CIBSE Weather Files 2016 release: Technical Briefing and Testing

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Test Reference Years

The TRY weather file represents a typical year and is used to determine average energy usage within buildings. The weather file consists of average months selected from a historical baseline. The previous release of the TRY used a baseline of 1984 to 2004 to select candidate months. The methodology used is based on the ISO method (British Standards & Institution 2005). The ISO selects the representative months using air temperature, relative humidity, and cloud cover (as a proxy for global solar irradiation) with wind speed as a secondary parameter. The primary variables are used to find the three months with the lowest ranking. From these months, the month with the most average wind speed is then chosen as the representative month for that location. The complete methodology for selecting the average months that make up a TRY are outlined in (Levermore & Parkinson 2006).

The new updated TRY files are created from an updated baseline of 1984 to 2013. TRYs are available for 14 locations across the UK. Further details of the methodology for updating the TRY weather files is outlined in (Eames et al. 2015). Table 1 shows the original and updated months per location. The paper contains an analysis of the temperature characteristics and a case study comparing how energy use is impacted by the new files. A summary of the case study within the paper is outlined after the Technical Briefing.

Table 1. Individual months selected for the original and updated test reference years for all 14 locations

Month	1	2	3	4	5	6	7	8	9	10	11	12
Belfast												
Original	2003	1985	1993	1998	1997	1997	2001	1999	2001	1988	1989	1985
Update	2000	2005	1993	1995	1988	2000	2008	1996	1997	1988	1984	2012
Birmingham												
Original	2000	2004	2004	2000	1995	1983	2001	1996	1995	1988	1991	2000
Update	2003	2005	2004	2006	1988	1984	2010	1996	1995	1988	2007	2007
Cardiff												
Original	1988	2003	1993	1988	2000	1983	1996	1996	1996	1988	1995	1983
Update	1986	2005	1993	2006	1988	1986	1997	1991	2010	2002	2008	2007
Edinburgh												
Original	1988	1982	1981	1985	1997	1999	1996	1980	1990	1988	1998	1979
Update	2003	2005	2004	2010	2013	1993	1987	2007	2013	2010	2008	1984
Glasgow												
Original	1986	1985	1978	1998	1997	1979	1996	1998	1997	1988	1998	1984
Update	1988	1999	2008	1988	1988	1998	1997	2005	2010	2010	1998	1996
Leeds												
Original	1995	1993	1993	1996	1997	2001	2001	1994	1995	1991	1990	1985
Update	1995	2005	2010	1995	2003	1993	2005	2013	2013	2000	1991	2007
London												
Original	1988	2004	2004	1992	2000	2001	1991	1996	1987	1988	1992	2003
Update	2011	2001	2004	1988	2004	1994	2005	2000	2007	2009	1991	2003
Manchester												
Original	1999	1992	2004	2000	1985	2001	1996	1996	1996	1986	1987	1987
Update	1999	2004	2001	1988	1985	1984	1996	1998	1989	1988	2007	1991
Newcastle												
Original	1988	1999	1992	1998	1997	2000	1996	1998	1996	1985	1989	1984
Update	1992	2001	1988	1998	1985	1998	1987	1984	1985	1988	1987	1984
Norwich												
Original	2004	1999	2004	1995	1993	1990	2002	1996	1985	1987	2001	1998
Update	2000	2005	2004	2005	2003	2005	2001	2012	2007	2002	2012	2003
Nottingham												
Original	1995	1999	1993	1998	2003	1984	2001	1994	1987	1999	1987	1994
Update	2003	2005	2004	1999	1988	2000	2008	2007	2007	1988	1990	2012
Plymouth												
Original	2004	1999	2001	2004	2000	2000	1994	1996	1988	1983	1984	1983
Update	1994	1999	2005	2006	2012	1994	1994	2000	2007	1986	2001	2003
Southampton												
Original	1982	1999	1983	1988	1985	1995	1981	1987	1988	1987	1987	1982
Update	2013	2004	2004	2008	1997	2013	1985	2000	1995	2002	2012	1997
Swindon												
Original	1988	1999	1993	2000	2000	1988	1996	1996	1996	2002	1987	1983
Update	2003	2005	2004	1995	1993	2008	2005	1987	1987	1985	2001	2007

Design Summer Years

The DSY represents warmer than typical year and is used to evaluate overheating risk within buildings. The previous methodology for selecting the DSY released in 2006 involved calculating the mean temperature over the period April to September inclusive for each year in an observational dataset. The DSY was the chosen as the third hottest year. The baseline dataset in the previous release was 1984 to 2004. Recently, probabilistic Design Summer Years were developed for the London area in TM49 (CIBSE 2014) in an effort to replace the Design Summer Year with a set of years which better describe overheating events, their relative severity and their expected frequency.

The latest release of the DSY updates the weather files in the remaining 13 locations across the UK using this new methodology and uses an updated baseline from 1984 to 2013 to select the files. (Eames 2016) outlines the methodology used to create probabilistic design summer years which are consistent in terms of the method over all fourteen CIBSE locations. A case study comparing how the previous and updated DSYs impact overheating is outlined after the Technical Briefing. The methodology in the (Eames 2016) paper is summarised next.

DSY: Updated methodology

The methodology is based on that used in TM49, which used a new metric to define the level of overheating. Three metrics are used to define overheating, these are defined first and then are used to rank and select suitable years for all 14 locations.

Conceptual Building

Using this methodology, a conceptual building is defined as free running and the operative temperature is equal to the external temperature at all times. This building is equivalent to a building with a high ventilation rate where all external gains are removed and the external temperature is similar to the internal temperature. While this conceptual building is a clear simplification, it is easy to implement as external temperatures can be considered as a proxy for the internal temperatures.

Comfort model

Using this conceptual building the external environment is highly correlated to the internal environment and a suitable comfort model must be considered. Using adaptive comfort criteria, the thermally neutral temperature is related to the running mean temperature given by

$$T_c = 0.33T_{rm} + 18.8\,,$$

where T_c is the predicted comfort temperature on a given day. T_{rm} is the running mean temperature given by

$$T_{rm} = 0.8T_{rm-1} + 0.2T_{mean-1}\,,$$

where T_{rm-1} is the running mean temperature of the proceeding day and T_{mean-1} is the average temperature of the proceeding day.

Weighted cooling degree hour (WCDH)

Using the definition of the comfort temperature, the WCDH is a quadratic expression given by:

$$\mathrm{WCDH} = \sum_{all\ hours} \Delta T^2$$

and

$$\Delta T = T_{op} - T_c \, , T_{op} - T_c > 0$$

where T_{op} is the internal operative temperature. The weighting puts a much greater emphasis on external temperatures which depart further from the comfort temperature. The WCDH approximation is related to the duration of the exceedance event as well as giving emphasis to more extreme temperatures which therefore takes into account the severity of the event.

The updated DSYs for London were selected using the WCDH metric for 3 locations within the city. These locations consist of some of the warmest in the UK with a high probability of this overheating metric being exceeded. In fact, each year contained some degree of overheating which will not necessarily be true of locations further north where the maximum temperatures are usually much cooler. To ensure the overheating metric is representative of each location, a number of metrics are considered with results compared in addition to the WCDH as described above.

