Department for Business, Energy & Industrial Strategy

NATIONAL ENERGY EFFICIENCY DATA-FRAMEWORK

Summary of analysis using the National Energy Efficiency Data Framework (NEED)

July 2017

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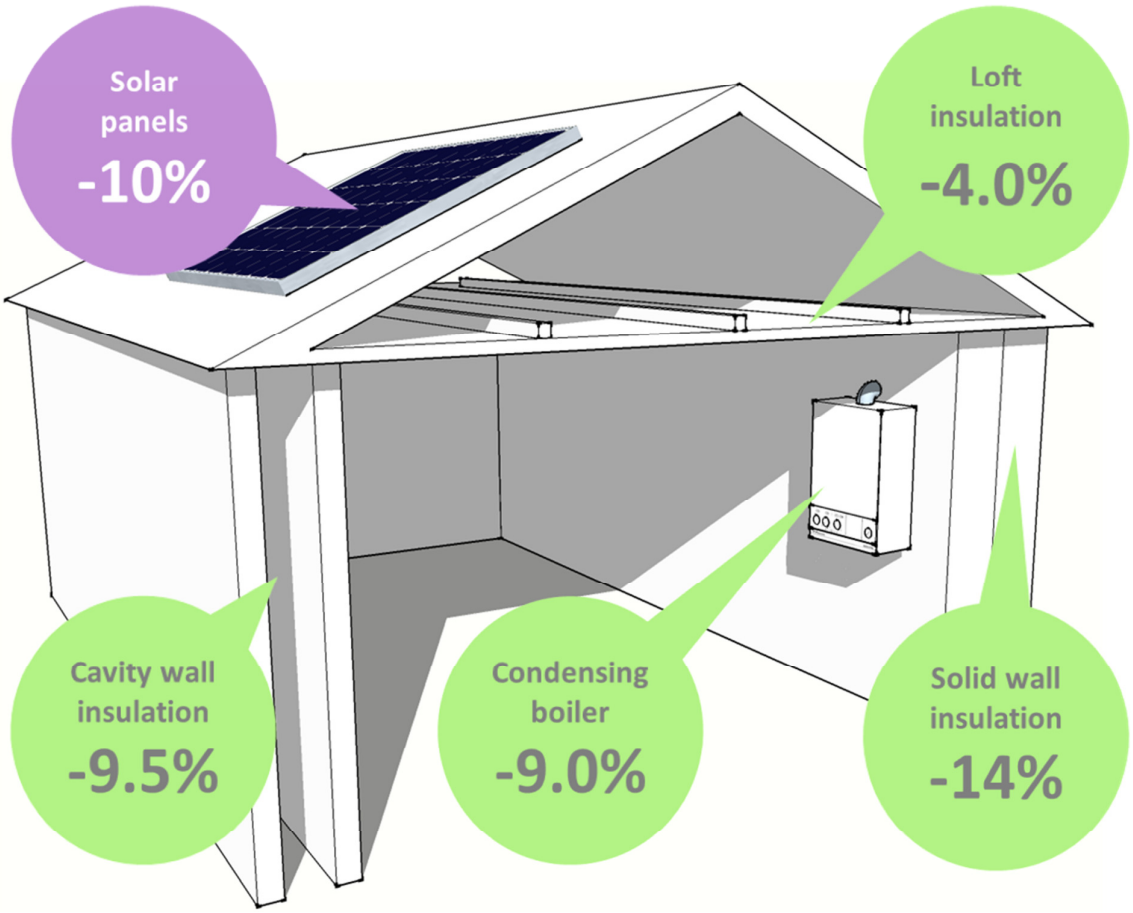


The National Energy Efficiency Data-Framework (NEED) was set up by DECC (now BEIS) to provide a better understanding of energy use and energy efficiency in domestic and non-domestic buildings in Great Britain. This publication presents:

- analysis of domestic gas and electricity consumption in 2015 by property attribute, household characteristics, geography and socio-demographic classification;
- analysis of the impact of installing energy efficiency measures in 2014 on a household's gas consumption; and
- an annex investigating the possibility of using NEED data, in conjunction with machine learning, to help identify fuel poor homes.

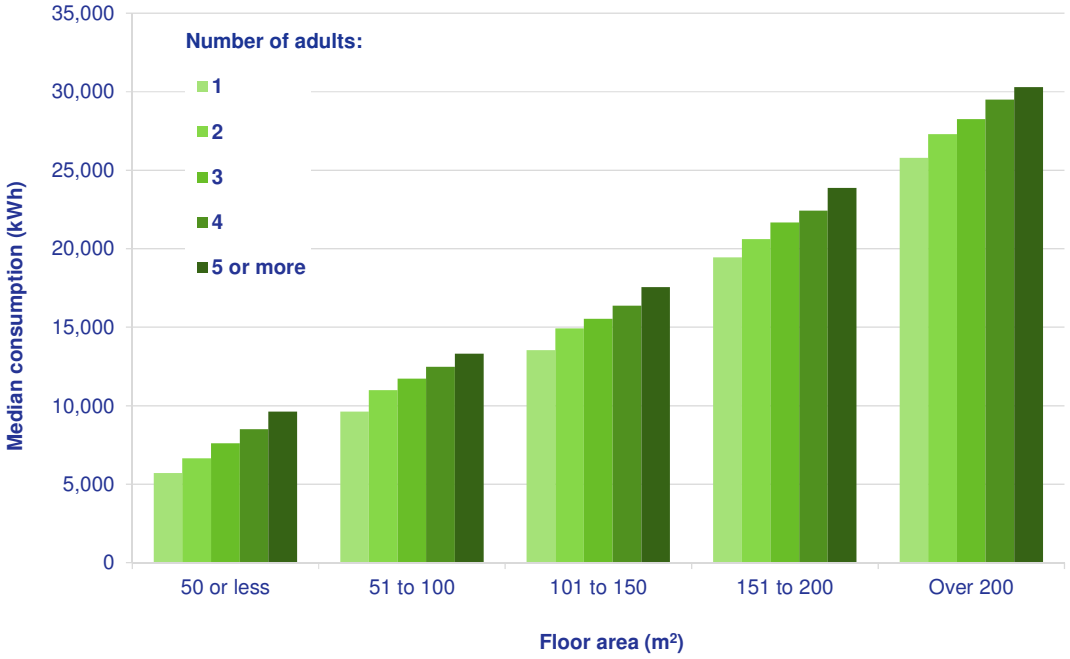
All results produced for this report are for annual consumption based on a representative sample of data for England and Wales unless stated. Results are produced using the

methodology outlined in the domestic NEED methodology note published alongside this report[1].

Domestic consumption

Chapter 3 presents evidence of how energy is used in households. For example, Figure 1.2 below shows the trend in median gas consumption by property size and the number of adult occupants. The relationship between floor area and gas consumption is roughly linear, with consumption per square meter remaining generally consistent across all of the size categories. The absolute increase in gas consumption associated with an increase in occupiers is also broadly constant across the area size categories; the difference in consumption between 1 occupier and 4 occupiers is 2,800-3,700 kWh regardless of how large the property is. Accordingly, for the same increase (from 1 to 4 occupiers) the *percentage* increase declines from 49 per cent in the 50 m^2 or less category, to 14 per cent in the over 200 m^2 category.

Figure 1.2: Median gas consumption (kWh) by floor area and number of adults, 2015



Although some of the variation in gas and electricity consumption can be explained by variables contained within NEED, there are other factors to consider, for example

[1] https://www.gov.uk/government/publications/domestic-national-energy-efficiency-data-framework-need-methodology

differences in building construction, differences in performance of heating systems and appliances, and importantly differences in the behaviours of the individuals within each household.

Impact of measures

Estimates of the impact of installing an energy efficiency measure on a household's gas consumption continue to show that considerable savings can be made by properties installing a single energy efficiency measure, or a combination (for example cavity wall insulation and loft insulation). Typical single measure savings across all property types are presented above in Figure 1.1. Figure 1.3 below shows the observed percentage savings in gas consumption for three bedroom properties installing cavity wall insulation in 2014 by property type. When looking at three bedroom properties, detached properties experienced the greatest typical saving, with mid terrace properties seeing the smallest reduction in gas consumption. This variation is largely due to the different number of external walls associated with each property type; mid terrace properties see the smallest savings since they only have two external walls, whereas detached, semi-detached and end terrace all have at least three.

Figure 1.3: Observed savings (weighted) in gas consumption for three bedroomed properties having cavity wall insulation installed in 2014, by property type

Footnotes:
1. Consumption data from sub-national gas and electricity consumption statistics 2015, https://www.gov.uk/government/organisations/department-of-energy-climate-change/about/statistics
2. Household characteristics data sourced from the Valuations Office Agency as at March 2017

Analytical developments

Machine learning (a field of study which uses algorithms to make predictions) has emerged as the de facto approach to predictive analysis in many industries. Annex A explores the possibility of using this approach, in conjunction with NEED data (and some supplementary sources), to identify fuel poor homes, in the hope that this might be useful for targeting fuel poverty policies more effectively. In this annex the modelling approach and the method used to determine the predictive accuracy of any potential algorithms is outlined. A description of the process used to develop the best performing algorithm, which made use of a genetic optimiser, is also provided. The results of the exercise are then presented, with an examination of the correct and false positive and negative predictions made. These indicate that this novel approach does indeed show some potential, and displays some advantages compared to more traditional methods. The algorithm correctly identifies 90 per cent of fuel poor households, but does exhibit a tendency towards false positives (predicting that households are fuel poor when in reality they are not). The algorithm does, however, correctly identify around two thirds of households that are *not* fuel poor, usefully eliminating them from any potential policy targeting scheme. A regional summary of predictions is also provided, in the form of a map.

2. Introduction

The National Energy Efficiency Data-Framework (NEED) project was set up by DECC (now BEIS) to assist in its plan to promote energy efficiency and support vulnerable consumers.

It is a key element of the evidence base supporting BEIS to:

- Develop, monitor and evaluate key policies (including the Green Deal and ECO);
- Identify energy efficiency potential which sits outside the current policy framework;
- Develop a greater understanding of the drivers of energy consumption; and
- Gain a deeper understanding of the impacts of energy efficiency measures for households and businesses

The data framework provides the largest source of data available for analysis of consumption and the impacts of installing energy efficiency measures. This report provides updated domestic/household energy consumption results to include 2015 gas and electricity consumption data. It also includes updated estimates of the impact of installing energy efficiency measures on a household's gas consumption for measures installed in 2014.

Headline results and key findings are presented in this report, with detailed data tables including breakdowns by property attributes and household characteristics published alongside this report (see Annex B for details of all published tables). In addition to the domestic consumption and impact of measures headline results there are a number of other outputs being published:

- Annex A: Machine learning and fuel poverty targeting: an initial investigation into whether machine learning can be used in conjunction with NEED data to help identify which households are fuel poor
- Annex B: Data tables: contains details of all published tables
- Annex C: Summary of Building Regulations - relating to loft insulation, wall insulation, boiler standards and heating controls

A domestic NEED methodology note has been published alongside this publication which includes details of how estimates of domestic electricity and gas consumption by property attributes and household characteristics are produced. It also sets out the methodology for estimating the saving in gas consumption following the installation of retro-fit energy

efficiency measures (e.g. cavity wall insulation, loft insulation) and provides background on the users and uses of the data and details of the revisions policy. This note can be accessed from the following link:

https://www.gov.uk/government/publications/domestic-national-energy-efficiency-data-framework-need-methodology

The statistics presented within NEED were previously assessed by the UK Statistics Authority against the Code of Practice for Official Statistics. The UK Statistics Authority published its report on 12 June 2014: https://www.statisticsauthority.gov.uk/publication/statistics-on-energy-and-climate-change/

The UK Statistics Authority designated these statistics as National Statistics in February 2015, in accordance with the Statistics and Registration Service Act 2007 and signifying compliance with the Code of Practice for Official Statistics.

