seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

INSIGHTS PAPER

Extensive survey of the commercial buildings stock in the Republic of Ireland

November 2015

This report is being published as the first in a new series of *Insights Papers* under development by the SEAI Energy Modelling Group (EMG).

Established in 2009, SEAI's Energy Modelling Group provides high-quality analysis and policy advice on a range of energy / climate issues at national and European level. It operates within SEAI's Low Carbon Technologies Development division in association with SEAI's Energy Policy Statistical Support Unit (EPSSU).

Insights Papers will be published as they are developed, to provide new information and insights to the policy and modelling community. Feedback and reaction to this and subsequent papers are welcome. Please email your thoughts to emg@seai.ie

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This report was commissioned by SEAI as part of a larger project investigating opportunities for energy efficiency across all energy-using sectors of the Irish economy. The final output is published as *'Unlocking the Energy Efficiency Opportunity',* SEAI (2015).

The work was undertaken by The Research Perspective and Element Energy Limited for SEAI.

elementenergy

The Research Perspective

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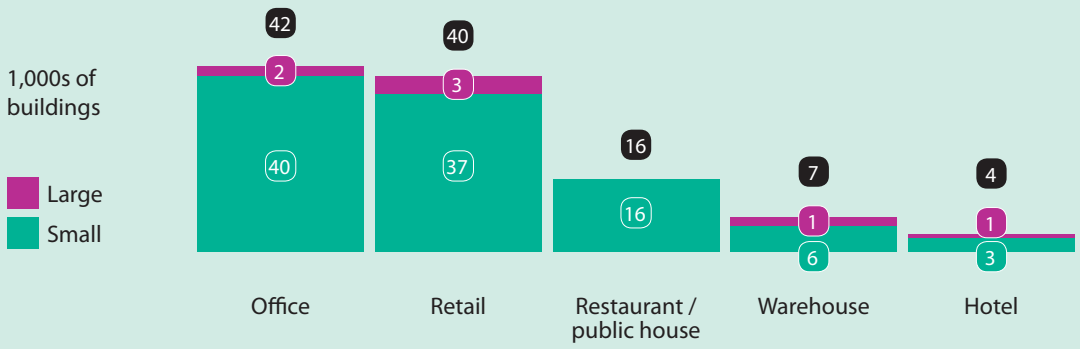
Commercial Buildings Report
Key Points

1. The total number of commercial buildings in Ireland is around 109,000.

2. Irish commercial buildings stock by activity type and size is broken down:

Number of commercial buildings in Ireland (Total = 109,000)



3. Annual primary energy demand in the commercial buildings sector is calculated to be around 18 TWh. Approximately 7 TWh of this is in buildings categorised as Retail. Although the number of buildings categorised as Hotel is less than 4,000, primary energy demand in this sector is comparable with the demand in the Office category, which has more than 40,000 buildings.

4. There is a high proportion of electrical heating in the commercial sector, making up around 60% of the buildings surveyed.

5. A wide variation in heating fuel was observed across the five building types. More than 80% of retail buildings are heated using electricity. In offices and restaurants/public houses, this fraction drops to approximately one half. The majority of the remaining offices and restaurants/public houses were heated by oil, natural gas or solid fuel. Hotels were heated predominantly by oil, with only a low share of electrical heating. Warehouses were mainly either electrically heated or unheated.

6. In almost all hotels surveyed (91%), 80–100% of the windows are double- or triple-glazed. This fraction was 78% for offices, and only 54% for both retail premises and restaurants/public houses.

7. In around half of the retail and restaurant/public house buildings surveyed, the windows are single-glazed. This suggests that there remains significant potential for energy savings through double/triple glazing.

8. 27% of all buildings are fitted with less than 20% low-energy lighting. This suggests that there remains significant potential for energy savings in this area.

9. Almost half (49%) of buildings having heating only (no cooling), with natural ventilation. The highest share of heating and cooling was observed in restaurants/public houses (32%) and retail buildings (29%), and those building types also showed the highest incidence of mechanical ventilation. 68% of warehouses were identified as unheated.

10. Centralised time controls for heating were relatively common, being present in nearly half of the buildings surveyed. In contrast, room-by-room time and temperature controls were much less common, being present respectively in only 9% and 15% of surveyed buildings.

11. Ireland has a relatively unsophisticated commercial buildings stock, and a high incidence of buildings in which relatively basic upgrades could lead to significant energy savings.

