Energy Demand for Heating

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1. Report Overview

An increase in average winter temperatures caused by climate change is expected to reduce the energy used for heating in Scotland[1]. However, energy demand for heating is affected by a whole range of factors, of which external temperature is just one. This report provides a summary of these factors and gives some context for the CXC Climate Adaptation Indicators that relate to energy demand for heating[2].

2. Factors affecting energy demand for heat

The key factors affecting energy demand for heating are shown in Figure 1 below and are as follows:

1. Total population, population demographics and total number of households
2. Household size and type: number and nature of occupants per dwelling
3. Income level and ability to pay
4. Heating choices of occupants including:
    a. chosen internal temperature of main and secondary living areas;
    b. size, extent and characteristics of internal areas selected for heating;
    c. hours of heating chosen for main and secondary living areas; and
    d. extent to which occupants monitor and control home energy usage.
5. External weather conditions and location of dwelling
6. Physical characteristics of the building - thermal properties and energy efficiency

As Figure 1 indicates, data are only publicly available for a small sub-set of the drivers of energy demand for heating. CXC is developing Indicators where possible, and those that will be completed in 2015 include the following:

BB20a:	Energy Performance of Scottish Housing Stock
BB20b:	Extent of insulation measures across Scottish Housing Stock
BB26/27:	Natural gas consumption (domestic usage / non -domestic usage)
S61:	Number of households in fuel poverty
S64:	Uptake of energy efficiency measures

It would be naïve to assume that tracking these physical aspects alone will tell the whole story about heating demand in Scotland. The influence and significance of other factors is described below.

[1] The Climate Change Risk Assessment (CCRA) for Scotland lists 'Reduced Energy Demand for Heating' as an opportunity.

[2] Note that while energy for cooling in summer will increase for some buildings, it is not yet considered to be a priority climate change risk for Scotland and so is not covered in this context paper.

