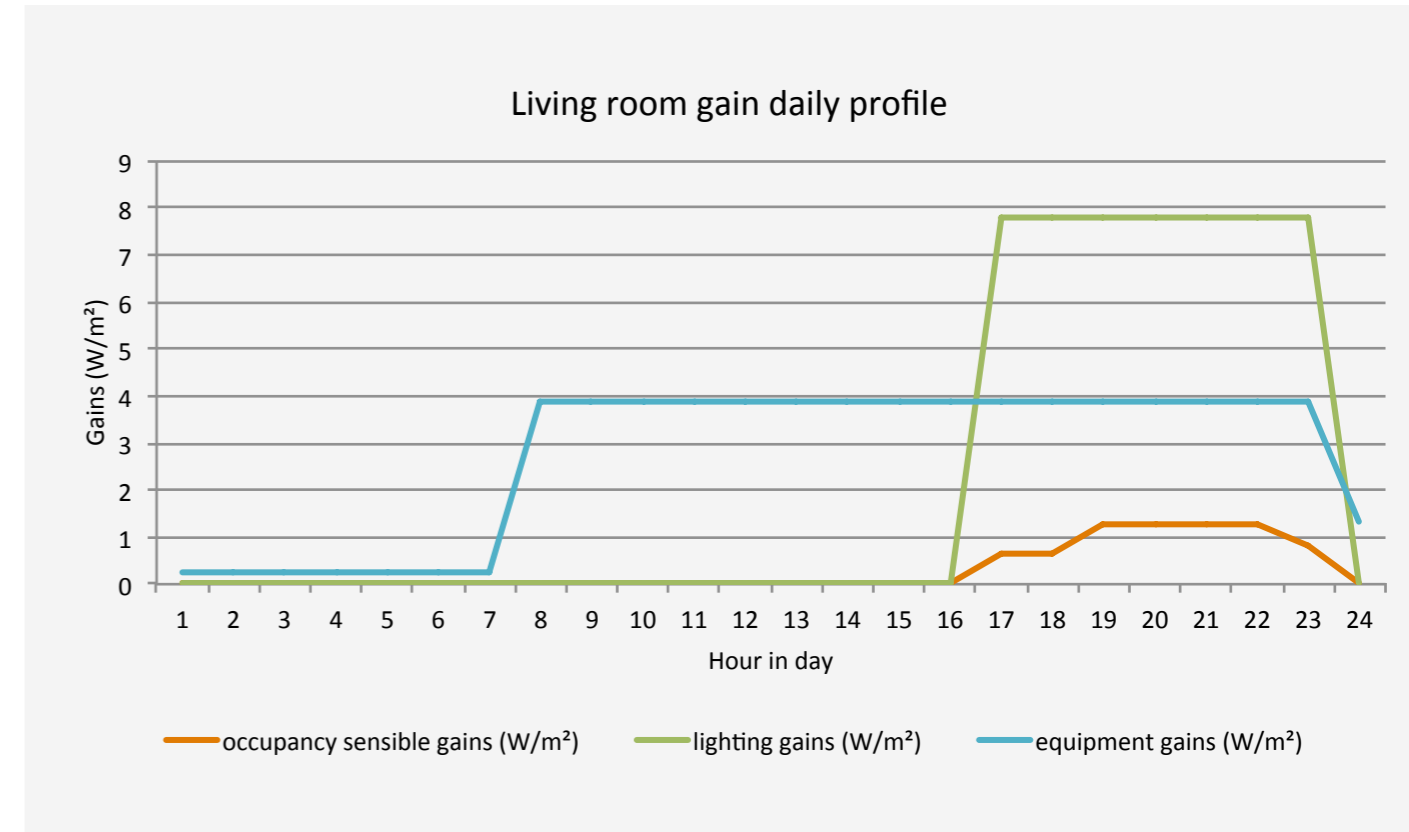
Figure 10. Annual energy consumption for lighting and equipment and number of occupants used in SAP 2012

### National Calculation Methodology (NCM) gains

The NCM provides a framework for carrying out assessments for Part L2A of the Building Regulations and the production of Energy Performance Certificates (EPCs). The methodology includes a database of 'gain profiles' for a variety of building types based largely on planning class. A set is included for dwellings.