Static Weighted Cooling Degree Hour (SWCDH)

Excess deaths can begin to be attributed at much lower temperatures than that defined by a heatwave and can be attributed to the 93rd centile temperature at each region with strong statistical significance (Armstrong et al. 2010) and therefore it could be argued that discomfort occurs at much cooler temperatures than the heatwave definitions.

In this second metric, the weighted cooling degree hours is calculated with the base temperature set to the 93rd centile temperature for that region for which the weather station is found, which in this case is a static temperature (SWCDH). The total for each location is therefore given by:

$$\mathrm{SWCDH} = \sum_{all\ hours} \left(T - T_{\mathrm{Threshold,region}}\right)^2, \qquad T - T_{\mathrm{Threshold,region}} > 0.$$

The regional threshold temperature ($T_{\mathrm{Threshold,region}}$) for each location can be seen in Table 2, the derivation of these thresholds is outlined in (Armstrong et al. 2010) for all locations except Belfast, Edinburgh and Glasgow, which were inferred, see (Eames 2016) for more details.

Table 2. Temperature thresholds where excess heat related mortality occurs

Location	Threshold Temperature / °C
Belfast	20.8
Birmingham	23.0
Cardiff	21.6
Edinburgh	20.9
Glasgow	21.1
Leeds	22.2
London	24.7

Location	Threshold Temperature / °C
Manchester	21.7
Newcastle	20.9
Nottingham	23.0
Norwich	23.9
Plymouth	22.3
Southampton	23.5
Swindon BN	23.5

Threshold Weighted Cooling Degree Hour (TWCDH)

The third metric combines the adaptation and comfort temperature of the WCDH metric with the regional threshold of SWCDH. This metric builds on the knowledge that regional mortality rates are correlated to different exceedance temperatures (Armstrong et al. 2010) while reconciling with the first metric – overheating is correlated to departures from the running average. Furthermore it is currently recommended that the threshold for more vulnerable occupants is reduced (CIBSE 2013), this method considers that this threshold is also related to the location. For this metric the Threshold Weighting Degree Hours (TWCDH) is given by:

$$\mathrm{TWCDH} = \sum_{all\ hours} (T - T_{\mathrm{conf}} + dT)^2 \,, T - T_{\mathrm{conf}} + dT > 0,$$

where *dT* is the difference between the average comfort temperature and the regional threshold as per Table 1 at that location. The value of *dT* for each location can be seen in Table 3. A positive value for *dT* has the effect of raising the adaptive comfort temperature while a negative value lowers the adaptive comfort temperature.

Table 3. Average difference between a locations average comfort temperature and the regional 93rd centile temperature threshold where excess heat related mortality occurs.

Location	*dT* / °C
Belfast	2.0
Birmingham	0.2
Cardiff	1.7
Edinburgh	1.9
Glasgow	1.7
Leeds	1.0
London	-1.2

Location	*dT* / °C
Manchester	1.5
Newcastle	1.9
Nottingham	-0.6
Norwich	0.1
Plymouth	0.9
Southampton	-0.2
Swindon BN	-0.2

To choose candidate years for DSY, the metrics can be used to rank historical years in terms of return period of hot events and the duration and intensity of these events.

Return Periods

The return period of a hot event refers to the frequency of the event with an associated exceedance value. The original DSY methodology considered the third hottest summer from a base period which was up to 21 years in length. This means that, assuming the current climate has no underlying trend, any given future summer has a 1-in-7 chance of being equal or hotter than the selected design summer year(Jentsch et al. 2013) or such a summer has a return period of 7 years. To provide a better estimate of the underlying distribution of the events, it is possible to fit different classes of functions to the data. To establish probabilistic design summer years and assign appropriate return periods, the most robust approach a Generalised Extreme Value (GEV) distribution fitted to the sum of the metric for the year.

A table with the return period analysis for each location is available at in the Appendix.

Events and warm spells

An event is defined as a continuous period where at least one hour of each day goes above the threshold temperature. Warm spells which are separated by up to three days are counted as the same warm spell. The intensity is simply the total of the metric divided by the number of days of the event.

A table with the characteristics of the warm events for each location is available in the Appendix.

Probabilistic DSY

Analysing the baseline dataset of 1984 to 2013, historical years can be ranked by their return periods and heat events per overheating metric. As with TM49 and the probabilistic design summer years, overheating events with three characteristics can be defined and used to select new candidate years.

DSY 1 – moderately warm summer

Represent a moderately warm summer year, defined as a year with a SWCDH return period closest to 7 years.

DSY 2 – short intense warm spell

Represents an intense extreme year, which is chosen as the year with the event which is about the same length as the moderate summer year but has a higher intensity than the moderate summer.

DSY 3 – long, less intense warm spell

The long extreme year is determined by the year with a less intense extreme than the high intensity year, more intense extreme than the moderate summer year but also has a longer duration than the moderate summer year.

Depending on data availability and location characteristics, the selection of the new years was not always straight forward. But the researchers were satisfied with the consistency of the years selected. The new probabilistic DSY for all locations are listed in Table 4. A simple modelled case study showing how the new and old files impact overheating is outlined after the Technical Briefing.

Table 4. Probabilistic design summer years for all locations

Location	DSY-1: Moderate	DSY-2: Intense	DSY-3: Long	Old
Belfast	2003	2006	1995	1999
Birmingham	1989	2006	1995	1989
Cardiff	2013	1995	1976	1988
Edinburgh	1989	1975	2006	1997
Glasgow	2003	1975	1976	1997
Leeds	1989	1990	1995	1995
London	1989	2003	1976	1989
Manchester	1997	1990	1995	1999
Newcastle	1996	1990	2006	1999
Norwich	1997	1990	1976	2004
Nottingham	1996	1990	1976	2002
Plymouth	1984	1990	1976	1990
Southampton	1989	2003	1995	1982
Swindon	2013	2003	1995	1999

Future weather files

Both TRY and DSY files will be available for future climate scenarios. The morphing methodology used to produce these future weather files builds previous work (Belcher et al. 2005) and is based on the same methodology used in TM49 (CIBSE 2014). Previous CIBSE future weather files were morphed using UKCIP02 climate projections (UKCP02 2002; CIBSE 2009). The updated weather files will use UKCIP09 projections (UKCP09 2010) and be available for the following scenarios:

- 2020s – High emissions scenario – 10^{th}, 50^{th}, 90^{th} percentile,
- 2050s – Medium – 10^{th}, 50^{th}, 90^{th},
- 2050s – High – 10^{th}, 50^{th}, 90^{th},
- 2080s – Low, 10^{th}, 50^{th}, 90^{th},
- 2080s – Medium – 10^{th}, 50^{th}, 90^{th},
- 2080s – High – 10^{th}, 50^{th}, 90^{th}.

Full details of the morphing methodology are due to be published soon.

Test Reference Year Testing

The aim of this document is to show how the updated Test Reference Year (TRY) weather files vary from the previous set. The updated files and the changes in the external conditions will have different impacts on building energy use depending on a variety of factors. These include the location, building construction and use. The modelled case studies presented provide indicative examples of how some standard building types will respond to varying some of these factors.

Overview

The TRYs had previously been based on the baseline 1984 to 2004. It was necessary to update the TRYs to a more recent baseline, 1984 to 2013, to reflect observed changes in the climate and therefore better represent the UK weather. Case studies showing how the new TRYs impact building energy use are summarised, the original studies were included in the update paper published in BSERT (Eames et al., 2015).