1 Executive summary

Background

SEAI has commissioned this detailed analysis of the potential for energy efficiency improvements economy-wide to 2020. This work will form a key evidence base to inform Ireland's national strategy to meet its ongoing obligations with respect to the EU (Re-cast) Energy Performance of Buildings Directive (2010) and Energy Efficiency Directive (2012), including its headline target of achieving an economy-wide reduction in primary energy consumption of 20% by 2020.

One of the key obligations of the Energy Efficiency Directive concerns the development of an overview of the national commercial buildings stock, an evidence-based estimate of the potential energy savings within the commercial buildings stock and a strategy through which to achieve those energy savings in a cost-effective manner.

Key to developing a useful representation of the commercial buildings stock is, first, to understand the frequency of the types of buildings present and, second, to gather representative data on the fabric of these buildings, their condition, the energy services present and their occupancy. A particular challenge with regards to the development of the building stock is the lack of robust data concerning commercial buildings in Ireland. The lack of data in this sector is not specific to Ireland, and provides a challenge that all EU member states will need to overcome.

This report describes a survey of commercial buildings to overcome this barrier. This represents a general approach that could be used to develop a more comprehensive evidence base in the commercial buildings sector across other member states.

Primary research has been combined with rigorous energy modelling

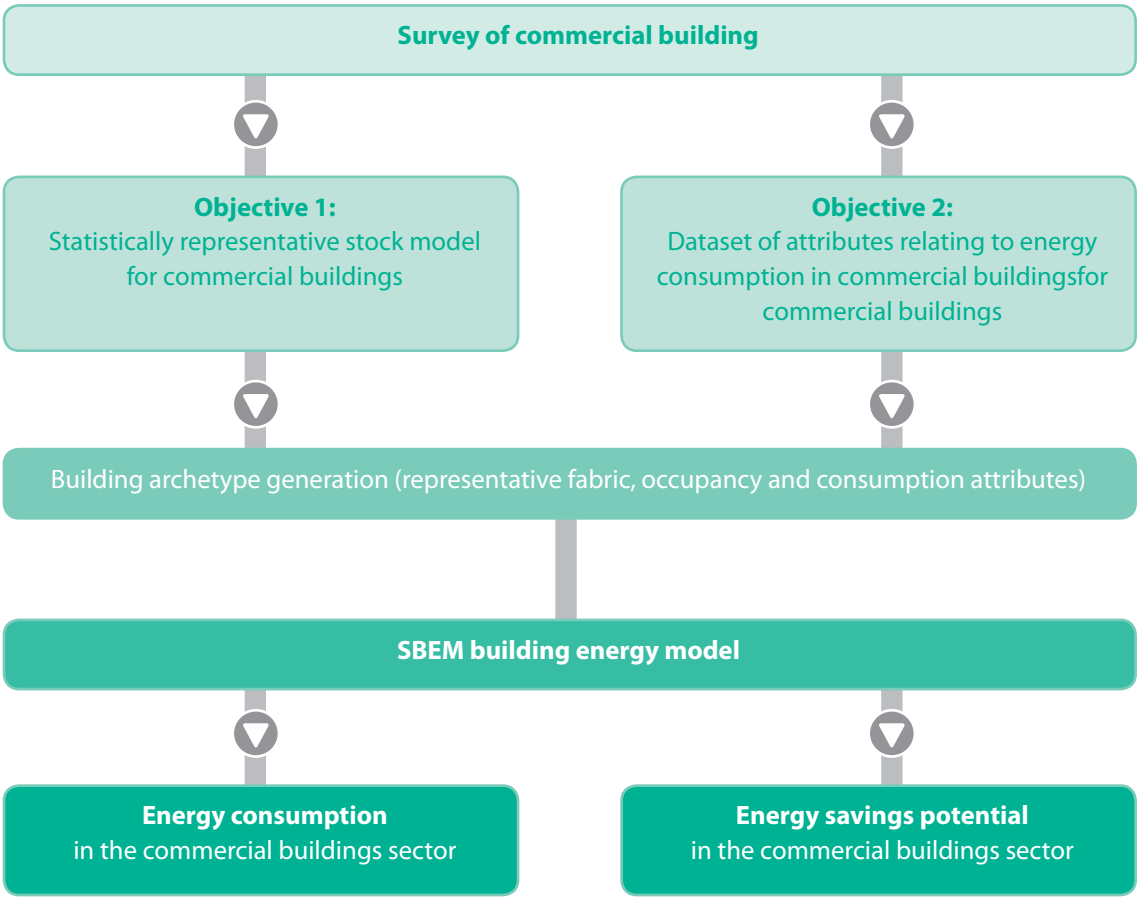
In order to build a detailed profile of energy consumption in the commercial sector, primary research on the commercial buildings stock in Ireland, by way of a survey, has been combined with a rigorous building energy model. As illustrated in Figure 1, the survey of commercial buildings was developed to provide two key outputs:

