climate change

Scotland's centre of expertise connecting climate change research and policy

Categorising emissions in non-domestic buildings

Hassan Waheed, Ben Sandles and Angela Rose, Turner & Townsend

June 2023

DOI: http://dx.doi.org/10.7488/era/3638

1 Executive summary

1.1 Aims

Scotland is committed to a 2045 net zero target. To meet this commitment, all of Scotland's 230,000 non-domestic buildings must reach net zero greenhouse gas emissions. Non-domestic buildings comprise a wide range of building types such as business premises, factories, public buildings (for example, libraries) and facilities (such as bus stations).

There are many challenges involved in decarbonising the sector, including limited information on how energy is used in non-domestic buildings, and considerable variation in what fuels are used and how they are used. Any guidance, support or regulation should be sensitive to the variety of needs across non-domestic buildings.

The aim of this research was to **identify and assess relevant options for a practical method to apportion measured direct emissions from heat use categories for the purposes of regulating direct emissions at a building level**. To assess this, we were interested in whether a proposed system would:

1. Be practical for a regulatory authority to gather and receive data
2. Enable building operators to collect and report data in a straightforward way
3. Provide a reliable and accurate representation of real activity
4. Be consistent in its outputs across variations in data sources and categorisation systems, should more than one be used
5. Allow effective and fair enforcement of regulations

The research involved a literature review and stakeholder engagement.

1.2 Findings

We found that multiple categorisation systems have already been developed for various purposes. These systems include:

1. Purpose-based (by this we mean that the ultimate purpose of the energy or heat consumption, such as providing hot water and heating)
2. Process-based (this term is defined as the form of heat or energy, such as high temperature process, low temperature process and drying)
3. Equipment type (defined by the equipment used for heat generation, such as combined heat and power unit, oil boiler and cooking stove)
4. Quantity of energy consumed (eg discrete intervals based on rated thermal input)
5. Fuel type (eg UK mains gas, fuel oil, coal)

We found that there are pros and cons to each system. The **first three systems** were designed to provide a high-level picture of energy use across a region's building stock rather than support enforcement of regulations. They are based on models that generalise fuel use from a small sample of buildings, and therefore do not provide a reliable picture of how much energy each individual building uses. **The latter two systems** are already used in existing regulation. However, these two systems are also limited by their simplicity.

We developed these findings through discussion with building operators in the public and private sector. Our research found that:

- Participants were apprehensive of additional regulatory burden. While they understand reaching net zero will require effort, they preferred simple and efficient reporting and compliance routes, such as automated and process-driven reporting.
- Participants universally backed using fuel type categorisation, for example, developing categories such as fuel oil, coal or mains gas. They described this as in line with almost all existing mandatory and voluntary reporting regimes, their financial and business reporting systems, and the preferred method of understanding, managing and reducing emissions. Categorisation by fuel type also lends itself to a higher degree of automation.
- Most participants did not consider it possible to accurately apportion data according to categorisation systems other than by fuel type. They were confused about other categorisation systems and were apprehensive about these approaches being used as the basis for regulation. They were critical of any system that would require the additional handling of resources without adding value to them.

1.3 Conclusions

We found that a **categorisation system based on fuel type would provide a practical and feasible foundation for developing and implementing decarbonisation regulations that are enforceable at an individual building level**. Systems of this type are already in use by regulatory authorities, voluntary reporting standards, and building and estate operators. However, it is unclear if a categorisation based on fuel type alone can provide sufficient information to identify decarbonisation pathways for individual buildings. This is because fuel type does not provide an indication of the type and energy intensity of activity (eg mains gas may be used for a gas boiler providing hot water and space heating, but it could also be used in a blast furnace, which may be harder to decarbonise).

1.4. Next steps

Based on our research, we suggest the following next steps:

- Detailed investigation of the options for using a categorisation system based on fuel-type for the regulation of direct emissions within non-domestic buildings
- Detailed investigation of the options for automating the reporting of fuel consumption within non-domestic buildings in Scotland.

Contents

2 Glossary / Abbreviations table

BEES	Building Energy Efficiency Survey
BEIS	Department for Business, Energy and Industrial Strategy
BMS	Building Management System
BRIA	Business and Regulatory Impact Assessment
CBECS	Commercial Buildings Energy Consumption Survey
CEUS	(California) Commercial End-Use Survey
DESNZ	Department for Energy Security and Net Zero
DUKES	Digest of UK Energy Statistics
ECUK	Energy Consumption in the UK
EPC	Energy Performance Certificate
ESOS	Energy Saving Opportunity Scheme
EU	European Union
GHG	Greenhouse gas
GHGP	Greenhouse Gas Protocol
HVAC	Heating, Ventilation and Air Conditioning
HVO	Hydrotreated Vegetable Oil
HiBS	Heat in Buildings Strategy
ISO	International Organization for Standardization
MEES	Minimum Energy Efficiency Standards
ND-NEED	Non-Domestic National Energy Efficiency Data-Framework
SECR	Streamlined Energy and Carbon Reporting
SEPA	Scottish Environment Protection Agency
SIC	Standard Industrial Classification

SPSEBT	Scottish Public Sector Energy Benchmarking Tool
SSN	Sustainable Scotland Network
UKAS	United Kingdom Accreditation Service
UK ETS	United Kingdom Emissions Trading Scheme

3 Introduction

3.1 Context

Scotland has approximately 230,000 non-domestic buildings which account for 7% of national greenhouse gas (GHG) emissions (The Scottish Government, 2021a). As part of its commitment to the 2045 net zero target, the Scottish Government has set out an ambition to decarbonise Scotland's non-domestic building stock in its Heat in Buildings Strategy (The Scottish Government, 2022).

Non-domestic buildings in Scotland are currently defined as those buildings listed on the Business Rates Valuation Roll (Scottish Assessors, 2023). Existing regulations which act on direct emissions from non-domestic buildings include the UK Emissions Trading Scheme (The UK Government, 2020).

3.2 The need for this research

The Scottish Government recognises that there is limited information on energy use within individual non-domestic buildings (discussed in section 5). Stationary combustion is the principal source of scope 1 direct greenhouse gas emissions from non-domestic buildings. This research project examines combustion-fuel uses within the curtilage of non-domestic buildings. This research has not examined the direct emissions from sites which are currently within the scope of the UK Emissions Trading Scheme (UK ETS).

There is a concern that a definition of heat in non-domestic buildings which is limited to space heating is not appropriate or sufficient to describe the diversity of activities in non-domestic buildings. However, different uses of the heat resulting from combustion can have varying decarbonisation pathways. The Scottish Government is seeking to develop a better understanding of how combustion-fuels are used in non-domestic buildings and this research is intended to lay the foundations for how this should be achieved.

3.3 Project aim and research questions

The aim of this research is to identify a categorisation system or systems which could be used to apportion greenhouse gas emissions resulting from heat use into separate uses within individual non-domestic buildings. The research questions were:

1. What category systems are available to distinguish separate combustion-fuel uses within non-domestic buildings?
2. What are the advantages and disadvantages of each categorisation system?

A categorisation system would comprise a set of categories among which a building's combustion-fuel use would be attributed. This would allow emissions from the combustion-fuel use to be apportioned to these categories which, in turn, could be used to regulate non-domestic buildings for the purpose of decarbonisation. We discussed the qualities required of categorisation systems for the enforcement of regulations with the Scottish Government at the outset of this project (Table 1).

Qualities required	Criteria for each quality
Practical to regulate	Will it be practical for a regulatory authority to gather/receive data and regulate activities using this approach?
Practical for building operator	Will it be practical for building operators of all sizes and types to collect and report data using this approach?
Reliability and accuracy	Will this approach provide a reliable and accurate representation of real activity? And how should that accuracy be defined?
Consistency of outputs	Will this approach allow for consistent outputs across variations in data sources and categorisation system?
Verification and enforcement	Can the reported data be verified and can the categorisation system allow a regulatory authority to effectively, fairly and uniformly enforce regulation?

Table 1: This lists the five qualities to consider when assessing possible categorisation systems.

3.4 Defining emissions from non-domestic buildings

The decarbonisation of buildings referred to in the Scottish Government's Heat in Building Strategy (The Scottish Government, 2022) requires the reduction of stationary combustion emissions (a subset of scope 1 emissions) from individual buildings.

The focus of the Heat in Buildings Strategy is on energy demand for space and water heating since these two end-uses generate a majority of direct emissions from domestic buildings. However, in non-domestic buildings, end-uses of heat produced by combustion can be more varied. This can include end-uses such as food processing, drying, electrical generation, cooling, and refrigeration cycle operation, in addition to heating of internal space for comfort or heating of water. All of these end-uses of heat are included within the energy use of Scotland's service sector, which includes all activity not counted as domestic, agricultural or industrial. This service sector definition is used by the Scottish Government to allocate non-electrical heat consumption and GHG emissions to non-domestic buildings within Scotland's energy statistics and Scotland's Climate Change Plan.

The energy required for various heavy end-uses can also be supplied from electrical or district-heating sources, neither of these sources would be considered as scope 1 or direct emissions from the buildings supplied.

We included the term **heat use** as part of the evidence search to incorporate the widest set of options for our analysis. However, studies which examine heat use consider both electrical and non-electrical energy use together, and typically do not make the distinction between direct and indirect emissions. This research was limited to only scope 1 stationary combustion emissions. This introduces ambiguity as heat use is not limited to scope 1 stationary combustion, but instead used in a much broader sense which also includes electrical energy.

For the purpose of the qualitative survey, the term **combustion-fuel use** was agreed upon following discussion with representatives of the Scottish Government. This term removed ambiguity by clearly excluding electrical energy and allowed the discussion with interview participants to focus on scope 1 direct emissions from their buildings. Thereafter, the use of combustion-fuel use was continued to avoid this ambiguity, including in this report, as it is a more accurate representation of the scope of this research.

Various terms are used in the sector to define the use of energy in non-domestic buildings (see section 5). For clarity, all of these are defined in Table 2.

Terms	Definition
Direct emissions / Scope 1 emissions	Scope 1 emissions, also known as direct emissions, are from sources owned or controlled by the building operator. For example, this could include a furnace, boiler, or any other sources which results in direct release of greenhouse gas emissions (Greenhouse Gas Protocol, 2015).
Stationary combustion	This is a subset within scope 1/direct emissions which includes emissions from stationary sources, such as furnaces, boilers and turbines, used to generate electricity, heat or steam (Greenhouse Gas Protocol, 2015).
Combustion-fuel	Any fuel which produces useable energy when combusted and (for our context) which results in direct/scope 1 greenhouse gas emissions.
Combustion-fuel use	Any purpose or use of combustion-fuel within a non-domestic building (for our context) as part of a stationary combustion process.
Heat use	This means any use of heat, whether it is from an electrical source or non-electrical source (i.e. combustion-fuels). We avoid the use of this term to exclude consideration for electricity, which is out of the scope of this research. We also avoid this term since it could be interpreted by some to exclude the use of combustion-fuel for cooling and electricity generation purposes (e.g. in generators), which is in scope of this research. Instead ‘combustion-fuel use’ is the preferred term. However, we do use ‘heat use’ when discussing categorisation systems as part of the evidence review since many sources combine electrical and non-electrical sources into overall uses of heat.