The alternative to using this dataset is for modellers to create their own bespoke internal gain profiles for any domestic projects they work on. This is a difficult exercise as, unlike offices which tend to have more predictable usage profiles, homes are occupied in a very wide variety of ways. There is often no way of knowing who will occupy a property at the design stage or what their lifestyle will be like. Therefore designers are left to make their own decisions on what is reasonable. This takes time and there is risk attached to making such decisions; therefore reliance is often placed on NCM datasets for dwellings, despite them not being designed for this purpose.

Figure 11 shows data taken from NCM v5.2, which is the most recent version of the data approved for use with Part L2A 2013. It shows the daily occupant, equipment and lighting gain profiles used for a living room area. These gain patterns are assumed to repeat every day throughout the year. Note that graphs for each room type can be created featuring different scales on the vertical axis.



It is interesting to note that equipment gains are active all day from 7am to 11pm, but occupants are only assumed to be present in the evening from 4pm to 11pm.

Another notable feature of this data is that the occupancy gains are low. They peak at 1.26W/m². Assuming 75W sensible gains per person and a smallish living room of 17m², this would be equivalent to 1/3rd of a person being present in the room. Clearly, applying gains in terms of average W/m² values is liable not to always produce whole numbers of occupants as room sizes are extremely variable.

### Relationship between internal gains and unit size

One important point to take into consideration is that internal gains are commonly described in terms of power per unit floor area (typically W/m²). This is convenient as many designers are accustomed to thinking in these terms and it allows for average figures to be taken and applied to all spaces of a similar nature. However, homes vary significantly in size, and whereas a larger office will usually accommodate a proportionately larger number of people, keeping the occupant density roughly the same, a larger house does not necessarily have the same occupant density as a studio apartment.

Figure 11. NCM living room gains – dwelling

In addition to occupant density, another factor to consider are the occupancy patterns. Some people work long hours and be away from home from early morning until late evening on a regular basis, whilst others may be retired, be caring for young children or work from home. All these lifestyles have different implications for the daytime internal gains and window opening patterns, which will affect the likelihood of overheating.

This variability suggests that guidance is needed on what internal occupancy patterns and level of gains to accommodate, including an upper limit on 'reasonable' gains that should be utilised when assessing overheating risk.

#### Box 11. Gains from appliances

Taking kitchens as an example, most homes will have a similar set of appliances, regardless of their size. Larger homes might run dishwashers and elaborate appliances, but most will include a fridge, cooker and hob, washing machine, kettle, toaster etc. Even a small kitchen will accommodate all these appliances. Thus the heat gains are compressed in smaller kitchens and the  $W/m^2$  are significantly higher than in a more spacious kitchen. The same applies to living rooms where the equipment included is likely to be similar regardless of the room size.

SAP does reflect this intensity in patterns to some extent, as internal gains increase slower than floor area, and occupancy gains have a minimum value of one occupant however small the unit size.

A large four-bedroom house might be occupied with a large family with two people sharing every bedroom (a couple, and six children, or four children and two grandparents). Equally the same house might be occupied by a retired couple living on their own. In terms of overheating, the former scenario presents the highest risk as more gains will be associated with higher occupancy density.

This raises questions about what level of 'overcrowding' and intensity of gains is reasonable to design for.



The gain profiles provided within the NCM are intended for use within an energy prediction calculation and have not been devised specifically to test overheating risk.

## 05 WEATHER DATA



### Weather data availability for building design

An important part in the assessment of a building's thermal performance is its response to external environmental conditions. The more a building is dependent on passive features to achieve acceptable internal comfort the more important the use of external weather information becomes. This is especially true for the domestic sector that is more likely to use passive responses to external hot events. This section describes the weather information available for building design.

