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Critical review of using metered energy consumption data on Scottish EPCs

Agnes Berner, Freya Burns, Hannah Dunne

Changeworks

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1 Executive summary

This project was commissioned to inform the Scottish Government on the evidence and arguments for and against the inclusion of metered energy consumption data in Energy Performance Certificates (EPCs). Methods included a literature review and interviews with stakeholders in Scotland, the UK and Sweden.

We outline the potential opportunities for and barriers to using energy consumption data; the practicalities of obtaining and using energy consumption data; and the value of including such data, when considering the variables that affect actual energy usage.

1.1 Key findings

Metered energy consumption data could be used in EPCs in two ways to provide information to occupants or potential occupants:

- to provide more accurate information on building fabric performance, known as an asset rating
- to give a rating of how energy is used in a building when compared with similar buildings, known as an operational rating.

These two uses of metered consumption data - asset rating and operational rating - are not mutually exclusive and could both be included in EPCs. This could be developed as a dynamic, digital EPC.

Neither of these two uses could be implemented immediately as 57% of homes in Scotland do not yet have smart meters, which are the most reliable means of collecting metered energy consumption data. Particular difficulties include:

- A small proportion of homes will never have smart meter capability, including homes with unregulated heating fuels such as oil, LPG, or solid fuels.

- There is no process to access smart meter data to generate EPCs. The Smart Meter Energy Data Repository Programme is investigating the commercial feasibility of a repository that would enable this.

The most straightforward use for metered energy consumption data is to include the operational rating value on an EPC alongside a reference figure, such as a national average, modelled archetype, or historic consumption data for a property.

- Correcting energy consumption in a property for weather and normalising it by floor area would enable potential occupants to compare properties.
- An operational rating could be included as a part of the EPC or exist as a separate document.

EPCs should retain an asset rating that is based on standard assumptions of occupancy and use, to allow comparison between properties. This could be based on modelled or measured data.

For an accurate asset rating, metered energy consumption data can be used to calculate the heat transfer coefficient of buildings. This requires collecting internal temperature data, as well as metered energy consumption data. The latest smart meter in-home display units have inbuilt temperature sensors. The possibility of transmitting temperature readings alongside meter readings is being investigated by the Data Communications Company.

Accurate heat transfer coefficient figures can inform retrofit decisions. Further consideration is needed around the level of retrofit recommendations provided by EPCs and how these are used in policy decisions. Using metered energy consumption data to inform retrofit recommendations may be more suited to detailed retrofit plans such as renovation roadmaps.

Consumer consent will be needed to collect and process metered energy consumption data.

1.2 Recommendations

This report explores whether it is possible for metered energy consumption data to be used within EPCs and outlines two ways in which this data could be useful. In order to progress with either or both of these options, we recommend that the Scottish Government define the purpose and intended outcome of using metered energy consumption data within EPCs.

Our research has highlighted that further work is needed in this area to explore:

1. The practicalities of collecting required data, including:
    - Metered energy consumption data at the individual building level, rather than from aggregated datasets. This will require a standardised process for collecting consumer consent. Public sector bodies can obtain household-level data without the need for individual consent through the legal basis of 'public task'. However, this is for aggregated data and there are no examples of data being used to provide insights into individual households, so further investigation is needed into the legal basis for this. Legal routes for this were not explored as part of this research.

- Processes for data collection, as these are mostly dependent on the rollout of smart meters. An alternative methodology will need to be developed for households using unregulated fuels, as their heating consumption will not be captured in smart meter data.
- Additional information from occupants, which can be used to contextualise energy consumption data when used for an operational rating. Examples of this kind of data include the number of occupants or typical heating regime. Further work is required to understand the minimum amount of contextual information to enable metered energy consumption data to be useful.
- Internal temperature data for the purpose of calculating a heat transfer coefficient as part of an asset rating. This would require the mass rollout of internal temperature sensors, which are already included in some in-home display devices. Internal temperature data could also be useful contextual data for an operational rating.

2. Different formats that could be used to display consumption data when used for an operational rating. This should consider whether consumption data would work best as one of multiple ratings within the EPC or separately.
3. For energy-generating homes, how total energy consumption, generation, export and cost can be displayed in a straight-forward manner.
4. Any regulatory or practical barriers to inputting the heat transfer coefficient as a measured value in Standard Assessment Procedure calculations for the asset rating.
5. The value of Display Energy Certificates for non-domestic public buildings in England and Wales, and whether there would be value in expanding their use in Scotland.

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Glossary / Abbreviations table

Term	Definition
Asset rating	A measure of building fabric performance. It provides no information about how the building is used in practice.
BEIS	Department for Business, Energy & Industrial Strategy. Split in 2023 to form three departments, including the Department for Energy Security and Net Zero (DESNZ).
CCC	Climate Change Committee. An independent, statutory body whose purpose is to advise the UK and devolved governments on emissions targets and then report to Parliament.
DCC	Data Communications Company. A licenced monopoly regulated by Ofgem. Responsible for linking smart meters in homes and businesses with energy suppliers, network operators and energy service companies.
DEC	Display Energy Certificate. Shows the energy performance of a building based on the operation rating, on a graphical scale from A (very efficient) to G (least efficient). Measures the actual energy usage of a building based on annual consumption.
DESNZ	Department for Energy Security and Net Zero. The UK Government department responsible for securing long-term energy supply, reducing bills, and encouraging greater energy efficiency.
DNO	Distribution Network Operator. A company licensed to distribute electricity in the UK.
DOR	Domestic Operational Rating. A proposed operational rating scheme for domestic properties that quantifies the actual, in-use energy demand, greenhouse gas emissions and energy costs of homes.
EER	Energy Efficiency Rating. A review of a property’s energy efficiency which is then scored. The energy efficiency charts are divided into rating bands ranging from A+ to G, where A+ is very efficient and G is least efficient.
EPBD	Energy Performance of Building Directive. The key policy instrument to increase the energy performance of buildings across the European Union. Originally introduced in 2002, it was recast in 2010 and revised in 2018 and 2021.

EPC	Energy Performance Certificate. A document that provides information about the energy efficiency of a building. Used in many countries including Scotland.
FIT	Feed-in-tariff. A support mechanism designed to pay small scale renewable energy generators for the electricity that is exported to the grid.
GDPR	General Data Protection Regulation. A regulation that enhances how people can access information about them and places limitations on what organisations can do with personal data.
HDD	Heating Degree Day. A measurement designed to quantify the demand for energy needed to heat a building. It is the number of degrees that a day's average temperature is below a base temperature of 15.5°C.
HTC	Heat Transfer Coefficient. A common metric for the thermal performance of a building. It describes the rate of heat transfer between two areas.
IEA	International Energy Agency. An international body that provides policy recommendations, analysis and data on the global energy sector.
IHD	In-home display. A portable device with a screen showing energy usage and its associated cost.
kWh	Kilowatt hour. A measure of how much energy is used per hour.
MEPI	Measured Energy Performance Indicator. A method to determine the energy performance of a building based on measured energy use.
MEP	Measured Energy Performance. A tool that utilises accurate measurements of the HTC of a property, along with an RdSAP-style survey to produce a more accurate EPC rating for a property.
MPG	Miles per gallon. Used to describe how many miles a vehicle can travel for every gallon of fuel used.
Operational rating	Shows the actual energy usage of a building.
Performance Gap	The difference between predicted and actual performance of a building's fabric. Also sometimes used to describe the difference between predicted energy usage and actual (metered) energy usage, therefore also including the impact of occupancy factors.
PHPP	Passive House Planning Package. Modelling software developed by the Passivhaus institute. Used when designing energy efficient

	buildings to calculate their operational energy use and carbon emissions.
RdSAP	Reduced Data Standard Assessment Procedure. A simplified version of SAP calculated using a set of assumptions about the dwelling based on conventions and requirements at the time it was constructed.
Regulated energy	The energy which is consumed by the building and its fixed utilities including space heating, cooling, hot water, ventilation, lighting.
RHI	Renewable Heat Incentive. A Government financial incentive to promote the use of renewable heat.
SAP	Standard Assessment Procedure. The method for calculating the energy performance of dwellings in the UK. Scores typically range from 1 to 100+, with higher scores indicating more efficient building stock. SAP is owned by the UK Government. Building Research Establishment (BRE) is responsible for the development of SAP.
SBEM	Standard Building Energy Model. Government approved methodology that calculates the energy required to heat, cool, ventilate and light a non-dwelling.
SHCS	Scottish House Condition Survey. A national survey designed to look at the physical condition of Scotland's homes as well as the experience of householders.
SMETER technologies	Smart Meter Enabled Thermal Efficiency Ratings technologies that measure the thermal performance of homes using smart meters and other data.
Unregulated energy	The energy which is consumed by the building in the form of fixtures or appliances like refrigeration, TVs, computers, kettles, microwaves, hobs, and ovens. The usage of these appliances varies based on occupants' choices and behaviours.
US DoE	United States Department of Energy. Department of the US federal government that oversees national energy policy and manages domestic energy production and conservation.
ZDEH	Zero Direct Emissions Heating systems are systems which produce zero direct emissions at the point of use.