Table 2: A definition of the key terms used in this report

4 Methodology

This section provides an abridged version of the research method. A more detailed methodology is available in the appendix (section 9).

A steering group was established to support the delivery of the project, and consisted of representatives from the Scottish Government, ClimateXChange, and the Turner & Townsend research team. At the project kick-off, the group confirmed objectives, project plan, and methodology. Throughout the project, findings and outcomes were reported to the steering group for comments and to confirm the research direction. The project was divided into two tasks.

4.1 Evidence review

Task 1 began with a developmental review, a technique which helps develop innovative ideas that are grounded in previous research (Templier & Pare, 2015). The developmental review was well-suited to this research as it goes beyond simply synthesising prior studies; its novelty lies within proposal of new ideas and an output that can solve an extant problem, and thereafter be generalisable throughout the domain of applicability.

Since the Scottish non-domestic building data inventory has limited information on the end use of combustion-fuels within individual buildings, we began the review with an investigation of all existing evidence. This allowed us to consider all possible options used or proposed for Scotland, the UK, across the EU, and globally[1]. It involved searching for:

- existing **building categorisation systems** to help understand the types of buildings, organisations and activities combustion-fuel is used for (section 5.3)
- existing **combustion-fuel use categorisation systems** to establish how and why combustion-fuels are used (section 5.4)
- **consumption data sources** and collection methods which could be used to capture real consumption data from individual non-domestic buildings (section 5.5)
- **apportioning data sources** and collection methods which could help apportion each building's consumption into the relevant categories (section 5.6)

Thereafter, we identified categorisation systems and associated data sources which could be considered. The five qualities discussed with the Scottish Government (Table 1) were used to analyse proposed categorisation systems. The outputs of the review were used to conduct a workshop and discussions with Scottish Government stakeholders representing various segments of the non-domestic buildings sector. Their input helped finalised the key categorisation systems and data sources to test in the subsequent qualitative research.

[1] As discussed in section 3 we used all the various possible terms including 'heat use,' 'fuel use' and 'energy use' in our evidence search to include the widest possible set of options.

4.2 Qualitative research

For **Task 2** we conducted interviews with several building operators to gain insights on the feasibility and practicality of these categorisation systems. Non-probability purposive sampling (otherwise known as ‘selective sampling’) was used as it allows us to select a sample of participants which can cover a range of business types and combustion-fuel use cases. The aim of the qualitative research was to recruit participants from various sectors who had a good understanding of combustion-fuel use in their facilities. A set of organisations were agreed with the Scottish Government to guide the recruitment; this included 11 participants in total, representing eight organisations: a financial institute; a university; two local authorities (containing schools, care homes, offices, and culture & leisure buildings); manufacturing and technology; multi-use campuses with offices, restaurants, and cafés; two swimming pools (one modernised, one significantly older). The sample of organisation type sought to cover complex and multi-use cases of combustion-fuels across multi-faceted estates.

We recruited directors of estates and heads of service from these eight organisations. The interviews provided illustrative rather than representative views, given the early-stage exploratory nature of the research. Due to the limited scope of the research, we did not recruit a representative sample of Scottish building operators.

A topic guide was developed in collaboration with the Scottish Government. We conducted 45-minute semi-structured interviews via online calls. These aimed to collect the comprehensive views on the categorisation systems and methods of data collection, including practicability (considering cost and time), usefulness to the building operator, the ability to integrate with existing data collection and or equipment, barriers and other open-ended questions that encouraged participants to expand further on topics they deemed relevant.

Framework Analysis (Hackett & Strickland, 2018), a dynamic qualitative analysis technique geared toward producing actionable policy outcomes with high quality standards, was used to analyse data. This involved allowing themes to emerge from the data to guide our analysis. This analysis is presented in section 6.

We combined the data from all sources (the review, workshops and discussions with Scottish Government representatives, and the qualitative research) into this report. The conclusion of this report draws on this data to discuss the key challenges and the possible approaches to a categorisation system which can be used to structure and enforce regulation. The conclusion is presented in section 7.

5 Review of existing evidence

5.1 Overview

The goal of this review was to propose new ideas and outputs (i.e. potential **heat use categorisation systems**) that could be used by a regulatory body. We began by identifying and organising all categorisation systems currently used for this and related purposes. Whilst a range of sources included methods for achieving this categorisation, they were not designed with the goal of regulating emissions. Rather, the primary focus of these methods was to improve the understanding of how energy use should be interpreted at a national level for policymaking and research purposes, instead of understanding how energy is used at the individual building level. The focus of these studies was typically on total energy use (including electricity consumption) rather than direct emissions. These issues raised various obstacles which would need to be overcome by a categorisation system. This is further discussed in section 5.4.

Most of the studies' methods for collecting fuel[2] **consumption data** for each category were geared towards a single large-scale and research-intensive data collection exercise, rather than continuous measurements. Studies typically collected this data as a one-off exercise on a sample of buildings. It took significant time and resources (in some cases years) to collect this data. This data from a limited sample then drove extrapolations in models which covered the whole building stock. Most studies used either surveys or interviews to collect information on fuel consumption and behaviour. This was accompanied by quantitative data collection such as temporary submeters to directly measure fuel consumption. Overall, these methods present issues around scalability as well as concerns around their ability to accurately represent heat use for each building using real data. They highlighted that data sources are as critical as the categorisation systems these would feed. This is further discussed in section 5.5.

It was apparent that consumption data by itself is not sufficient to enable a categorisation system to work. In many instances, consumption data cannot be sorted into the appropriate categories without another data source to apportion the correct volume or mass of fuel into each category. This fuel **apportioning data** was collected and extrapolated in various ways across the studies. Within these studies, apportioning data was gathered for the same purpose as consumption data. Thus, these data sources are not suited for scaling or reliable at apportioning data to individual buildings. This is further discussed in section 5.6.

The review also highlighted that heat use categories are not the only way in which energy in non-domestic buildings is analysed. Sources also used a variety of **building categorisation systems**. The categorisation systems and their individual categories were defined based on the study aims and the data sources utilised by the studies. For example, some categorisation systems used the scale or type of buildings to understand how, where and

[2] This included electricity in various studies thus is described as "fuel" and not "combustion-fuel" at times in this paragraph.

why energy is used. Although distinct from heat use categorisation systems, building categorisation systems might also be considered (further discussed in section 5.3).

The review established that heat use categories were rarely used with the intention of describing the performance of each individual building. However the review identified characteristics of categorisation systems which could be developed for the purposes of regulation.

5.2 Categorisation framework

The evidence review led us to identify two groups of categorisation systems and two groups of data sources.

The two categorisation systems are:

- Building – examples include:
    - Primary activity e.g. retail, office
    - Standard Industrial Classification (SIC) codes
    - Floor area
    - EPC ratings
- Heat use – examples include:
    - Purpose-based e.g. hot water, space heating
    - Process-based e.g. high temperature process, drying
    - Fuel type e.g. UK mains gas, fuel oil, coal

The two groups of data sources are:

- Apportioning – examples include:
    - Metering e.g. submeters
    - Self-reported e.g. verified or unverified declaration
    - Supplementary data during assessments e.g. EPCs
    - Benchmarks or model
- Consumption – examples include:
    - Self-reported e.g. estimated or measure to use
    - Invoices e.g. utility bill, fuel purchase receipts
    - Metering e.g. smart meter links or utility company data

This information is also summarised in the image below (Figure 1).

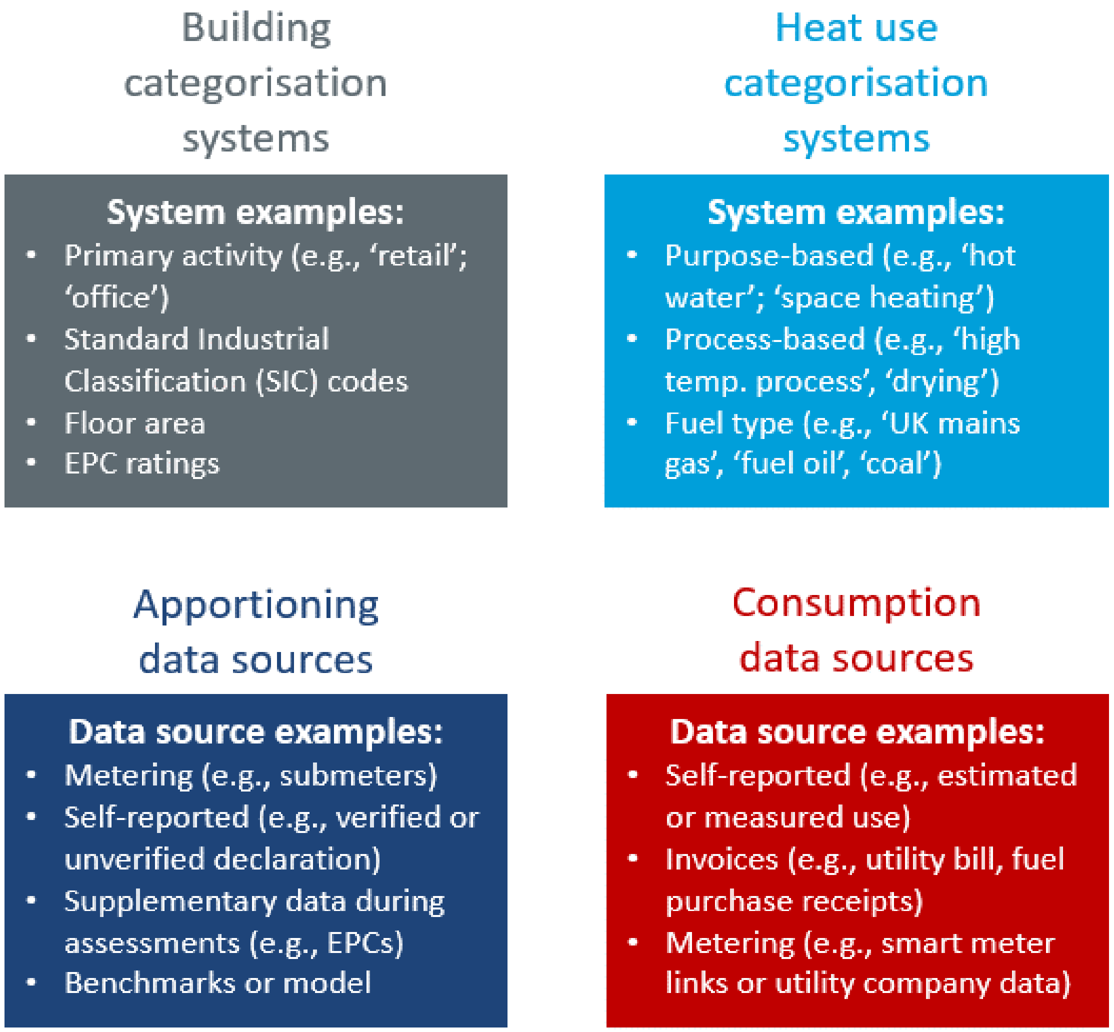

Figure 1: This figure summarises the four components of the framework and provides examples of each. Top row: the two categorisation systems, each with examples of system options and further examples of individual categories within the respective system. Bottom row: the two data sources, each with options of how this data could be collected and further examples of individual data sources.