Comparison of temperature characteristics

The temperature characteristics between the original and updated TRYs are compared using three different measures. Figure 1 shows the annual mean temperature of both sets for each location. Figure 2 shows the heating degree day for the two sets, with a base temperature of 15°C and Figure 3 shows the cooling degree days with a base temperature of 21°C.

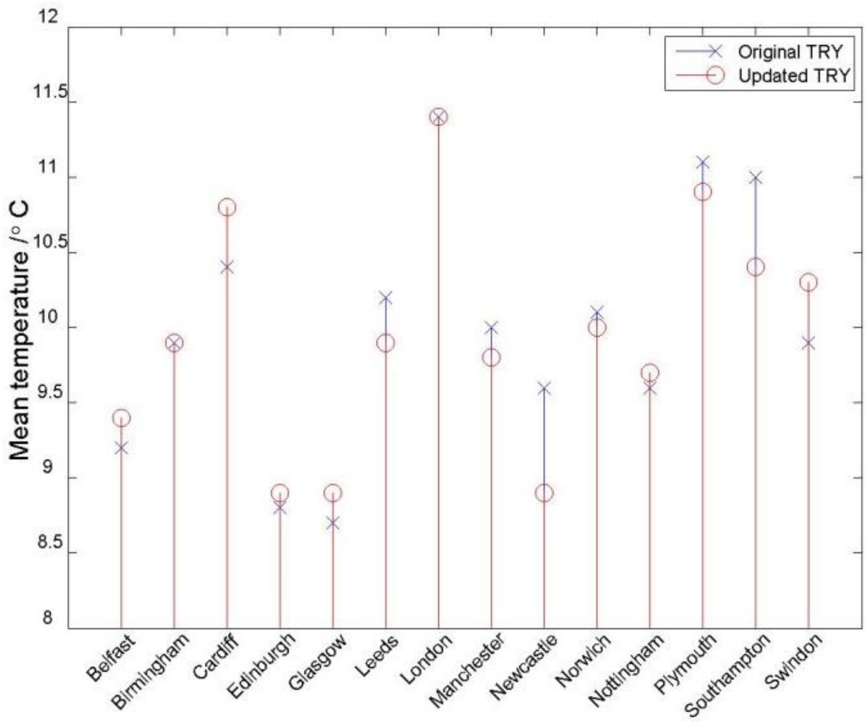

Figure 1. Mean Temperature of the original and updated TRYs

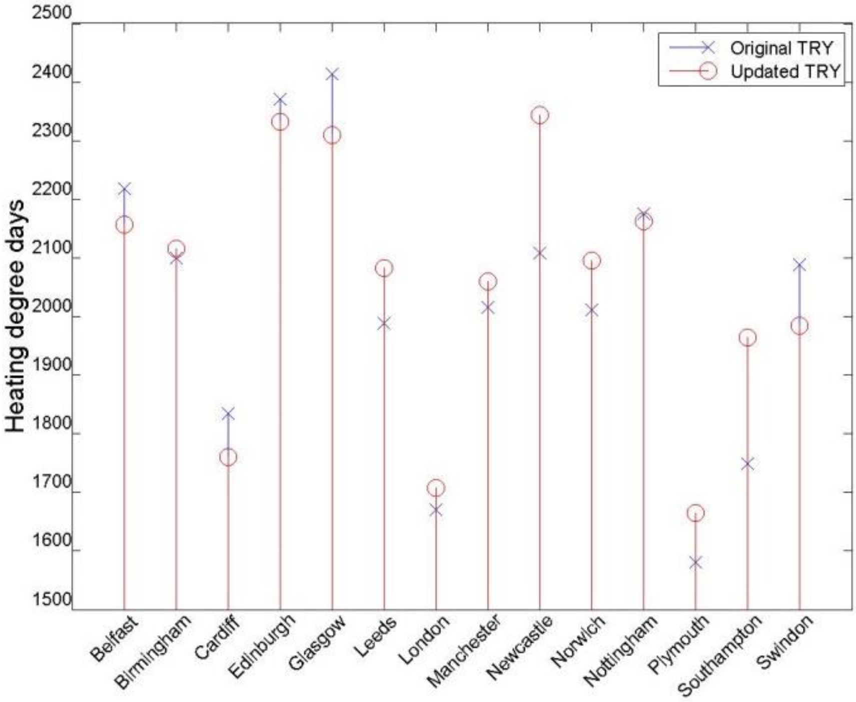

Figure 2. Heating degree days of the original and updated TRYs with a base temperature of 15 ℃

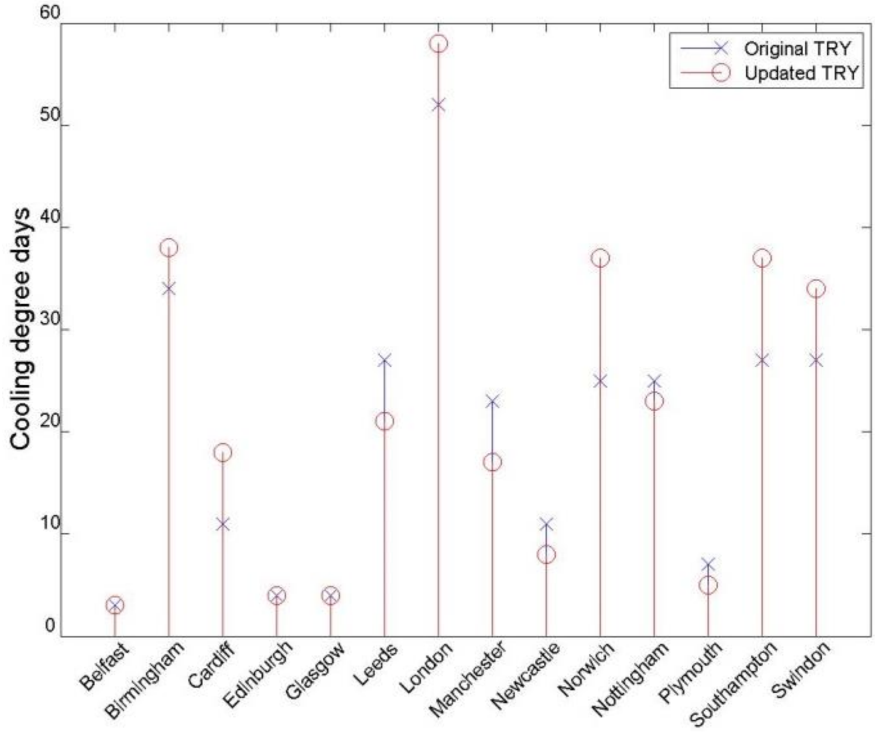

Figure 3. Cooling degree days of the original and updated TRYs with a base temperature of 21 ℃

The temperature differences between the original and updated TRYs using the three measures can be summarised as:

- There are 6 locations with an increased yearly mean temperature and 8 with a decrease. The largest difference is for Newcastle (0.7°C) and this could be explained by the location of observations between 2003 to 2014 moving to a more rural location.