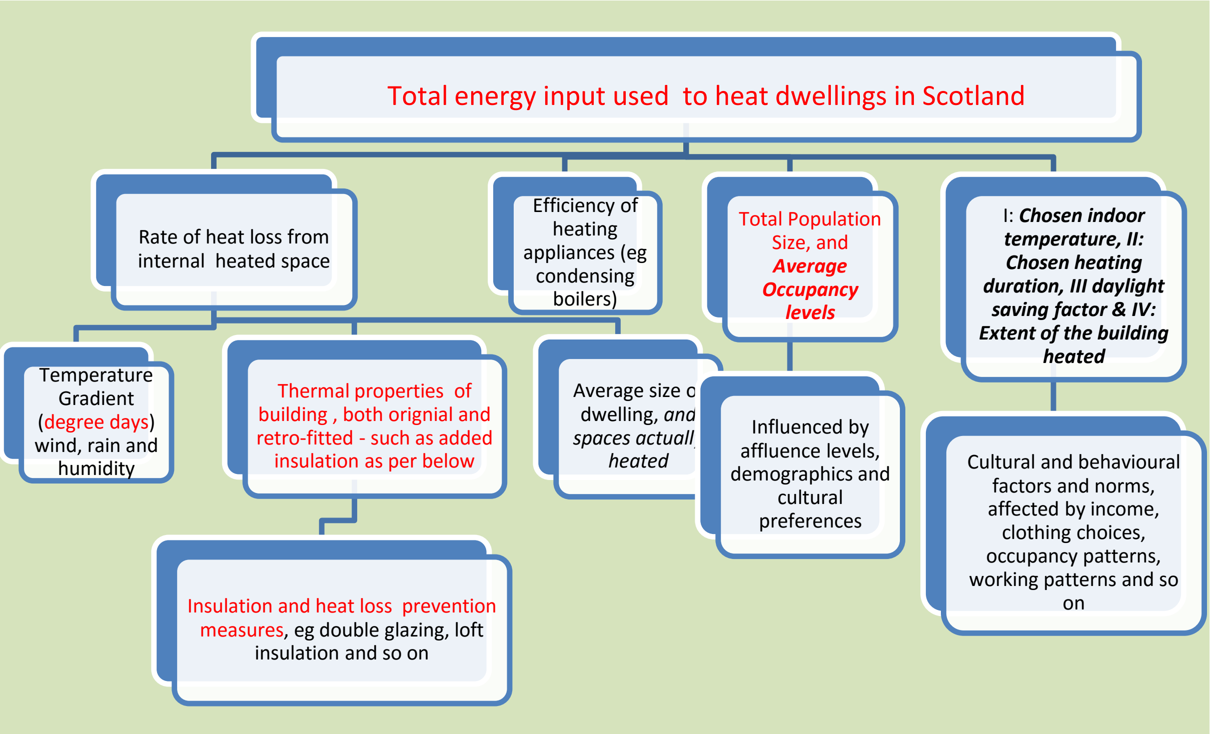

Figure 1 Factors affecting total energy demand for heating of dwellings

KEY: Red – some metrics or proxy metrics exist. **Black** – metrics not yet publicly available;
Italic (Black & Red) *– Norms, social practices & behaviours that could be influenced by policy and advocacy.*[3]

3. Total population, population demographics and total number of households

In 2013 the estimated population of Scotland was 5.33 million[4]. As shown in Figure 2 below, the population is expected to grow by 9% over the twenty five years between 2012 and 2037.

In 2013, there were 2.4 million households and 2.5 million dwellings in Scotland. Household numbers have increased by 8% over the last ten years, and this upward trend is predicted to continue. The number of households is expected to grow more rapidly than overall population, and is predicted to increase by 17% over the 25 years from 2012, thus reaching 2.78 million by 2037 (15,800 additional households per year on average). This greater increase in household numbers will be partly due to more people living alone or in smaller households. Scotland's population is ageing, and older people are more likely to live alone or with just one other person.

All these increases - in overall population size, the share of this represented by older people, and overall household numbers - will increase Scotland's total demand for heat energy[5].

[3] There are many policies that relate to physical factors (eg insulation, energy efficiency), but fewer aimed at influencing social norms (eg heating of rooms even when not in use) and behaviours (eg willingness to 'dress for the season').
[4] http://www.nrscotland.gov.uk/files/statistics/high-level-summary/j11198/j1119818.htm
[5] In the absence of other, countervailing factors.

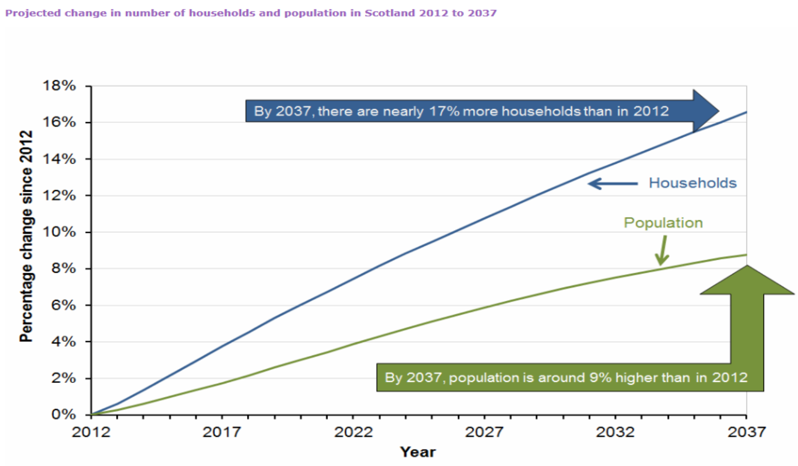

Figure 2 Projected change in households and population in Scotland 2012 to 2037

4. Household Size: Number and type of occupants per dwelling

Household size is also an important variable, and affects not only heat demand, but a whole suite of other resilience issues. Greater occupant numbers will generally result in a greater energy demand for heating *per household*. However, if those people then chose to live in separate houses the total energy demand for that group will increase. This trend is evident, and average household sizes have been falling since the 1960's, as more people live alone or in smaller households (see the figure below). All local authorities saw a decrease in average household size over the last decade. Average household size decreased from 2.23 people per household in 2003 to 2.18 people in 2013[6].

Heating behaviours will also vary according to the type of household and its occupants. For example, a household consisting of several unrelated professionals will have different space heating requirements to that of a family[7].