2 Introduction

This research has been commissioned in response to calls on the Scottish Government to make use of metered energy consumption data within Scottish EPCs. A common criticism of EPCs is that they do not provide useful information to householders about the actual energy consumption and real-life performance of properties. As a result, EPCs can be perceived as unreliable and unhelpful.

Increasing evidence shows that there are significant and consistent gaps between properties' actual energy consumption and the consumption modelled in EPCs (BEIS, 2021; Few et al., 2023; The Times, 2023). EPCs were not designed to predict actual consumption (see Section 3). This raises the question of whether the methodology or format would benefit from including metered consumption data. The installation of smart meters in an increasing number of Scotland's homes presents an opportunity to collect this data. In this report, we explore how such data could be incorporated into EPCs to potentially improve their usefulness and reliability.

The question of using energy consumption data is complex – there are many ways it could be included, and each has different implications. This report sets out two key uses for energy consumption data: to inform an asset rating; and to inform an operational rating.

3 EPC Overview and Research Scope

3.1 Energy Performance Certificates (EPCs)

An EPC is a document that provides information about the energy efficiency of a building. Their introduction was driven by the European Union's Energy Performance of Buildings Directive (EPBD). Article 11 of the EPBD states the original purpose of EPCs was "to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance" (Directive 2010/31/EU, 2010). Article 2 specifies that EPCs are intended to show "the energy demand associated with a typical use of the building" (ibid.). This makes it clear that the original purpose of EPCs was to enable the comparison of building performance under 'typical' conditions.

Annex I also states that the energy performance of buildings can be evaluated using either the calculated (producing an asset rating) or actual energy consumption (producing an operational rating) (Directive 2010/31/EU, 2010). Methods based on measured energy consumption must separate out building performance from other factors, primarily occupancy. The variability of these other factors can be controlled when using calculated methods. However, calculated methods are often associated with inaccuracy (Crawley et al., 2019; Hardy and Glew, 2019) and pose the problem that what is built can be different from what was designed or modelled (the performance gap).

In practice, most EPC methodologies use a calculated approach, incorporating real building data from surveys or physical tests (Arcipowska et al., 2014). In Scotland, as in the rest of the UK, EPCs are produced using SAP, RdSAP and SBEM methodologies. SAP (Standard Assessment Procedure) is used to generate EPCs for both new and existing residential buildings. Full SAP is primarily used for new dwellings whereas RdSAP (Reduced Data SAP) is used for existing dwellings. RdSAP uses the same calculation as full SAP but with a simplified data collection process. This enables the calculation to take place where a complete data set for a property is unavailable, and for a lower cost than full SAP.

Existing SAP methodologies used to calculate the domestic asset rating use standard assumptions for occupancy, energy-use, and climate to ensure that the thermal performance can be compared under the same set of conditions. This asset rating is not reflective of how the building is used, for example due to the specific energy requirements of the occupants or the local climate.

SBEM (Standard Building Energy Model) is used to produce EPCs for non-domestic buildings. SBEM utilises a different calculation methodology to SAP. For the generation of an EPC, the SBEM calculation utilises standardised information for several factors to allow comparability between similar building types. Like SAP, SBEM requires a certain amount of standardisation to enable comparability between buildings for benchmarking purposes.

3.2 Research scope

This report considers whether metered energy consumption data can and should be used in the production of EPCs in Scotland. This brings with it questions around the suitability of EPCs for their various uses. However, the purpose of this report is not to assess whether EPCs (or SAP / RdSAP) are the most appropriate tool for the functions set out in Section 4. Additionally, this report does not detail the limitations of EPCs or SAP. There is an existing body of research which evidences these limitations, for example Jones Lang LaSalle (2012), Kelly et al. (2012), Jenkins et al. (2017), Hardy et al. (2019), and BEIS (2021).

The scope of this research is to consider whether it is possible to access and include metered energy consumption data on Scottish EPCs, and whether this would be a valuable addition. In some instances, we have suggested that the information provided by metered energy consumption data may be useful but would be better presented elsewhere and not as part of an EPC. The focus of the research is on domestic EPCs as tools for providing information to occupants, rather than EPCs as a policy tool or for benchmarking purposes.

The focus of this report is domestic EPCs. The use of metered energy consumption data for non-domestic EPCs is briefly explored in Section 10.

4 Functions of EPCs in Scotland

EPCs in Scotland are used for a range of purposes, including (but not limited to):

- Providing information to potential buyers and tenants on a building's energy use, and estimated energy costs.
- Providing information to property owners on suggested retrofit measures.
- Serving as a policy tool to measure, regulate and set targets for the reduction of carbon emissions from housing.
- Facilitating housing stock analysis by landlords to plan and implement improvements.
- Supporting national housing stock analysis through the Scottish House Condition Survey (SHCS).
- Acting as a proxy indicator to support the identification of households in fuel poverty, for example for the targeting of fuel poverty prevention or alleviation services.

This report does not assess how well EPCs can perform each of these functions. The use of energy consumption data within EPCs will have implications for all of the above uses. Our research considers whether the use of energy consumption data could improve EPCs for the following specific purposes:

- Providing information on a building's fabric performance.
- Providing an estimate of energy costs.
- Providing information on how buildings are actually used.
- Informing retrofit decisions.

5 The case for including energy consumption data

The arguments for using energy consumption data depend on the use-case of EPCs that is being considered. As outlined in Section 4, EPCs now serve a number of purposes for which they were not originally designed. This, along with issues such as inconsistencies between assessors, means that they are perceived as unreliable (Crawley et al., 2020; Kelly et al., 2012). A major driver for using energy consumption data is the premise that this will make EPCs more reliable for users, by reducing reliance on assumptions and assessor judgement.

Currently, EPCs can be of limited value to householders who may expect EPCs to provide information reflecting actual energy consumption. Similarly, for policy or housing stock management decisions, EPC asset ratings do not reflect the actual energy consumption of buildings. The need for policy decisions to be based on actual rather than modelled energy efficiency of buildings is also a key argument for the use of metered energy consumption data in EPCs (Baker & Mould, 2018; Lomas et al., 2019).

This report considers two key uses for energy consumption data in EPCs. It can be used to provide a more accurate asset rating or to provide an operational rating. An asset rating is a measure of building fabric performance and does not consider how a building is used. An operational rating based on energy consumption data can help understand how a building is used, which is not currently addressed by EPCs. This has the potential to provide information to householders on actual energy costs associated with a building, as well as supporting wider decarbonisation policy.

5.1 Reducing the performance gap

Improving the accuracy of EPCs through the use of energy consumption data is intended to reduce the performance gap. The performance gap refers to the difference between modelled energy performance (e.g. through SAP) and measured energy performance (Fitton et al., 2021). There are a significant number of variables which influence this gap. These include factors related to the building fabric, building use, and the accuracy of the model.

The term 'performance gap' usually refers to the discrepancy between designed and as-built fabric performance, particularly for new-builds. However, it is also used to refer to the difference between predicted energy usage and actual (metered) energy usage. When used in this way, the term is also incorporating the impact of occupancy factors.

Recent research found that even when other factors are accounted for (i.e. in households that meet EPC standard assumptions), EPCs overpredict energy use (Few et al., 2023). This suggests that the methodology and its underlying assumptions also contribute to the performance gap.

5.2 Improving the accuracy of asset ratings

Energy consumption data can provide a more accurate calculation of a building's fabric performance. Utilising real-world data to calculate actual space heating demand could improve accuracy and therefore, increase consumer confidence in the reliability of the asset rating. A more accurate asset rating would enable more accurate predictions of annual energy cost. The cost metric would be predicted under standardised conditions, which would maintain the ability to make comparisons between buildings.