### Weather statistics for steady state design tools

For less complex building designs a steady state calculation of HVAC loads might be more appropriate. Those calculation methodologies use statistics of temperature, solar radiation and wind to inform the sizing of the building heating, cooling and ventilation systems (including window sizing for ventilation purposes). CIBSE Guide A, Chapter 2, (CIBSE 2006) offers such statistics for use in steady state tools for 14 UK locations as hourly weather datasets. These temperature statistics are available for current climate (1982-2012), but also for future time periods based on the UKCP09 climate projections (see page 28).

Although such statistics offer a quick way to size the HVAC systems of a building, they do not fully explore the potential of passive measures and the level of overheating risk, both of which depend on a dynamic relationship between the internal and external environment. This static approach is currently adopted by SAP.

## Weather files for simulation

### Current climate

The current standard weather datasets in the UK are the Test Reference Years (TRYs) and Design Summer Years (DSYs), provided by CIBSE.

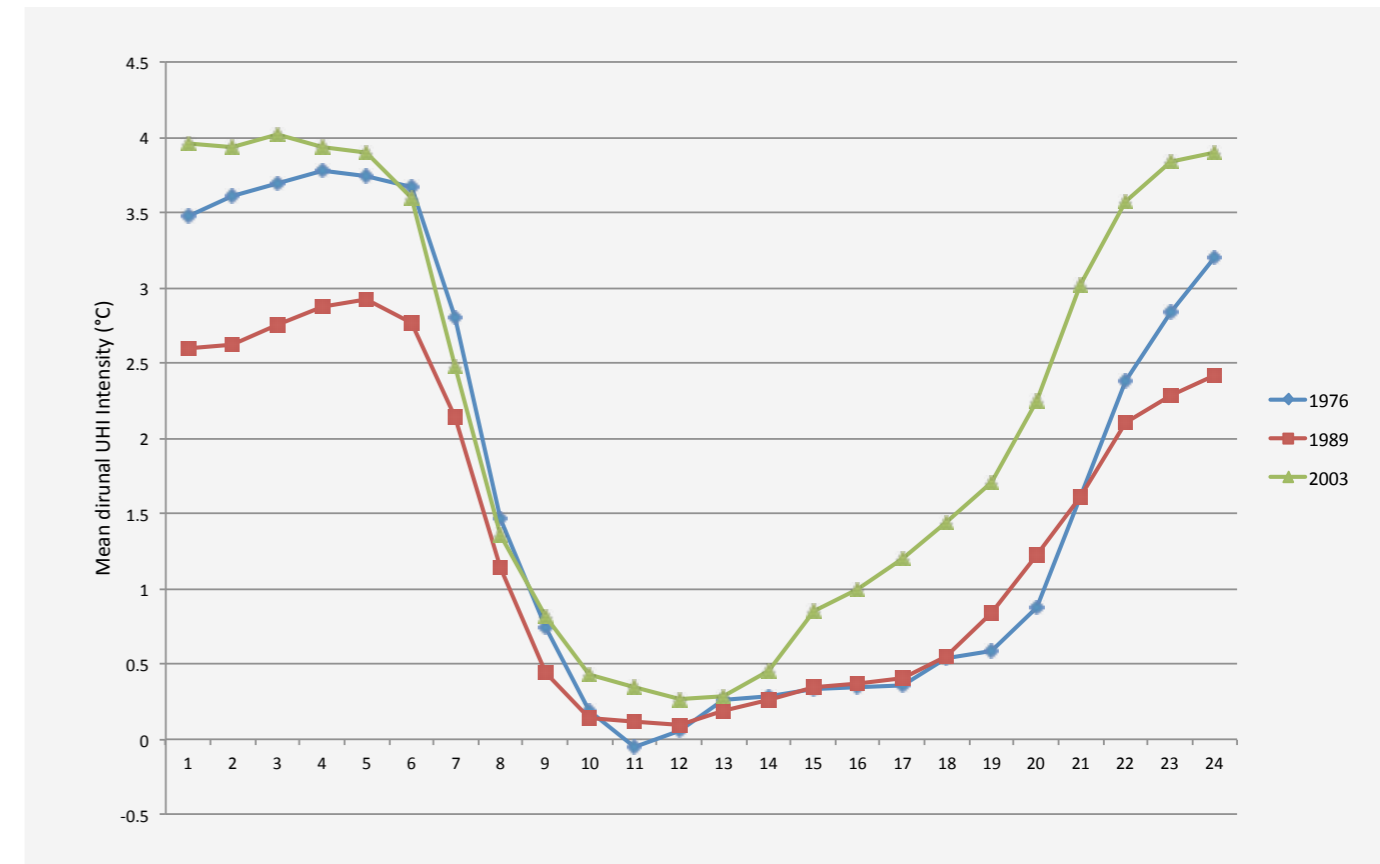
These are used with most mainstream simulation software. They are hourly weather files based on past observations (1981–2012) and are available for 14 locations in the United Kingdom (Belfast, Birmingham, Cardiff, Edinburgh, Glasgow, Leeds, London, Manchester, Newcastle, Norwich, Nottingham, Plymouth, Southampton and Swindon).