We organised these into the following framework which demonstrates how these characteristics could function within a regulatory framework based on real-world consumption (Figure 2).

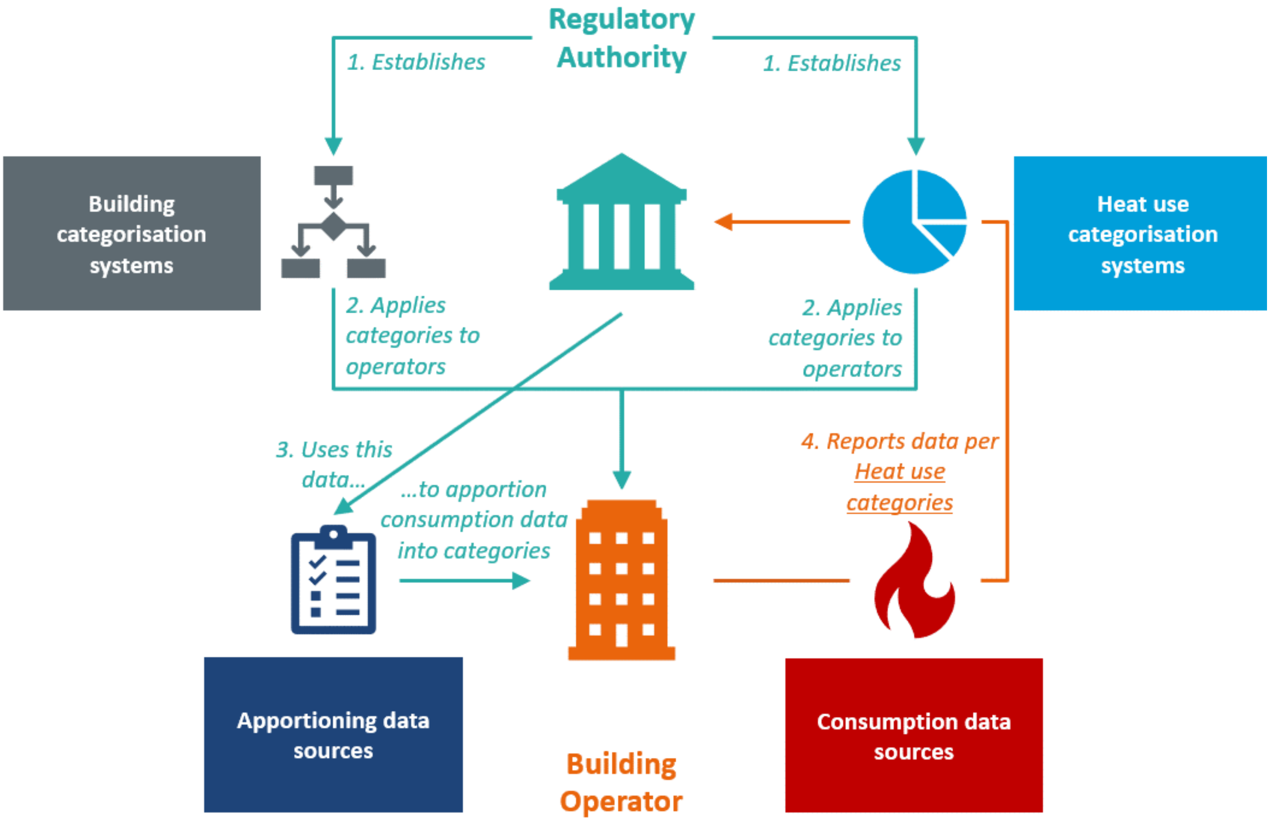

Figure 2: This framework displays the two types of categorisation systems (top) as well as the two types of data collection sources (bottom). The teal lines represent actions of the regulatory authority, whereas the orange line represents the actions of the regulated building operator. The numbers provide an overview of the process laid out in the following sections.

This framework allowed us to understand, communicate, develop, and assess the various options against the five qualities (section 3.3) in a systematic way.

It is important to note that these four components are not mutually exclusive. In fact, multiple sources used a combination of approaches. For example, many studies used multiple data sources across different building operators and even the same building operator to arrive at the overall energy consumption.

The following four sections detail each component of the framework and the various approaches examined in the review.

5.3 Building categorisation systems

5.3.1. Overview

It is critical to recognise that non-domestic buildings are significantly more diverse than domestic buildings as they vary considerably in size and nature of activity. For example, a large commercial office building with a centralised heating system will most likely have different requirements compared to a small retail shop. Categorising buildings by size and/or activity may help breakdown and organise them into more manageable subsets.

Building categorisation systems can be viewed as tools to enhance analysis in addition to heat use categorisation systems.

We did not identify a standardised building categorisation system used to understand heat use across all studies. Building categorisation systems are selected depending on the purpose of each study and can be used in combination to develop a more granular approach. The systems identified from the review are summarised in Table 3.

System name	System type	Category examples
Primary economic activity	Building use	'Retail' and 'office'
Business classifications	Building use	Standard Industrial Classification (SIC) codes
Floor area	Building characteristics	Gross internal area brackets
Building value	Building characteristics	Property value brackets
Building owner revenue	Building characteristics	Revenue brackets
Total energy use	Building characteristics	kWh consumption brackets
EPC	Building performance	EPC ratings
Energy intensity metrics based on building metrics	Building performance	Energy use per floor area,

Table 3: This table presents the various building categorisation systems relevant to this research along with a classification of 'system type' to recognise closely linked systems. Examples of specific categories are also given, though it should be noted that these are illustrative only and there may be other ways in which individual categories are formed.

5.3.2. Review of building categorisation systems

The following list explores the main sources for this summary and the high-level approach taken by each:

- The **Building Energy Efficiency Survey (BEES)** reports on the non-domestic building stock in England and Wales and splits the stock into 10 sectors, which in turn are made up of 38 sub-sectors (BEIS, 2016, p. 10).
- **Energy Consumption in the UK (ECUK)** (DESNZ, BEIS, 2022a), which provides information on overall energy consumption in the UK, sources its 9 service building categories and 10 industry building categories from the Digest of UK Energy Statistics (DUKES), which in turn classifies consumers of energy "*according to their main business, as far as practicable*" using UK Standard Classification codes (UK SIC) (BEIS, 2022). UK SIC codes are five-digit codes used to describe activities undertaken by a business; there are currently over 600 individual codes.
- The **Non-Domestic National Energy Efficiency Data-Framework (ND-NEED)** 2022 summarises energy consumption in England and Wales and uses 10 building-use categories chosen to align "*as far as possible with the categories used in ECUK and BEES*" (Department for Business, Energy & Industrial Strategy, 2022, p. 22).
- The **California Commercial End-Use Survey (CEUS)** categorises buildings into 12 categories, but also acknowledges that it would be "*easy*" to develop a finer

resolution of building types (California Energy Commission, 2006, p. 16). The study further separates these building categories into small, medium and large, based on total energy use, with different thresholds implemented across building types. This demonstrates a combination of multiple categorisation systems to develop a more granular approach.

- The 2018 **Commercial Buildings Energy Consumption Survey (CBECS)**, which provides national-level data on the characteristics and energy use of commercial buildings in the US, designed their building categories to "*group buildings that have similar patterns of energy consumption*" (U.S. Energy Information Administration, 2021, p. 11).
- **New York City's Local Law 97** aims to reduce emissions from the city's largest buildings and categorises (and regulates) these based on 18 broad categories with over 80 sub-categories (City of New York, 2022), taken from ENERGY STAR Portfolio Manager property types – a government-backed energy efficiency and certification scheme.
- The **Non-Domestic Energy Efficiency Baseline** provides an estimate of the baseline energy efficiency performance of Scotland's non-domestic buildings and categorises building types into 10 categories (Scottish Government, 2018). These categories are taken from Energy Performance Certificates (EPC) in Scotland, which in turn are based on The Town and Country Planning (Use Classes) Order 1987, a statutory instrument relating to planning permissions in England and Wales.

The most common way to implement building categories is by primary economic activity. On average, 10-12 common building categories were identified in each of the above sources. Whilst some proposed categories (such as 'Retail') are consistent between sources, some are unique to just one source (such as 'Emergency Services'). The most common categories which aligned across multiple sources are:

- 'Retail'
- 'Office'
- 'Storage or Warehouse'
- 'Hotels'
- 'Health(care)'.

Other categories closely aligned across sources included:

- 'Hospitality,' 'Restaurants' and 'Restaurants & Cafés & Takeaways'
- 'Education' and 'Schools'
- 'Industrial' and 'Factory'.

Categories that appear less frequently include 'Emergency Services'; 'Military'; and 'Physical Exercise'.

5.3.3. Summary

Categorisation by building use was the most common method. Most sources did not explore categorisation by building characteristics or building performance; while some studies, such as CEUS, used these but only to help develop a representative sample. Most studies did not carry building characteristics or building performance systems through to their overall analysis.

The above examples are not exhaustive, and many more building categorisation systems exist, such as Standard Industry Classification codes referenced in Table 3, though these fell outside of the scope of this research as they are not explicitly linked to energy use. No single categorisation system for non-domestic buildings is used as a standard, even within governmental bodies of the same nation. Rather, building categorisation systems are developed to fit a specific purpose; and they can be based on existing systems or built from the ground up.

There was no evidence that building categorisations by themselves could provide a reliable understanding of which combustion-fuels are being used, how much, how and why. While they can help break down the stock into manageable categories, and as such may have clues as to the type of activities using heat that might take place in a building, they cannot currently be relied on as descriptors of the heat use in and of themselves. Further investigation could be used to understand how these systems are linked to energy use in buildings.

5.4 Heat use categorisation systems

5.4.1. Overview

Heat use categories are central to the research question as these determine how combustion activities are defined and regulated. Our approach to analysing these categorisation systems included reference to decarbonisation pathways. Such categorisation systems are summarised in Table 4 and their use in each source is discussed in detail thereafter.