- There is little difference between the heating degree days for both the original and updated set.
- There is also little difference between cooling degree days between both sets. The largest percentage increase is found Cardiff (64%), Norwich (48%) and Southampton (37%) however this only amounts to an increase of 7, 12 and 10 cooling degree days respectively.

To compare how the updated baseline and weather files impact energy use within buildings, the dynamic thermal model EnergyPlus is used. To compare the impacts of a large number of buildings, the input parameters of a base case building are varied.

Case Study

Modelling details

The base case building is a single story non-domestic building with a footprint of 100m^2 and with a height of 2.8m. There are 159m^2 of internal partitions but is treated as a single zone. The zone was conditioned to maintain the room temperature to 21°C for all occupied hours with an idealised plant load for all models. The electrical gains and occupancy profiles are based on the Micro CHP Acceleration project of the Carbon Trust (Trust, 2011) and a high resolution occupancy model is used (Richardson et al., 2008).

By varying the input parameters, a large proportion of buildings can be modelled.

Table 5 shows the range of building input parameters, in total 1000 buildings were generated from the parameters space. The wall and roof constructions were kept constant, but the level of insulation was varied to test a range of U-Values. For each building at each location, the total heating load, total cooling load (as a proxy for overheating) and the total space conditioning load is calculated using both the original and updated weather years.

Table 5. Minimum and maximum values for the five variable building parameters.

Building parameter	Parameter minimum	Parameter maximum
Aspect ratio	0.33	3
Wall U Value (Wm^{-2}K^{-1})	0.05	0.6
Roof U Value (Wm^{-2}K^{-1})	0.05	0.4
Infiltration (ACh^{-1})	0.05	2
Glazing percentage	10	60

Results

The distribution of the percentage change of the difference between the two weather years energy loads is displayed for the locations of Edinburgh (Figure 4), London (Figure 5), Manchester (Figure 6) and Plymouth (Figure 7).

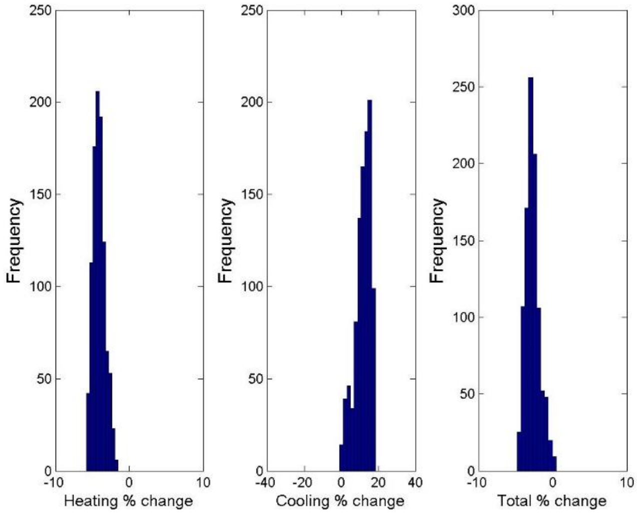

Figure 4. Distribution of the percentage change of the difference between the new and original test reference years for heating energy, cooling energy, and total space conditioning load for Edinburgh.

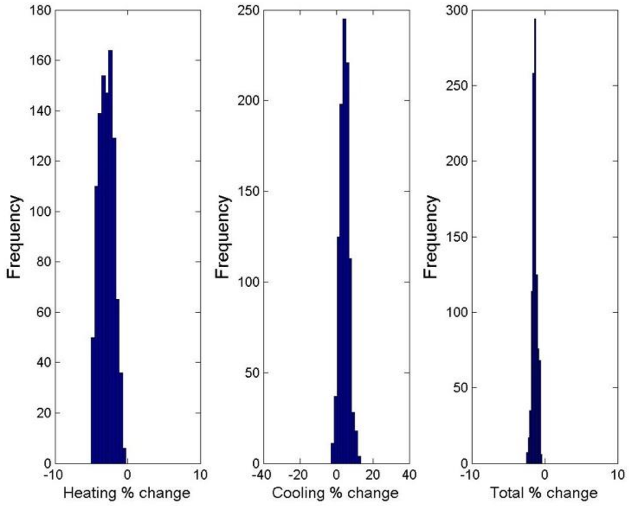

Figure 5. Distribution of the percentage change of the difference between the new and original test reference years for heating energy, cooling energy, and total space conditioning load for London.

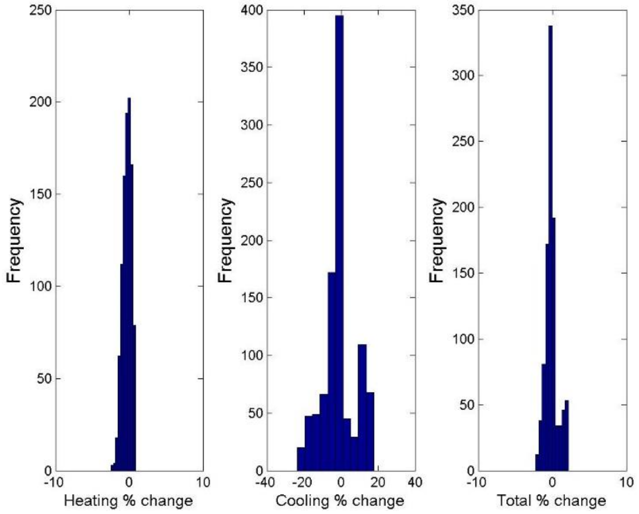

Figure 6. Distribution of the percentage change of the difference between the new and original test reference years for heating energy, cooling energy, and total space conditioning load for Manchester.

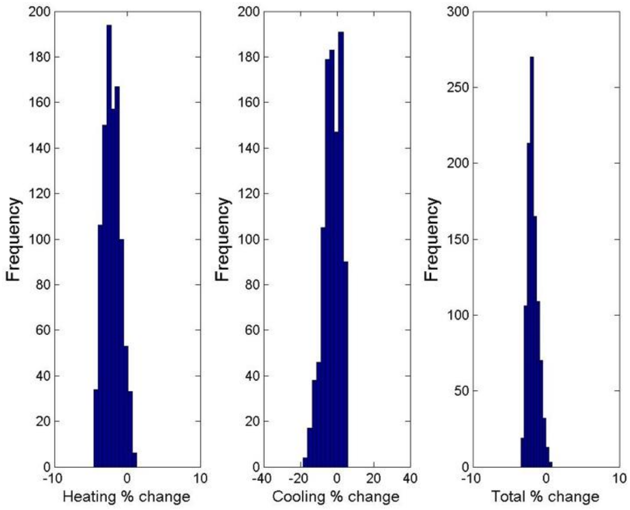

Figure 7. Distribution of the percentage change of the difference between the new and original test reference years for heating energy, cooling energy, and total space conditioning load for Plymouth.

The differences in heat and cooling energy use between the original and updated files for the sites presented can be summarised as:

- For Edinburgh, buildings are likely to use less heating and more cooling energy consumption. Both files have similar temperature distribution above 19°C and result in a similar number of cooling degree hours, see Figure 3. The revised weather file has on average a lower coincident cloud cover which would contribute to the cooling load.
- For London, the updated file has a greater number of heating degree days, but lower heating energy consumption. This implies cooler, but sunnier winter weather.
- For Manchester, although there is a higher percentage change in cooling energy use compared to other sites, the absolute difference in heating and cooling energy is similar.
- For Plymouth, there is a decrease in both heating and cooling loads, but the total change is largely determined by the change in heating load.