- The TRYs are average years, and so are appropriate for energy performance calculations (Levermore and Parkinson 2006).
- The DSYs represent a year with a hot, but not extreme, summer and so are appropriate for thermal comfort assessment.

### The Urban Heat Island effect and the new DSYs

Another environmental aspect that needs to be considered in the design of homes is the Urban Heat Island (UHI) effect, a consequence of the dense build-up of urban centres and the lack of green areas which manifests as a temperature difference between the urban centres and their rural surroundings.

Urban centres have high capacity for absorbing and storing solar radiation during the day which is then re-emitted back to the local environment during the night. The deep street canyon geometry, decreased wind speeds, reduced evapotranspiration from soil and vegetation and heat gains from anthropogenic sources (people, cars etc.) further contribute to the UHI effect. UHI intensities are usually high during the night and during summer days with clear skies and reduced wind speeds.



The Greater London Authority, recognising the intensity of the UHI effect in London and its impact on the risk of overheating, especially in dense urban locations, funded a study to address the need to introduce the UHI effect in building design. The results of the study were made available by CIBSE as 'TM49 Design Summer Years for London' (CIBSE 2014b, 49) with the accompanying DSY datasets for building thermal simulation. This means that instead of having a single DSY for London (based on observation at Heathrow area), three DSYs are now available capturing the local climate in three different London sites: London Weather Centre, Gatwick and Heathrow (urban, semi-urban, and rural), and for three years (1989, 2003 and 1976) of varying severity of hot events.

The new DSYs are currently available only for London, but the new methodology will be applied to the rest of the 13 CIBSE locations and revised DSYs (and TRYs) based on a more recent baseline for those locations, will be available in early 2015.

The new DSY methodology is an improvement on the original method which required the selection of the third warmest year, based on temperature alone, from the April to September inclusive. A number of issues were identified with this methodology. First, there are no guaranteed hot periods within the chosen year as it is only an averagely warm year (over a relatively long period of time). Second, the choice of 'third warmest year' was independent of the number of years that were available from the observations. Third, if a given year is missing from the time series this could influence the selected year (if all 'warm' years are unavailable, a cool year would be chosen). The principle impact this had on the building industry was that, for a number of locations, the DSY had a tendency of creating less overheating in the designs than the respective TRY, the opposite of what designers would normally expect.

Figure 12. Mean diurnal UHI intensity in London (Gatwick compared to London Weather Centre) for the three years (June to August period) (created by Gurdane Virk, UCL)



Early examination of the data has shown that Manchester and Birmingham would potentially benefit from a second more urban DSY for designs in the urban centres of those cities.



The new methodology, based on the TM49 study, addresses the above issue by using a new measure, the 'weighted cooling degree hour' which is based on the adaptive comfort temperature. This method more accurately represents periods of hot events and avoids inconsistencies with their equivalent TRYs.