(i) a statistically representative model of the commercial buildings stock in terms of the type and frequency of buildings present

(ii) a detailed dataset on the attributes relating to energy consumption in those building types.

Using these outputs, it was possible to construct a set of commercial building 'archetypes', a number of building types defined as representative of the entire stock. These archetypes were then modelled using the Simplified Building Energy Model (SBEM) – the officially recognised building energy model used in Ireland and across other EU member states to demonstrate compliance with building regulations in the non-domestic sector – in order to develop a detailed profile of energy consumption in the Irish commercial sector and a robust estimate of the potential for energy savings.

Figure 1: Objectives of the survey



Useful new information on the Irish commercial buildings stock has been gathered through statistically robust sampling and careful survey design

A survey sample was developed using a database containing all known business addresses in Ireland. Prior to constructing the survey sample, an initial literature review was undertaken in order to define the set of building archetypes to be used to represent the Irish commercial stock in the final building energy model. The sampling process was then tailored to ensure that, as well as being representative of the commercial stock as a whole, the survey results would be statistically representative of each of those key building activity types.

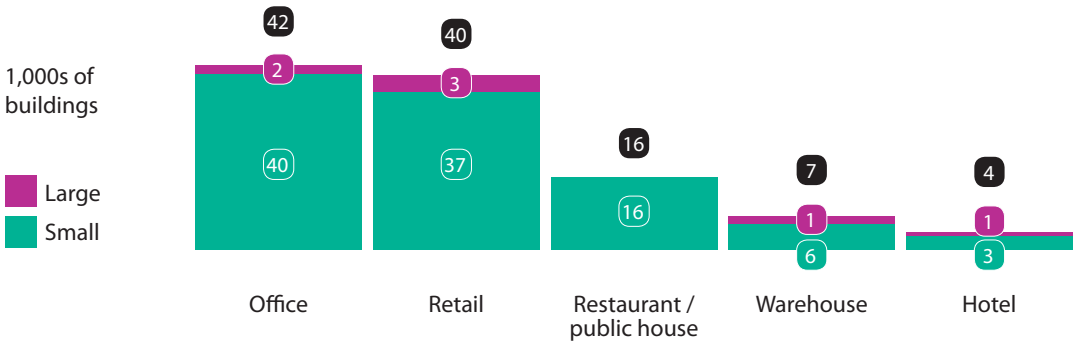
The survey questions were designed carefully to ensure that sufficiently detailed data could be collected to populate the building energy model, without putting at risk the likelihood of high response and completion rates during the survey. This was achieved by making use of further sources of data such as the Irish non-domestic building energy rating (ND-BER) database, defining the survey questions in order that the combination of these datasets provided a sufficiently reliable input to the modelling process.

Furthermore, surveyors qualified in construction and engineering were chosen to carry out the fieldwork, and were trained extensively before embarking on the survey. As a result of the careful design process and extensive training, the survey was highly successful 'on the doorstep'. The surveyors reported a high level of co-operation and engagement, achieving 1,500 site visits and data captures on time, with a very low refusal rate estimated at 5% at point of contact. Survey results were then used with the SBEM energy model to construct a detailed model of energy consumption in the Irish commercial sector.