Designation can be broadly interpreted to mean that the statistics:

- Meet identified user needs.
- Are well explained and readily accessible.
- Are produced according to sound methods.
- Are managed impartially and objectively in the public interest.

Once statistics have been designated as National Statistics it is a statutory requirement that the Code of Practice shall continue to be observed.

The remainder of this section gives a brief overview of NEED. For any queries or feedback on this publication please email:

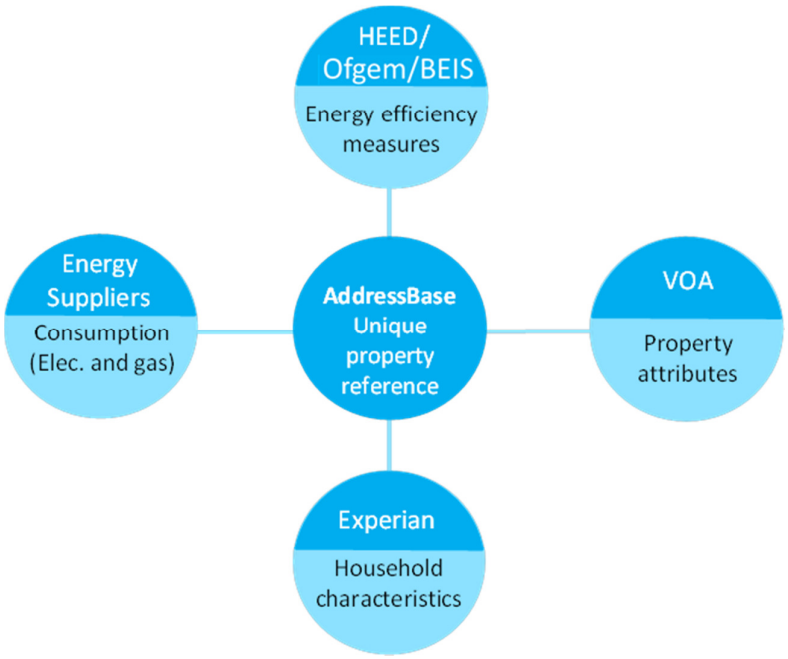
EnergyEfficiency.Stats@beis.gsi.gov.uk

2.1 NEED overview

NEED is a framework for combining data from existing sources (administrative and commercial) to provide insights into how energy is used and what the impact of energy

efficiency measures are on gas and electricity consumption, for different types of properties and households. The address information in each dataset is used to assign a unique property reference number (UPRN) to each record. Data from different sources can then be matched to each other via the UPRN (Figure 2.1). The principle is the same for both the domestic and non-domestic sector, though different data sources are used.

Figure 2.1: Structure of domestic NEED



Six key data sources have been used to analyse domestic energy consumption and the impact of installing energy efficiency measures: meter point electricity and gas consumption data, Valuation Office Agency (VOA) property attribute data, the Homes Energy Efficiency Database (HEED), Central Feed-in Tariff Register[2], Green Deal and ECO data held by BEIS[3], all of which contain information on energy efficiency measures installed, and data modelled by Experian on household characteristics. In addition to these six main data sources feeding into the framework at a property level there are a number of other indicators that have been assigned to the property based on its geographic location. For example, an index of multiple deprivation and a fuel poverty indicator are assigned based on the Lower Layer Super Output Area (LSOA).

[2] Further information on the Central Feed-in Tariff register can be found via this webpage: https://www.gov.uk/government/statistical-data-sets/monthly-central-feed-in-tariff-register-statistics

[3] BEIS collect the Green Deal and ECO data from a number of different sources. Further information on this can be found in the Domestic Green Deal and ECO Statistics Methodology Note: https://www.gov.uk/government/statistics/domestic-green-deal-and-eco-statistics-methodology-note

NEED has supported a number of BEIS policies. It has been used to understand the reduction in consumption for households installing energy efficiency measures. To date NEED has looked at savings from a number of measures, including cavity wall insulation, loft insulation, installation of condensing boilers and solid wall insulation. The estimates from NEED were used to inform “in use factors” for the Green Deal. Data on consumption has informed Fuel Poverty analysis so there is a better understanding of actual consumption for different types of properties and households and therefore a better understanding of how policy options will impact on different households.

BEIS would like to thank all those who made this analysis possible, including: Energy Suppliers, Gas Safe, the Energy Savings Trust and the Valuation Office Agency.

All analysis of domestic properties presented in this report is based on a representative sample of properties in England and Wales, stratified by local authority, number of bedrooms, property type and property age.

The rest of this report covers:

- Domestic Energy Consumption: analysis of domestic gas and electricity consumption by property attributes, household characteristics, geography and socio-demographic classifications.
- Impact of Energy Efficiency Measures in Homes: analysis of the impact of installing energy efficiency measures on a household’s gas consumption.

3. Domestic energy consumption

This section presents analysis of domestic gas and electricity consumption by property attributes, household characteristics, geography and socio-demographic classifications.

Results are based on a representative sample of approximately four million properties for England and Wales, with the exception of trends in consumption which covers only England between 2005 and 2010 and both England and Wales for 2011 to 2015[4]. A sample is used rather than the complete dataset in order to increase processing speed, reduce cost and to ensure that BEIS is not processing more data than necessary.

For the first time this year, BEIS has included the analysis of consumption trends in Scotland as a sub-section in this chapter. In previous editions of the publication, the Scottish analysis was included in a separate annex. Unlike, England and Wales, the analysis is carried out on all properties in Scotland, since this is a smaller dataset and requires less processing time. The sub-section on Scotland consumption will go into further detail on the other differences compared to England and Wales.

All consumption figures presented in this section are based on valid domestic gas and electricity consumption[5] and are rounded to the nearest 100 kWh. All gas consumption data are presented on a temperature corrected basis[6]. The consumption for each household has been adjusted to account for differences in temperature and wind in each year. This allows for a more consistent comparison of gas consumption over time[7]. Electricity consumption data are not weather corrected. This is because gas is predominantly a heating fuel and hence its use depends heavily on the weather whereas electricity is used for a much wider variety of reasons (and far less often as a heating fuel) so consumption is less affected by the weather.

The relationship between energy use and any individual characteristic is complex, but there is a high correlation between certain characteristics and a household's energy use

[4] Results for 2005 to 2015 presented in this report can be considered as a continuous trend. Refer to the methodology note for further detail: https://www.gov.uk/government/publications/domestic-national-energy-efficiency-data-framework-need-methodology

[5] Valid domestic gas consumption readings are taken to be values between 100 kWh and 50,000 kWh (inclusive). Domestic electricity consumption is considered valid if it is between 100 kWh and 25,000 kWh (inclusive). Gas and electricity consumption values which are suspected to be estimated readings are excluded.

[6] More information about the weather correction methodology can be found here: https://www.gov.uk/government/statistics/overview-of-weather-correction-of-gas-industry-consumption-data

[7] Users should note that the weather correction factor applied to the consumption data is modelled and as such may not entirely remove the effects of extreme weather in a single year.

(for example, size of property or household income). This section provides insight into how each characteristic relates to energy use, but makes no attempt to control for other characteristics[8]. The results presented here are consistent with results for earlier years presented in previous reports.

3.1 Headline domestic consumption

In 2015, the median[9] gas consumption for all properties in the sample was 12,000 kWh, with median electricity consumption at 3,300 kWh. However, within the distribution there is a range of consumption as can be seen from the lower and upper quartiles[10] shown in Table 3.1. The table also shows that mean consumption is larger than median consumption, by 9 per cent for gas and 21 per cent for electricity. In the rest of this section, median consumption has been used to represent typical consumption. It is a more appropriate measure of typical consumption than the mean because the mean can be influenced by a relatively small number of high consuming households that are not typical of the rest of the population.

Table 3.1 also shows that there is more variation in electricity consumption than gas consumption. The standard deviation[11] is 57 per cent of the mean for gas and 75 per cent for electricity. The larger variability (or spread of data) for electricity is likely to be due to the wider range of uses of electricity, including the variation between households that use electricity as the main heating fuel and those that do not, as well as the use of electricity for secondary heating.

The distribution of gas and electricity consumption in 2015 is shown in more detail in Figure 3.1. It shows that generally most households consume around 12,000 kWh of gas, and fewer households consuming higher volumes of gas, which is indicated by the positive skew of the distribution. The same can be said about the distribution of electricity with the positive skew being more pronounced.

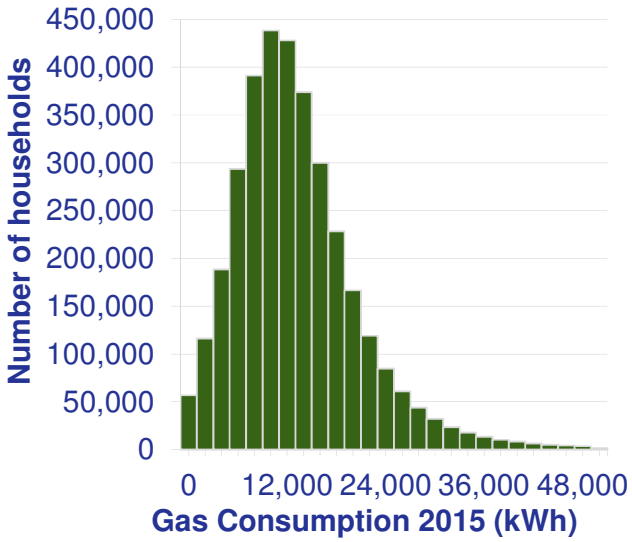
[8] See Annex C in NEED 2016 where principal component analysis is used to investigate the main drivers of gas demand, with determining factors considered simultaneously.
[9] The median is the middle value of the distribution, i.e. the consumption value where half of the households have lower consumption and half have a higher one.
[10] Quartiles (including the median) divide the consumption values into four parts containing the same number of households. The lower quartile is the consumption value where 25 per cent of households have lower consumption and 75 per cent have higher. The upper quartile is the consumption value where 25 per cent of households have higher consumption and 75 per cent have lower.
[11] The standard deviation is a number which measures the spread of a group of values from the average (mean).

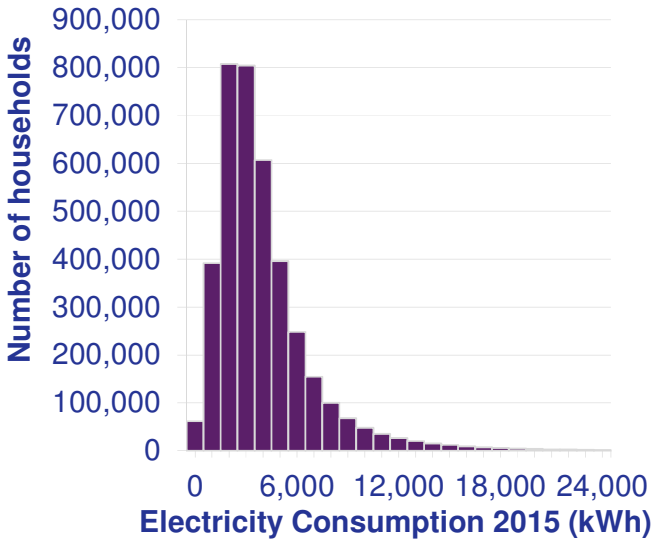
Table 3.1: Annual consumption summary statistics, 2015

(kWh)

	Mean	Standard deviation	Lower quartile	Median	Upper Quartile
Gas	13,100	7,500	8,000	12,000	16,800
Electricity	4,000	3,000	2,100	3,300	4,900

Figure 3.1: Distribution of consumption, 2015





3.2 Domestic consumption breakdowns

This section presents domestic gas and electricity consumption by property attributes, household characteristics, geography and socio-demographic classifications. Annex B shows details of all consumption tables available from NEED. For all variables, the numbers of households in the sample along with mean and median figures for consumption are included in the headline tables published alongside this report. Additional statistics to describe the pattern of consumption such as standard deviation and quartiles are included in the additional tables published alongside this report.