Although an improvement from the previous methodology, there are still some limitations of the new DSYs. The number of locations for which DSYs are available has not been increased, mainly due to the availability (or lack) of observations from the Met Office. While hourly temperature observations are more common, other weather variables, such as solar radiation and wind, are not as commonly measured. This means that a lot of projects will not have a dedicated weather file to work with, in which case it's the engineer's responsibility to make assumptions and select a suitable weather file.

Furthermore, although more DSYs for London mean that engineers can better explore the impact of UHI effect in their designs, the further impact of the microclimate has not been integrated in the design of buildings. The microclimate will often create hot or cold spots, based on neighbouring building geometry and urban form that will have a significant impact on the building's thermal performance. This is difficult to address by standard weather files, but models exist that could potentially create such bespoke environments. Most of those models have been developed by and are used in research but have not found their way to industry practices yet.

Finally, the weighted cooling degree hour measure used for the selection of the new DSYs is based only on temperature. It is well documented that direct solar radiation, localised draft and humidity play an important role in occupant's comfort levels and perception of overheating.

## Climate change

Climate Projections for the UK (Murphy, Hadley Centre for Climate Prediction and Research, and UK Climate Impacts Programme 2009), published by Defra in 2009, illustrate the projected changes in climate based on three socioeconomic scenarios of global greenhouse gas emissions; Low, Medium and High.

The UKCP09 information is presented in various ways from maps and graphs to detailed numerical outputs (for several weather variables at 25km grid squares, for various temporal periods), available to be customised and downloaded from the UKCP09 User Interface (UKCP09 Data, 09). A downscaling tool, the UKCP09 Weather Generator (WG) (Jones et al. 2009), has also been made available for the spatial and temporal downscaling of the UKCP09 projections, producing hourly values at a 5km<sup>2</sup> resolution.

This better representation of uncertainty in the projections encourages a risk-based approach in design which is appropriate to the treatment of future risks by those interested in the future resilience of their buildings. The availability of the UKCP09 has made it possible to produce future weather files to be used in building simulation for thermal and energy analysis. CIBSE created future weather files for the same 14 locations as the current weather file availability, while a research team in Exeter (PROMETHEUS) created weather files for multiple UK locations (University of Exeter 2014).



The main advantage of the UKCP09 information is its probabilistic nature that quantifies uncertainty ingrained in the projections due to their modelling (by including information from other global climate models) and the natural climate variability (Murphy, Hadley Centre for Climate Prediction and Research, and UK Climate Impacts Programme 2009).

1. Downscaling is a term used to describe the process of generating climate change information at spatial and temporal scales below those provided by the general circulation models (GCMs).

All datasets are available for three time periods 2020–2049 (2030s) or 2010–2039 (2020s), 2040–2069 (2050s) and 2070–2099 (2080s), for three emissions scenarios (Low, Medium and High) and for variable probability levels, consistent with the UKCP09 projections.

Users of the above weather datasets need to know that there are fundamental differences between them and that recommendations will vary depending on the weather datasets used (Mylona 2012). For example, the CIBSE future weather files use as a baseline climate current TRYs and DSYs (based on the 1981 – 2012 period), which are then morphed to the UKCP09 projections (UKCP09 changes are relevant to the 1961-1990 baseline climate). The PROMETHEUS datasets use the UKCP09 WG (1961 – 1990) as the baseline climate. This would mean that the CIBSE datasets could potentially overestimate the overheating risk in a building by 'morphing' the changes to a potentially hotter baseline.

The Design for Future Climate (D4FC) competition funded around 50 live projects, a mixture of domestic and non-domestic, to undertake a 'future' analysis of their design solutions (ARCC). The D4FC projects used a mixture of datasets and other UKCP09 products to undertake an analysis of climate risks for their buildings, including risk to flooding, water availability, subsistence, energy use increase and overheating (Gething, Bill 2013; CIBSE 2014a, 55).

Most design teams found it difficult to "sell" the concept of future proofing of the building design, especially for overheating risk, to their clients as it was attached to higher capital costs. A more powerful way of presenting the future-proofing of the building was the evidence that adaptation solutions have immediate payback, such as energy savings, or that they could be implemented at a later stage in the life of the building.