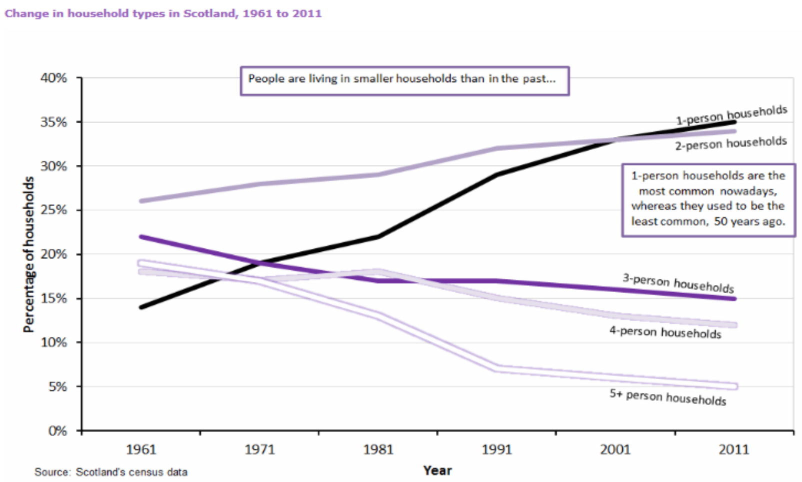

Figure 3 Change in households types in Scotland, 1961 – 2011

[6] http://www.nrscotland.gov.uk/files/statistics/high-level-summary/j11198/j1119818.htm
[7] Dr Keith Baker 2015, Glasgow Caledonian University, pers. comm., 5 Feb

In general, low occupancy is likely to be more resource intensive and less sustainable[8]. It also increases the cost per head of a range of household measures such as Flood Defences, Weather tightness, Energy Efficiency Measures and Cooling Measures.

5. Income level and ability to pay

Household income is an important factor in determining energy use (Santin et al, 2009[9]), and some have found an almost linear relationship between expenditure and energy use, confirming that the higher the disposable yearly income, the higher the energy use (Biesiot and Noorman, quoted in Santin et al, 2009). It should be noted that low income rural households spend more on heating than those in low income urban settings regardless of all other factors (Mould, Baker and Emmanuel, 2014[10]). The reasons for this are not yet fully understood.

Some metrics on the relationship between income and fuel spend are publicly available, for example at DECC[11] and Scottish Government[12]. A range of other metrics and details relating to energy usage and fuel poverty are also given in the CXC Society Indicators, and include these:

- No. of households in fuel poverty (S61 & S64)
- Number of disconnected supplies due to non-payment of bills (S62)
- Assessment of Energy Efficiency Measures and uptake rate of these (S63 & S64)

6. Heating choices of Household Occupants

Heating choices such as preferred temperature, length of heating periods, and extent of space heated are important factors that can have a big impact on heating demand, but no publicly available data exist to examine them directly. Some qualitative, case study and modelled data are available. Furthermore, heating choices and societal trends in chosen heating regimes are not accounted for in methods such as the 'Standard Assessment Procedure' (SAP)[13], which is designed to model and assess the energy rating of residential dwellings. As a result, this important set of variables may be routinely overlooked when considering trends in national energy demand (Shove et al, 2014). While there are no directly publicly available data for the variables within this category, the following observations and contextual data may be useful.

Chosen Internal Temperatures, and extent of heated areas

The 'Housing Energy Fact File', commissioned by DECC has information about heating levels and behaviours[14]. It should be noted that the averaging of data masks '***significant segmentation due to income, geography, behaviour and other influencing factors'***. DECC has modelled internal temperatures since 1970 as shown here:

[8] See for example D Dorling 'All that is Solid' http://www.penguin.co.uk/books/all-that-is-solid/9780141978192/
[9] http://www.sciencedirect.com/science/article/pii/S0378778809001388
[10] See https://queenspoliticalreview.files.wordpress.com/2014/10/qpr-volume-2-issue-2-fuel-poverty-edition-2014.pdf
[11] https://www.gov.uk/government/collections/fuel-poverty-statistics
[12] http://www.scotland.gov.uk/Topics/Statistics/Browse/Housing-Regeneration/TrendFuelPoverty
[13] https://www.gov.uk/standard-assessment-procedure
[14] https://www.gov.uk/government/statistics/united-kingdom-housing-energy-fact-file-2013