Key findings

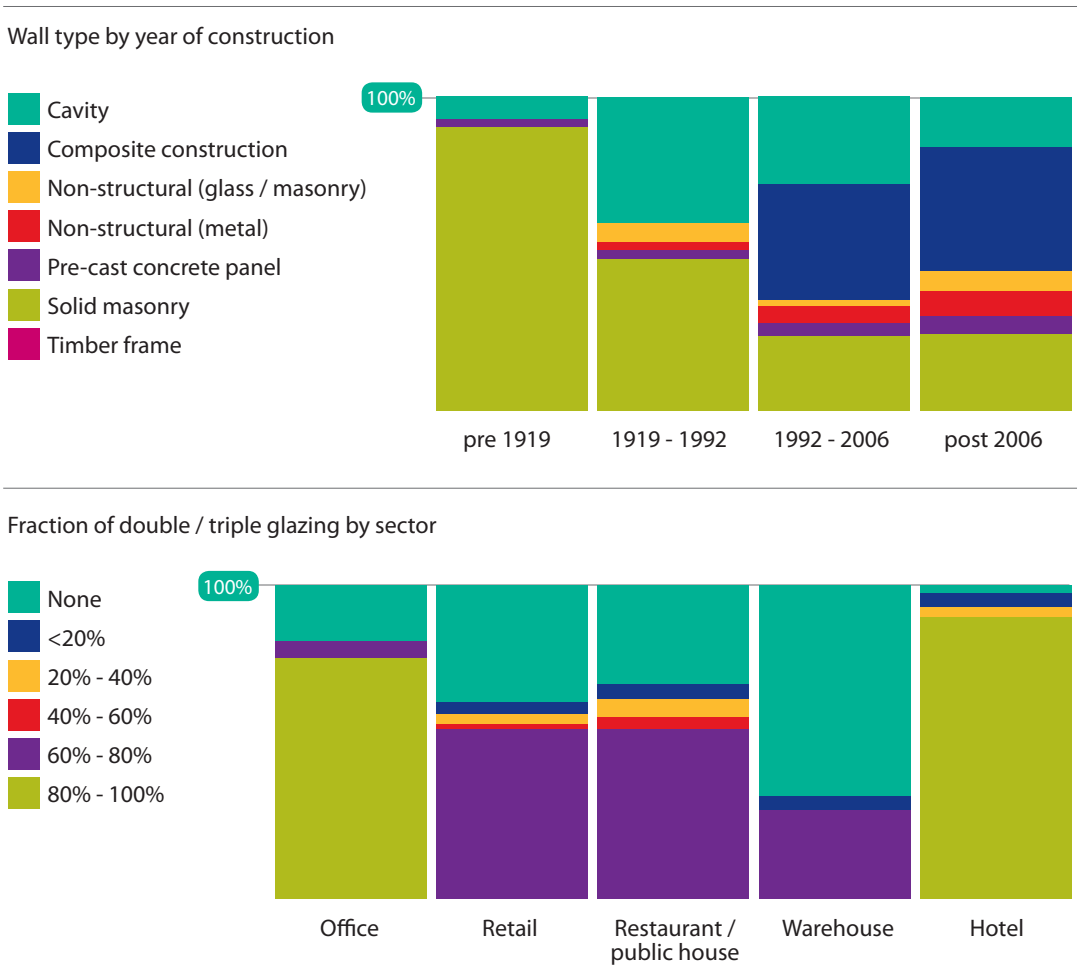
Based on the survey results, the commercial buildings stock was derived in terms of the five building activity types: Office, Retail, Restaurant / public house, Warehouse and Hotel. All buildings with a gross floor area over 1,000 m^2 were classified as Large; the remainder were classified as Small. The resulting model of the Irish commercial buildings stock is presented in Figure 2. The total number of commercial buildings is estimated to be around 109,000, of which 82,000 are categorised as either Retail or Office.

Figure 2: Number of commercial buildings in Ireland (Total = 109,000)



The survey results provide detailed insight into the Irish commercial buildings sector as well as the potential for energy savings in the sector. Example outputs from the survey are shown in Figure 3. The wall construction types observed during the survey reflect the age profile of the buildings included in the survey. A large majority of the buildings built before 1919 have solid masonry walls, while cavity walls are more common in the buildings built between 1919 and 2006. It was also found that for around half of the retail and restaurant / public house buildings surveyed, the windows are single-glazed. This suggests that there remains significant potential for energy savings through double / triple glazing.

Figure 3: Key survey results for building fabric variables



The survey data also shows that relatively basic upgrades such as low-energy lighting could lead to significant energy savings in the commercial sector. As shown in Figure 4, it was found that 27% of all buildings are fitted with less than 20% low-energy lighting. A moderate variation was observed between building activity types, with hotels having the largest share of low-energy lighting, and restaurants / public houses and warehouses having the lowest share.

A further key finding from the survey is the high proportion of electrical heating in the commercial sector, making up around 60% of the buildings surveyed. It was also found that more than 80% of retail buildings are heated using electricity. In offices and restaurants / public houses, this fraction drops to approximately one half. Hotels were found to be heated predominantly by oil, with only a low share of electrical heating.