A programme of work by the International Energy Agency known as Annex 71 sought to test demand amongst industry stakeholders[1] for a method to calculate HTC. Their survey results indicated a high level of demand for this across several different use-cases including energy certification (Fitton et al., 2021).

5.3 Providing an operational rating

Currently EPCs are based on a building fabric model, and do not consider how energy is used by occupants. Asset ratings alone are not sufficient to reduce energy demand. This requires

[1] Survey respondents included engineers, architects, product manufacturers, social housing providers, policy makers and researchers.

measuring and achieving reductions in actual energy consumption in buildings (Few et al., 2023; Jones Lang LaSalle, 2012; The Times, 2023).

The use of energy consumption data can provide tailored information for consumers regarding the potential energy costs to occupy a specific property, i.e., a measure of the operational performance of the property. Research has shown that the ability to compare energy use with that of similar dwellings is perceived as beneficial to householders (Zuhaib et al., 2021). In order for comparisons between dwellings to be useful, some contextual information is needed to account for occupancy factors which impact energy use (Section 6).

The ways in which this contextual information could be collected and used are discussed in Section 9. However, some stakeholders (Richard Fitton, Professor of Building Performance; Alan Beal, Bacra; Thomas Levefre, Managing Director, Etude) were wary of using energy consumption data in this way, as we will never be able to fully account for or control all the variables that affect how energy is used in the home.

A significant benefit of introducing an operational rating is to provide more accurate cost saving figures to improve the energy efficiency improvement recommendations. Actual consumption data could also enable a better assessment of the impact of retrofit measures and whether they perform as intended.

There is evidence that householders would find it useful to see actual energy costs on an EPC. There are number of ways this information could be contextualised or compared. A study of five European countries (Zuhaib et al., 2022) found that the majority of householders who responded to their survey would like to see the energy costs of the previous occupier included in EPCs, as well as the energy cost of ‘similar’ households[2]. However, the same study notes that energy consumption comparisons were was perceived as more useful when comparing against the previous year than with similar households. Year-on-year comparisons of energy use may be more appropriately provided by energy suppliers rather than on an EPC (see Section 7.2 for detail on dynamic EPCs).

5.4 Informing retrofit decisions

Another purpose of EPCs (as described in EBPD) is to provide improvement recommendations for householders. The Scottish Government’s latest consultation on EPCs states that EPCs are intended as a starting point for householders, but not to provide bespoke recommendations for retrofit (Scottish Government, 2023). However, the information currently provided to householders on an EPC could still be improved using energy consumption data, particularly in relation to predicted savings (Baker & Mould, 2018). Energy consumption data could be used to provide accurate predictions of savings from retrofit measures (Cozza et al., 2020).

[2] The term ‘similar households’ was not defined in the study. Because of the variance of occupancy influence on energy use, this could be interpreted as similar age or number of occupants, heating pattern, income, or other factors.

Aside from informing individual householders, retrofit recommendations on EPCs and their associated predicted savings are also used to support the targeting of investment in retrofit. The scale of investment required for retrofit means that estimates of potential financial savings must be accurate. Laurent et al. (2013) argue that the economics of retrofit should not be evaluated using normative models. This is because all normative models (not just SAP) have been shown to overestimate potential savings and the cost effectiveness of retrofit measures. For these reasons, if the Scottish Government intends to continue to use EPC retrofit recommendations as a policy tool for directing funding, further investigation is needed into how energy consumption data could support this (Baker & Mould, 2018).

The use of energy consumption data in EPCs could better reflect the actual energy performance of building fabric (Section 8). This would provide a more realistic baseline asset rating on which to base recommended retrofit measures. However, the recommendations on an EPC would still be generated automatically by SAP based on general property characteristics. Metered energy consumption data could also play a role in measuring the impact of retrofit, as explained in Section 8.

Energy consumption data provides information on how a building is used. It can therefore be used to support the development of bespoke retrofit recommendations. However, such EPCs are not the tool for developing bespoke retrofit plans (Scottish Government, 2023). PAS 2035 or renovation roadmaps (Small-Warner & Sinclair, 2022) provide a more appropriate framework for this. This view was supported by interviewees (Kevin Gornall and Sam Mancey of DESNZ; Richard Atkins, Chartered Architect) who stated that retrofit plans should be delivered through the industry professionals and not through EPCs. An example of a tool being developed to support this is provided in Box. 1

Box 1: HTC-Up: Informing retrofit using metered energy consumption data

Chameleon Technology were recently awarded funding through the Green Home Finance Accelerator project from DESNZ to develop the HTC-Up project (Chameleon Technology, 2023). Using smart meter data alongside internal and external temperature data, a more accurate HTC figure can be generated which better reflects the actual thermal energy performance of a property. With this data, Chameleon Technology designs a programme for retrofit specific to the home. They direct householders to approved suppliers and installers, and also offer financing solutions if needed.

5.5 Validating models and assumptions

The Elmhurst Almanac (Elmhurst Energy, 2022) refers to the need to use the 'Golden Triangle' to inform decision-making. This refers to a building's asset rating (predicted energy cost and consumption based on standard occupancy), occupancy rating (predicted energy consumption based on how the building is used), and actual energy consumption (smart meter data). In the Golden Triangle, smart meter data is used as a validation point for comparison with figures generated as part of the asset and occupancy ratings. This validation can help to identify issues with performance and where to focus improvements.

Metered consumption data could also be used to improve assumptions contained within SAP/RdSAP. For example, Hughes et al. (2016) showed that the difference between modelled and actual energy consumption could be reduced by using assumptions for internal temperature, number of heating hours, and the length of heating season, that are developed based on actual consumption data.

At a larger scale, metered energy consumption data could also be used to calibrate and improve the modelling used for EPCs (Thomson and Jenkins, 2023). Similar exercises have been undertaken to validate the PHPP model (Mitchell and Natarajan, 2020; Passipedia, n.d.). Using real energy consumption data for this purpose was explored as part of the X-tendo project (Zuhaib et al., 2021). The project findings suggest that real energy consumption data from large housing stock datasets can be used to improve models and for benchmarking performance levels. This particular use is not explored further in this report as it is out of scope. Our focus is on EPCs as a tool for providing information to building occupants.

6 Factors affecting metered energy consumption

Many variables impact on the energy use of a building. These can be broadly split into variables impacting the building fabric, system efficiency (e.g. heating) and those that impact how energy is used within the building. All of these are influenced by wider variables such as fluctuations in energy prices, deprivation levels, social and cultural norms, and changes in climatic conditions.

There is no consensus on the relative importance that can be attributed to either building characteristics or to consumption behaviour in terms of their impact on domestic energy consumption. The variables affecting household energy consumption are understudied (Fuerst et al., 2019) and strong conclusions about how to control or account for them cannot be drawn. Jones et al. (2015) found that 62 household level factors have been studied in the literature as potentially influencing domestic electricity use[3], with varying significance.

In terms of occupancy factors, the review suggests that the number of occupants, the presence of teenagers, and level of household income and disposable income all have a significant impact on electricity consumption. Electrical appliances make a very significant contribution to a household’s electricity consumption (ibid.), however the review noted that only a few previous studies have analysed the effects of the ownership, use and power demand of appliances. The review also indicates that the following building fabric characteristics have a significant effect: dwelling age, number of rooms, number of bedrooms, and total floor area.

[3] For most studies included in the review the electricity use of dwellings may include electric space heating, electric water heating and electric space cooling. Not all studies explicitly stated whether these were included which makes it difficult to draw clear conclusions.

6.1 Building fabric

When considering the physical building characteristics alone, there is little consensus on the significance of physical building characteristics, other than floor area, that impact energy consumption. Research consistently suggests a significant positive correlation between floor area and consumption (ibid.), mostly associated with demand for space heating.

There is little consensus on the impact of dwelling age. Some studies reviewed by Jones et al. (2015) found newer dwellings have a higher electricity demand, attributed to high consumption appliances such as air conditioning. Other studies observed that newer homes had lower consumption due to efficient appliances and better insulation levels. Several studies also concluded there was no relationship, including a UK study by Hamilton et al. (2013).

Built-form type (such as terraced, detached, semi-detached) has also been investigated and a large number of studies concluded that electrical energy consumption increases with the degree of detachment of a building. However, it is not clear whether this relationship is explained by the building fabric or by occupancy factors. In general, the literature suggests that the influence of built-form type on electricity consumption is related to floor area. However, building occupancy is also a possible reason. For example, Wyatt (2013) attributed lower electricity consumption in bungalows to the fact they are normally occupied by elderly residents with comparatively lower energy consumption than the rest of the population. The review by Jones et al. (2015) suggests that there is a relationship between the level of detachment of dwellings and electricity consumption, but the effect could not be determined as either positive or negative.