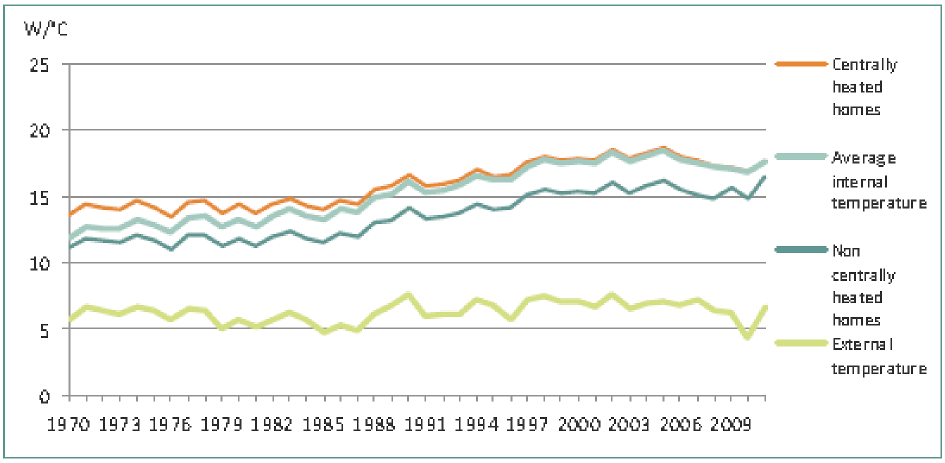

Figure 4 Average UK winter external and internal temperatures

Their 2013 report states that 'people in the UK now run their homes at significantly higher temperatures in the winter than they did forty years ago' (pg 45). In 1970, during the winter, the average internal temperature in homes with central heating was estimated at 13.7C. Forty-one years later, this estimate had risen by 4 degrees to 17.7C. (Note that the average temperature is for the whole house, and the *duration and extent* of heating is at least as significant here as the temperature of the living room). The report suggested that people in 1970 had "very different expectations of thermal comfort ….. "Most families in 1970 lived in homes that would be cold by modern standards in winter – as cool as 12C on average." In response, the press concluded that … "despite the typical household seeing their bills rise by £200 in real terms …….. people no longer accept "the need to wear thick clothes at home in winter"[15] This is of course a generalisation, and as noted earlier, there may be very low levels of heating in some low income households.

Chosen Heating Periods

The amount of time a home is heated is likely to be affected by various factors including

1. Care status (e.g. the parents / carers of young children and other dependents): carers are likely to be at home for longer than people who go out to work. In addition, Scotland's population is ageing, and heat demand from this sector of the population is likely to rise (though again income will be an important influencer here).
2. Home workers are likely to require more home heating. In Scotland 10.7% of workers are home-based, an increase of 1.4% since 2008[16]. Not surprisingly, research has shown a correlation between home working and increased energy consumption (Baker and Rylatt, 2008).
3. Occupant choices about how much to adjust and control home heating levels, versus using a fixed heating regime. A proxy indicator for this can be provided by the proportion of people who report that they monitor home energy usage. This proportion has increased over recent years. Choices about which rooms to heat, and to what level will also affect demand.
4. Some sources suggest that adjusting 'Daylight saving' in the UK could reduce energy usage for both heating and lighting (Yu-Foong Chong, Elizabeth Garnsey, Simon Hill and Frederic

[15] http://www.telegraph.co.uk/finance/personalfinance/household-bills/10603400/Homes-heated-at-least-4C-warmer-than-in-1970-study-finds.html

[16] http://www.ons.gov.uk/ons/rel/lmac/characteristics-of-home-workers/2014/sty-home-workers.html

Desobry "Daylight Saving, Electricity Demand and Emissions; Exploratory Studies from Great Britain", October 2009).

Monitoring and Management of Home Energy usage by Occupants

Energy usage may also be affected by the extent to which occupants monitor (and thus go on to modify and reduce) their household energy usage. Some data are available from the SHCS, but it does not differentiate between the monitoring of different energy sources (electricity, gas and so on). It may be used as a proxy indicator for the management of home energy use for heating. Figures show that home energy monitoring is rising. The proportion of households that 'do not monitor energy usage at all' has dropped from 31% in 2008 to 20% in 2013, while the proportion that monitor either 'fairly or very closely' rose in the same period from 44% to 56%.[17] There is no evidence of a relationship between energy use monitoring and income.