System name	System type	Category examples
Purpose-based	Activity type	‘Hot water’, ‘space heating,’ ‘catering’
Process-based	Activity type	‘High temperature process,’ ‘low temperature process,’ ‘drying’
Equipment type	Equipment or asset-based	‘Process equipment,’ ‘cooking equipment’
Quantity of energy consumed	Equipment or asset-based	Brackets based on total thermal input of combustion units
Fuel type	Fuel type	‘UK mains gas,’ ‘fuel oil,’ ‘coal’

Table 4: This table presents the various combustion-fuel use categorisation systems with a classification of 'system type' to recognise closely linked systems. Examples of specific categories are also given, though it should be noted that these are illustrative only and there may be other categories and ways in which individual categories might be formed.

5.4.2. Review of heat use categorisation systems

ISO 12655 provides a "set of clear definitions, terms and procedures for presenting the energy use in buildings in a consistent and uniform way, including … Classifications of building energy use by purpose (e.g. energy for space heating, energy for cooking, energy for lighting)" (International Organization for Standardization, 2013). The standard identifies 12 purpose-based uses of energy in buildings, five of which relate to combustion-fuel use resulting in direct emissions; 'space heating', 'space cooling', 'domestic hot water', 'cooking', and 'other specific functional devices'.

The 2014-15 **Building Energy Efficiency Survey (BEES)** (BEIS, 2016) identifies 23 end uses and combines them into 10 categories, "informed by" ISO 12655. Categories relevant to combustion-fuel uses are: 'heating', 'hot water', 'cooling and humification', 'catering', and 'other'**.** Of the 23 end uses, it identifies five that use non-electrical energy: 'space heating', 'hot water', 'medical equipment', 'catering', 'pool/leisure'. BEES does not include an 'other' category in its list of end uses to capture industry processes as industry was excluded from the scope of the study. The inclusion of pool/leisure as a separate category is notable and was defined by "all energy use associated with pool and sport leisure facilities within the premises. This should include heating, lighting, pumps, ventilation, humidification, and dedicated controls, alarms etc." Similarly, the inclusion of 'medical equipment' as its own category within non-electrical energy use is potentially significant, given that the reported total non-electrical energy consumption of medical equipment was greater than the electrical energy consumption (of medical equipment) in 2014-15 (1,960GWh vs 1,440GWh) (BEIS, 2016). However, it is not clarified by BEIS whether this non-electrical energy consumption is due to combustion-fuels or not.

The **California Commercial End-Use Survey (CEUS)** assessed energy use across 12 different types of 'Commercial Buildings' and established 13 distinct end uses of energy (California Energy Commission, 2006). Most sources reviewed define each end use with a short description, whereas CEUS – to avoid ambiguity and ensure accuracy in their results – included detailed specifications on what type of equipment an end use encompassed. For example, ovens and kilns used in an industrial setting such as a factory would be mapped to 'Process Equipment', but in a restaurant, it would be mapped to the 'Cooking' end use. This extensive study took several years to complete and whilst now quite dated, a new iteration looking at data from 2018-2022 is to be released sometime in 2023.

Many of the sources reviewed align on five core end use categories (California Energy Commission, 2006) (CIBSE, 2019) (DESNZ, BEIS, 2022b) (Building Research Association of New Zealand, 2014) (U.S. Energy Information Administration, 2018):

1. (space) heating
2. (space) cooling
3. (domestic) hot water
4. catering/cooking
5. an additional catch-all category including 'miscellaneous' and 'other'

The **Energy Consumption in the UK report (ECUK)** takes a slightly different approach. It looks at energy consumption by four sectors (Services, Industry, Domestic, and Transport) and uses data from a collection known as the Digest of UK Energy Statistics (DUKES) (DESNZ, BEIS, 2022a) (BEIS, 2022). It categorises end uses across all these sectors by space heating, water, cooking/catering, lighting/appliances, process use, motors/drivers, drying/separation, other non-transport. However, it also considers end uses by each sector, in which case the end use categorisations are adapted to the sector. The two sectors associated with non-domestic buildings have the following categories:

- Service sector end uses – space heating, water heating, cooking/catering, cooling & ventilation, other
- Industry sector end uses – space heating, high temperature process, low temperature process, drying/separation, other.

The **UK ETS** is based on regulating greenhouse gas emissions from 28 categories, which uses a combination of systems including quantity of energy consumed and purpose-based activities. For example, it covers combustion units above 20 megawatts capacity (regardless of what the activity is), activities such as production of coke (regardless of the size of combustion units), as well as combinations of activity and size such as paper manufacturing capacity exceeding 20 tonnes per day. Emissions can be monitored using two calculation methodologies. First, the operator can use a calculation-based methodology which determines emissions based on activity data (i.e. amount of combustion-fuels or materials consumed in relation to the relevant activity) used in combination with an appropriate emission factor (DESNZ, BEIS, 2021). Second, the operator may use a measurement-based methodology whereby the concentration of the relevant greenhouse gas is monitored consistently from the flue gas. UK ETS calculation methodology and accounting principles are closely aligned to the **Greenhouse Gas Protocol (GHGP)**, which in turn encourages the use of fuel type as a central categorisation system (EUR Lex, 2018).

The **Climate Change (Duties of Public Bodies: Reporting Requirements) (Scotland) Order 2015** requires all Scottish public bodies (including local authorities, NHS, educational institutions, emergency services, central government, and many others) to report on their greenhouse gas emissions as well as fuel[3] use (The UK Government, 2015). This Order directly references the GHGP as the emissions accounting methodology and mandates scope 1 and 2 fuel use and emissions reporting (scope 3 is encouraged but optional). The scope 1 sub-category ‘stationary combustion’ is closely aligned to the intended coverage of this research; and as discussed in relation to UK ETS this requires data to be collected according to fuel use categories or via direct measurement of flue gases. While fuel use data is aggregated and reported at an organisational level for the GHGP, it nevertheless requires data to be collected from the specific source of emissions, which might be as granular as a single combustion unit or a building.

Streamlined Energy and Carbon Reporting (SECR) (BEIS, 2022) and **Energy Savings Opportunity Scheme (ESOS)** (DESNZ, Environment Agency and BEIS, 2014) oblige

[3] We use “fuel” and not “combustion-fuel” at times in this section as the regulations also cover electricity use.

organisations above a certain threshold to report their energy use (and also the associated greenhouse gas emissions in the case of SECR). These reporting requirements rely on the fuel type categorisation system albeit on the organisational level and not an individual building level. However, to report to these requirements organisations almost always need to collect fuel consumption data by fuel type at the building level before aggregating that for reporting. For organisations with more sizeable estates or appetite for advanced reporting, **ISO 50001** and GHGP are used as allowable substitutes or to support enhanced ESOS and SECR reporting.

5.4.3. Summary

Heat use categorisation systems vary depending on the research or policy need. Multiple systems are sometimes combined to provide a richer understanding of energy use, such as in CEUS. However, each categorisation system also provides unique challenges in implementation. These will be explored as part of the qualitative analysis and in section 7.

5.5 Consumption data sources

5.5.1. Overview

Sections 5.3 and 5.4 dealt with categorisation systems. However, developing categorisation systems is not sufficient. It is also necessary to understand, firstly, how consumption data would be collected and reported for each building (covered in this section) and, secondly, how this data would be apportioned into the relevant categories (covered in section 5.6).

Studies examined in this review did not seek to allocate emissions to specific end uses within individual buildings. The aggregation of sample data through extrapolation and modelling has been sufficient to plot trends and investigate total fuel use and carbon emissions at a regional level. The most feasible way to estimate direct emissions from an individual building is typically by understanding the volume of combustion-fuel used by stationary combustion sources in that building[4]. Possible data sources to monitor consumption are summarised in Table 5 and discussed in detail thereafter.

Consumption data sources	Examples
Self-reported	Measured or estimated fuel usage provided via surveys or an online system (with or without a possible verification process)
Invoices	Utility bill records and fuel purchase receipts submitted
Metering	Collected automatically via smart meters or shared in bulk by utility companies and combustion-fuel suppliers

Table 5: This table presents the various combustion-fuel consumption data sources along with examples of how these could be deployed.

[4] Due to the scope of this research, we focus on combustion-fuel use as the main source of emissions data. However, it is plausible that a regulatory framework might also consider direct monitoring of greenhouse gases via flue gases. This is recognised as a primary way of calculating emissions within the GHGP. As such, it is a method used under the UK ETS, and quite possibly also under the Scottish Public Body Reporting Requirements.

5.5.2. Review of consumption data sources

A variety of data collection methods were used throughout the previously described studies. **BEES**, whose aim was to apportion energy use in into categories, collected data primarily through over 4,000 25-minute telephone surveys. These were designed to gather basic information for most buildings and further information on significant end uses of energy (BEIS, 2016). This data was fed into an energy use model, which estimated energy use in each building, split by end use and fuel type. This model was not intended to provide accurate total energy or energy use breakdowns at the building-level. The limitations of the model included:

- the insufficiency and potential unreliability of the data available from the telephone surveys
- the modelling software did not account for building geometry
- dynamic effects such as solar gains were not included
- inherent limitations associated with extrapolating data via a model, which is unable to match the variability of real-world data

However, the model is considered capable of producing a plausible energy prediction for each non-domestic building, as confirmed via 214 site surveys. When aggregated, the inaccuracies within the model were “considered to balance themselves out” and overall energy end use predictions for sub-sectors are claimed as reasonable (BEIS, 2016). However, ‘reasonable’ sector-level data and ‘plausible’ building-level data may not be sufficient for the enforcement of regulations.

The **California CEUS** objectives included the development of estimates of energy by end use within commercial sectors (California Energy Commission, 2006). The project undertook 2,800 on-site surveys, collecting information on equipment stocks, operating schedules, efficiency levels, and shell characteristics. This was achieved through facility manager entry and exit interviews, building inspections, inspection of site documents and records, and the use of data loggers on 500 of the sites. In addition, the project obtained billing records and interval-metered energy use data, provided by the five largest utility companies that supplied California’s energy. All data was then analysed using a custom-built software system (DrCEUS) to develop site-specific modelled estimates of end-use energy consumption. This system was calibrated using real world data and could simulate energy use conditions during different weather conditions and seasons. The study was able to estimate natural gas energy intensities of all commercial building types and end uses (see Table 6).

Whilst published almost two decades ago, the CEUS remains one of the most comprehensive and in-depth studies on energy by end use. It required a major effort over 4 years, including dedicated surveyors who underwent several days of training, collaboration with five utilities companies, and the development of custom modelling software. Despite this, it was still ultimately a model, and it was not within the scope of the study to estimate fuel use on an individual-building basis, but rather gain an understanding of the entire commercial building stock.