6.2 Occupancy factors

A regression analysis of household energy consumption in England concluded that gas usage was largely determined by occupancy characteristics such as income and household composition, rather than physical characteristics of the building (Fuerst et al., 2019). This contrasts with the findings from other regression model studies across several countries which report that building characteristics have a greater effect on domestic energy consumption than occupancy characteristics (such as Santin et al., 2009, Estiri, 2014, Huebner et al., 2015).

Fuel poverty is another factor which impacts energy consumption. Levels of fuel poverty in Scotland are geographically uneven across the country, and are higher in rural areas (Changeworks, 2023). Fuel poverty is associated with coping mechanisms such as only heating one room – behaviours which would have a significant impact on energy use. It is well-recognised that households in homes with poor energy efficiency tend to ration energy, known as the 'prebound effect' (Sunikka-Blank and Glavin, 2012).

Any use of energy consumption data will need to be attuned to, for example, the difference between energy rationing and energy saving behaviours, and avoid approaches that inadvertently 'reward' underheating through favourable EPC ratings. For example, it would be problematic if a household with higher-than-standard heating regimes, such as for health reasons, received a more negative EPC rating. This highlights the importance of collecting internal temperature data (to measure heating outcomes), alongside consumption data (Section 8.1.1).

6.3 Regulated and unregulated energy use

The question of how and whether to include consumption data on EPCs largely relates to the purpose of doing so. Not all energy use is relevant to all audiences. The SAP calculations used for EPCs only consider regulated energy use, which includes energy used for heating and cooling, domestic hot water, mechanical ventilation, and fixed lighting. The total energy consumption of a property includes other uses (unregulated energy), such as appliances. This is primarily dependent on the occupants. Although unregulated energy generally accounts for a minority of the total energy consumption in most properties, it is also more likely to fluctuate more often. Factors that can impact this could be an occupant starting to work from home, an occupant moving out, or purchasing a new electrical appliance (Jones et al., 2015).

A householder may be interested in understanding the efficiency of their appliances, but this is less relevant to a building technician working to improve the building fabric or heating system. However, industry experts have suggested that SAP 11 should consider both regulated and unregulated energy use (BEIS, 2021). In part, this is to enable EPCs to better support Net Zero, which requires a reduction in all energy use – not just regulated energy. Another reason is that unregulated energy use is becoming a larger proportion of total energy use as buildings become more energy efficient and use less energy for heating.

6.3.1 Disaggregating energy use

Metered energy consumption data will account for both regulated and unregulated energy, and unless submetering is used it will be difficult to disaggregate these without relying on assumptions. This disaggregation issue was highlighted in the European X-tendo project (Hummel et al., 2022), where four countries tested a methodology for including energy consumption data on EPCs. Three of the countries encountered challenges around determining the energy consumption used for different purposes in the buildings. Metered data for the different energy uses was not available, so the consumption data for space heating and hot water were estimated based on energy bills. This was perceived as complex, time consuming, and inexact (ibid.).

In properties with natural gas heating, disaggregation is not a significant issue, as most of the metered gas consumption can be assumed to be used for heating. However, it poses a challenge in the increasing number of properties with electric heating. There is a risk that relying on assumptions of typical use will replicate the issues that the inclusion of metered data is trying to solve. In Sweden, the disaggregation of energy uses is carried out by the energy assessor based on their competence and judgement. Considering the existing inconsistencies identified among assessors in the generation of UK EPCs (Jenkins et al., 2017), it is likely this approach would introduce further inaccuracies in EPC output.

Box 2: An example scenario of the need to disaggregate energy use

A property with electric heating has recently had internal wall insulation installed. The household is interested in using an energy consumption metric to understand whether the wall insulation has resulted in the expected decrease in energy consumption. However, the same month they also bought an electric vehicle which they charge at home. Without disaggregating their electricity usage, they are unable to tell if their wall insulation is performing as predicted.

The use of sub-metering could help to alleviate these challenges. Chartered Architect Richard Atkins suggested that, in the future, smart meters will be fed into from a series of data points within the home (e.g., heating system, renewable generation assets, storage assets). However, Alan Beal of Bacra indicated that this granularity of metering is unlikely to be available for at least 10 years, and as noted in Section 8.1, regular smart meters are far from fully rolled out in Scotland.

6.3.2 Properties with energy generation

Further consideration is needed for properties with energy generating assets, which adds a layer of complexity to the question of how different aspects of household energy data can be displayed for different audiences.

MCS standards already require a generation meter, and smart meters record the amount of energy exported to the grid, so this data should already be available (Jon Stinson of Building Research Solutions), but it will need to be represented in a way that is legible to the relevant audiences. For example, David Allinson (Building Energy Research Group, University of Loughborough) suggested that consumers would want to see historic levels of energy generation displayed on an EPC.

Overall, the challenge is to design a methodology and an output that works for all properties in Scotland, from properties with no metered heating system and no smart meters, to those with complex systems that include various types of energy generation.

7 Considerations for using metered energy consumption data

7.1 Practicalities of data collection

The potential for using metered data to understand buildings' energy performance is largely linked to smart meters, which provide accurate and frequent meter readings. The number of smart meters continues to increase. As of March 2023, 57% of all gas and electricity meters in the UK were smart (National Audit Office, 2023). However, in most of Scotland, the rates of domestic smart electricity meters were lower (43%), with rates below 10% in Na h-Eileanan Siar, the Orkney Islands, and the Shetland Islands (DESNZ, 2023). This has implications for the approaches reviewed in this report.

7.1.1 Accessing smart meter data

Aside from the rollout, the main challenge associated with accessing smart meter data relates to where the data is stored and how it can be shared. This also relates to General Data Protection Regulation (GDPR) (Section 7.3). Energy consumption data is considered personal data under current GDPR and requires the consumer's consent to access it. Consumption data (and export profiles in homes with generation technologies) are stored on individual meters.

There are currently two ways that third parties can access smart meter data (Energy Systems Catapult, 2023), though both require explicit consent from the consumer:

1. Organisations (such as energy suppliers) can be integrated into the smart metering system. These organisations must lay out their approach to obtaining householder consent during the onboarding process. Work is underway within the DCC to make the on-boarding process easier and more streamlined.
2. Through a Consumer Access Device (CAD). This is a read-only monitor fitted to the home area network. These can only be fitted by registered users of the DCC's systems.

DESNZ are currently exploring options for creating a central repository for smart meter data through their Smart Meter Energy Data Repository Programme. The aim of this is to explore the feasibility of creating a central repository which would support the innovation of services and products for the benefit of consumers and the wider network. This could include all types of smart meter data, either aggregated or at householder level. The primary focus of projects funded through this programme is to enable access to aggregated data sets.

Public sector bodies, or any organisation carrying out a specific task in the public interest, can access household metered energy data without the need for individual consent. This is through the legal basis of 'public task'. However, currently this route is only used to access aggregated consumption data. There are no current examples of data being used to provide insights at the individual level. For example, metered gas consumption data is collected by

DESNZ from individual households (through Xoserve[4]) for the purpose of compiling subnational consumption statistics. In this instance, individual consent is not required from the householder, and data is presented in aggregate. Legal routes for accessing individual household consumption data under the basis of public task were not explored as part of this research. Further investigation is needed to understand the GDPR considerations.

Aggregated data sets could be used as a validation point to support the improvement of the existing SAP methodology (Section 5.5), though would have little benefit for the two approaches outlined in later sections of this report (improving the asset rating or calculating operational rating for individual EPCs). Our discussions with stakeholders indicate that the current focus of work is to enable access to aggregated smart meter data.

Matt James of the DCC explained that organisations seeking to access smart meter data via DCC must undertake a series of technical, security and administrative steps to on-board and integrate with the smart meter system.

Several policy initiatives, such as 'Data for Good' (Energy Systems Catapult, 2023) are making the case for improved, appropriate access to smart meter data for public benefit. An alternative access route to aggregated data is through the electrical Distribution Network Operators (DNOs). DNOs currently have access to anonymised half-hourly smart meter data, for the purpose of delivering an efficient network. By February 2024 DNOs will be obligated to report smart meter data as aggregated and anonymised open access data (interview with Matt James of the DCC). Phase 2 of the Smart Meter Energy Data: Public Interest Advisory Group Project is exploring how smart meter data collected by DNOs could be of value in delivering wider public policy objectives (Sustainability First & Centre for Sustainable Energy, 2021).