7. External Weather Conditions and Location of Dwellings

The influence of external temperature on heating demand is calculated through 'Heating Degree Days' (HDD), which provide a measure of how mild or cold a winter is. Heating degree days are defined relative to a base temperature—the outside temperature above which a building should not need heating. The base temperature used to calculate degree days in the UK is generally 15.5ºC, because at this temperature most UK buildings do not need supplementary heating[18]. 'Degree days' are a measure of the difference between the baseline and the actual outdoor temperature multiplied by the number of days.[19]

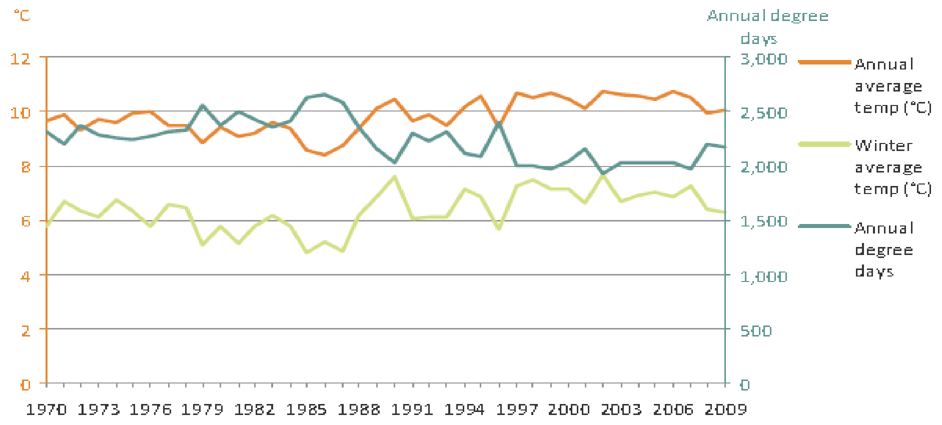

Figure 5 Average UK Air Temperatures and Heating Degree Days[20]

As can be seen from Figure 5, degree days are almost a mirror image of average winter temperature, as cold winters have many more degree days than mild ones. Degree days allow the normalisation of space heating energy use (or CO_2 emissions) between years with different weather.

[17] SHCS Key Findings Report 2013. Available at http://www.gov.scot/Topics/Statistics/SHCS/Downloads
[18] Note - it is **not** possible to have a negative degree day value. When the outdoor temperature exceeds the baseline of 15.5ºC no heating deemed to be is needed and degree days are set to zero
[19] Cooling degree days are used in a similar way to calculate the demand for cooling in hot weather. Demand for cooling is not yet seen as a priority climate change risk for Scotland and so is not covered in this summary.
[20] From DECC's Housing Energy Fact File 2013, pg 34

Degree days vary considerably across the UK and Scotland, and datasets are available for different regions and locations. For the purposes of considering energy for heat use, it may be sufficient to use an averaged figure for Scotland as a whole, or to divide Scotland into three regions - namely West, East and North Scotland.

Met Office data collected between 1960 and 2006 show a clear trend towards lower HDDs in Scotland, as shown below[21]. They also illustrate the high variability in winter temperatures. If only a few years are considered the downward trend could easily be masked. This trend has occurred in each of the three Scottish regions as shown in Fig 7.

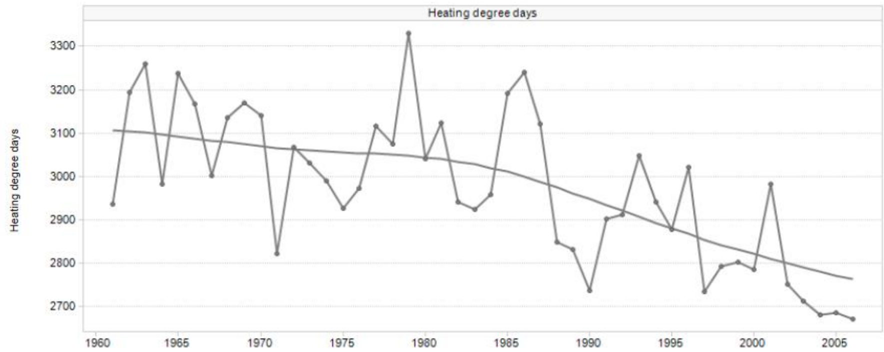

Fig 6 HDDs for Scotland, 1961 to 2006 (smoothed curve shows running averages)

Source: Scotland's Climate Trends Handbook, Sniffer 2014.