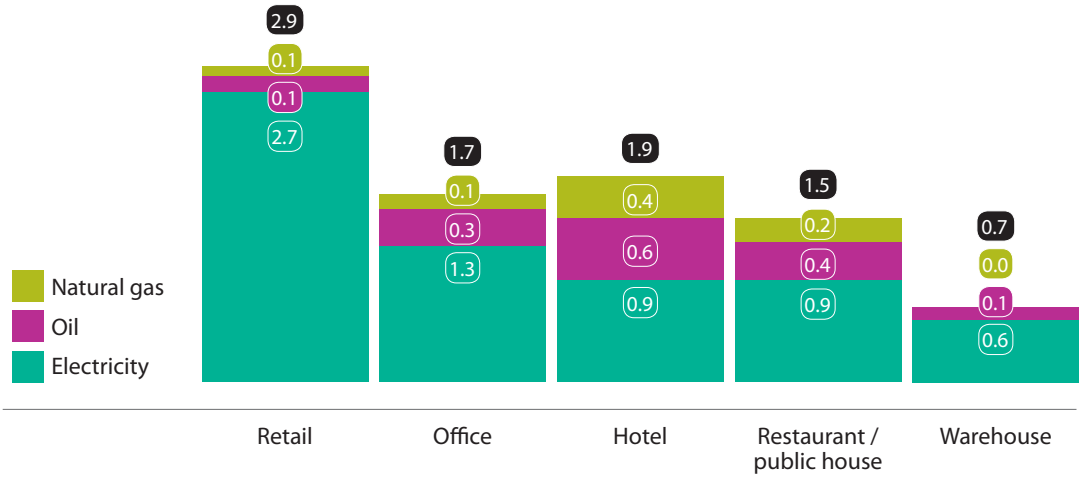
Figure 4: Key survey results for building energy services

Using the survey outputs, a set of representative commercial building archetypes was constructed. These archetypes were modelled using the project's SBEM energy model in order to develop a detailed profile of energy consumption in the commercial buildings sector. Based on this energy modelling, annual primary energy demand in the commercial buildings sector is calculated to be around 18 TWh. Approximately 7 TWh of this is in buildings categorised as Retail. Another interesting finding is that although the number of buildings categorised as Hotel is less than 4,000, primary energy demand in this sector is comparable with the demand in the Office category, which has more than 40,000 buildings. Modelling also suggests that electricity dominates the primary and final energy demand in the commercial sector. The electricity fraction in Irish commercial buildings is high due to the high fraction of electrically heated buildings, as well as to high lighting and equipment consumption and, in some buildings, demand for cooling.

Figure 5: Primary and final energy demand by fuel type

Primary energy demand by fuel type in the commercial buildings sector (Total = -18 TWh)

Final energy demand by fuel type in the commercial buildings sector (Total = ~9 TWh)



Further reports

This document is a deliverable from the *'Unlocking the Energy Efficiency Opportunity',* study for SEAI (2015), available at www.seai.ie. The full report includes:

- Technical energy savings potential: The results of the survey have recently been used with the SBEM energy model to derive the technical potential for energy savings in the sector for a variety of energy efficiency measures.
- Energy efficiency cost curves: Cost curves have been derived for each of these energy efficiency measures as well as for 'packages' of the energy efficiency measures (i.e. 'shallow', 'medium' and 'deep').
- Energy efficiency uptake in Ireland: A survey of consumer investment behaviour in the commercial sector in Ireland has been completed. Realistic uptake of energy efficiency packages is modelled considering decision-making frequency, engagement in energy efficiency, payback requirement, capital constraints and attitudes to intervention types such as Energy Performance Contracting.