7.1.2 Properties without smart meters

For homes without smart meters there are sources of data for analogue (non-smart) meters. ElectraLink is responsible for operating the UK's central energy data transfer function. They have access to metered electricity data, including from analogue meters, every time the meter is settled[5]. ElectraLink estimates that 95% of UK households with analogue meters have at least annual electricity meter data available (interview with ElectraLink) which may be a useful source of energy consumption data for EPCs. Similar daa is collected for gas meters by Xoserve. However, infrequent meter readings from occupants can result in assumed energy use based on the suppliers' algorithms. This would not be an accurate measure of energy consumption.

Different strategies would be needed to collect non-smart metered data for the different approaches explored in Sections 9 and 10. The SmartHTC approach (see Section 9) developed by Build Test Solutions overcomes this by being able to also work with just an opening and closing meter reading over a set period. In such cases the meter readings could be read by an energy assessor or surveyor, or could be supplied manually by the

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[4] Xoserve is the Central Data Service Provider for Britain's gas market.
[5] Meters are 'settled' each time a meter reading is provided from the consumer.

householder. The latter could introduce a risk of incorrect readings, deliberately or not (Zuhaib et al., 2021).

Alternatively, an assessor could take the manual meter readings, though this would add additional cost. As a workaround for homes undertaking retrofit monitoring without smart meters, JG Architects fit additional monitors to capture live energy data over a set time period. The representative from JG Architects suggested it is more valuable to capture time series energy use data than static meter readings. Time series data provides more detail about how the property is performing.

The risk from incorrect readings depends on how the data is used; it is more serious if the data is used as the input data on an EPC with policy implications, but less concerning if the data only serves the purpose of providing an additional metric for householders to better understand their energy usage. Given the large number of properties in Scotland without smart meters, this should be given significant consideration.

7.1.3 Properties heated with unregulated (unmetered) fuels

The stakeholders agreed that properties heated with unregulated fuels (such as oil, coal, wood, and biofuels) pose the most difficult challenge. As noted by Richard Fitton, Professor of Building Performance, these properties are out of scope of the smart meter rollout and at risk of being excluded from new approaches to EPCs that use metered data. Lomas et al. (2019) state that their proposed Domestic Operation Rating method (Section 9) will not work for homes using these types of fuels.

Different solutions could be implemented depending on the specific approach but would be associated with significant uncertainty and be difficult to implement. Build Test Solutions suggested an overnight test that uses direct electric heaters[6]. This requires a property to be vacant for the 15-hour test period. It is also possible to add meters into LPG and oil supply feeds, which could be installed temporarily and then removed and reused. These are not generally fitted as standard. This does not overcome the issue of metering solid fuels.

Jon Stinson discussed that Building Research Solutions (BRS) has navigated this challenge by backtracking energy consumption from invoices, though noted that this is a time-consuming process. He also suggested a requirement for those using solid fuel to install some sort of heat meter (as with RHI, FIT and generation meters). This would still rely on some form of modelling and would also need an interface or programme through which people can submit their meter readings.

Alternatively, Richard Atkins, Chartered Architect, suggests instigating a requirement on coal and oil suppliers to keep a record and to provide this– though there would be no certainty of how the fuel is used in the property. Sam Mancey from DESNZ noted that for this data to be useful you would also need to know the length of time between refills to understand how long it takes to use a specific quantity.

[6] Examples of these tests include QUB and Veritherm.

Given the move toward ZDEH (Zero Direct Emissions Heating) systems, consideration should be given to whether it is proportionate to develop a system for assessing the metered energy consumption of properties using alternative fuels. An estimation based on an annual measure of fuel use may be more appropriate and proportionate (Lomas et al., 2019), although less accurate.

7.2 Dynamic EPCs

Most stakeholders supported proposals for dynamic EPCs. These will provide improved opportunities to utilise energy consumption data. Dynamic EPCs are live reports, and this will allow for some data inputs to be updated on a more regular basis than the required EPC timeline (currently 10 years but proposed to be 5 years). This could result in the inclusion of energy pricing or carbon emission factors.

Dynamic EPCs could also allow users to input their own contextual data (see 9.3) to tailor the reported consumption data to their own usage patterns. Stakeholders proposed a public EPC which contains building performance information, and a separate private element which allows users to input their occupancy data. A representative from Build Test Solutions suggested that if EPCs enabled householders to input their specific occupancy hours and set points, this would achieve an EPC much more closely aligned with actual consumption. This could overcome the challenges around collecting data on occupancy. Users can input this data if they would find the output useful, but otherwise a standard EPC for the building exists without the need for any occupancy data.

7.3 GDPR

Energy consumption data is considered as personal data under GDPR. GDPR is not a barrier to collecting and using energy consumption data for the purpose of EPCs, as exemplified by its use in Sweden and Germany. However, any process for collecting and processing energy consumption data will need to be GDPR compliant. Below are some of the key GDPR considerations for the use of metered energy consumption data at the individual household level.

7.3.1 Data ownership

Energy consumption data is owned by the person who consumed the energy (usually the energy bill payer). The stakeholders we consulted believed that householder consent would be required to access and use this data, and this was confirmed by the DCC. There was disagreement between the stakeholders we interviewed about the degree to which this poses a challenge for the use of energy consumption data.

The impact of GDPR on energy consumption data depends on how it is used and stored. For example, Build Test Solutions explained that they do not identify the individual or specific address associated with the energy consumption data they collect in order to calculate the heat transfer coefficient (Section 8), and they only hold location data at a partial postcode level. Kevin Gornall from DESNZ also noted that as part of the SMETER project (Section 8.1), there was a central database of metrics based on the metered data, but the metered data itself was not stored.

7.3.2 Data management

The stakeholders we interviewed agreed that the processing and management of personal energy data and consent poses a significant challenge. This is particularly true if live data is collected at scale, as mentioned in Section 7.2. The actors currently involved in energy consumption data management include energy utilities, DNOs, 'Other Users' (other registered users of the smart meter system), and the DCC.

Andrew Parkin at Elmhurst Energy highlighted the challenge of accessing energy consumption data which is decentralised and held by the energy utilities. Several stakeholders suggested that energy consumption data could be stored in a central repository. Householders could then have the option to consent to their energy data being used for different purposes. As indicated previously, work is being undertaken by DESNZ to explore the feasibility of this (Section 7.1.1).

Jon Stinson at Building Research Solutions pointed to the US Department of Energy (US DoE) as an example of how this could be done. He explained that the US DoE collates all energy data from utilities. Initially, this was done to enable academics to access these large data sets for research purposes. In this way, energy data is centralised, and there are fewer issues should the consumer change supplier or meters regularly.

7.3.3 Impact of tenancy type

There are also potential challenges associated with different tenancy types. Crawley et al. (2020) note that EPCs are often commissioned by a landlord, not the owner of the consumption data. In such cases the building owner would require the tenant to provide consent to access these data, adding a layer of complexity to the process.

8 Energy consumption data to improve the asset rating accuracy

Metered consumption data could be used to calculate a heat transfer coefficient (HTC), which is part of the calculation for EPC ratings. HTC is a common metric for the thermal performance of buildings. For the purposes of producing EPCs, HTC is predicted using SAP/RdSAP for domestic properties and SBEM for non-domestic properties. This is based on assumptions about the heat loss of various aspects of the building (walls, floor, roof, windows etc.) It is used as part of the calculations to estimate annual heating bills, CO_2 produced by the building, and the A-G asset rating (Fitton, 2020).

HTC can also be measured in-situ through a co-heating test. This is an intrusive and expensive test which measures the rate of heat loss over a certain period (usually one to three weeks) (Hollick, 2020) and must take place whilst the building is unoccupied.

Research is currently ongoing to investigate how metered energy consumption data could be used to calculate the HTC more accurately than the current predictions in RdSAP, and a more cost-effective way than the co-heating test.

Several stakeholders interviewed[7] discussed the potential for energy consumption data to be used to calculate the HTC of individual properties. All were of the view that calculating an HTC using energy consumption data is more accurate than the HTC values predicted by RdSAP. However, some stakeholders did question the usefulness of this to householders. For example, the representative from the Climate Change Committee (CCC) suggested that this would be useful for improving building standards, but the information is unlikely to be something that householders want or need.