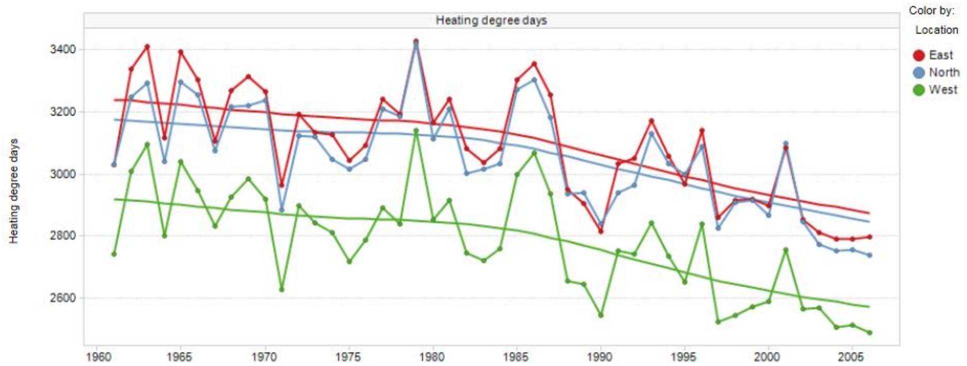

Fig 7 Heating degree days for Scottish regions 1961 to 2006 (smoothed curves show running averages)

Source: Scotland's Climate Trends Handbook, Sniffer 2014.

[21] Graphics are based on Met Office data and are shown in Scotland's Climate Trends Handbook, Sniffer 2014.

Looking at these regional trends in more detail[22] shows the following:

- Typical figures at the start of the 1961 to 2006 period were about 3,100 HDD for Scotland, and this had decreased to 2,750 by 2006 (a decrease of around 11%).
- The number of HDDs has reduced in all Scottish areas and appears to be part of a clear downward trend.
- The rate of decrease was faster from 1985 to 2006 than before 1985.

Future projections show the trend in reducing HDDs continuing. Based on a medium emissions scenario, a reduction of 642 to 924 HDD is projected for Scotland as a whole by the mid 21st century. This corresponds to 19% to 29% of current values. The reduction is projected to be 23% to 37% by the late 21st century[23].

Given such projections, one might reasonably assume that, all other things being equal, energy demand for space heating will steadily decrease in Scotland. However, it should be noted that heating demand is also affected by other weather variables. In windy weather the moving air transfers heat more rapidly from buildings. Precipitation, rain in particular, is likely to increase heat demand for drying, as will humidity levels[24]. While changes in wind patterns are unclear from the UK's latest Climate Projections (CP09), winter precipitation in Scotland is expected to increase considerably, particularly in the North and West. This is likely to increase heating demand[25].

8. Energy Efficiency and Thermal Properties of Buildings

Data on building energy ratings and insulation levels are available[26]. Trends are largely positive and show an increase in insulation and energy performance over the past ten and more years (see Indicator BB20a). However, these improvements may not reduce energy demand a great deal for two reasons. Firstly, more affluent households may choose to maintain their buildings at a higher, more comfortable temperature once insulation is installed (the 'rebound' effect). In addition, households in fuel poverty may already be spending very little on heating and so additional insulation may not change their demand significantly (though again they should benefit from improved thermal comfort).

9. Conclusion

Energy demand for heating is affected by many factors, and it is not possible to track many of these, due to lack of accessible data. Data do exist for various physical factors, such as Building Energy Ratings, energy consumption and winter temperatures, but it would be naïve to assume that tracking these aspects alone will tell the whole story about trends in winter heating demand. Long term trends towards lower household occupancy levels and higher internal temperature regimes (where income levels permit) will also have an impact. Additional understanding can be gained from work modelling average UK indoor temperatures, and from studies that combine energy consumption data with methods that collect information on occupant heating behaviours and choices.

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[22] From http://www.environment.scotland.gov.uk/climate_trends_handbook/Chapter01/1_09.html

[23] Dr C Holmes, CXC / Edinburgh University, pers. comm., 4 August 2015

[24] Dr K Baker 2015, Strathclyde University, pers. comm., 5 Feb 2015

[25] For example, the use of heating to dry wet garments, and to reduce any internal dampness in homes

[26] See Indicator BB20a, and the Scottish House Condition Survey - http://www.scotland.gov.uk/Topics/Statistics/SHCS

To date, policy initiatives aimed at reducing energy use for heating have been predominantly focused on physical measures such as insulation and other improvements to the thermal properties of buildings, and boiler and heating appliance efficiency. Policy initiatives to encourage prudent heating behaviours have been more limited, but with the proposed rollout of smart metering for both gas and electricity there may be scope to extend these in future. A broad policy front will maximise the opportunity to reduce Scotland's energy use for heating and will also improve energy security.