In line with previous years, domestic electricity and gas consumption have been published by fuel poverty quintile, index of multiple deprivation quintile and rural urban classification. These data are available for annual electricity and gas consumption between 2011 and 2015.

Figure 3.2 shows typical electricity and gas consumption for households in 2015, by property type. It can be observed that flats consume the least amount of electricity and gas, in particular purpose-built flats, which consumed 19 per cent less gas in 2015 than converted flats, with typical consumptions of 6,500 kWh and 8,100 kWh respectively. This could be a result of the high proportion of purpose-built flats constructed for social housing, which are known to be more energy efficient[12] and therefore consume smaller quantities of gas.

[12] The energy efficiency of the housing stock has improved between 2005 and 2015 for all households. Figure 2.9 of the English Housing Survey headline report 2015-16 shows that in particular properties owned by a housing association have a higher Standard Assessment Procedure (SAP) rating. The report can be found on the following link: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/595785/2015-16_EHS_Headline_Report.pdf .

Figure 3.2: Median consumption (kWh) by property type, 2015

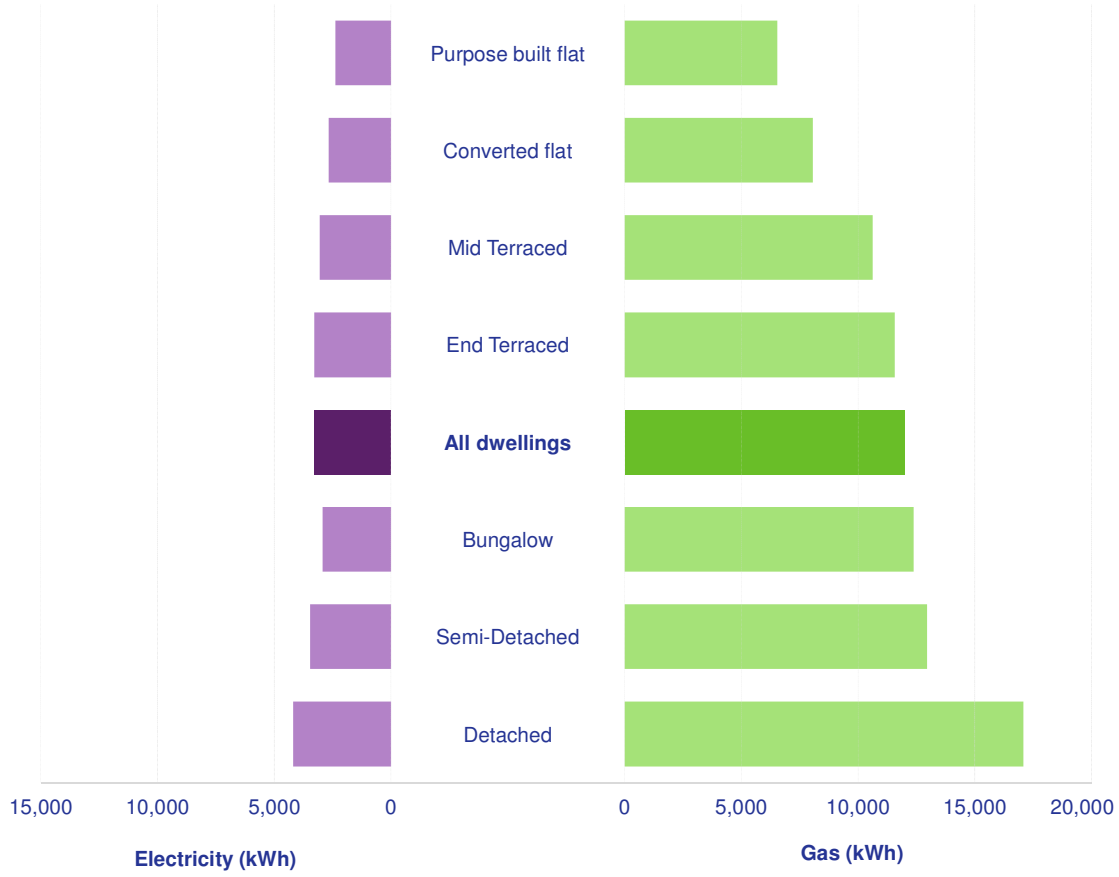


Figure 3.2 also shows that detached houses typically consume more electricity and gas than any other property type. In 2015, a detached house typically consumed 4,200 kWh of electricity and 17,100 kWh of gas, which equates to a consumption percentage difference of 161 per cent more gas and 76 per cent more electricity than a purpose-built flat in 2015. The large difference in gas consumption can be partly explained by the use of gas as a heating fuel and the isolation of a property. As a detached house is not attached to another property, a higher proportion of heat is likely to be radiated from the walls, whereas a flat is surrounded by other flats that also generate heat, which means it is a more efficient property type for keeping the occupants warm. It is also important to note that detached houses are typically the largest property type and therefore will require more gas to heat than a smaller property.

Bungalows typically consume more gas than their typical electricity consumption would suggest. Figure 3.2 shows that although a bungalow generally consumed less electricity than a mid-terraced property in 2015, its typical consumption of gas exceeded that of a mid-terraced property and an end-terraced property. This is due to a higher number of exposed walls, therefore less insulation and higher gas consumption to heat the property.

Figure 3.3 shows typical gas consumption by property size and the number of adult occupiers[13]. As can be seen from the chart, floor area is an important determinant of gas demand, with the largest floor area category (over 200 m^2), consuming over four times as much gas as the smallest category (50 m^2 or less). The relationship between floor area and gas consumption is roughly linear, with consumption per square meter remaining broadly consistent across all of the area categories.

Figure 3.3 also shows the effect of the number of household occupants on gas consumption, within each property size band. As the chart shows, the amount of gas used increases for every additional adult that lives in the property. This could reflect the fact that as the number of occupants increases, the proportion of time that a home is occupied by at least one person increases, and so the proportion of time that the property is heated is likely to increase. It is also likely that as the number of occupants increases, the proportion of a property that is heated increases. It is interesting to note that the absolute increase in gas consumption associated with an increase in occupiers is generally consistent across the area size categories; the difference in consumption between 1 occupier and 4 occupiers is 2,800-3,700 kWh regardless of how large the property is. Accordingly, for the same increase (from 1 to 4 occupiers) the *percentage* increase declines from 49 per cent in the 50 or less m^2 category, to 14 per cent in the over 200 m^2 category.

[13] Available data shows only the number of adult occupiers within each property; children are excluded.

Figure 3.3: Median gas consumption (kWh) by floor area and number of adults, 2015

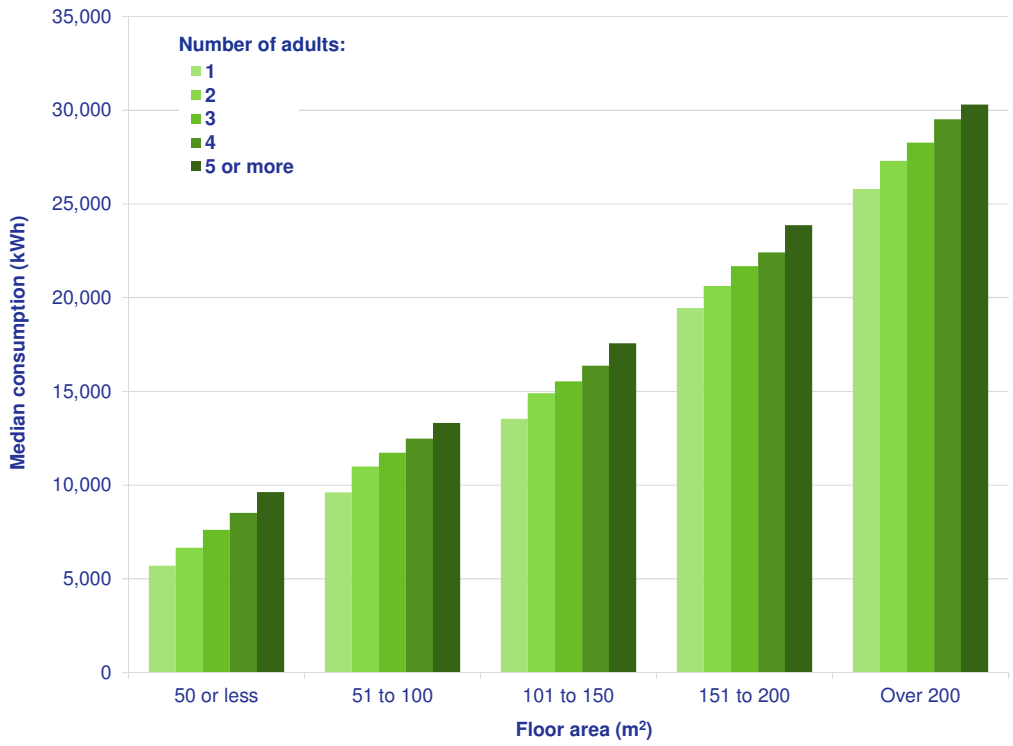


Figure 3.3 was created using data from the NEED table creator tool using rounded data. This tool is designed to provide users with the ability to create bespoke cross tabulations on electricity and gas consumption by property attributes and household characteristics. Two variables can be selected (e.g. Index of Multiple Deprivation quintile and number of bedrooms) and the table will show the number of observations, mean and median consumption. There is also a choice of fuel (electricity or gas). Where available, data for each year from 2005 to 2015 are included. The data used in the creation of the tables can also be downloaded as a comma separated values (.csv) file for ease of reuse. The tool and data files can be found at the following location: https://www.gov.uk/government/statistical-data-sets/need-table-creator.

3.3 Trends in domestic consumption

This section provides analysis of the trends in median gas and electricity consumption between 2005 and 2015 for different property attributes and household characteristics. Figure 3.4 shows the median gas and electricity consumption for all households in the

NEED sample with valid consumption in each year from 2005 to 2015. Data for 2005 to 2010 cover England only and later data (2011 onwards) cover both England and Wales.