Building category	Building Type	Heat	Cool	WH	Cook	Misc.	Proc.	Total
Offices	Small Office	31.20	0.00	6.00	0.50	0.10	0.40	38.10
Offices	Large Office	113.70	3.60	17.20	1.50	0.70	8.10	144.80
All Offices		**144.90**	**3.60**	**23.20**	**2.00**	**0.80**	**8.40**	**182.90**
Warehouses	Refrigerated Warehouse	0.80	0.00	0.80	1.20	0.00	2.70	5.30
Warehouses	Unrefrigerated Warehouse	14.80	0.00	1.80	0.10	0.20	0.10	17.00
All Warehouses		**15.60**	**0.00**	**2.60**	**1.20**	**0.20**	**2.80**	**22.40**
Commercial	Restaurant	11.50	0.00	72.40	228.20	0.00	0.50	312.60
Commercial	Retail	21.20	0.00	5.50	3.60	1.90	0.30	32.50
Commercial	Food Store	13.70	0.00	11.00	14.90	0.00	0.10	39.80
Commercial	School	44.60	0.60	20.90	4.70	0.10	0.30	71.10
Commercial	College	40.80	7.10	17.30	3.40	1.80	0.00	70.50
Commercial	Health	76.10	3.60	73.00	7.80	3.40	11.80	175.70
Commercial	Lodging	19.70	0.20	78.20	11.90	3.90	0.70	114.50
Commercial	Miscellaneous	77.40	4.00	102.70	11.20	10.90	50.30	256.60
All Commercial		**465.50**	**19.10**	**406.70**	**289.10**	**23.00**	**75.20**	**1278.60**

Table 6 Natural gas usage (Mtherms) by (commercial) building type and end use (California Energy Commission, 2006). 1 therm = 29.3 Kilowatt hour.

Energy Performance Certificates (EPC), as used for non-domestic buildings in Scotland, provide a rating which indicates the expected scope 1 and 2 emissions associated with the building from A (lowest emissions) to G (highest emissions) under standard use conditions. They are required on the sale or lease of all non-domestic properties in Scotland. Assessments are carried out by an energy assessor who is a current member of an accreditation scheme. As of 2017, 3,200 non-domestic assessors operate in Scotland (Delorme & Hughes, 2017). Approximately 15% of all non-domestic building in Scotland currently have a valid EPC (Energy Saving Trust, 2023). In their current format, EPCs assess only the heat demand associated with space heating and domestic hot water.

Projects such as X-tendo aim to develop a framework of “next-generation EPC features”, which will aim to improve compliance, usability, and reliance of EPCs (Buildings Performance Institute Europe, 2020) as they are used across the European Union. This project suggests that the integration of real energy consumption data in EPCs can provide added value to the existing energy performance evaluation methods or can even serve as the basis for alternative evaluation methods.

The **UK ETS** monitoring regime requires the building operators to collect and report emissions data via a digital platform. This data is based on the GHGP-aligned emission calculations and outputs described previously. The operator must appoint a United Kingdom Accreditation Service (UKAS)-accredited ‘verifier’ who must carry out appropriate checks and provide a verification report before submissions to the regulator (Scottish Environment Protection Agency, 2020). This includes checks on errors and misstatements. The Scottish Environment Protection Agency (SEPA) regulates building operators in Scotland. **Scotland’s Public Body Reporting Requirements** entail public bodies self-reporting emissions (as well as the additional fuel consumption data) to the Scottish Ministers (via Sustainable Scotland Network (SSN)), but verification of these reports has not been required thus far.

5.5.3. Summary

A variety of methods are used to collect data on consumption. These methods vary in accuracy, with self-reported data particularly open to inaccuracies (or requiring an additional auditing system), whereas submitted invoices or use of metering provide much more reliable data. Additionally, the resources required to both set-up and undertake the data collection varies greatly too. Studies such as CEUS used bulk collection of data directly from utility companies to minimise and automate the process for, both, the researchers and operators. Such methods reduced the need for more resource intensive and less reliable sources of data.

5.6 Apportioning data sources

5.6.1. Overview

The final section of this review covers data sources which can assign consumption data into heat use categories. These are data sources which can reliably assign the correct volume of fuel into the respective categories at an individual building level. The possible apportioning data sources are summarised in Table 7 and discussed thereafter.

Apportioning data source	Examples
Self-reported	Surveys, an online system or landlord/tenant declaration, with or without verification
Metering	Sub-meters required to be installed as per categorisation system needs
Supplementary data gathered during common assessments	Additional data collected during routine EPC assessments, Energy Saving Opportunity Scheme (ESOS) assessments, or other assessments for non-domestic buildings
Building fuel use benchmarks or model	Energy benchmarks to apportion fuel use in buildings based on characteristics, possibly supplemented with or calibrated on real or live data

Table 7: This table presents the various apportioning data sources along with examples of how these could be deployed.

5.6.2. Review of apportioning data sources

In the 'Clean Growth - Transforming Heating' report BEIS estimated that 37% of all UK GHG emissions are a result of heating (BEIS, 2018). Using data from ECUK and other national statistics, this report estimated that across the UK space heating (and cooling) accounted for 17%, industrial processes 14%, hot water 4% and cooking 2% across all (domestic and non-domestic) sectors. Looking at the non-domestic sector and industry combined (i.e. everything outside of domestic), this report estimates that 48% of fuel for heat is used for space heating, 41% for process heat in industry applications, and 11% combined for cooking and hot water. Several end uses are omitted due to a lack of granular data, and the report highlights the diversity of fuel uses within industry, comparing extremely high temperatures used in blast furnaces with much lower temperature steam used to thaw frozen food. The report acknowledges the diversity in energy use and the lack of data to be able to disaggregate these uses; non-domestic buildings predominantly use fuel for space heating, however hot water use is particularly significant in health, hospitality, and education sectors, and cooking and catering uses are more important within many businesses (BEIS, 2018). It also highlights that the space cooling requirements are very small in total (roughly 1% across all) but does not describe how this may vary between building types.

The Building Energy Efficiency Survey (BEES) used energy use models to estimate non-electrical energy consumption by sector in England and Wales (see Figure 3). Whilst this provides a useful overview of sectors, this method is unable to accurately apportion emissions for individual buildings (BEIS, 2016). It should be noted that this data may quickly become outdated and inaccurate, especially given the current rates of decarbonisation and electrification of technologies, alongside the impacts climate change will have on our heating requirements.

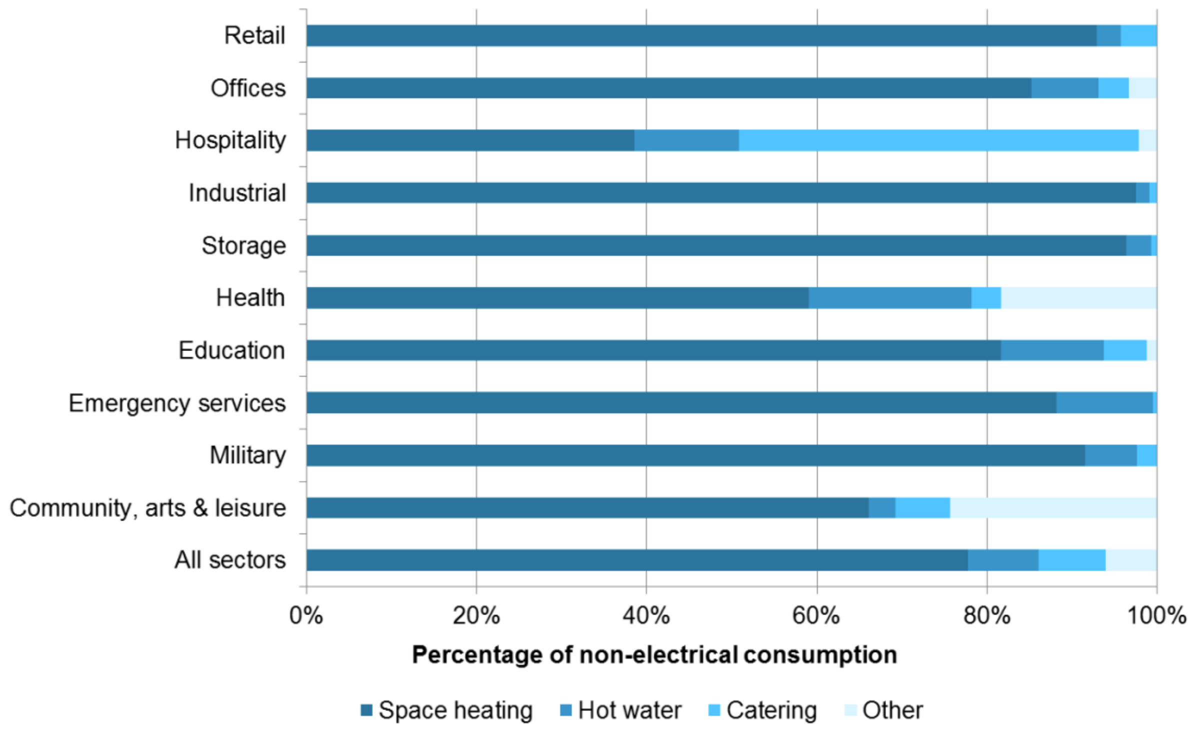

Figure 3: Non-electrical energy consumption by sector in England and Wales, 2014-15 *(BEIS, 2016)*. The figure shows that, of the ten listed sectors, industrial, retail and storage have the highest percentage of their non-electrical consumption of energy comprised of space heating- nearly 100% in the case of industrial. In each category except for hospitality, space heating is the largest energy consumer. In the case of retail, approximately half of the overall energy consumption is for catering and approximately 20% for hot water. The overall message of the figure is that space heating accounts for the largest use of energy across most sectors.

A separate study from BEIS and DESNZ, 'Evidence update of low carbon heating and cooling in non-domestic buildings,' explores the data from BEES in further detail, and highlights six building types with high energy use, or complex, HVAC systems (DESNZ, BEIS, 2022b). Whilst this study does not differentiate between electrical and non-electrical consumption regarding end uses as BEES does, it goes into further detail for specific building types, highlighting the diversity of emissions sources (see Figure 4). However, this study does not explore fuel uses in individual buildings and only provides a picture for the entire building stock.