The idea of a simple process for assessing future overheating risk has been proposed by various organisations. A previous ZCH report (Zero Carbon Hub and National House Building Council Foundation 2010) suggested that a more simplistic way of assessing future performance would be a better way of introducing the industry to the concept of future proofing.

### Box 12. BREEAM

BREEAM for non-domestic buildings has recently introduced an assessment of future performance for thermal comfort, which suggests (for free running buildings) the use of TRY for the 2050s, medium emissions scenario and for mechanically ventilated or mixed mode buildings, the TRY for the 2030s, medium emissions scenario.

The BREEAM standard states that "the above weather files represent the minimum requirements to perform thermal modelling under a climate change scenario and subsequently demonstrate compliance. Where design teams feel that added consideration of building occupant risk/sensitivity to overheating is necessary, weather files can be used that exceed the minimum requirements outlined above".



Currently, the use of the future weather files is usually client driven, i.e. if the client has specifically requested a future projection of the building's performance, or by funding initiatives such as the TSB funded Design for Future Climate (D4FC) competition.

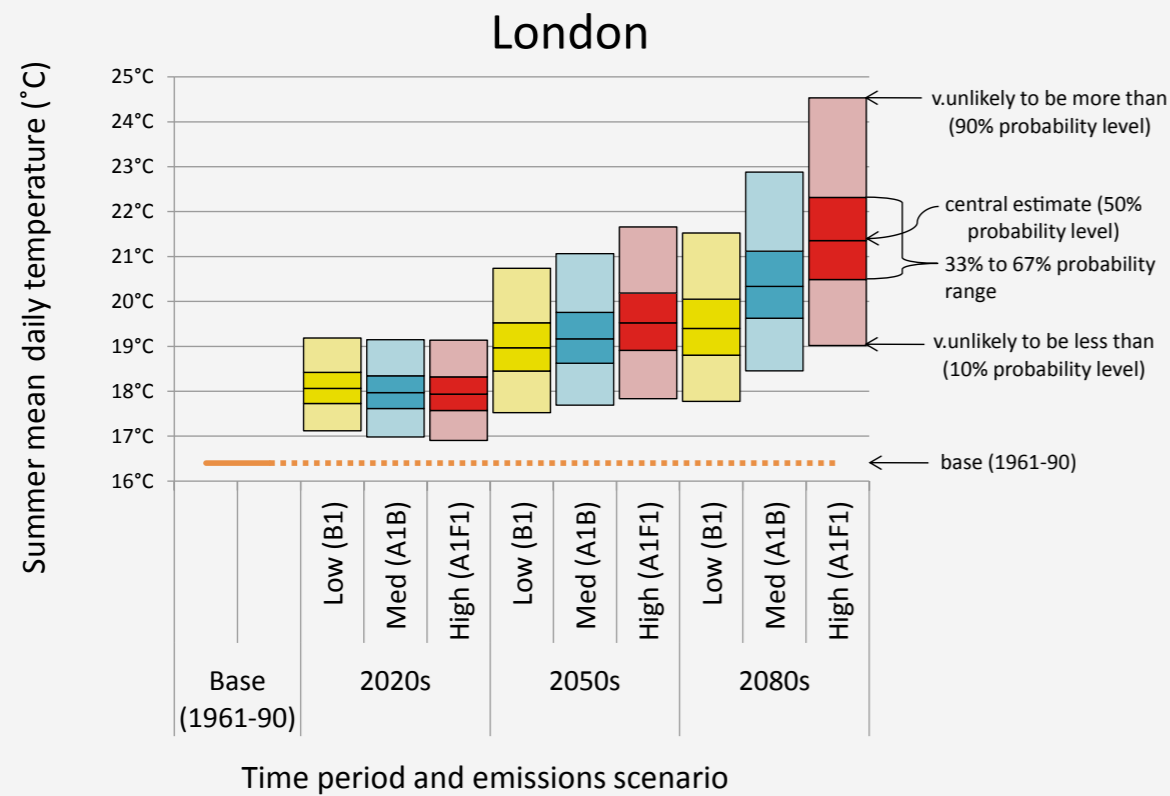
CIBSE has also published the Probabilistic Climate Profiles (or ProCliPs) (Shamash, Metcalf, and Mylona 2014) which provide a visual representation of the UKCP09 projections to enable designers to easily digest their complexity and advise their clients appropriately (Figure 13). The ProCliP methodology aids the understanding of risk for an individual building, based on its location, vulnerability of occupants, and design characteristics. These profiles aim to assist building designers in familiarising themselves with the likely future climate. This can be helpful in the early stages of design, for communicating climate risk and uncertainty within the design team and with the client, and at the stage of choosing future weather data for design analysis.