8.1 Current research

Several approaches are currently being developed and tested. The Smart Meter Enabled Thermal Efficiency Ratings (SMETER) Innovation Programme has undertaken field trials to test nine SMETER technologies. The trials took place in a non-representative sample of 30 homes (BEIS 2022). The accuracy of each SMETER technology was evaluated by comparison with the measured HTC[8].

Build Test Solutions has developed the SmartHTC method, which is commercially available and has been applied to over 10,000 buildings at time of writing. . SmartHTC is a technology agnostic algorithm. It can either be delivered as an assessment service led by an assessor, or embedded into smart devices such as a smart meter IHD or a smart thermostat. The algorithm was used by the two best-performing HTC technologies in the SMETER research (BEIS, 2022). The IEA's Annex 71 is also investigating methods for measuring HTC, including through smart meter data (Fitton et al., 2021).

Common to all these approaches is the need for three key pieces of information; metered consumption data (provided by smart meters for gas and electricity), internal temperature data and external temperature data.

8.1.1 Internal temperature data

Internal temperature is critical to collect. Senave et al. (2019) demonstrate that estimated internal temperatures can lead to errors in the HTC of up to 26.9% compared to internal temperature data from one room in the home. Ideally indoor temperatures should be measured in two locations. The literature points to the increasing popularity of "on-board devices" (Fitton, 2020) such as smart heating controls as a valuable source of internal temperature data. However, this is not currently a viable option in the context of producing EPCs. The majority of homes do not have this technology, and it is unclear how this data could be collected centrally.

Newer models of smart meter in-home displays (IHD) also have the capacity to record temperature data. For example, Chameleon's IHD7 IHD which is already being deployed in the smart meter rollout. The UK Government is currently funding projects to explore

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[7] including a representative of Build Test Solutions, a representative of the Climate Change Committee, Sam Mancey and Kevin Gornall of the SMETER Implementation Team at DESNZ, Jon Stinson from Building Research Solutions, and Thomas Lefevre from Etude.

[8] Determined using the QUB test, which is an alternative to the co-heating test and can estimate the HTC within a day.

whether smart meter infrastructure can be used for more than just energy data (DESNZ, 2023b). As part of this, Matt James explained that the DCC is involved in an ongoing pilot to investigate whether temperature and humidity data can be transmitted through the system, alongside meter readings.

Research has also explored whether it is possible to use smart meter data to estimate thermal performance without the need for temperature data. Chambers and Oreszczyn (2019) only used smart meter data and used the building's location to make assumptions about local temperatures[9]. Three of the SMETER trials also did not use internal sensors and demonstrated that it is possible to generate an HTC figure without collecting internal temperature data. However, these SMETER technologies were found to generate less accurate HTCs than those which also measured internal temperatures.

An interim solution, suggested by Baker and Mould (2018), is that until in-home sensing equipment is mainstream, homeowners and landlords could be incentivised to record this data voluntarily for inclusion in domestic EPCs. For their SmartHTC method, if internal temperature data cannot be collected via existing devices such as smart thermostats, Build Test Solutions send several low-cost temperature sensors to householders to collect temperature data over a period of 3 weeks.

8.1.2 External temperature data

External temperature is a key factor influencing the amount of energy used in a building. Whilst some smart heating controls do have external temperature sensors (for weather compensation), most studies and trials to date have relied on data from nearby weather stations and online tools. Stakeholders we spoke to commented that, generally, external weather data is readily available, detailed, and reliable (Richard Fitton, Professor of Building Performance and Build Test Solutions).

8.2 Potential applications

As an input to EPC calculations

The HTC is not weighted or normalised in any way. It does not account for the size, shape or age of a building. In general, the HTC is higher for larger homes (Fitton, 2020), and therefore does not allow buildings to be compared. For this reason, the majority of stakeholders interviewed for this research felt that the HTC figure should not be presented on EPC certificates and instead should be used in the calculation of EPC metrics.

As a standalone figure on EPCs

In contrast to the above, the IEA Annex 71 report recommends that the raw HTC figure is reported on EPCs. The report authors compare the HTC to the miles per gallon (MPG) metric used for vehicles. The MPG metric is widely understood by consumers and is not normalised

[9] Note that this study calculated Heating Power Loss Coefficient (HPLC) rather than HTC. The difference is that HPLC incorporates thermal losses from the heating system as well as the building fabric.

for size (the cylinder capacity of the engine). Similarly, they propose the HTC value could become a recognised and well-understood metric. This would require householders to be provided with a bespoke annual heating degree day (HDD) figure, in the same way that motorists are usually aware of their annual mileage.

We did not find that this view was widely reflected amongst stakeholders that we interviewed, though David Allinson also used MPG as an analogy. He noted that when looking a purchasing a vehicle, we would not expect to know or predict exactly how much a particular vehicle would cost to run and that MPG is a useful metric to understand the relative fuel efficiency of a vehicle. He suggests that in the same way we should not look at an EPC and expect to know exactly how much a property will cost to run, though we could be using HTC figures in a more useful way. Richard Fitton suggested that if the HTC value is included on EPCs it should be normalised by floor space (m^2) to become the 'heat loss parameter' or better still by volume (m^3) to account for high ceilings.

The performance gap

The HTC can be used to identify where new buildings or retrofitted buildings are not performing in line with modelled predictions (Fitton, 2020). As outlined in Section 5, this is not uncommon.

In relation to new builds, Kevin Gornall from DESNZ suggested that one of the most promising applications for in-use HTC is to identify issues with building fabric. He suggested that if the modelled HTC derived through SAP is vastly different to the measured in-use HTC figure, then it may point to construction problems which needs to be addressed. This can prompt further investigation help to identify issues that would usually go unnoticed.

HTC readings can also be an effective tool for monitoring the impacts of retrofit. For example, Elmhurst suggests that their Measured Energy Performance (MEP) tool[10] is most effective as a tool for evaluating the impacts of retrofit projects. Calculating the HTC pre- and post-installation can provide a more accurate assessment of the impacts that retrofit measures have had on the thermal performance of the property. MEP can also be used as a part of meeting the PAS 2035 requirements for monitoring and evaluation (Elmhurst, 2021).

8.3 Challenges to this approach

As outlined in Section 7 there are a number of challenges around relying on smart meter data. Technologies to measure and transmit internal temperature data are also not widely available in most homes. Both interviewees from DESNZ, Jon Stinson from BRS and a representative from Build Test Solutions all discussed the use of a co-heating test as an alternative method for homes without smart meters. This is not a practical or cost-effective solution for generating EPCs at scale. Overnight HTC tests or temporary meters are likely to

[10] This tool uses four temperature and humidity monitors throughout the home to record internal data for a three-week period. Measured energy use during this period is also taken to calculate the HTC figure.

be the most practical solutions for homes with unmetered fuels. Additionally, the SmartHTC algorithm can be used with only opening and closing meter readings for non-smart meters.

A representative of Build Test Solutions stated that another challenge is accounting for electrical loads outside the building envelope such as electric cars, outdoor offices or hot tubs. Ideally, these should be metered separately.

Annex 71 (Fitton et al., 2021) highlights that the regulatory energy models in the UK do not allow for the HTC to be directly entered as a measured value. Multiple stakeholders confirmed that this is technically possible to overwrite the HTC value in SAP. Therefore, further investigation is required as to whether there are regulatory or practical barriers to doing this.

9 Energy consumption data for operational performance

Metered energy consumption data can be used to produce an operational rating which is more closely aligned with actual energy use and gives an indication of how a building is used. This type of metric will include the impact of occupant behaviour. The influence of occupant behaviour makes this approach less suitable for comparison between buildings. However, this can also be an advantage, especially when combined with a good benchmark. Comparison against a benchmark can be used to encourage both building energy performance and user behaviour change (Zuhaib et al., 2021).

The most straightforward use for metered energy consumption data is to include the value on an EPC alongside a reference figure. The reference figure could be historical energy consumption data for that property (Zuhaib et al., 2021). This would not allow for comparison against other buildings unless the data is normalised to account for factors such as size and occupancy.

9.1 Current examples

Display Energy Certificates

Display Energy Certificates (DEC) for public non-domestic buildings[11] are an example of an operational rating (section 10). Energy consumption is compared to a benchmark for similar types of buildings (Lomas et al., 2019).