Summary of results

For all locations the change in heating energy and total space conditioning is small (less than 10%) and clearly heating energy is the dominant energy source for both the original and the new weather files. The cooling energy can change by up to 40% but in absolute terms this change is small.

The results for the predicted energy use for modelled buildings can be summarised as: ten locations (Belfast, Birmingham, Cardiff, Edinburgh, Glasgow, London, Manchester, Nottingham, Plymouth and Swindon) are expected to have less modelled total space conditioning energy dominated by a reduction in the heating energy; for the other four locations (Southampton, Leeds, Newcastle and Norwich) buildings are expected to have an increase in modelled total space conditioning. More detailed analysis of the results is in the paper accompanying the release (Eames et al., 2015).

Design Summer Years Testing

This document aims to highlight how the updated Design Summer Year (DSY) weather files impact the calculation of the level of overheating within buildings. These case studies do not aim to provide definitive evidence of how the updated files will impact overheating levels with building. Factors such as location, construction and usage of a building will determine how it responds to external conditions. The case studies provide indicative examples of how certain buildings will respond to changes to the new files.

Overview

Two simple case studies are presented in which the level of overheating is analysed using the 2006 released and the new DSY files. The dynamic thermal model EnergyPlus v8.4.0 is used to simulate the a domestic and non-domestic building (U.S. Department of Energy (US-DOE), 2014). The level of overheating is calculated based on the following overheating criteria (2006 CIBSE Guide A), where overheating is assessed as the percentage of occupied hours that the operative temperature (Top) exceeds a threshold temperature:

- Bedrooms: 1% annual occupied hours over 26°C
- Open plan offices: 1% annual occupied hours over 28°C

Two scenarios are tested for each building, an uninsulated poorly designed base case and an insulated case which meets current Part L1A building regulations (DCLG, 2010). The case studies aim to show relative differences between the files, as an introduction to the new DSYs.

The new DSY files have been selected from an updated baseline period (1984 – 2013 compared to 1984 – 2003) and using a new methodology. The DSY1 represents a moderate year with a return period of 7 years (1-in-7 year chance of occurring) as ranked by the Static Weighted Cooling Degree Hour (SWCD) metric, (see the Technical briefing for more details). To represent warmer summer conditions, DSY 2 and DSY 3 were selected depending on the duration and intensity of the warm events within the year chosen. DSY 2 represents a summer where the warmest event is the same duration as the year chosen for DSY 1, but more intense event. DSY 3 represents a year where the duration of the warmest event is much longer in duration than both DSY 2 and DSY 3, but less intense than DSY 2 and more intense than DSY 3. The new DSY files were produced with the aim of better describing hot events, their relative severity and their expected frequency.

Case Study A – Semi-detached dwelling

Model details

The dwelling model represents a 2 story, three bedroom, post-war, semi-detached house. The archetype is one of the most common dwelling types found in England (Oikonomou et al., 2012). The base case building has uninsulated cavity walls and an uninsulated pitched roof, double glazed windows and low thermal mass, see Table 6 for building parameters. The insulated wall has cavity-inserted insulation. Windows are orientated North and South, the main bedroom is on the 1st floor and is South facing. Occupancy schedules are for a typical working family, the main bedroom is occupied 23:00 – 07:00 all week. The window control has a comfort temperature of 24 °C, once the internal temperature exceeds this temperature it is opened. Building airtightness is modelled by applying a permeability, or an air leakage rate per hour at 50Pa, to the building fabric. Typical internal gains are taken from CIBSE Guide A. The operative temperature for the summer period (May to September) is used to calculate the level of overheating for the main bedroom for each location.

Table 6. Building parameter values

Building parameter	Value
Uninsulated Wall U Value ($Wm^{-2}K^{-1}$)	1.03
Insulated Wall U Value ($Wm^{-2}K^{-1}$)	0.30
Uninsulated Roof U Value ($Wm^{-2}K^{-1}$)	4.71
Insulated Roof U Value ($Wm^{-2}K^{-1}$)	0.18

Results[1]

Figure 8 shows the percentage of occupied hours the operative temperature the main bedroom exceeds the benchmark temperature for the uninsulated case:

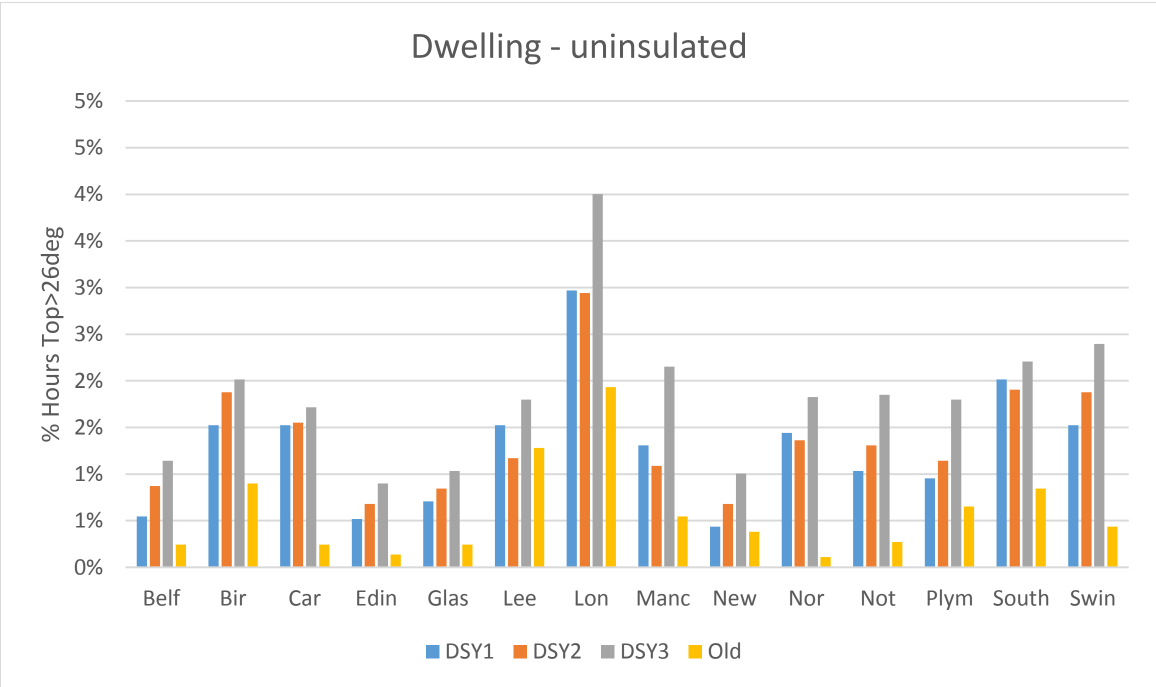

Figure 8 Percentage of hours (occupied) Top is greater than 26 °C for each DSY location for each of the new and old files

[1] It should be noted that London Heathrow is used as the London weather file in these case studies.