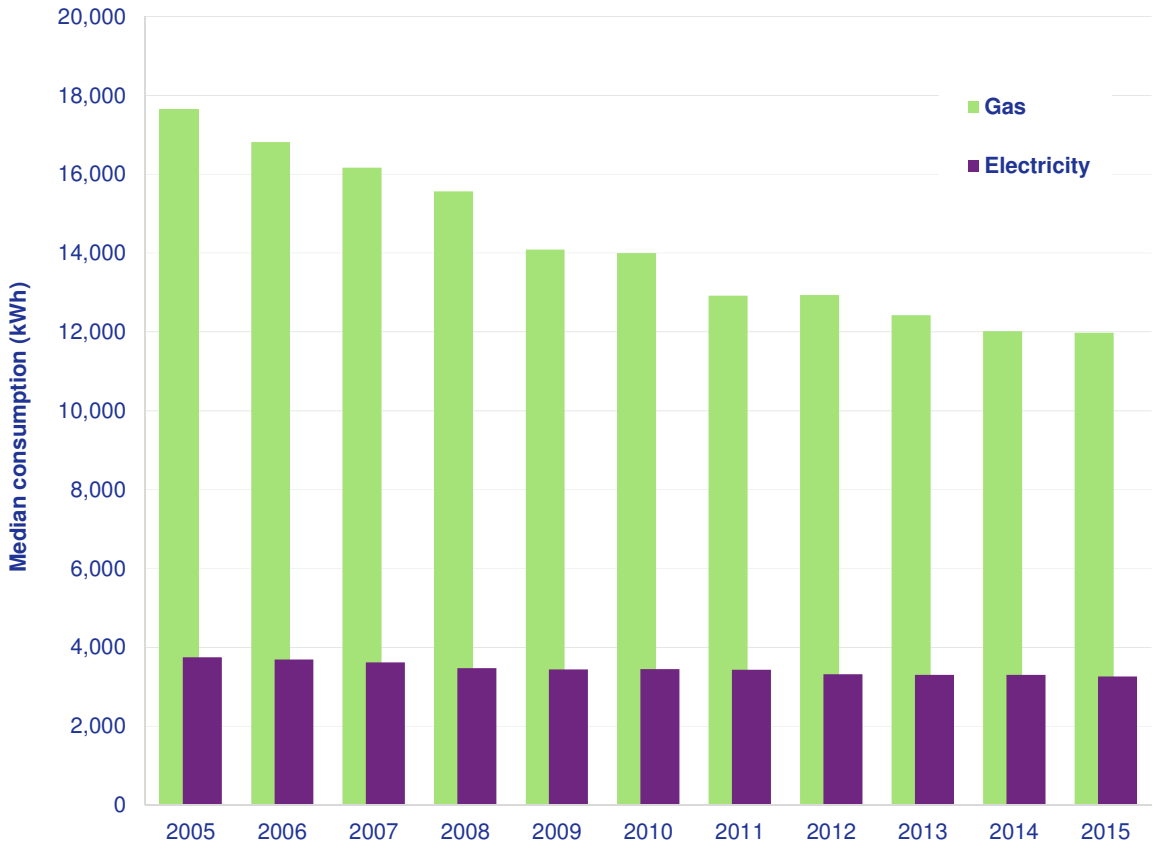
Figure 3.4 shows that median consumption for both gas and electricity has been steadily declining over the period. Median gas consumption has fallen by 32 per cent between 2005 and 2015. Between 2014 and 2015, the change was negligible. The largest drop was between 2008 and 2009, with a decrease in median annual consumption of 9 per cent. Median electricity consumption decreased by 13 per cent between 2005 and 2015. Between 2014 and 2015 median electricity consumption remained constant.

This reduction in consumption over time could be a result of a number of factors. These potentially include: energy efficiency improvements in households[14] such as: new boilers, insulation and more efficient appliances; higher prices[15] and the recession; or changes in the building stock and household composition.

[14] The energy efficiency of the housing stock has improved between 2005 and 2015. The average SAP rating of a dwelling increased by 9.5 points from 49.0 in 2005 to 58.5 in 2012. The SAP rating is a measure of the overall energy efficiency of a dwelling. English Housing Survey Headline Report 2016, Annex Table 19: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/284649/Headline_Report...

[15] See Annex D, NEED 2016 for a discussion of the evidence of how gas price changes affect consumption levels

Figure 3.4: Median gas and electricity consumption (kWh), 2005 to 2015



The fall in median consumption is seen consistently across all property types, household characteristics, geographies and socio-demographic classifications. However, certain households will have been more or less affected by the different factors described above. The remainder of this section provides some highlights of changes over time for different property attributes and household characteristics. All changes in consumption are shown as an index relative to a 2005 baseline[16].

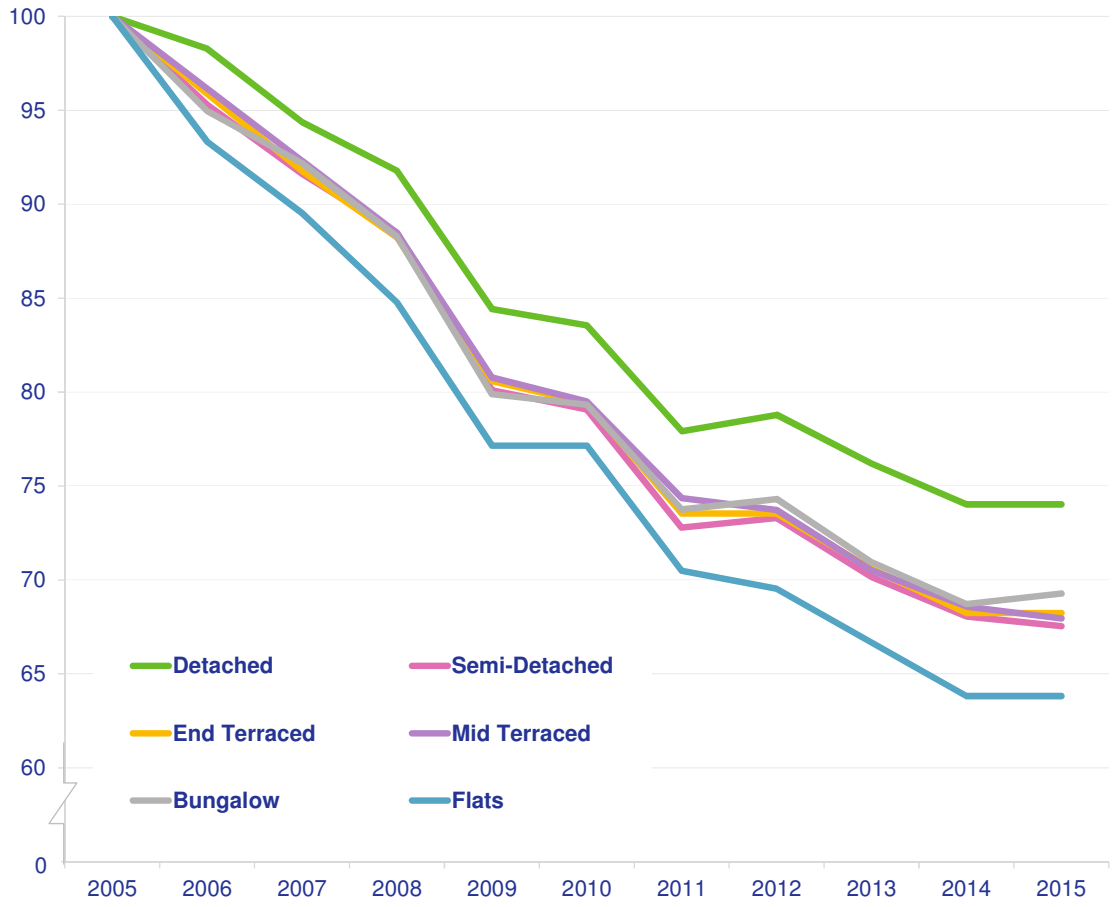
3.4 Trends in domestic consumption by property attributes

Figure 3.5 shows the trend in median gas consumption by property type. It demonstrates that between 2005 and 2015, the fall seen in overall consumption was evident among all

[16] Note that the y-axis for these charts does not start at zero in order to allow differences between groups to be seen more clearly.

property types. However, in general, smaller properties showed a greater percentage decrease in median consumption when compared with larger properties. For example, in 2015 typical gas consumption for flats was 36 per cent lower than in 2005, but for detached dwellings this reduction was only 26 per cent. The mid-size property types (bungalows, semi-detached and terraced) followed an almost identical pattern to each other.

Figure 3.5: Percentage change in median gas consumption over time by property type (2005=100)

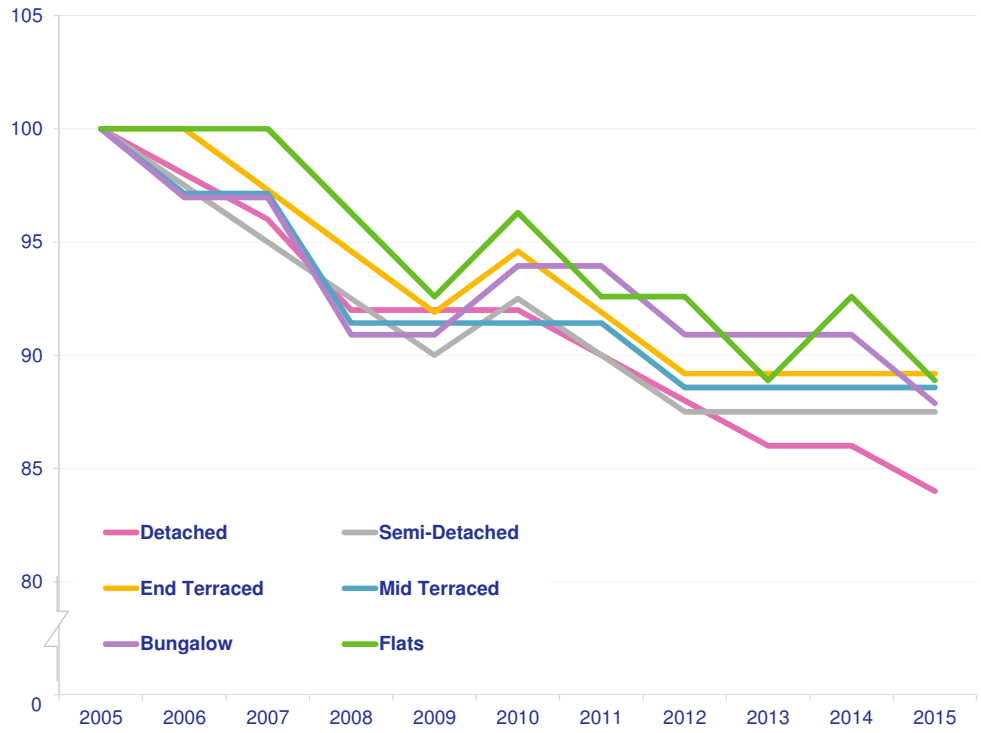


In contrast to gas consumption, where smaller property types showed the greatest decline, the reverse was apparent when looking at the equivalent pattern for electricity. Figure 3.6 shows that detached properties saw the largest decline in average consumption between 2005 and 2015 (16 per cent) while flats, mid and end terraced saw the smallest (11 per cent).

Analysis presented in Annex D of NEED 2016, indicates that increases in gas prices have made a notable contribution to the overall decline in domestic gas consumption seen over the last decade. Preliminary evidence within the annex also suggests that lower income households are more sensitive to price rises and reduce consumption to a greater extent, in response to a rise in price, compared to higher income households. As lower income households are more likely to live in smaller properties, this might explain why gas consumption has fallen faster in these categories. Meanwhile, electricity prices have not risen to the same extent as gas prices in recent years, which perhaps explains why the suspected price effect seen in Figure 3.5 is not apparent in Figure 3.6. There are, however, additional factors which may also have had some influence on the observed pattern. For instance a far higher proportion of small properties (particularly high-rise flats) use electricity for heating, compared to larger properties that predominantly use gas.

The increased volatility in Figure 3.6 compared to Figure 3.5 likely reflects the fact that, unlike gas, the electricity consumption figures are not weather corrected to adjust for variation in the demand due to temperature and wind conditions. Around a fifth of properties are, however, off the gas grid and use alternative fuel sources, including electricity to heat their homes.