Measured Energy Performance Indicator (MEPI)

The X-tendo project (Verheyen et al., 2019; Zuhaib et al., 2021) developed the Measured Energy Performance Indicator (MEPI) to be compatible with EPCs. It proposes that real energy consumption data is used to generate an ‘energy use indicator’ on EPCs. To enable comparison between buildings, this figure is weather-corrected and normalised for building

[11] Public buildings in England and Wales over 250 m^2 must have a DEC. In Scotland, public buildings are required to have an EPC rather than DEC.

size and primary energy factors[12]. This method relies on sub-metering to disaggregate consumption for heating and hot water. Sub-metering is not widely used in domestic buildings in Scotland.

This method has undergone testing in four European countries. This revealed that further corrections are needed to be able to make useful comparisons, for example the number of hours the heating system is used. The method contains an optional module to correct for indoor temperature.

EPCs in Sweden

A representative from Boverket explained that EPCs in Sweden are based on real energy consumption data, which is disaggregated by the energy assessor to only consider energy used for heating, cooling, domestic hot water, and fixed lighting, and then corrected to reflect typical use. This results in an operational rating than enables comparisons between buildings. A challenge of this approach is that it requires the energy assessor to make assumptions about a building's energy use, since disaggregated metered data rarely exists for each of the different energy uses.

Domestic Operational Rating (DOR)

Researchers from Loughborough University and De Montfort University have proposed and tested a DOR scheme for assessing the energy performance of occupied dwellings (Lomas et al., 2019). They propose this scheme as separate and complementary to existing SAP methodology, similar to DECs for non-domestic buildings.

The DOR uses metered energy consumption data alongside the existing survey data for a property collected for an EPC. For example, a key piece of information needed to normalise the energy consumption figure is total usable floor area (Lomas and Allinson, 2019). The proposed DOR scheme provides three operational ratings for energy demand (DORED), GHG emissions (DORGG) and energy costs (DOREC). These are intended to correspond with current metrics on an EPC. The energy cost metric is derived from the energy demand figure. It could be based either on a nationally standardised fuel cost (similar to SAP look-up tables) or on the actual fuel prices paid by each household.

The authors also explore the idea that a DOR certificate could be used to convey additional energy-related behaviour and advice to households. It could also have particular relevance for identifying homes in fuel poverty or residents that are under-heating their homes. Another key benefit of DOR is that it accounts for all energy used (regulated and unregulated).

David Allinson (Building Energy Research Group, University of Loughborough) suggests that moving towards DOR with normalised data to account for anomalies (e.g., a particularly cold

[12] The amount of primary energy used to generate a unit of electricity or a unit of useable thermal energy in a building.

winter), would allow people to compare with other people in the neighbourhood or the same property type.

9.2 Enabling comparison

9.2.1 Normalisation of data

Experts have proposed different methods which use different degrees of correction or normalisation. In its purest form, annual metered data could be included as-is. With no correction, this would result in a worse score during colder years where the heating requirements are higher. Conversely, recommendations for a new heating system based on a particularly mild winter where the heating demand of the property was lower than usual, or energy savings measured between non-typical years would be misleading.

There is consensus in the reviewed literature that a metric of this type should be normalised at least by floor area (Baker and Mould, 2018; Lomas et al., 2019). In France, EPCs for pre-1948 buildings were previously calculated based on an average of three years of metered data corrected by floor area (Crawley et al., 2020). However, this option was removed as part of recent EPC reforms due to issues related to buildings with irregular occupancy (Rosemont International, 2021; Thomson and Jenkins, 2023).

9.2.2 Weather-correction

The DOR uses weather-correction to enable the comparison of ratings between homes in different locations across the country. The metered daily gas and electricity consumption of homes is corrected based on the number of heating degree-days. An alternative to weather-correcting the energy demand data is to instead correct the benchmark that the energy is compared to (see below).

Corrections for standard user behaviour have also been proposed (Zuhaib et al., 2021). The latter is possible if occupancy profile data is available, but the authors note that this is hard to obtain.

9.2.3 Benchmarks

The DOR proposes that weather-corrected and normalised energy demand is compared against a benchmark of the average energy demand for the UK. Selecting an appropriate benchmark requires careful consideration (Lomas et al., 2019).

Jon Stinson of BRS also recommended inclusion of an average energy use figure across the previous three years, normalised with internal and external temperature data. He suggests that this could be a rolling figure, updated annually, linked to a dynamic EPC.

Non-domestic DECs use a building-specific benchmark corrected to account for the duration of occupancy and weather conditions. However, this approach is less appropriate for domestic buildings, since the proportion of energy that is used for space heating (and therefore should be weather corrected) varies significantly (Lomas et al., 2019).

9.3 Contextual occupancy data

If energy consumption data is provided on EPCs then some level of contextual data about the occupants is also required. For example, a potential tenant or buyer would need to know some details of the previous occupant(s) to understand the relevance of their energy usage.

Three stakeholders (from Build Test Solutions; Thomas Lefevre of Etude; Alan Beal of Bacra and Richard Fitton, Professor of Building Performance) were wary of using energy consumption data in isolation as it is difficult to account for all variables and to collect this data from occupants.

Several stakeholders (Kevin Gornall, DESNZ; Barbara Lantschner, JG architects; and a representative of the CCC) suggested that a small number of key questions regarding in-use occupancy information could be sufficient to generate an output which is accurate enough for the purposes of an EPC. Key information identified included:

- Occupancy (number of people in the household)
- Heating regime (hours of heating and preferred temperatures)
- Energy behaviours (information on unregulated energy use, e.g., large appliances)

Kevin Gornall from DESNZ suggested that in future there could be the option for occupants to answer several survey questions surrounding how they use energy in the home at the point of assessment. This information alongside internal temperatures and patterns of energy consumption could replace the occupancy assumptions used within SAP to generate more tailored outputs. His view was that the existing SAP model can generate accurate outputs providing that accurate information is fed in, and the key is to provide an open version of SAP where assumptions can be altered.

A similar exercise has been done with EPCs before, through the Green Deal Occupancy Assessment. This used standard EPC inputs and amended these with data from a series of additional questions. For example, standardised occupancy patterns were amended to reflect the household.

A representative of Build Test Solutions suggested that metered data could be used to achieve a more accurate baseline asset rating (see Section 8), with further occupational data added as a separate metric to achieve an output much more closely aligned with the total energy consumption.

As highlighted in Section 8.1.1, and by Jon Stinson of BRS, internal temperature data could be used to understand heating outcomes to contextualise the energy consumption data.

Alternatively, the DOR is designed so that it does not require any contextual data from occupants. Metered consumption data is normalised and compared to a national benchmark (Lomas et al., 2019). The authors note that not accounting for number of occupants may result in a poorer DOR for homes occupied by more people. They note privacy concerns over collecting this information, and the practicalities of defining occupant numbers, particularly in HMO properties (ibid.).

9.4 Presenting the data

An operational rating could be presented on an EPC alongside the asset rating. However, Lomas et al. (2019) suggest that the DOR is provided on a separate certificate. This would be similar to DECs for non-domestic buildings[13]. The move to dynamic EPCs will have implications for how an operational rating can be displayed (Section 7.2).

In contrast, Baker and Mould (2018) suggest that consumption data should replace the existing modelled SAP methodology rather than complement it, with all EPCs being based on an operational rating.

It is possible to use asset ratings and operational ratings to produce two different kinds of EPCs. This is the case in Germany, where EPCs can take the form of either a demand certificate, which provides an asset rating, or a consumption certificate, which provides an operational rating (Lomas et al., 2019). While the resulting energy certificates differ, they are both considered to be EPCs that fulfil the requirements of EPBD. It should be noted that in Germany, the operational rating based EPCs are only available for buildings with more than five flats, since including multiple households approximates normalisation for different occupant behaviours. This would not be possible in Scotland where EPCs are produced for individual dwellings rather than buildings.

9.5 Challenges to this approach

One challenge to developing an operational rating is determining whether and how much contextual data to collect from occupants. Additionally, Lomas et al. (2019) state that it is desirable for a DOR to disaggregate energy used for space heating, domestic hot water, and electrical energy use. Sub-metering is not widely used in domestic properties (see Section 6.3.1), so this will be challenging.

10 Non-domestic EPCs

The most obvious use for metered energy consumption data in non-domestic EPCs in Scotland is to extend the use of DECs. This was suggested as the best way to use metered consumption data for non-domestic buildings by Joshua Wakeling of Elmhurst Energy. The operational rating on a DEC is based on meter readings for 12 months of energy consumption and compared to a benchmark. The operational rating is a numerical indicator and is also illustrated on an A-G scale.