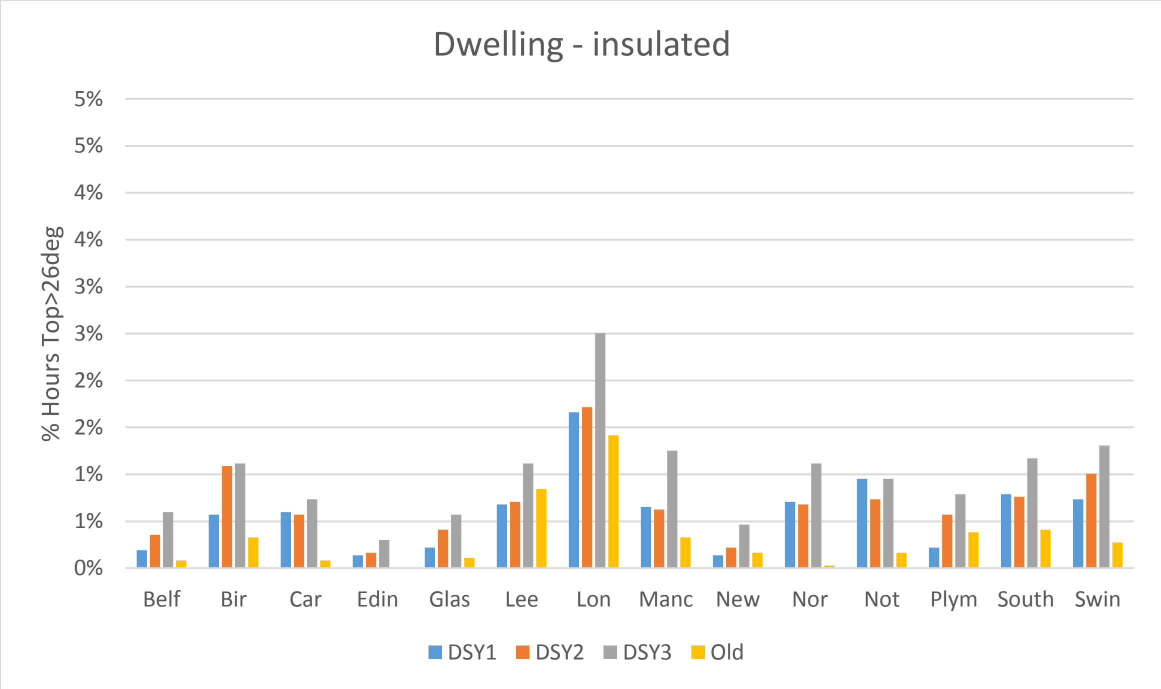

Figure 9 shows the results for the insulated case:

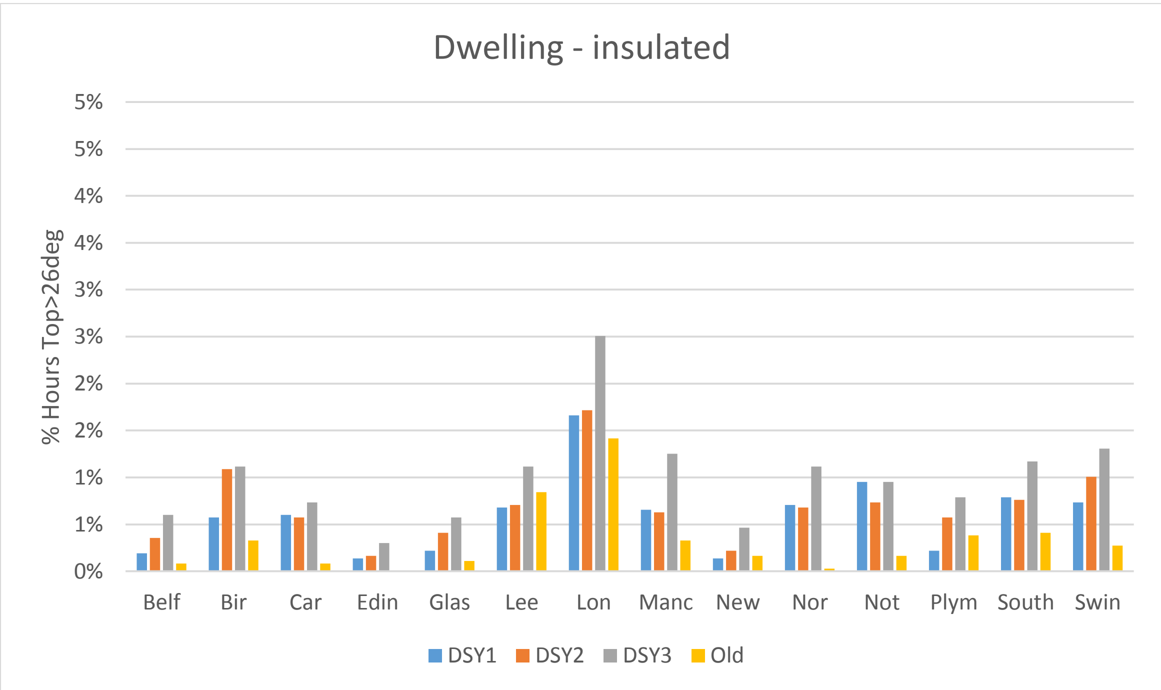

Figure 9 Percentage of hours (occupied) Top is greater than 26 °C for each DSY location for each of the new and old files

The uninsulated results can be summarised as:

- The new DSY files result in higher levels of overheating compared to the old files in all locations except Leeds. The old DSY file for Leeds is the same year as selected for the new DSY 3.
- Use of a DSY 3 file, which represents a summer with a long heat event[2] results in the highest level of overheating for all locations.
- Use of DSY 2 file results in higher levels of overheating than DSY 1 in all but 5 locations (Leeds, London, Manchester, Norwich and Southampton).
- Cities located furthest North (Edinburgh, Glasgow and Newcastle) overheat for the least amount of time compared to other locations.
- London has the highest level of overheating. DSY 1 overheats for greater periods of time compared to all other files in other locations.

Comparing the uninsulated and insulated results:

- Overheating levels are reduced by almost 50% in all locations.
- The use of the old DSY files results in lower levels of overheating compared to the new files in all but 3 locations. For Leeds, Newcastle and Plymouth, the old files overheat for longer periods of times compared to DSY 1 and DSY 2.
- Per location, DSY 3 overheats for greatest amount of time.
- Per location, use of DSY 2 again generally results in higher levels of overheating compered to DSY 1 in all but in 5 locations (Cardiff, Manchester, Norwich, Nottingham and Southampton).

Case Study B – Office

Model details

The model represents a single floor of a deep-plan office – the archetype has been used in previous work (Virk et al., 2015). The base case building has uninsulated external walls and flat roof, double glazed windows and low thermal mass. The North and South facades have 50% glazing ratio, with 60% opening ratio. The East and West facades have no glazing. During occupied hours, windows are opened when the internal temperatures exceeds a setpoint of 22°C. The model is ventilated at night time, with a night ventilation setpoint of 14°C. Building airtightness is modelled by applying a permeability, or an air leakage rate per hour at 50Pa, to the building fabric. The building is occupied 07:00 – 19:00 during weekdays. Typical internal gains are taken from CIBSE Guide A for an open plan office.