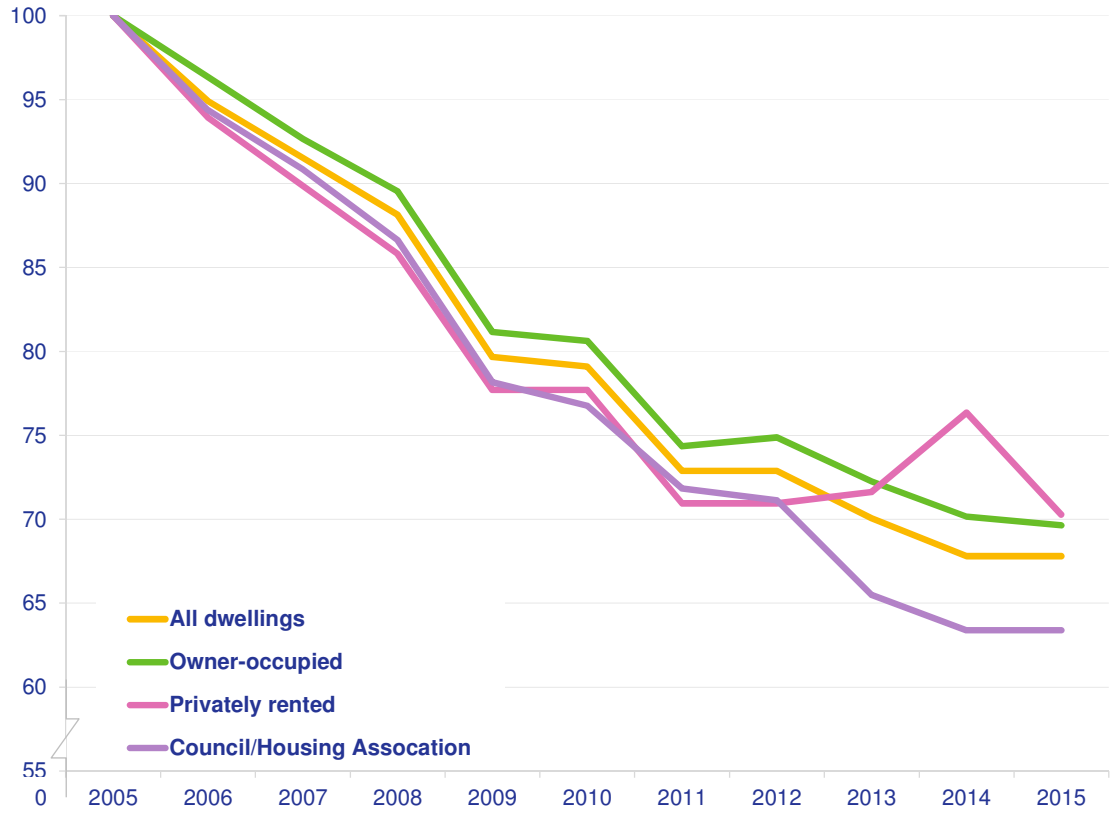
Figure 3.6: Percentage change in median electricity consumption over time by property type (2005=100)



3.5 Trends in domestic consumption by household characteristics

Figure 3.7 shows the trend in consumption of gas since 2005 split by tenure. Over this time council/housing association properties have consistently exhibited a faster decline in consumption when compared to owner-occupied properties.

Figure 3.7 Percentage change in median gas consumption over time by tenure (2005=100)



Footnotes:
1. The apparent outlier in the privately rented sector in 2014 is being investigated

3.6 Scottish consumption

As already mentioned at the start of this chapter, this year is the first time BEIS has included the analysis of consumption trends in Scotland as a sub-section in this chapter. In previous editions of the publication, the Scottish analysis can be found in an annex. Unlike, England and Wales, the analysis is carried out on all properties in Scotland, since this is a smaller dataset and requires less processing time. The other difference is that modelled data from Experian have been used for property attributes and household

characteristics in this analysis with the exception of property type, where the Scottish Assessor data (equivalent to the Valuation Office Agency data) has been used. Comparisons between the Experian and Scottish Assessor data shows that property type in both data sets are broadly in line.

The use of modelled data for property attributes in Scotland allows analysis to be undertaken. However, it also increases uncertainty in the estimates. Therefore these results should be treated as provisional and interpreted with caution. To help reduce uncertainty, the results for Scotland are based on all properties in Scotland that could be matched to valid consumption data, unlike England and Wales where a sample of properties is used for analysis[17].

This section outlines the domestic gas and electricity consumption statistics for 2015 (and 2011 to 2014 in the accompanying tables) by property attributes and household characteristics.

In 2015, the median gas consumption for properties in Scotland was 12,600 kWh with median electricity consumption at 3,400 kWh. The equivalent figures for England and Wales are 12,000 kWh and 3,300 kWh respectively, showing that typical consumption in Scotland is higher than in England and Wales (5 per cent higher for gas and 3 per cent higher for electricity).

Table 3.1: Annual consumption summary statistics, Scotland 2015

(kWh)

	Mean	Standard deviation	Lower quartile	Median	Upper Quartile
Gas	13,900	8,200	8,200	12,600	17,900
Electricity	4,500	3,800	2,300	3,400	5,200

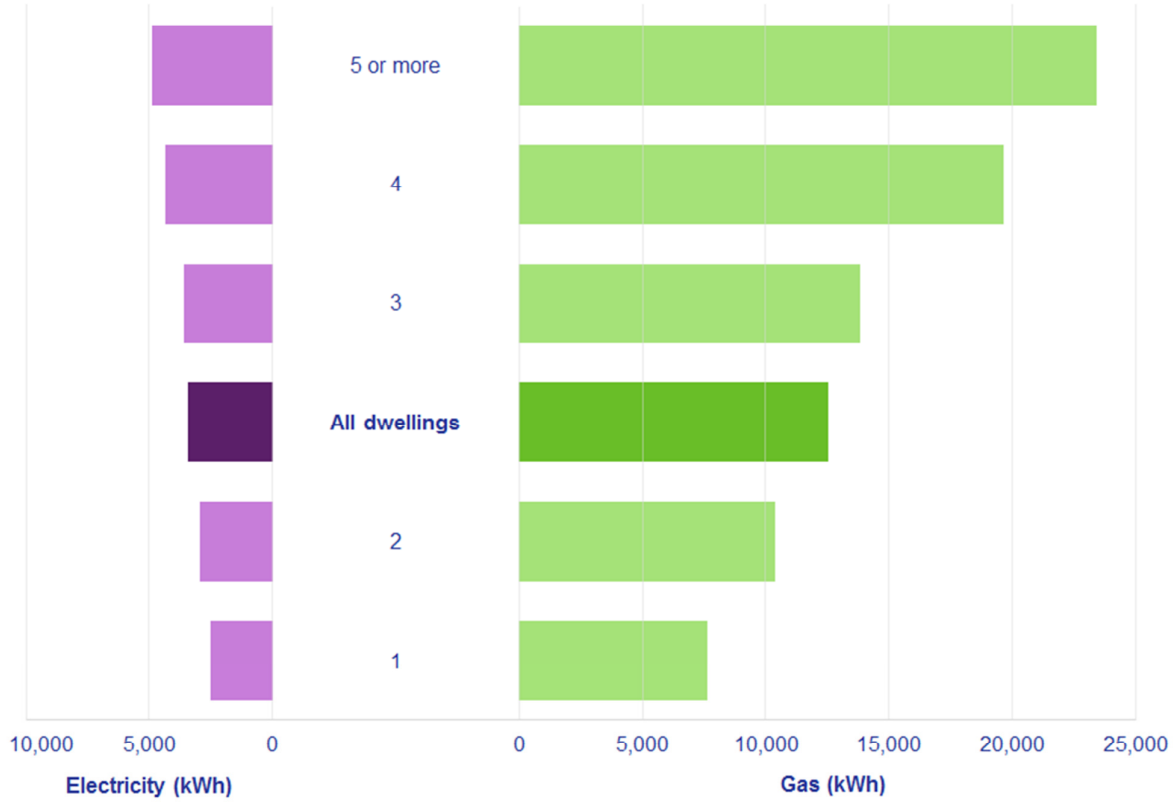
There is more variation in electricity consumption than gas consumption. This is because gas is primarily used for heating and cooking, while electricity can be used for a range of purposes.

[17] Match rates for England, Wales and Scotland combined are shown in Methodology guidance note.

3.6.1 Trends in domestic consumption by property attributes

Properties with more bedrooms typically consume a larger amount of gas and electricity than properties with fewer bedrooms since there is more space to heat (Figure 3.8). Properties with five or more bedrooms typically consumed 23,400 kWh of gas and 4,900 kWh of electricity. The equivalent figures for properties with one bedroom are 7,700 kWh of gas and 2,500 kWh of electricity. When looking at typical consumption for properties in England and Wales by number of bedrooms the same pattern is seen, i.e. properties with more bedrooms typically consume more gas and electricity.

Figure 3.8: Median consumption (kWh) by number of bedrooms, Scotland 2015

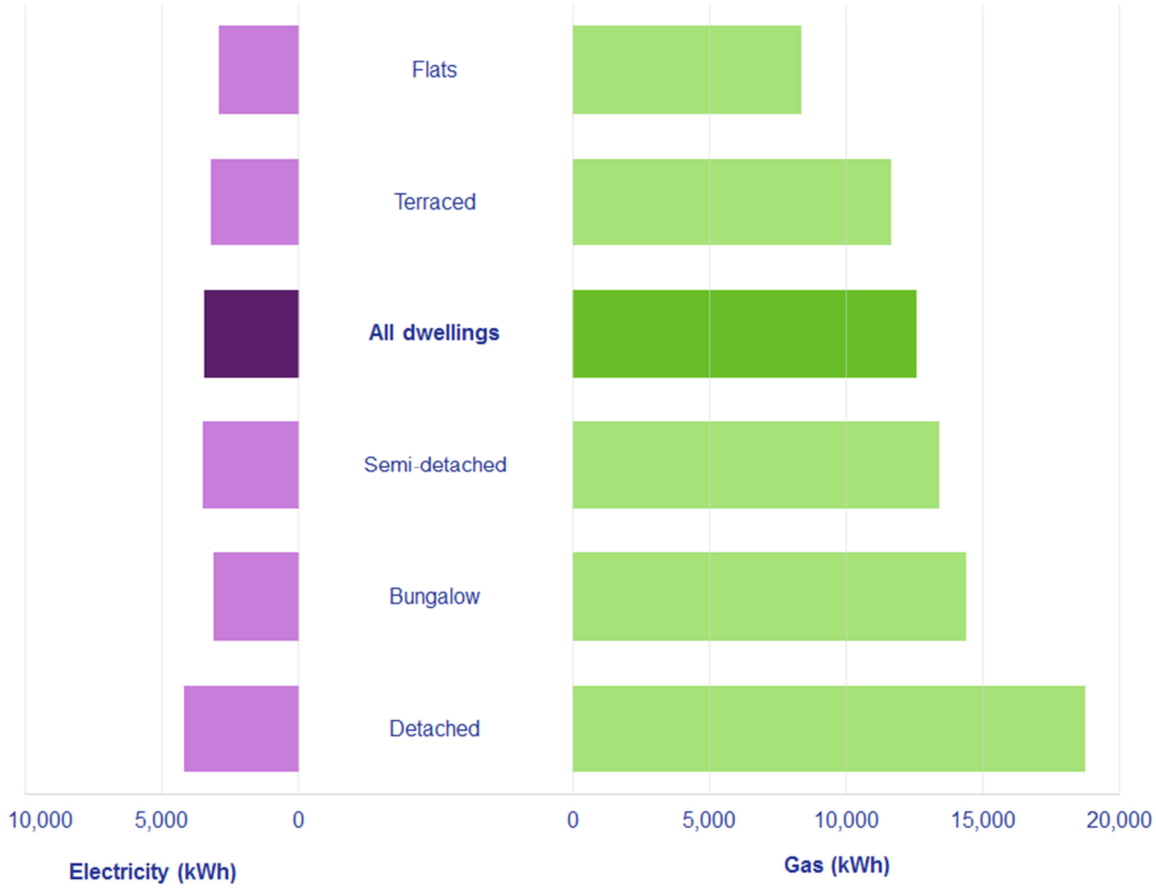


The number of bedrooms can also act as an indicator of property size, as there is a strong correlation between the number of bedrooms in a property and the floor area of the property.