2 Development of a commercial buildings sample

2.1 GeoBusiness address database

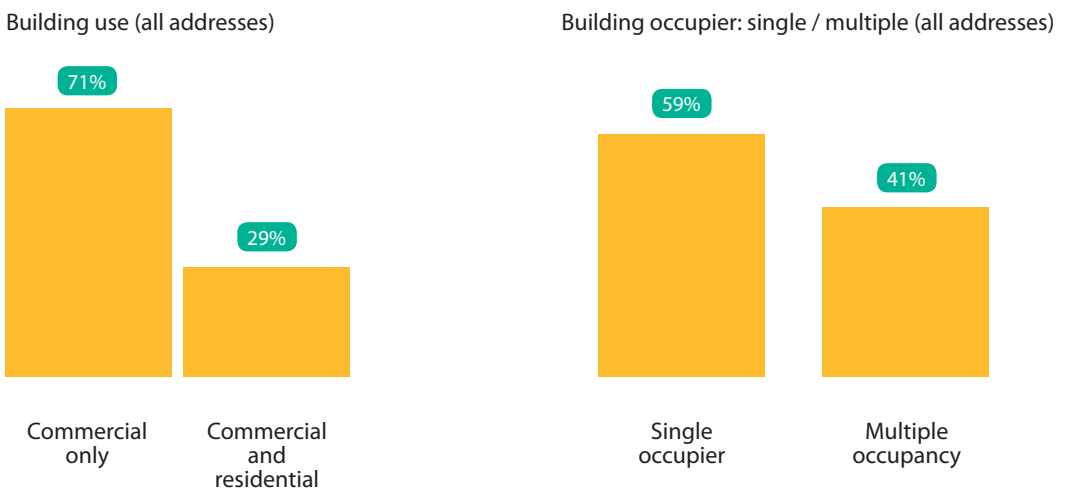
The population of commercial buildings was based initially on GeoDirectory's GeoBusiness product, a database developed by An Post in association with Ordnance Survey Ireland that contains all known addresses in the Republic of Ireland. GeoBusiness, an electronic register of every business address in the State, provides a complete geographical database covering close to 200,000[1] businesses across the Republic of Ireland.

The basic unit of the GeoBusiness directory is the building address. In order to develop a target sample from the population of commercial buildings, it was necessary to profile the population of businesses at address level. In addition, for increased precision, it was important to account for the following:

- the proportion of addresses from which there is a single organisation operating (single enterprise occupancy)
- the proportion of addresses from which there are several organisations operating (multiple enterprise occupancy)
- the proportion of addresses where there is a combination of residential and commercial occupants (dual purpose).

It was found that 30% of the addresses in the database comprise a combination of commercial and residential occupants, and that just over 40% of the addresses are multiple occupier premises (Figure 6). It should be noted that a building with a single commercial occupant is identified as single occupancy even if the building also includes residential units.

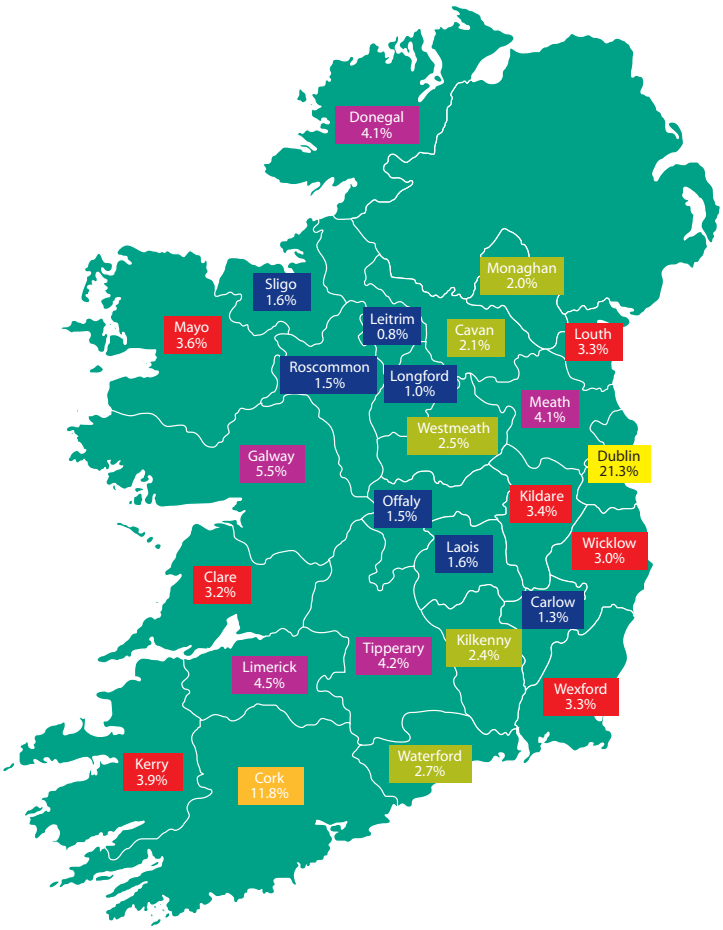
Figure 6: Fraction of addresses by building use and building occupier



1 The population of commercial addresses included a series of entries that were not valid for the purpose of this sample, such as unknown or residential buildings. From the total entries of 199,894, 304 entries were removed, leaving a total of 199,565.