10. Further information – Reports and HDD Data

National Statistics on Population and Migration - see http://www.scotland.gov.uk/Topics/Statistics/Browse/Population-Migration?utm_source=website&utm_medium=navigation&utm_campaign=statistics-topics

National Records of Scotland – see http://www.nrscotland.gov.uk/statistics-and-data/statistics

Baker, KJ & Wood, G 2015, *A Critical Review of Scottish Renewable Energy Policy,* Palgrave, in press

Chappells H & Shove, E 2005, 'Debating the future of comfort: environmental sustainability, energy consumption and the indoor environment' *Building Research & Information* Vol. 33, Iss. 1, 2005

Mould, Baker, Emmanuel 2014, 'Behind the Definition of Fuel Poverty; Understanding Differences between the Fuel Spend of Rural and Urban Homes'. Available at https://queenspoliticalreview.files.wordpress.com/2014/10/qpr-volume-2-issue-2-fuel-poverty-edition-2014.pdf

Baker, KJ & Rylatt, M 2008, 'Improving the prediction of UK domestic energy-demand using annual consumption-data' *Applied Energy* 85 (2008) 475–482

Boardman, B 2007, *'Home Truths, A Low Carbon Strategy to reduce Housing Emissions'* Available at http://www.eci.ox.ac.uk/research/energy/downloads/boardman07-hometruths.pdf

Isaac, M, Van Vuuren, DP 2009, 'Modeling global residential sector energy demand for heating and air conditioning in the context of climate change' *Energy Policy,* Volume 37, Issue 2, February 2009, Pages 507-521 Available at http://www.sciencedirect.com/science/article/pii/S0301421508005168

Jenkins, D, Liu, Y, & Peacock AD 2008, 'Climatic and internal factors affecting future UK office heating and cooling energy consumptions' *Energy and Buildings*, Volume 40, Issue 5, 2008, Pages 874-881. Available at http://www.sciencedirect.com/science/article/pii/S0378778807001880

Santin, OG, Itard, L & Visscher, H 2009, 'The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock', *Energy and Buildings*, Volume 41, Issue 11, November 2009, Pages 1223-1232. Accessed 9 Feb 2015 from http://www.sciencedirect.com/science/article/pii/S0378778809001388

Shove, E Walker, G & Brown, S 2014, 'Material culture, room temperature and the social organisation of thermal energy' *Journal of Material Culture* June 2014 19: 113-124

Sniffer, 2014, Scotland's Climate Trends Handbook. Available at: http://www.environment.scotland.gov.uk/climate_trends_handbook/index.html

11. Sources of HDD Data

Via the ECI, Oxford: Data from the Met Office is available to download via the ECI (Oxford). See http://www.eci.ox.ac.uk/research/energy/degreedays.php#degreedays Monthly HDD data is given at http://www.eci.ox.ac.uk/research/energy/degreedays-weekly-monthly.php

At the time of writing this gives data from September 2007 until March 2012.

Historic data is also available (20 year average from 1987 to 2006) for a just a subset of stations – 55 – as some of the others had significant gaps in the data or the station wasn't operating at the beginning of the 20 year period

Via the NHS: An accessible source of recent, regional Scottish HDD data is based on Met Office data recorded in Glasgow, Leuchars and Aberdeen and published by the NHS for their Facility Managers[27]. At the time of writing, this provided readings for a couple of years, up to March 2013. See HDD information published by the NHS at http://www.hfs.scot.nhs.uk/publications-1/environment/

From Eurostat: HDD from 2000 to 2009 is available from the (new) Eurostat website (http://ec.europa.eu/eurostat/help/new-eurostat-website#relevance1400061921152). HDDs are given for 21 Scottish Stations. This can be downloaded as an excel spreadsheet. But data is only given up to 2009. See

http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_esdgr_a&lang=en

	Reviewer / Date	Actioned
Internal review: Research team	Darcy Pimblett; July 2015	KB, July 2015
Internal review: Steering group & CXC	Andy Kerr; August 2015	KB, August 2015
External stakeholder review		
External peer review (sample only)		
Final internal review		

[27] See HDD information published by the NHS at http://www.hfs.scot.nhs.uk/publications-1/environment/