Detached properties have the largest typical consumption for both gas and electricity. Bungalows have the second highest median consumption for gas at 14,400 kWh - a finding which is not consistent with England and Wales where instead semi-detached properties typically consume the second highest amount of gas (Figure 3.9). This is

because Scotland has a proportionally greater number of larger bungalows (based on number of bedrooms) compared to England and Wales. In contrast to last year, Semi-detached properties had the second highest median consumption at 3,500, for electricity in Scotland.

Figure 3.9: Median consumption (kWh) by property type, Scotland 2015



3.6.2 Trends in domestic consumption by property attributes

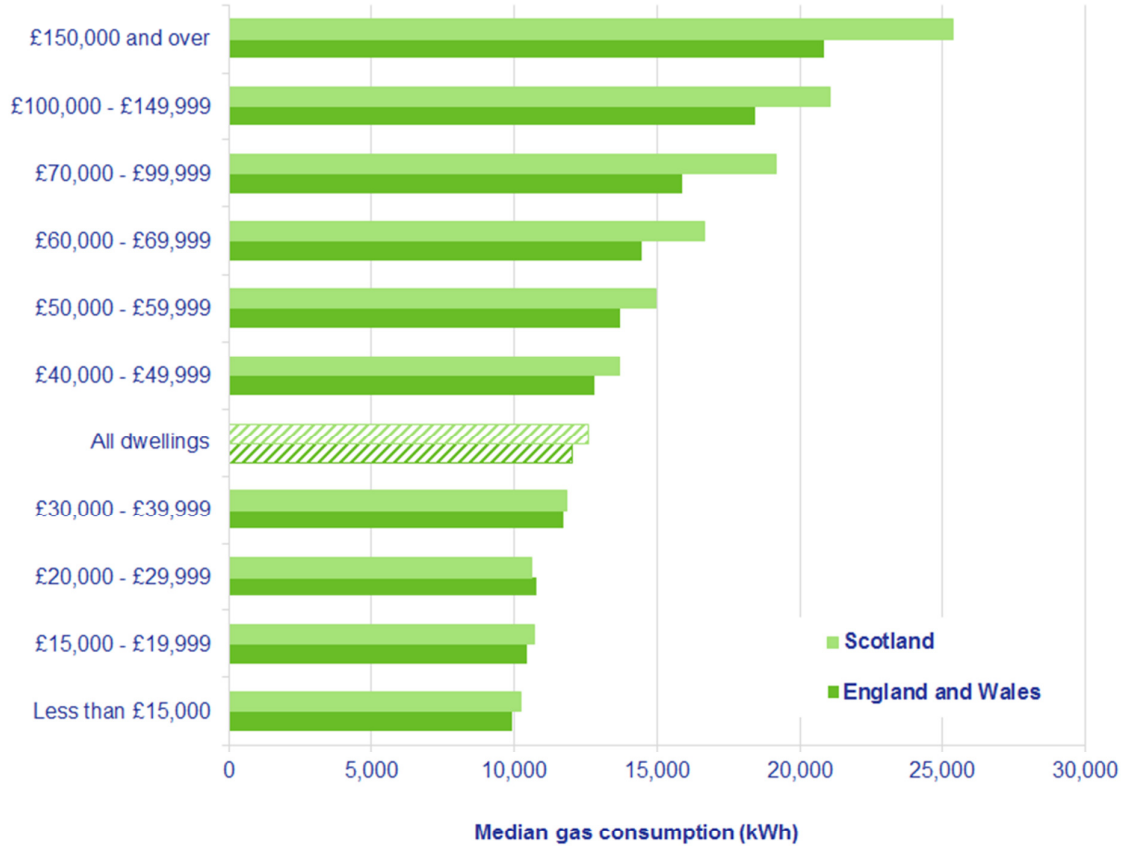
The household characteristics of household income, tenure and number of adult occupants for Scotland are based on the same source as data for England and Wales. This allows direct comparisons between typical consumption results from Scotland with those from England and Wales. Scottish households typically consume more gas than households in England and Wales, with this difference generally becoming wider as income increases (Figure 3.10). Typical gas consumption of households with an income less than £15,000 in Scotland in 2015 was 10,200 kWh compared with 9,900 kWh in England and Wales (a difference of 3 per cent); for households with an income over

£150,000, typical gas consumption in Scotland was 25,400 kWh compared with 20,900 kWh in England and Wales (a difference of 18 per cent)[18]. Fifty-six per cent of households with an income of over £150,000 lived in detached properties who typically consumed the most gas (29,900 kWh) compared to other property types in this income band.

Despite this, gas consumption exhibited a very similar pattern when comparing Scotland with England and Wales, with typical gas consumption generally increasing as household income increased.

On average, electricity consumption for each income band follows a very similar pattern to gas.

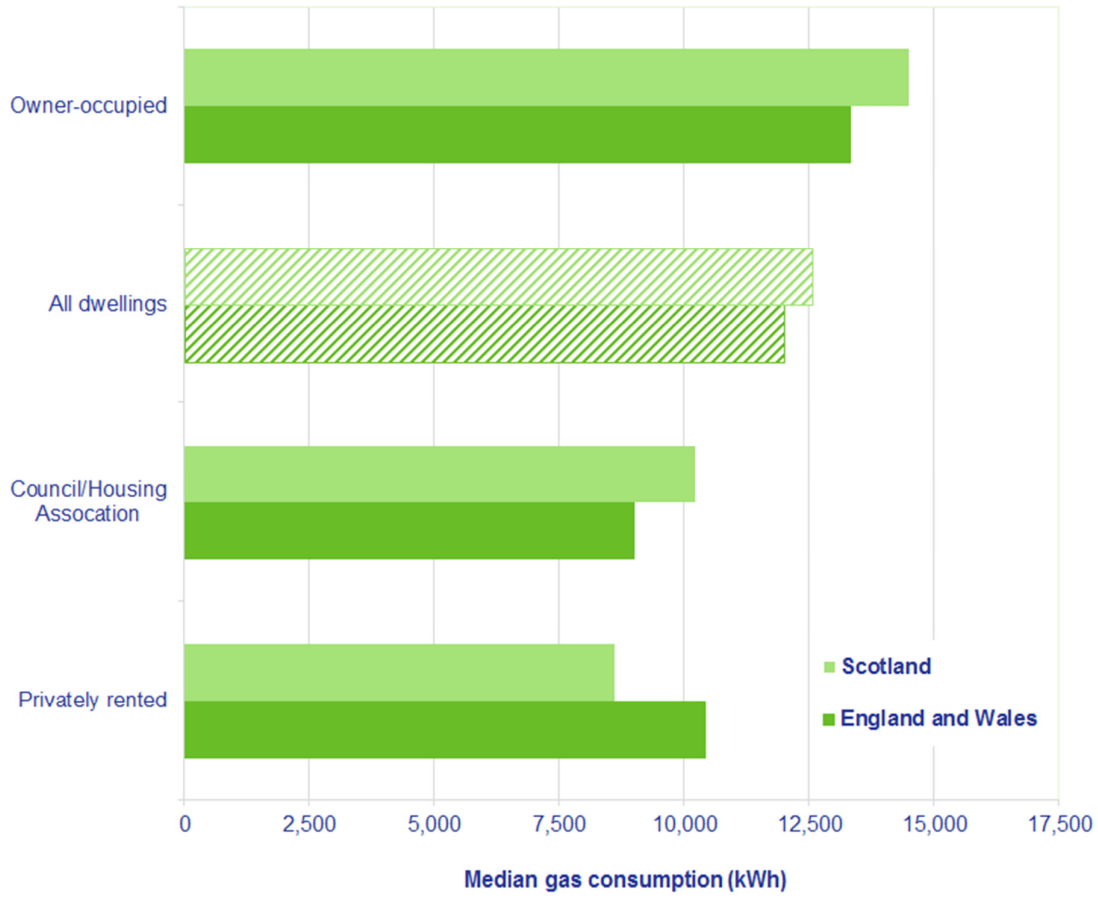
Figure 3.10: Median domestic gas consumption (kWh) by household income, 2015



[18] Only 0.6 per cent of all properties in Scotland had household income of £150,000 or more compared to 0.9 per cent of properties in England and Wales. It is possible the figure for Scotland is biased by a relatively small number of very wealthy higher consumers.

For both Scotland and England and Wales, owner-occupiers were the highest typical consumers for gas compared to the other tenure groups (14,500 kWh in Scotland and 13,300 kWh in England and Wales) (Figure 3.11). This is because 67 per cent of owner-occupied properties in Scotland (and around 75 per cent in England and Wales) were larger in size (3 or more bedrooms) compared to privately rented properties and council housing, which generally consists of smaller properties (1 or 2 bedrooms). Households typically consuming lower levels of gas were in different tenure categories when comparing Scotland with England and Wales (privately rented, 8,600 kWh in Scotland and council housing, 9,000 kWh for England and Wales).

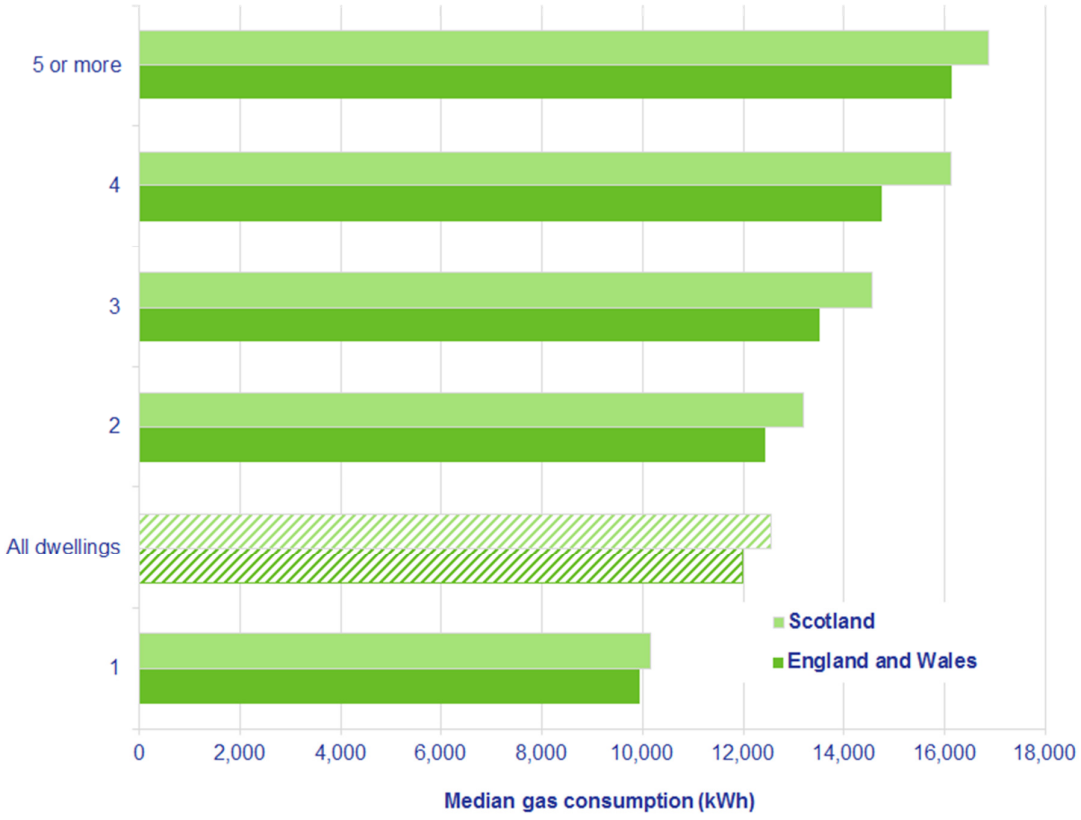
Figure 3.11: Median domestic gas consumption (kWh) by tenure, 2015



Owner occupiers also consumed more electricity compared to the other tenure groups. Scottish owner-occupiers typically consumed 3,600 kWh, higher than England and Wales (3,400 kWh). Council households in Scotland and England and Wales generally consume the least amount of electricity. Council households in Scotland typically consume 3,000 kWh, higher than England and Wales (2,900 kWh). Across the tenure groups, in both

Scotland and England and Wales, flats typically consumed the least amount of electricity, of which council houses consumed less than privately rented and owner-occupied properties.