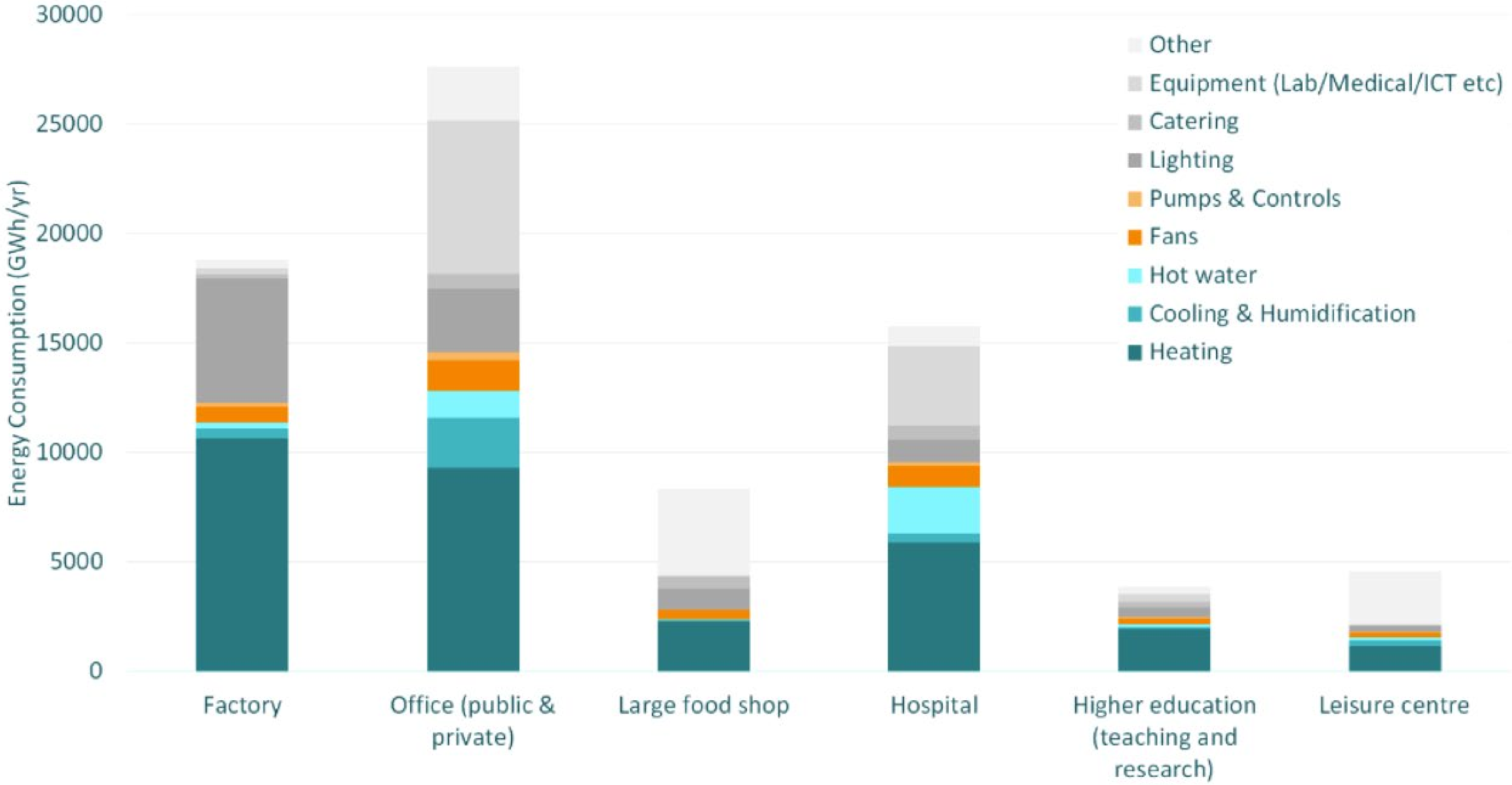

Figure 4: Energy consumption by end use by sector of 6 building types in England and Wales *(DESNZ, BEIS, 2022b)*. The figure shows the different energy consumption by end use and by building type. It shows that: factories consume most energy in providing cooling and humidification; offices spend most on cooling and humidification with equipment (medical, lab etc.) being second; large food shops spend most on category 'other'; hospitals spend most on cooling and heating, as do higher education and leisure centres.

Additional studies such as the CEUS, ECUK and CBECS all explore methods of apportioning energy use to end uses in buildings, however all also rely on sampling data and extrapolation in order to create accurate high-level views on whole building stocks (California Energy Commission, 2006) (DESNZ, BEIS, 2022a) (U.S. Energy Information Administration, 2018). Whilst useful to gain an understanding of how energy is used on average in all buildings or specific sectors, none have developed methods to apportion energy, emissions or consumption to heat uses in individual buildings.

Similarly, the Scottish Public Sector Energy Benchmarking Tool (SPSEBT) analysed over 9,000 public sector buildings in Scotland to produce energy benchmarks for 24 categories of building (Zero Waste Scotland, 2022). Alongside benchmarks, the tool can also be used to show the variation in heating consumption per building (see Figure 5). These variations reinforce the inadequacy of high-level averages for buildings (which can be rather uncertain) when needing to determine building-specific emissions.

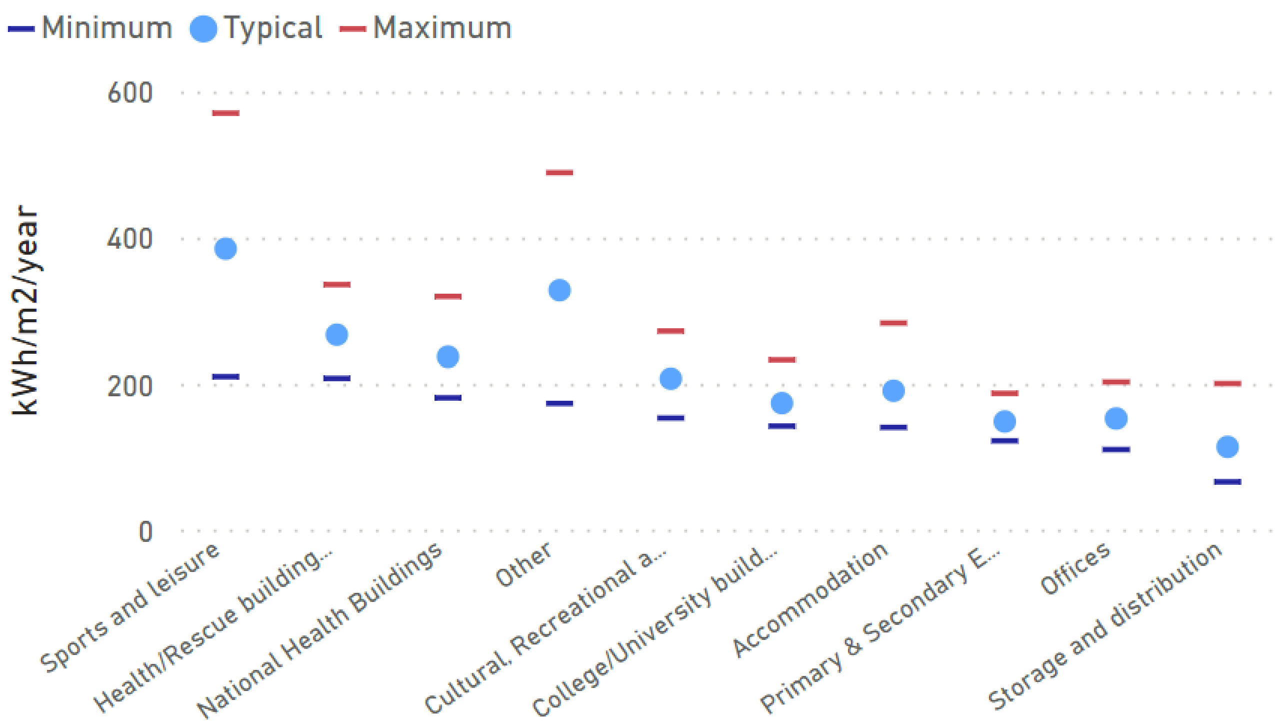

Figure 5 Heating consumption per building type in Scotland using SPSEBT *(Zero Waste Scotland, 2022)*. The image shows that sports and leisure centres have the highest maximum energy consumption.

5.6.3. Summary

Whilst various methods were used to obtain the data on which to 'train' models, none of the models can accurately apportion real consumption to heat-use categories at the individual building level. All studies which used activity or equipment/asset-based categorisation systems apportioned energy or emissions to individual categories through estimation, sampling, and extrapolation. Modelling data appears to be the only feasible method to apportion consumption into end-use categories across a larger building stock. This is one of the reasons that there is no fit-for-purpose non-domestic building data inventory for emissions associated with activities or equipment or assets in Scotland or anywhere else in the world. The diversity of the non-domestic building stock and equipment, the range of end uses for heat and the seasonal and daily fluctuation of activity mean that energy-use models cannot be applied consistently across all non-domestic buildings within a region.

6 Results of qualitative research

The framework described in section 5.2 was used to develop three possible categorisation systems with the Scottish Government, which were then being selected for testing in qualitative research. The systems selected were:

- Purpose-based (e.g. hot water, space heating)
- Process-based (e.g. high temperature process, low temperature process and drying)
- Fuel type (e.g. UK mains gas, fuel oil and coal)

We gathered responses from eight organisations, represented by 11 individuals in various senior estate-related roles. Participant responses were gathered, analysed, and organised into key themes and sub-themes summarised in Table *8* and detailed in the following sections.

Theme	Description
Regulatory burden (section 6.1)	The additional burden that a new regulatory requirement could place upon an organisation.
Fuel type as preferred option (section 6.2)	Using a categorisation system which apportions consumption by fuel type.
Automation (section 6.3)	Opportunities for automated systems and preference for systems requiring little manual input.
Apprehension of other categorisation systems (section 6.4)	Heat end-use isn't easily measured by purpose or process at a building level.
Lack of data for apportioning (section 6.5)	Very little existing data that could be used to separate consumption of individual fuels into further categories.
Other opportunities (section 6.6)	EPCs subtheme: current state of EPCs and opportunities for future development
Other opportunities (section 6.6)	Behaviour change subtheme: the role behaviour change has in decarbonisation
Other opportunities (section 6.6)	Aging and inefficient building fabric subtheme: difficulties in improving building fabric and how this inhibits decarbonisation
Other opportunities (section 6.6)	Decarbonisation technologies subtheme: are alternative technologies available for all combustion-fuel uses?

Table 8: This summarises the overall themes and sub-themes of the analysis.

6.1 Regulatory Burden

Early indications reveal that businesses were averse to a new approach which they did not consider would aid them in any other way than to fulfil regulatory requirements. There was clear resistance to any new systems or active participation in additional ongoing data collection activities.

"We just don't want another thing we need to report against and not add value, and only make things harder. Need to be careful we aren't asked to record more information on top of that." – Local Authority

"No way I'd want to report anything to Scot Gov that's outside of our audited reporting process." – Financial Institute

Participants made it clear that any new reporting regime which required additional resource commitments would not be welcome in either the public or private sector.

"Our concern is that whatever is used will just be another hoop to jump through and use resources that we don't have."- Local Authority

"We would need additional resources in order to provide data outside of what we already do, and that's not going to happen. We are often asked to do more or comply with new regulations without any extra funding." - Manufacturing

On this basis, building operators were largely in favour of aligning with existing regulations and systems, or deriving any new reporting requirements from existing reporting.