[13] Public buildings in England and Wales over 250 m^2 must have a DEC. In Scotland, public buildings are required to have an EPC rather than DEC.

Additionally, Joshua Wakeling (Elmhurst Energy) noted the need for more investment in improving the DEC methodology and to better understand occupancy assessment. The DEC methodology has not been updated for over 10 years (Elmhurst Energy, 2022).

The considerations around different types of energy use, as discussed in Section 7, are also relevant to non-domestic buildings. An analysis by Jones Lang LaSalle (2012) of 200 non-domestic buildings in the UK found little or no correlation between EPC ratings and actual energy performance. This significant performance gap has been attributed to a combination of uncertainty in the modelling, occupant behaviour, and poor operational practices (van Dronkelaar, 2015).

Jon Stinson of BRS has found that accessing metered data is more straightforward for non-domestic buildings than for domestic. Many occupants of non-domestic buildings will already have processes in place to collate energy consumption data, and larger buildings tend to have sub-metering arrangements as well as Building Energy Management Systems (BeMS). However, Joshua Wakeling of Elmhurst Energy noted that in England and Wales the deployment of DECs to private sector buildings has been hampered by a reluctance to share energy data.

Stakeholders discussed the use of metered energy consumption data for the purpose of an operational rating, but not for an asset rating. The comparison of HTC figures is not as important for non-domestic buildings as it is for domestic buildings. This is because building fabric has a comparably lower impact on heat loss than ventilation and air-conditioning systems (Jon Stinson, BRS).

11 Conclusions and recommendations

This report has explored two ways in which metered energy consumption data can be used in EPCs and the factors that need to be considered to enable this. Metered energy consumption data can provide more accurate information on building fabric performance (asset rating) and give an operational rating of how energy is used in a building.

A more accurate asset rating can be generated by using metered energy consumption data to calculate the HTC (heat transfer coefficient) in properties. Although various methods have been tested in recent years, they are not yet sufficiently developed for widespread roll out in EPCs. This approach requires collecting internal temperature data and is limited in properties without smart meters. Further work is required within the industry to enable the reliable collection of internal temperature data and consumption data across properties with different meters and fuel types.

Accurate HTC figures calculated using energy consumption data will also have value for informing retrofit decisions. This is currently being explored through projects such as Chameleon’s HTC-Up project. The use of energy consumption data in EPCs will provide a more realistic baseline asset rating on which to base recommended retrofit measures. However, the recommendations on an EPC would still be generated automatically by SAP.

Metered energy consumption data can be used to produce an operational rating to give an indication of how a building is used. A wide range of different approaches have been explored in the literature. The most straightforward use for metered energy consumption data is to include the value on an EPC alongside a reference figure. Another option is a DOR showing the energy consumption of a property, corrected by weather and floor area. This rating could be included as a part of the EPC or exist as separate document.

Using energy consumption to provide an operational rating has the challenge that different energy uses are not yet disaggregated. As a result, it can be difficult to determine what causes increases or decreases in energy consumption. Sub-metering has been suggested as a potential solution, though this technology is not commonplace in Scottish homes at present. The X-tendo project also proposes a method to achieve an operational rating but requires further normalisation of the data to account for different energy uses.

This operational rating could be included as part of existing EPCs or could be presented separately to provide additional information as to how efficiently energy is used in the home. Generation of an operational rating has the potential to be incorporated as part of dynamic, digital EPCs where data can be updated and adjusted without the need for a new EPC to be created. This format could enable occupancy-related data to be separate from the public asset rating.

Energy consumption data could be used in both or either of the two ways outlined above. EPCs should retain an asset metric (whether based on modelled or measured data) that is based on standard occupancy assumptions to allow comparison between properties regardless of who occupies them. This should not be replaced with an energy use metric, which contains occupancy variables that cannot be fully accounted for. Such a metric could be useful in addition to a standardised metric for comparison. It was suggested that metered data could be used to achieve a more accurate baseline asset rating, with further occupational data added as a separate metric to achieve an output much more closely aligned with the total energy consumption.

In both cases, consumer consent will be needed to collect and process metered energy consumption data and further consideration must be given as to how this can be facilitated.

11.1 Recommendations

This research has highlighted that further work is needed in this area to explore:

- The practicalities of collecting required data. This will include:
    - Metered energy consumption data at the individual building level, rather than from aggregated datasets. This will require a standardised process for collecting consumer consent. Currently, public sector bodies can obtain household-level data without the need for individual consent through the legal basis of public task'. However, this is for aggregated data and there are no current examples of data being used to provide insights at the individual household level. Further investigation is needed into the legal basis of public task for collection of

metered data for reporting at the household level. Legal routes for this were not explored as part of this research.

  - Processes for data collection, as these are mostly dependent on the rollout of smart meters. An alternative methodology will need to be developed for households using unregulated fuels, as their heating consumption will not be captured in smart meter data.
  - Additional information from occupants which can be used to contextualise energy consumption data when used for an operational rating. Examples of this kind of data include the number of occupants or typical heating regime. Further work is required to understand the minimum amount of contextual information to enable metered energy consumption data to be useful.
  - Internal temperature data for the purpose of calculating HTC as part of an asset rating. This would require the mass rollout of internal temperature sensors, which are already included in some IHD (in-home display) devices. Internal temperature data could also be useful contextual data for an operational rating.
- Different formats that could be used to display consumption data when used for an operational rating. This should consider whether consumption data would work best as one of multiple ratings within the EPC or separately.
- For energy-generating homes, how total energy consumption, generation, export, and cost can be displayed in a straight-forward manner.
- Whether there are regulatory or practical barriers to inputting the HTC as a measured value in SAP calculations for the asset rating.
- The value of Display Energy Certificates for non-domestic public buildings in England and Wales, and whether there would be value in expanding their use in Scotland.

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13 Appendix: Research methodology

13.1 Desk research

This report was informed by desk research in the form of a literature review of academic articles and grey literature such as reports, statements, policy literature, and consultations.

An initial literature search was carried out using the search terms listed in table 1. The list expanded throughout the research process as key terms and concepts were identified. Further sources were identified from relevant sources cited in included literature. Literature from the past five years was prioritised, though some older works also informed the research. Through the search, 51 relevant pieces of literature were identified.

Table 1 Search terms

List of search terms (non-exhaustive)	
Calculated (energy) use	EPC(s)
Measured (energy) use	Performance gap
Real/actual (energy) use	Building
Energy use/usage	Assessment
Consumption data	Heat transfer coefficient
Energy performance	Operational performance/rating
Smart meter(s)	GDPR

13.2 Stakeholder interviews

Fourteen interviews were carried out with stakeholders in Scotland, the UK, and Sweden. These were semi-structured, 30–45-minute interviews undertaken in July and August 2023.

Interviews were held with the following stakeholders:

- A representative from Boverket, the Swedish National Board of Housing, Building and Planning.
- Richard Fitton, Professor of Building Performance, University of Salford.
- A representative from the Climate Change Committee.
- David Allinson, Building Energy Research Group, School of Architecture, University of Loughborough.
- Richard Atkins, Chartered Architect.
- Jon Stinson, Managing and Technical Director, Building Research Solutions.
- Thomas Levefre, Managing Director, Etude.
- Alan Beal, Bacra.

- Barbara Lantschner, Building Performance Specialist, John Gilbert Architects.
- A representative from Build Test Solutions.
- Sam Mancey, SMETER Implementation Team, DESNZ.
- Kevin Gornall, SMETER Implementation Team, DESNZ.
- Andrew Parkin, Director of Technical Development, Elmhurst Energy
- Joshua Wakeling, Director of Operations, Elmhurst Energy.
- Matt James from the Data Communications Company.

13.3 Qualitative analysis

The literature and interviews were analysed in NVivo using inductive coding. This allowed key concept (e.g. performance gap) and categories (e.g. asset vs operational ratings) to emerge throughout the analysis process. Findings from the interviews and the evidence review were analysed using the same coding structure. This approach also facilitated the identification of research gaps.

ClimateXChange
Edinburgh Climate Change Institute
High School Yards
Edinburgh EH1 1LZ
+44 (0) 131 651 4783

info@climatexchange.org.uk
www.climatexchange.org.uk

If you require the report in an alternative format such as a Word document, please contact info@climatexchange.org.uk or 0131 651 4783.