Figure 3.12: Median domestic gas consumption (kWh) by number of adults in a household, 2015



Scottish households typically consumed more than households in England and Wales, with this difference generally getting larger as the number of occupants increased (Figure 3.12). Typical gas consumption of households with one adult occupant in Scotland was 10,100 kWh compared with 9,900 kWh in England and Wales. For households with five or more adult occupants typical consumption in Scotland was 16,900 kWh compared with 16,100 kWh in England and Wales. A similar pattern was observed for electricity consumption.

4. Impact of energy efficiency measures in homes

4.1 Background to the analysis

This chapter analyses the impact of installing energy efficiency measures on a household's gas consumption, in England, Wales and Scotland[19]. Headline tables summarising the results for the 2017[20] publication are available here. The energy efficiency measures included in this analysis are:

- cavity wall insulation;
- loft insulation;
- boiler; and
- solid wall insulation.

The impact of installing a combination of these measures has also been explored in section 4.3 of this chapter.

Analysis has also been conducted on the effect which installing solar photovoltaic[21] (solar PV) panels has on mains **electricity** consumption (see Section 4.2).

The measures used in this analysis are recorded by BEIS through government funded schemes. It is important to understand how the energy efficiency measures impact on a household's energy use, both to help understand the impact of past policy and help with the effective design of new policies.

[19] Impact of measures analysis for Scotland is calculated separately to England and Wales, and is included in a subsection of this chapter.

[20] 2017 NEED publication presents data to end 2015. The impact of measures analysis is presented for measures installed in 2014, as the saving is calculated by looking at the difference between 2015 and 2013 gas and electricity consumption.

[21] The electricity consumption savings made by installing solar PV panels cannot be compared with the gas consumption savings made by installing one of the energy efficiency measures listed above.

Policy Context

The Energy Company Obligation (ECO) and **Green Deal (GD)** are Government energy efficiency schemes which began operating in 2013. They replaced the previous schemes: Carbon Emissions Reduction Target, Community Energy Saving Programme and Warm Front. Their aim is to encourage the uptake of energy efficiency measures so that the efficiency of the building stock is improved. This has impacts such as reduced consumer bills and increased comfort in the home.

Results presented in this section refer to the savings in households' gas consumption. All gas consumption data are presented on a weather corrected[22] basis – which means the consumption for each household has been adjusted to account for difference in temperature each year. The estimated savings are observed; savings following 'comfort taking'[23] but do not take into account the quality or coverage of the energy efficiency measure installed. For example, estimates could include some properties which have only had cavity wall insulation installed in three of their four walls. Individual households therefore have the potential to make a greater saving than the headline results presented in this report. There is also potential for households to make smaller savings than those presented here, since there are a number of factors that can impact the amount of gas a household consumes, such as the number of people, or how long the house is vacant for.

The analysis compares the gas consumption in properties before and after an energy efficiency measure is installed, with the change in consumption over the same period for similar properties which have not had any measure installed. To do this, an intervention and comparator group are created. The intervention group contains properties which have received the energy efficiency measure being considered (and no other measure as recorded by BEIS). The comparator group contains properties with similar characteristics that have not had an energy efficiency measure installed at any point[24].

[22] An overview of the weather correction of gas industry consumption data can be accessed here: https://www.gov.uk/government/statistics/overview-of-weather-correction-of-gas-industry-consumption-data.
[23] Comfort taking is where some households take the benefit of the insulation measure through increased warmth rather than entirely through energy saving. For example, a household may have had their thermostat set lower than they wanted in order to lower their gas use, but after installing an energy efficiency measure they could choose to increase the temperature on their thermostat and use the same amount of energy since their property should now retain the heat better than before due to the improved energy efficiency.
[24] This group has no energy efficiency measure recorded as being installed in HEED, Green Deal, ECO or FiTs. These properties may have had a measure installed which has not been recorded in any scheme, for

Year-on-year it is becoming increasingly difficult to isolate intervention and comparison groups, as more homes are having measures installed, the number of homes in the comparison group is falling. Additionally, with changes in government schemes and increases in the number of different measures which could be installed, the number of homes with one measure only is reducing – making it more challenging to isolate the effect of installing one measure. In particular, this has been the case for solid wall and loft insulation analysis in the current 2017 publication. For the combination of boiler, solid wall and loft insulation group the number in this group was too low to provide a robust saving estimate and so these results have not been published here.

Given the above, results have been boosted by using records from all households in England and Wales rather than a sample of the full NEED dataset.

Results cover the installation of energy efficiency measures over the period 2005 to 2014. Therefore, ECO and GD measures installed after 31 December 2014 are not presented in the current publication. The effect of more recent measures funded through ECO and GD will be explores in future publications.

Not all households are included in the analysis:

- Flats, due to insufficient address information when matching meter readings, are excluded to avoid matching flats to wrong meter point readings which would produce inaccurate estimates;
- In previous publications, properties built post-1999 have been excluded from cavity wall and loft insulation analysis due to a change in building regulations[25] and the requirement for all newly built properties to have loft and cavity wall insulation as standard as of that date. However, key revisions were made to building regulations regarding cavity walls between 1985 and 2001, with the requirements for wall U-value changing each time. Due to these iterative changes in building regulations, the flexibility in the regulations and the number of allowable technical solutions, there is uncertainty regarding the extent to which these cavities were insulated, their method of construction, and their baseline U-values. As a result, in the 2017 publication, all properties to have received cavity wall insulation were used in the analysis;
- Properties with unusual or estimated patterns of gas or electricity consumption have been excluded also.

example the homeowner installing their own loft insulation. It should be noted that - with the exception of professional loft insulation - it is equally possible that properties in the intervention group could have installed their own loft insulation, and this will also not be recorded.

[25] Further information about building regulations can be found in Annex G of this publication.

All headline figures in this report are weighted - savings have been adjusted to be representative of the complete housing stock rather than just the properties which have had the measure installed through a government scheme in the year under consideration.

The estimates set out in the rest of this chapter provide insight into the range of savings experienced and how savings vary for different types of properties and households. A negative figure indicates the observed saving in consumption for the intervention group following the installation of an energy efficiency measure, compared to the comparator group.

The Domestic Energy Consumption section of this report (Chapter 3) presents gas and electricity consumption figures for the representative NEED sample and this may assist in putting results in this chapter into context.

Further details about the how the impact of measures analysis is put together, can be found in the NEED methodology note: https://www.gov.uk/government/statistics/domestic-national-energy-efficiency-data-framework-need-methodology.

4.2 Impact of installing a single energy efficiency measure

This section presents headline results and key findings for the impact of installing a single energy efficiency measure in a household in 2014. Table 4.1 below shows the average savings experienced in gas consumption for properties having the following installations in 2014:

Table 4.1: Summary of observed savings (weighted) – single energy efficiency measure installed in 2014[1,2,3]

Energy efficiency measure		Number in group	Percentage saving	Saving (kWh)
Cavity wall insulation	Median	43,240	-9.5%	-1,300
	Mean	43,240	-8.6%	-1,400
Loft insulation	Median	21,510	-4.0%	-500
	Mean	21,510	-3.8%	-700
Condensing boiler	Median	185,150	-9.0%	-1,300
	Mean	185,150	-8.0%	-1,400
Solid wall insulation[4]	Median	4,350	-14.1%	-1,700
	Mean	4,350	-13.2%	-1,900
Solar PV[4,5]	Median	6,130	-10.2%	-500
	Mean	6,130	-8.3%	-500

Source: NEED 2017

[1] Sample sizes have been rounded to the nearest 10 and consumption to the nearest 100 kWh.

[2] Only households with valid gas consumption between 2,500 and 50,000 kWh have been included.

[3] Households with suspected estimated gas consumption readings have been excluded.

[4] Solid wall insulation and solar PV figures should be interpreted with care since they are based on a much smaller number of records and a less diverse housing stock than other energy efficiency measures presented in this report.

[5] The results for solar PV show electricity savings, unlike the rest of the table which show savings in gas consumption.

Further information about each energy measure is provided below. Additionally, looking at the savings made by property type provides an opportunity to identify the typical property characteristics which seem to benefit the most from having a particular energy efficiency measure installed.

The detailed data tables including breakdowns by property attributes and household characteristics will be published as part of the 2018 NEED report. Examples of the analysis are included in the following section of how the type of property can help to explain the savings shown.

Cavity wall insulation

Typical median savings for properties installing cavity wall insulation were 9.5 per cent (representing a saving of 1,300 kWh).

According to VOA data, the most common house type in England and Wales is a 3 bedroom semi-detached property. In 2014, the highest majority (41 per cent) of cavity wall measures were installed into semi-detached home types.

Figure 4.1 below shows the observed percentage savings in gas consumption for properties installing cavity wall insulation in 2014 by **property type**.

Detached properties experienced the greatest typical saving (around 10 per cent), with mid-terrace properties seeing the smallest reduction in gas consumption (around 5 to 6 per cent) – this pattern has remained unchanged since the 2011 results. It is to be expected that mid-terrace properties would see the smallest savings since they only have two external walls, whereas detached, semi-detached and end-terrace all have at least three.

Figure 4.1: Observed savings (weighted) in gas consumption for properties having cavity wall insulation installed in 2014, by property type

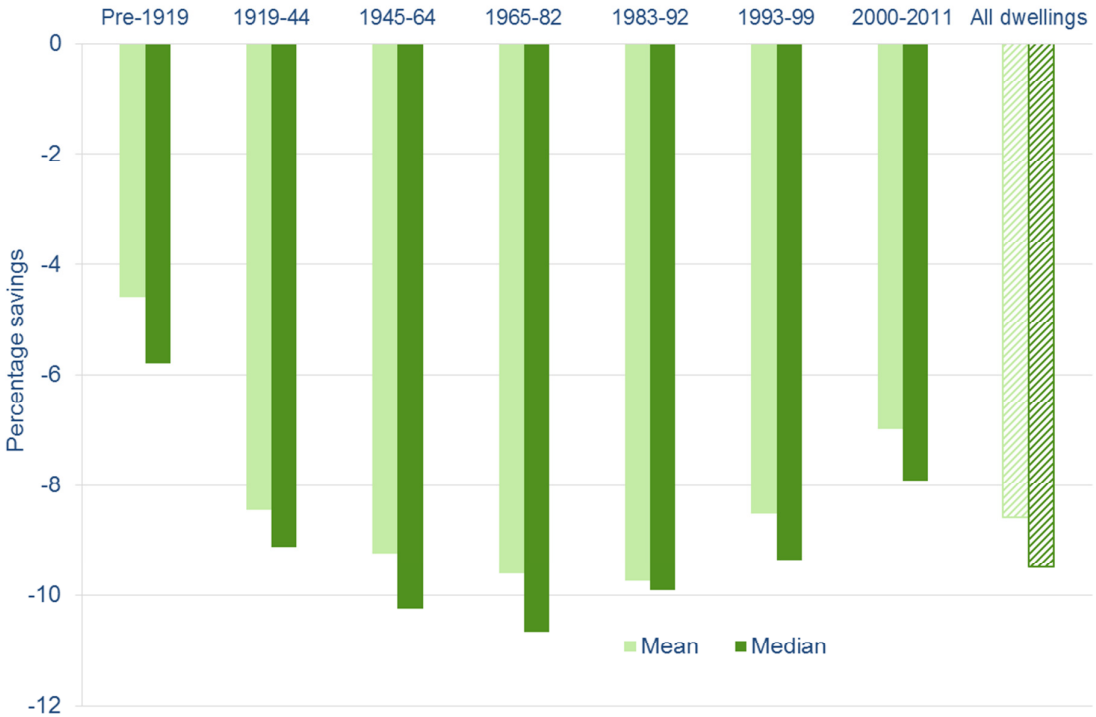
Footnotes:
1. Consumption data from sub-national gas and electricity consumption statistics 2015, https://www.gov.uk/government/organisations/department-of-energy-climate-change/about/statistics
2. Household characteristics data sourced from the Valuations Office Agency as at March 2017

Figure 4.2 shows the observed percentage savings in gas consumption by **property age**.