6.2 Consumption by fuel type as preferred option

Categorisation by fuel type is currently relied on by multiple Scottish and UK regulations as well as by voluntary reporting regimes. When this categorisation system was described, it was immediately recognised by most participants as a common and achievable way of reporting combustion-fuel use:

"Yes, we can apportion fuels – this is already captured in our BMS."- Local Authority

"We can definitely say how much of each fuel is used." – Financial Institute

"We already monitor [fuel use] through sub-metering, carbon accounting and reporting." – Higher education

This system is already widely in use as it is critical for running business operations and is the preferred way for organisations to calculate their greenhouse gas emissions. Organisations typically know (or are able to easily find out) how much of each type of combustion-fuel they use as this information is recorded and thoroughly used in existing monitoring systems and practices.

When questioned, none of the participants interviewed had used or considered purpose- or process-related categories to record and analyse their combustion-fuel use. Instead, they reinforced categorising by fuel type:

"We look at the overall building fuel use, rather than categorising further." – Financial Institute

"We look to decarbonise by removing gas, and oil etc, not uses." - Manufacturing

In practice, categorisation by fuel type is the only system currently used due to its simplicity and alignment with existing business management practices and regulatory regimes.

Specified combustion-fuels included natural gas, oil, coal, biomass, fuel oil, diesel, and hydrogenated vegetable oil. These are purchased, stored, and used separately throughout their value chains across the entire global market. Recording consumption by fuel type is a necessity for most businesses and there are entrenched systems in place to achieve this. Several participants also highlighted monitoring systems and reporting software linked to emission calculations as part of fulfilling their reporting duties.

6.3 Automation

Since data on consumption by fuel types is readily available and well-understood it also has a high potential to be automated. This could be achieved by targeting data collection upstream at the utility and fuel provider level. By tapping into these data sources, a regulatory body could gain access to a comprehensive dataset of combustion-fuel use by each building (or operator).

Five participants mentioned (without prompting) that their existing fuel reporting systems already had a large degree of automation. They were keen to highlight this, particularly following conversations around additional regulatory burdens described in section 6.1. When asked if participants had a preferred method of apportioning and reporting emissions, all but one participant preferred sub-metering, primarily due to ease of use, resource efficiency, and automation potential, with modelled benchmarks mentioned once for similar reasons.

> "Sub-metering would be the easiest option as it would require the least input." – Local Authority

> "We would like to move to a place where everything is sub-metered. Benchmarks would be useful because it would be easy for us." – Financial Institute

> "Sub-metering makes the most sense and is fiscally robust. If you're going to benchmark you might as well sub-meter given the data collection you'd need to do." – Manufacturing

The remaining participant did not support sub-metering as they believe the overall cost for sub-meters in every building would be too great.

> "Rule out sub-metering, it's far too costly to put in all of our buildings." – Estate including pools and leisure, education

6.4 Apprehension about other categorisation systems

Process- and purpose-based categorisation systems are not currently used in practice. Though limited and only illustrative, the data from this research indicates that they would not align with existing business practices[5]. Participants did not recognise any benefit to these systems, whether for helping understand and reduce consumption or for

---

[5] It would also involve a potentially unwelcome additional resource for building operators, as discuss in section 6.1.

decarbonisation. The largest sources of emissions (in terms of equipment, purpose or process) were typically already known and being targeted by reducing the associated combustion-fuel consumption.

> "No. We already know the majority of emissions is due to [space] heating and this has a clear decarbonisation route." – Financial Institute

Buildings or even entire estates were considered as a whole to reduce fuel-use, rather than trying to understand individual purpose or process types. Fuel consumption was not recorded or attributed to specific activities or processes.

> "I'd be looking at a building as a whole and making it more efficient overall." - Local Council

> "No- we just want rid of gas in its entirety." – Campus incl. sports, leisure, catering

However, when pressed to comment on the two options, purpose-based categories (e.g. dividing combustion-fuel use into space heating, hot water and catering/cooking) was preferred over process-based activities (e.g. dividing combustion-fuel use into high temperature process, low temperature process and drying/separation) as it was perceived to be easier to understand and possibly more useful in practice. Some participants were confused by the terminology across these two systems, particularly process-based categories, and the majority felt that the terms did not describe their activities:

> "Restrictive and not commonplace." – Manufacturing

> "Doesn't really apply to our estate, unsure of what the terms actually mean." – Local Authority

> "Not something we've ever used, not sure how this would translate for our operations." – Leisure centre

These points were expressed with a degree of concern.

6.5 Lack of data for apportioning emissions

Almost all participants stated that if they were nevertheless required to report data according to purpose- or process-based systems it would not be possible with their current monitoring systems. This was due to a lack of separation of heating/hot water systems, lack of sub-meters, and the need for significantly more monitoring data and data processing.

> "Not possible- possible to do with electric boilers but not combustion. On the whole would require a lot of data processing." – Higher education

> "We have combined heat and hot water boilers so we cannot differentiate in most of our branches. Some larger buildings we may be able to with sub-metering." – Financial Institute

> "Not possible with our current BMS." – Local Authority

Despite the support for sub-metering only two participants already had any sub-meters installed, and these were only in a small portion of their estates.

> "In big offices we use sub-meters, and a large amount of local branches." – Financial Institute

> "Sub meters are used in some instances where we need to track inefficiencies and losses." – Manufacturing

This revealed that reporting via sub-metering may achieve partial coverage, but it would not be possible to report all combustion-fuel use by purpose or process categories in this manner. The remaining gaps might have to be filled by other means such as modelled benchmarks and self-reported estimates.

6.6 Opportunities and barriers

Throughout the interviews, participants highlighted topics that they felt were worth discussing in the context of decarbonisation. These included opportunities, barriers, and other ideas for further discussion.

6.6.1. EPCs

When discussing modelled benchmarks or estimates, two participants flagged the low uptake and low accuracy of the existing EPC system, highlighting how this may affect benchmarking models which would rely on this data. However, they also noted that if these issues with EPCs were addressed there may be more opportunities to use them.

> "If you could get the EPCs working that would be useful (regarding benchmarking)." – Financial Institute

> "There are all sorts of problems with the current EPC system. If we could get that done properly, that would be good." – Local authority

EPCs are a well-known tool to assess building performance and energy demand of buildings. However, participants expressed that they would not be useful for the purpose of accurately discerning combustion-fuel use in their current state.

6.6.2. Behaviour change

Two participants felt that behaviour change was the cornerstone to decarbonising the Scottish non-domestic building stock. Whilst beyond the scope of this research, understanding each organisation's views on these more complex, system-wide matters may provide useful.

> "Behaviour change is the biggest factor in reducing energy." – Local authority

> "Behaviour change is at the epicentre of decarbonisation; identify where the behaviours are causing emissions, and people can then gain an understanding much quicker to then implement change." – Higher education

6.6.3. Aging and inefficient building fabric

Five participants highlighted the challenges of building fabric for decarbonisation, and how this issue should be addressed alongside or prior to decarbonising heat. A range of factors impeding the improvement of building fabric were cited, including listed buildings, rural estates, and the economics of rebuilding vs refurbishment.

> "It's more a case of the building fabric that poses a problem. We have buildings from the 60s/70s that are problematic to transition to renewables or for fabric improvements to be efficient enough." – Local authority

> "Improving the fabric of larger buildings is more of a challenge than decarbonising fuels. Rural colleges can make it difficult to retrofit and integrate new technologies." – Higher education

> "The main problem in decarbonising is building fabric, not how we fuel the heating system." – Campus including sports, leisure, catering

> "All building stock will need to be replaced [by 2045], so we don't want to wrap everything in insulation now. Replacing multiple old buildings with one new highly efficient hub provides much better value for money." - Estate including pools and leisure, education

Participants highlighted the importance of improving building fabric or new buildings to be considered and clearly reflected in categorisation and regulatory systems.

6.6.4. Decarbonisation technologies

When asked if there were any combustion-fuel uses that would be harder to decarbonise, five participants felt that there were no uses that would be difficult to decarbonise, and the remaining three agreed that all but certain uses of oil would be easy to decarbonise. The use of oil is limited to cases where access to zero direct emission fuels is not possible, for example in rural sites with grid constraints, or on sites requiring high-resilience backup power generation.

> "Oil sites are the most difficult as there's no clear replacement. Use of hydrogen would mean a rework of all the infrastructure, and doesn't align to our long-term plans." – Local Authority

> "For the average building, blockers are unblocked thanks to clarity on the Net Zero direction from the Government, business cases are easier to put forward. Where we cannot decarbonise is on sites where we need to have backup power for critical infrastructure – we need oil for these." – Financial Institute

> "There aren't any uses of combustion fuels that will be harder to decarbonise; technology-wise, and given an endless budget, we can electrify all of our buildings. All of our new buildings are entirely electric." - Campus including sports, leisure, catering

> "We don't have any activities that we don't know how to electrify." – Manufacturing

7 Conclusions

7.1.1. Comparison of combustion-fuel use categorisation systems

Table 9 presents a comparative analysis of categorisation systems based on criteria agreed with the Scottish Government.

The literature review and the interviews with participants allowed the three category systems to be assessed according to the criteria as follows:

Quality criteria/ categorisation system	Purpose-based category system (e.g. space heating, hot water)	Process-based category system (e.g. high-temperature process, drying/separating)	Fuel-type category system (e.g. mains gas, coal, oil)
Practical to regulate?	Yes	Yes	Yes
Practical for building operator	No	No	Yes
Reliability & accuracy	No	No	Yes
Consistency of outputs	Depends on quality of data sources	Depends on quality of data sources	Depends on quality of data sources
Verification & enforcement	Depends on quality of data sources	Depends on quality of data sources	Depends on quality of data sources

Table 9: A Summary of the analysis of the three key categorisation systems. This states the relative advantages and disadvantages of each against the five qualities.

7.1.2. Categorising by fuel type

The evidence suggests that a categorisation system for heat in individual buildings based on consumption by fuel type could be applied across all non-domestic buildings in Scotland:

- This form of this categorisation system is currently used for the purposes of regulation.
- This form of categorisation system came closest to fulfilling the criteria established at the start of this research project.

- This form of categorisation is currently used by building operators. It is entrenched in business practices and economic systems throughout the value chain globally.

Such a system could provide a foundation upon which to build a regulatory framework. It is unclear if this categorisation system alone would allow differentiation of emissions associated with specific purposes or activities. This may limit the understanding of the decarbonisation potential of specific process and activities within individual buildings.

Thus, we suggest further research establishing whether understanding fuel type in itself is sufficient or if it would be better to build on it with an additional process-, activity- or equipment/asset-based system, for example, to cover a subset of buildings or sectors.