ProCliPs are location and weather variable specific, and they present changes for three time periods (2020s, 2050s and 2080s, three emissions scenarios (Low, Medium and High) and five probability levels (10%, 33%, 50%, 67% and 90%).

Although the use of future weather files cannot guarantee the future performance predicted using modelling processes, it can give a good indication of the building's exposure to future increases in temperature and the most effective solutions to mitigate those risks. A simple consistent approach to future proofing would be easier for the building industry in general, and the domestic industry in particular, to digest and implement provided climate risks are understood and explored appropriately.

**i**  
Due to their resource intensity and the specialised expertise needed, future weather files are currently used mainly for non-domestic projects.

Figure 13. Probabilistic climate profile (ProCliP) graph based on UKCIP09 data – London summer mean daily temperature (°C) (Shamash, Metcalf, and Mylona 2014)



## 06 LIMITATIONS



The existing tools and methodologies reviewed in this report were largely developed for use in the commercial sector. There are a number of key limitations to these tools and methodologies when applied specifically to the domestic sector. These are summarised below.

### Definition of overheating

The definitions used within the current methodologies tend to focus on thermal comfort rather than health impacts. There is evidence that prolonged exposure to even moderately high temperatures (>25°C) can be detrimental to health and sleep and have significant impacts on mental and physical wellbeing. The methodologies reviewed do not assess in detail prolonged exposure to moderately high temperatures, generally focusing instead on the number or percentage of hours above a threshold per year or season, or on average temperature.

### Timing of periods of elevated temperature

Domestic buildings are occupied very differently to commercial ones, and the overnight temperatures will have a significant impact on the comfort of the occupants. Therefore, there is a strong argument that testing the ability of a building design to cool down at night could be a valuable exercise. Night time temperature is not specifically assessed in the methodologies reviewed.

### Single vs. multi zone models

Single zone models distribute heat gains across the floor plan evenly. If a building has high solar gains concentrated in one room or one side of the building, the average results may not reflect the actual comfort conditions in parts of the building. It is important that models are selected appropriately considering the building to be assessed.

### Microclimate and boundary layers

Most building overheating models do not take into account the effects of local microclimates or the boundary layer between inside and outside a building. This means that effects such as Urban Heat Island effect and localised heating from (for instance) dark coloured cladding materials are rarely included.

It is not necessarily the case that models cannot be constructed to take these elements into account, but to do so is complex and requires more sophisticated knowledge and software tools, so the additional cost may be difficult to justify.

### Overheating to communal areas

Whilst DSM software is capable of modelling overheating in communal areas, there is rarely the impetus to do so as assessment of overheating is usually focussed on 'occupied areas'.

### Inclusion of internal heat gains from pipework losses

As with the point above, heat gains from hot water pipework losses (particularly when community heating is installed) are possible to include within many models, but are often not considered. These losses are often small (in terms of Watts) but can be applicable 24 hours per day throughout the summer period and can lead to heat build-up in the building structure. Without effective ventilation the heat gains can cause or exacerbate overheating locally and to neighbouring spaces.

### Refurbishment

There is currently no requirement to check overheating risk in existing dwellings when they are refurbished. This is a key point as only a small proportion of new dwellings are built every year, compared to the existing building stock.

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