Table 7. Building parameter values

Building parameter	Value
Uninsulated Wall U Value ($Wm^{-2}K^{-1}$)	1.38
Insulated Wall U Value ($Wm^{-2}K^{-1}$)	0.31
Uninsulated Roof U Value ($Wm^{-2}K^{-1}$)	1.29
Insulated Roof U Value ($Wm^{-2}K^{-1}$)	0.30

[2] An event has been defined as a continuous period where at least one hour of each day goes above the threshold temperature. Warm spells which are separated by up to three days are counted as the same warm spell. The intensity is simply the total of the metric divided by the number of days of the event.

Results

Figure 10 shows the percentage of occupied hours the operative temperature the office exceeds the benchmark temperature for the uninsulated case:

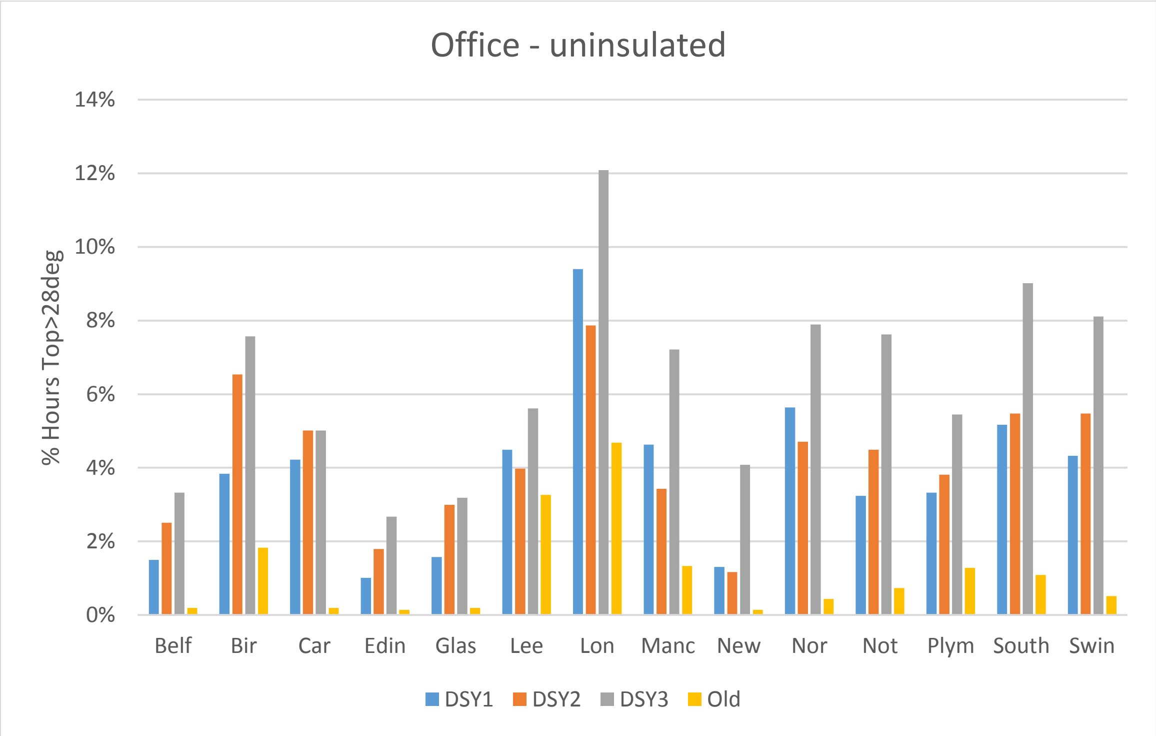

Figure 10 Percentage of hours (occupied) Top is greater than 28 °C for each DSY location for each of the new and old files

Figure 11 shows the results for the insulated office:

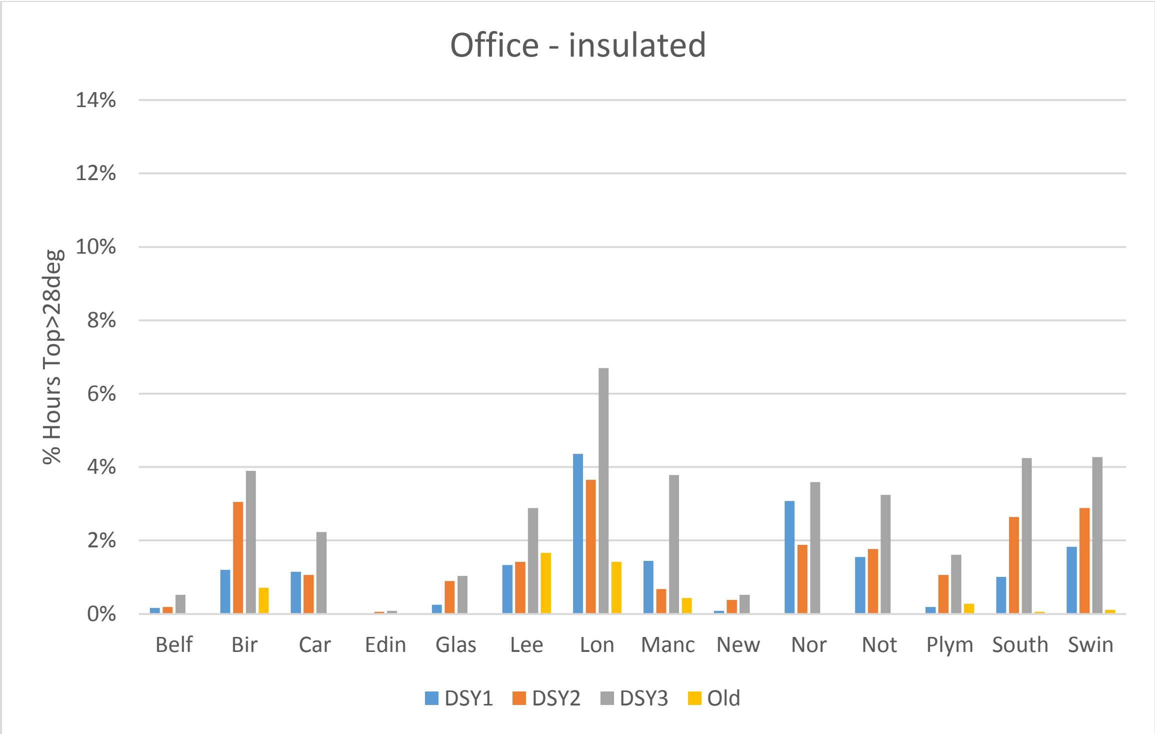

Figure 11 Percentage of hours (occupied) Top is greater than 28 °C for each DSY location for each of the new and old files

The results for both office models can be summarised as:

- As with the dwelling case study, the old DSY files overheat less than all the new DSY files for all locations.
- Per location, the DSY3 always overheats for the greatest amount of time.
- Per location, overheating is higher for DSY2 than DSY1 in all but 4 locations for uninsulated case (Leeds, London, Manchester and Norwich) and 4 locations for the insulated case (Cardiff, London, Manchester and Norwich).
- Adding insulation reduces the level of overheating, but the relative differences between the files are generally the same.
- The most northerly locations (Edinburgh, Glasgow and Newcastle) overheat for the least amount of time.
- London again has the highest levels of overheating.