Cavity wall insulation appears to have less of an impact at the extremes of the age distribution. Some possible explanations for this pattern are:

- Energy efficiency measures tend to be less effective in older homes due to issues such as draftiness;
- newer properties tend to more efficient and/or already have some wall insulation not recorded by BEIS, therefore the savings in this analysis are lower;
- changes in building materials used to meet building regulations[26] potentially impact the effectiveness of installing an energy efficiency measure.

Figure 4.2: Observed savings (weighted) in gas consumption for properties having cavity wall insulation installed in 2014, by property age



Footnotes:
1. Consumption data from sub-national gas and electricity consumption statistics 2015, https://www.gov.uk/government/organisations/department-of-energy-climate-change/about/statistics
2. Household characteristics data sourced from the Valuations Office Agency as at March 2017

Loft insulation

Typical median savings for properties installing loft insulation were 4.0 per cent (500 kWh).

[26] Further information about building regulations can be found in Annex G of this publication.

When analysing savings as a result of loft insulation installations, the following points need to be considered:

- The loft insulation intervention group covers installations into lofts which had no insulation (virgin loft insulation), and installations into lofts which were already partially insulated (top-up loft insulation). Therefore, households with very little or no existing insulation can expect to save more than the typical savings outlined.
- Conversely, properties which already have a reasonable amount of loft insulation, or where the existing insulation is being replaced, are likely to experience smaller savings.
- Savings may be underestimated because of the potential for DIY loft insulation to be installed in the comparator group, but not in the intervention group. This will mean the comparator group may have experienced some savings as a result of insulation which is not accounted for in the intervention group.

Results for impact of **room-in-roof insulation** are also available from the analysis of this chapter. A typical median saving achieved in a year after installing room-in-roof insulation is 736kWh (a median saving of 3.7 per cent). These results must be treated with caution as the intervention group for this measure consists of only 109 properties, for which the results range significantly.

Further breakdowns for this measure will be made available in 2018 NEED publication.

Condensing boiler

Typical median savings for properties receiving boilers were 9.0 per cent (1,300 kWh).

Data for boiler installations prior to 2009 are not available and therefore historical data have not been included within this publication.

Policy Context

The Energy Company Obligation (ECO), which was launched in 2013, provides grants for eligible households to replace boilers that are over ten years old. The proportion of boilers installed in older properties, which are more likely to have older boilers, was consequently higher in 2013 and 2014 compared to previous years.

Further breakdowns for this measure will be made available in 2018 NEED publication.

Solid wall insulation

Typical median savings for properties installing solid wall insulation were 14.1 per cent (1,700 kWh).

When interpreting the results for solid wall insulation, the small number of properties in this group should be taken into account. There are approximately 4,350 properties included in the impact of solid wall insulation section of this report. For comparison, cavity wall insulation results for 2014 are based on 43,240 properties.

There are a number of reasons for this reduced group size:

- According to the English Housing Survey, only around 30 per cent of all homes have solid wall as opposed to cavity wall;
- Solid wall insulation is often installed in flats, which are excluded from the impact of measures analysis as stated in the background section of this chapter;
- Solid wall insulation is often installed in properties which do not have gas as the main heating fuel, and therefore these properties could not be included in this analysis, since record-level consumption data are not available for non-metered fuels.
- Solid wall insulation is often installed in combination with another energy efficiency measures, such as a new boiler or loft insulation, and so these properties could not be included in the analysis of the impact of solid wall insulation on its own.

Continued research is also being carried out by BEIS to improve understanding of the performance of solid wall properties in the UK housing stock and the effect on energy post-insulation. The research investigates heat losses through solid walls and other parts of the dwelling, before and after insulation, with the intention to improve models of solid wall dwellings, understand the unintended consequences of solid wall insulation, and improve tools for assessing the energy savings from solid wall properties[27].

Further breakdowns for this measure will be made available in 2018 NEED publication.

[27] Further information can be accessed at: https://www.gov.uk/government/publications/solid-wall-heat-losses-and-the-potential-for-energy-savings-literature-review

Solar Photovoltaic (PV)

The effect on a household's mains **electricity consumption** after installing solar PV has also been explored in this chapter. The 2017 publication considers measures installed through Green Deal schemes as well as Feed-in-Tariffs (FITs).

The impact of installing solar PV showed typical median savings in mains **electricity** consumption of 10.2 per cent (500 kWh).

Policy Context

BEIS introduced the Feed-in Tariff (FIT) scheme in April 2010 to promote the deployment of a range of small-scale low-carbon electricity generation technologies in Great Britain.

The FIT scheme subsidises solar PV, hydro, wind, anaerobic digestion installations below 5 MW, and micro combined heat and power below 2 kW. Microgenerators receive guaranteed payments from electricity suppliers based on the amount of electricity produced, along with export tariffs for electricity not used on-site but fed ('exported') to the grid. Unless the microgenerator installs a second electricity meter specifically for exports, 50 per cent of the electricity generated is deemed to be used on-site, and the other 50 per cent, exported to the grid, and export payments are made accordingly.

For more information about the FIT scheme, please visit www.ofgem.gov.uk/environmental-programmes/feed-tariff-fit-scheme and Annex B of the 2015 publication

4.3 Impact of installing a combination of energy efficiency measures

This section looks at the impact of installing a combination of energy efficiency measures. The combinations of measures considered in this section are:

- cavity wall and loft insulation;
- cavity wall insulation and boiler;
- loft insulation and boiler;
- solid wall insulation and boiler; and
- boiler, cavity wall and loft insulation.

The limitations of the data sources as outlined in the background section of this chapter also apply to data used for the analysis set out in this section. Combinations involving solid wall insulation, loft insulation and a boiler have not been presented in this section due to the small number of households in these combined groups.

Solar PV has also not been included in this section as savings are based on electricity consumption and cannot be compared with the savings in gas consumption achieved by installing one of the other measures (cavity wall insulation, loft insulation, a condensing boiler or solid wall insulation).

Table 4.2 below summarises the median and mean percentage and kWh savings experienced in gas consumption when installing a combination of energy efficiency measures in the same year.

Table 4.2: Summary of observed savings (weighted) – combinations of energy efficiency measures installed in 2014[1,2,3,4,5]

Combination of measures		Number in sample	Percentage saving	Saving (kWh)
Cavity wall insulation and loft insulation	Median	14,540	-12.5%	-1,700
	Mean	14,540	-11.5%	-1,900
Cavity wall insulation and boiler[4]	Median	3,130	-18.2%	-2,700
	Mean	3,130	-16.6%	-3,000
Solid wall insulation[4,5] and boiler	Median	610	-24.9%	-3,000
	Mean	610	-22.6%	-3,300
Loft insulation and boiler	Median	2,980	-13.8%	-2,000
	Mean	2,980	-12.5%	-2,300
Cavity wall insulation, loft insulation and boiler[4]	Median	820	-25.2%	-3,500
	Mean	820	-24.1%	-3,900

Source: NEED 2017

[1] Sample sizes have been rounded to the nearest 10 and consumption to the nearest 100 kWh.

[2] Only households with valid gas consumption between 2,500 and 50,000 kWh have been included.

[3] Households with suspected estimated gas consumption readings have been excluded.

[4] Care should be exercised when interpreting the figures, in particular figures which are based on a small sample size.

[5] The combination of solid wall and loft insulation has also been excluded from 2017 analysis due to a much smaller number of records in this years data.

Headline figures presented above are weighted to be representative of the complete housing stock, rather than just the properties which had the combination of measures installed in the year under consideration.

The greatest typical savings can be made by installing cavity wall insulation, loft insulation and a condensing boiler (25.2 per cent), followed by solid wall insulation and boiler (24.9 per cent).

In 2017 analysis, all but two (cavity wall insulation and a boiler; and cavity wall and loft insulation) of the combinations of measures, the saving from installing the measures in combination are slightly higher than the sum of the savings for each individual measure.

For example, for the combination of solid wall insulation and boiler, the median saving in gas consumption is 24.9 per cent (Table 4.2). However, adding the impact of each single measure together (14.1 per cent for solid wall and 9.0 per cent boiler) results in a sum of 23.1 per cent (see Table 4.1). This is lower than the saving presented in Table 4.2 for the installation of both measures in the same year.

4.4 Scotland

This section outlines the impact of installing energy efficiency measures on a household's gas consumption specifically for properties in Scotland.

As already mentioned in the domestic consumption chapter, this year is the first time BEIS has included the analysis of consumption trends in Scotland as a sub-section in this chapter. In previous editions of the publication, the Scottish analysis can be found in an annex. Unlike, England and Wales, the analysis is carried out on all properties in Scotland, since this is a smaller dataset and requires less processing time. The other difference is that modelled data from Experian have been used for property attributes and household characteristics in this analysis with the exception of property type, where the Scottish Assessor data (equivalent to the Valuation Office Agency data) has been used. Comparisons between the Experian and Scottish Assessor data shows that property type in both data sets are broadly in line.

The use of modelled data for property attributes in Scotland allows analysis to be undertaken. However, it also increases uncertainty in the estimates. Therefore these results should be treated as provisional and interpreted with caution. To help reduce uncertainty, the results for Scotland are based on all properties in Scotland that could be matched to valid consumption data, unlike England and Wales where a sample of properties is used for analysis.

Table 4.3 below shows the savings experienced in households' gas consumption for cavity wall insulation, loft insulation, solid wall insulation and condensing boilers installed in 2014. It shows that the greatest typical saving is seen for properties installing solid wall

insulation, with a typical saving of 13.5 per cent, or 1,600 kWh. Properties installing cavity wall insulation saw a typical saving of 9.1 per cent, which represents a saving of 1,300 kWh.

Table 4.3: Summary of observed savings – single energy efficiency measure installed in 2014, Scotland

Energy efficiency measure		Percentage saving	Saving (kWh)
Cavity wall insulation	Median	-9.1%	-1,300
	Mean	-8.6%	-1,400
Loft insulation	Median	-3.5%	-500
	Mean	-3.2%	-600
Solid Wall insulation	Median	-13.5%	-1,600
	Mean	-12.6%	-1,900
Boiler	Median	-8.7%	-1,300
	Mean	-7.8%	-1,400

Detailed results by property attributes and household characteristics have not been included in this report due to the increased impact the uncertainty surrounding these estimates has on individual groups. The methodology used for calculating the estimates means that any mismatches in properties being matched with similar properties as a result of modelled data not being accurate will be accentuated when results for different break downs are considered. However, like results for England and Wales, households experience a range of savings. The actual savings experienced by households will depend on a variety of factors including the consumption in a property before the measure is installed, physical attributes of the property and how householders use energy.

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