7.1.3. Alternative categorisation systems

The evidence review demonstrated that systems which are primarily based on allocating emissions to specific processes, equipment/asset or activities have been used, albeit at a regional rather than building level. The division of Scotland’s non-domestic building sector into sub-sectors based on building type, size, process, activity or other system types would allow the development of an alternative categorisation system or systems. However, it should be noted that the examples of the CEUS survey in California and BEES in England and Wales required significant resources to develop. Further, this would result in a model well-suited for research, target-setting and policymaking but unsuitable for regulating individual buildings.

7.1.4. Additional regulation

Building operators were concerned that any additional reporting requirements would demand more of their time and energy. Requirements which would not add value to the business other than enable regulatory compliance were especially unwelcome. Participants were supportive of the net zero agenda but eager to see this approached in a way that was efficient and valuable to their organisations. Categorisation systems which align with existing systems are likely to be the most welcomed by building operators.

Both the evidence review and the qualitative research demonstrated strong links to the Greenhouse Gas Protocol (GHGP). In the case of existing policies, such as the Scottish Public Bodies: Reporting Requirements, there is a direct reference to GHGP. This influence was visible when participants described their reporting practices and preferences. However, this was also indirectly referenced by participants when they described their data collection and emission calculation approaches outside of regulation; these are also based on the GHGP.

The Public Bodies: Reporting Requirements were cited by some participants as an existing form of reporting which required categorisation by fuel type. This reporting was considered as purposeful, aligned to business practices, and sufficient.

Both the evidence review and the qualitative survey demonstrated opportunities for automation of reporting, either through the sharing of metered data or direct collection from utility suppliers. Building operators welcomed categorisation systems and reporting options which could be automated and would require limited manual input.

We suggest further research into understand how this automation could be achieved by collecting consumption data from utility providers, combustion-fuel suppliers and other organisations ‘upstream of building operators.

8 References

BEIS, 2016. *Building Energy Efficiency Survey, 2014-14: Overarching Report,* London: Crown.

BEIS, 2018. *Clean Growth - Transforming Heating,* London: Crown.

BEIS, 2021. *The Non-Domestic Private Rented Sector Minimum Energy Efficiency Standards: Implementation of the EPC B Future Target,* London: Crown.

BEIS, 2022. *Digest of UK Energy Statistics - Annual data for UK, 2021,* London: Crown.

BEIS, 2022. *Streamlined Energy and Carbon Reporting (SECR) for academy trusts.* [Online]
Available at: www.gov.uk/government/publications/academy-trust-financial-management-good-practice-guides/streamlined-energy-and-carbon-reporting

Building Research Association of New Zealand, 2014. *BUILDING ENERGY END-USE STUDY (BEES) PART 1: Final Report,* s.l.: BRANZ.

Buildings Performance Institute Europe, 2020. *Energy Performance Certificates: Assessing Their Status and Potential,* s.l.: BPIE.

California Energy Commission, 2006. *California Commercial End-Use Survey,* California: California Energy Commission.

CIBSE, 2019. *Heat Decarbonisation - Review of Evidence,* London: BEIS.

City of New York, 2022. *1 RCNY §103-14, Chapter 100, Subchapter C Maintenance of Buildings,* New York: New York City.

Delorme, L. & Hughes, A.-M., 2017. *EPBD Key Implementation Decisions in The UK Scotland,* s.l.: Concerted Action.

Department for Business, Energy & Industrial Strategy, 2022. *The Non-domestic National Energy Efficiency Data-Framework 2022 (England and Wales): Methodology note,* London: Crown.

Department of Energy & Climate Change, 2012. *Emissions from Heat,* London: Crown.

DESNZ, BEIS, 2021. *Using UK greenhouse gas inventory data in UK ETS monitoring and reporting: the country-specific factor list.* [Online]
Available at: www.gov.uk/government/publications/using-uk-greenhouse-gas-inventory-data-in-uk-ets-monitoring-and-reporting-the-country-specific-factor-list

DESNZ, BEIS, 2022a. *Energy Consumption in the UK,* London: Crown.

DESNZ, BEIS, 2022b. *Evidence update of low carbon heating and cooling in non-domestic buildings,* London: Crown.

DESNZ, Environment Agency and BEIS, 2014. *Energy Savings Opportunity Scheme (ESOS).* [Online]
Available at: www.gov.uk/guidance/energy-savings-opportunity-scheme-esos

Energy Saving Trust, 2023. *Scottish EPC Register.* [Online]
Available at: https://www.scottishepcregister.org.uk/
[Accessed April 2023].

EUR Lex, 2018. *Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council and amending Commission Regulation (EU).* [Online]
Available at: www.eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A32018R2066

Greenhouse Gas Protocol, 2015. *The Greenhouse Gas Protocol Corporate Accounting and Reporting Standard.* [Online]
Available at: www.ghgprotocol.org/corporate-standard

Hackett, A. & Strickland, K., 2018. Using the framework approach to analyse qualitative data: a worked example. *Nurse Researcher,* 26(2).

International Organization for Standardization, 2013. *ISO 12655:2013(en) Energy performance of buildings — Presentation of measured energy use of buildings.* [Online]
Available at: https://www.iso.org/obp/ui/#iso:std:iso:12655:ed-1:v1:en:term:3.6.5

Scottish Assessors, 2023. *The Valuation Roll.* [Online]
Available at: https://www.saa.gov.uk/non-domestic-valuation/the-valuation-roll/

Scottish Environment Protection Agency, 2020. *UK emissions trading escheme for installations: How to comply.* [Online]
Available at: www.sepa.org.uk/media/594230/how-to-comply-uk-ets-installations.pdf

Scottish Government, 2018. *Scotland's Non-Domestic Energy Efficiency Baseline,* Edinburgh: The Scottish Government.

Scottish Government, 2023. *Scottish energy statistics hub,* Edinburgh: Scottish Government.

Templier, M. & Pare, G., 2015. A Framework for Guiding and Evaluating Literature Reviews. *Communications of the Association or Information Systems,* 37(6), pp. 112-136.

The Scottish Government, 2021a. *Scottish Greenhouse Gas Statistics: 1990-2019.* [Online]
Available at: www.gov.scot/publications/scottish-greenhouse-gas-statistics-1990-2019/documents

The Scottish Government, 2021b. *Regulation of energy efficiency in existing non-domestic buildings: call for evidence,* Edinburgh: The Scottish Government.

The Scottish Government, 2022. *Heat in buildings strategy - achieving net zero emissions in Scotland's buildings.* [Online]
Available at: www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings

The UK Government, 2015. *The Climate Change (Duties of Public Bodies: Reporting Requirements) (Scotland) Order 2015.* [Online]
Available at: www.legislation.gov.uk/ssi/2015/347/contents/made

The UK Government, 2020. *The Greenhouse Gas Emissions Trading Scheme Order 2020.* [Online]
Available at: www.legislation.gov.uk/uksi/2020/1265/schedule/2/made

U.S. Energy Information Administration, 2018. *Commercial Buildings Energy Consumption Survey,* Washington: EIA.

U.S. Energy Information Administration, 2021. *2018 Commercial Buildings Energy Consumption Survey: Building Characteristics Highlights,* Washington: EIA.

Zero Waste Scotland, 2022. *Scottish Public Sector Benchmarking Tool,* Stirling: Zero Waste Scotland.

9 Appendix: detailed methodology

9.1 Developmental Review

The research began with the developmental review, which consisted of six steps (Templier & Pare, 2015);

1. **Formulating the problem:** the research team developed the research question to guide the evidence review, and defined the scope, boundaries, key concepts and justification for research. The steering group then confirmed and clarified these to be fully clear on scope and expected results.

2. **Searching the literature:** the research team identified a range of possible sources and studies. We drew on our team's existing knowledge and library of evidence to gather the comprehensive set of literature and data in the field. A literature search was also conducted to supplement this; a list of search terms, keywords and phrases was developed and combined with different Boolean operators to search for sources using Google Scholar. This was further supplemented with citation searches on each document.

3. **Screening for inclusion:** all sources were screened; they were included or excluded based on an evaluation of their applicability to this research. This was mainly based on a source's ability to help answer the research question and objectives such as: is it relevant to the Scottish non-domestic building landscape? Does it provide suggestions for categorising combustion-fuel use or apportioning emissions? Is it up to date? Does it shed light on barriers in data collection?

4. **Assessing quality:** quality of evidence (e.g. research design and methodology) was appraised. If poorer quality evidence was determined to negatively affect the quality of the review's results, it was excluded.

5. **Extracting data:** the team gathered applicable information from each of the selected sources.

6. **Analysing and synthesising data:** the team (1) collated and organised, (2) compared, (3) summarised, (4) aggregated and interpreted information to (5) suggest a set of options for categorising fuel use within non-domestic buildings and an insight into apportioning emissions. This resulted in a framework consisting of four components, which helped to develop a language and structure we could use to test various options. Some sources also provided insight into advantages & disadvantages in terms of primary data collection as well as implementing new policy or strategies.

Following an internal quality assurance review, outcomes from the developmental review were first shared with the steering group for feedback. Thereafter, they were used to develop and deliver a workshop and several interviews involving ClimateXChange and key stakeholders from the Scottish Government. During these engagements, options and recommendations were formulated for categorising fuel use to take forward to the next task.

9.2 Qualitative Research

Using outputs from Task 1, topic guides were developed to help guide the semi-structured interviews with individual building operators. This data collection method was used rather than focus groups to allow anonymity and to reduce possible bias from stronger voices.. Non-probability purposive sampling was used to recruit the most knowledgeable participants representing various sectors to provide a variety of heating patterns, given the exploratory nature of the research. Recruitment targets were heads of estates or equivalent roles who had a good understanding of fuel use in their facilities, and who would be able to provide information without needing to refer to other sources or colleagues.

Framework analysis, a dynamic qualitative analysis technique geared toward producing actionable policy outcomes with high quality standards, was used to analyse the data (Hackett & Strickland, 2018):

1. **Familiarisation of raw data:** the research team acquainted themselves with the raw data and began to identify emerging themes.

2. **Identifying themes:** themes and sub-themes were formulated into a coherent thematic framework and discussion points and issues were identified.

3. **Indexing:** the research team then used qualitative coding to categorise the data according to final themes.

4. **Charting and summarising:** data was arranged into a discernible order using a matrix.

5. **Interpretation/Mapping:** the framework analysis concluded with researchers linking the data to the research questions by summarising participant viewpoints and developing an overarching narrative.

This analysis was used alongside the developmental review to inform the conclusions.

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

With special thanks to Professor David Jenkins, Heriot Watt University, for his subject matter expertise and guidance on this project.

climate X change

Scotland's centre of expertise connecting climate change research and policy

info@climatexchange.org.uk
+44(0)131 651 4783
@climatexchange_
www.climatexchange.org.uk

ClimateXChange, Edinburgh Climate Change Institute, High School Yards, Edinburgh EH1 1LZ