Discussion of results

The overheating results from the case studies presented can be explained by the different criteria used to select the old and new files per location. The new DSYs represent summers with warmer weather events than the previous set (released in 2006). In both case studies, the use of the old files results in lower levels of overheating compared to the new moderate year DSY 1. The only exception is Leeds. The old DSY for Leeds was 1995, which happens to be the most extreme year analysed ranked by SWCDH. The other sites with which the old DSY is the same as one of the new files are London Heathrow DSY 1, Birmingham DSY 1 and Plymouth DSY 2. The reason that the results differ from each other is that although the air temperatures are the same for both files, the solar data used to produce the files are different.

The new DSYs now include years with more extreme overheating characteristics, longer and more intense hot spells for each location. This is reflected in the results, for most locations the DSY 3 overheats for the longest period of time compared to DSY 1 and 2 and DSY 2 overheats for longer periods of time than DSY 1. There are some locations where DSY 1 overheats for longer periods of time than DSY 2, notably Manchester and Norwich in all of the models. The possible explanation for this could be that the duration of the DSY 1 heat events are almost double the duration of the heat events in DSY 2 when ranked by SWCDH and WCDH for both locations, but less intense.

The level of overheating within the case studies will be determined by a number of factors. The most northerly locations overheat for the least amount of time due to the lower air temperatures and also lower levels of solar radiation. Other external factors such as wind speeds and direction will potentially impact overheating. Most of the Met Office weather stations used to produce the DSYs are located in rural areas, often in airfields. This will also have an impact on the level of overheating, as nocturnal air temperatures within cities will generally be higher than rural temperatures due to the Urban Heat Island effect. The archetype size and layout, construction, amount of glazing, usage and ventilation strategies will all impact how the internal environment responds to changes in external conditions. What is clear from the case studies is that the new DSYs are overall warmer than the previous set. The results from these case studies further emphasise the recommendation in TM49 (CIBSE, 2014) of the need for all available DSY files to be modelled during overheating assessment, in order to highlight these differences and test the sensitivity of the building design to these different heat events.

The case studies also highlight how the relationship between the weather variables and subsequent level of overheating is complex. The differences between different heatwave periods, peak day time and minimum night time temperature profiles and wind speeds for different years will vary the level of overheating and needs to be further investigated.

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Appendix

Table 8. Characteristics of the events within three DSY candidate years ordered by the total Static Weighted Cooling Degree Hour (SWCDH) for all 14 locations.

Location	DSY Type	Date	SWCDH	Duration	Intensity
Belfast	DSY-3: Long	15/07/1995	1827	32	57
	DSY-2: Intense	11/07/2006	1315	13	101
	DSY-1: Moderate	11/08/2003	374	9	42
Birmingham	DSY-3: Long	13/07/1995	4569	30	152
	DSY-2: Intense	14/07/2006	3187	19	168
	DSY-1: Moderate	14/07/1989	1487	12	124
Cardiff	DSY-3: Long	13/06/1976	4634	21	221
	DSY-2: Intense	13/07/1995	4218	35	121
	DSY-1: Moderate	13/07/2013	1430	20	72
Edinburgh	DSY-3: Long	12/07/2006	1272	24	53
	DSY-2: Intense	12/07/1975	1203	17	71
	DSY-1: Moderate	12/07/1989	649	15	43
Glasgow	DSY-3: Long	15/06/1976	1826	19	96
	DSY-2: Intense	13/07/1975	1647	17	97
	DSY-1: Moderate	12/08/2003	786	9	87
Leeds	DSY-3: Long	12/07/1995	4597	31	148
	DSY-2: Intense	14/07/1990	2461	12	205
	DSY-1: Moderate	14/07/1989	1425	15	95
London	DSY-3: Long	22/06/1976	5754	28	206
	DSY-2: Intense	02/08/2003	3921	17	231
	DSY-1: Moderate	15/07/1989	1551	15	103
Manchester	DSY-3: Long	13/07/1995	6389	30	213
	DSY-2: Intense	14/07/1990	2349	11	214
	DSY-1: Moderate	14/08/1997	2036	20	102
Newcastle	DSY-3: Long	12/07/2006	1728	16	108
	DSY-2: Intense	11/07/1990	1784	10	178
	DSY-1: Moderate	10/08/1996	674	7	96
Norwich	DSY-3: Long	11/06/1976	3586	28	128
	DSY-2: Intense	11/07/1990	1377	9	153
	DSY-1: Moderate	10/08/1997	1662	18	92
Nottingham	DSY-3: Long	13/06/1976	4511	27	167
	DSY-2: Intense	12/07/1990	2103	11	191
	DSY-1: Moderate	14/08/1996	956	7	137
Plymouth	DSY-3: Long	15/06/1976	1747	15	116
	DSY-2: Intense	10/08/1990	892	4	223
	DSY-1: Moderate	11/08/1984	224	5	45
Southampton	DSY-3: Long	10/07/1995	3586	33	109

	DSY-2: Intense	12/08/2003	1922	15	128
	DSY-1: Moderate	17/06/1995	718	9	80
Swindon	DSY-3: Long	19/07/1995	4615	38	121
	DSY-2: Intense	03/08/2003	2115	15	141
	DSY-1: Moderate	05/07/2013	1541	23	67

Table 9. Return period analysis against the overheating metrics for the candidate DSY for all 14 locations ordered by the number of Static Weighted Cooling Degree Hours (SWCDH).

Location	**DSY Type**	**Year**	**SWCDH**
Belfast	DSY-3: Long	1995	22
	DSY-2: Intense	2006	13
	DSY-1: Moderate	2003	6.2
Birmingham	DSY-3: Long	1995	21
	DSY-2: Intense	2006	17
	DSY-1: Moderate	1989	7
Cardiff	DSY-3: Long	1976	49.3
	DSY-2: Intense	1995	37.5
	DSY-1: Moderate	2013	7
Edinburgh	DSY-3: Long	2006	11.1
	DSY-2: Intense	1975	12.6
	DSY-1: Moderate	1989	7.3
Glasgow	DSY-3: Long	1976	14.5
	DSY-2: Intense	1975	10.5
	DSY-1: Moderate	2003	6.9
Leeds	DSY-3: Long	1995	28.9
	DSY-2: Intense	1990	14.3
	DSY-1: Moderate	1989	6.7
London	DSY-3: Long	1976	23.7
	DSY-2: Intense	2003	15.5
	DSY-1: Moderate	1989	6.7
Manchester	DSY-3: Long	1995	34
	DSY-2: Intense	1990	9.8
	DSY-1: Moderate	1997	6.5
Newcastle	DSY-3: Long	2006	19.5
	DSY-2: Intense	1990	19.2
	DSY-1: Moderate	1996	7.5
Norwich	DSY-3: Long	1976	50.8
	DSY-2: Intense	1990	12.6
	DSY-1: Moderate	1997	8.2
Nottingham	DSY-3: Long	1976	26.9
	DSY-2: Intense	1990	11.6
	DSY-1: Moderate	1996	7.1

Plymouth	DSY-3: Long	1976	24.6
	DSY-2: Intense	1990	13
	DSY-1: Moderate	1984	5.8
Southampton	DSY-3: Long	1995	33.4
	DSY-2: Intense	2003	15.7
	DSY-1: Moderate	1989	9.1
Swindon	DSY-3: Long	1995	20
	DSY-2: Intense	2003	11.5
	DSY-1: Moderate	2013	6.3