In addition, over 44% of the commercial addresses were found to be based in Dublin, Cork, Galway and Limerick (Figure 7).

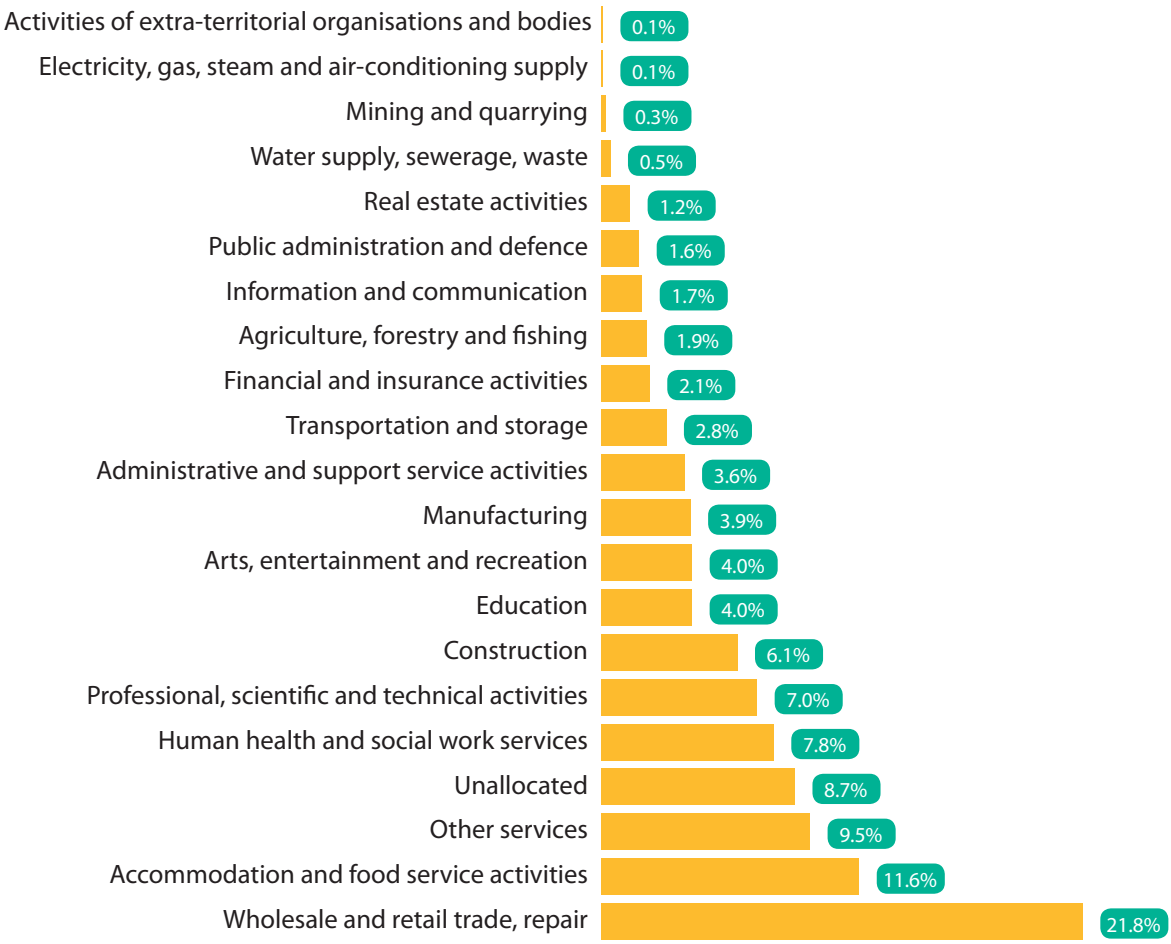
Figure 7: Distribution of addresses across counties in the GeoBusiness database



County	% of Addressess in County
Dublin	21.2
Cork	11.8
Galway	5.5
Limerick	4.5
Tipperary	4.2
Donegal	4.1
Meath	4.1
Kerry	3.9
Mayo	3.6
Kildare	3.4
Wexford	3.3
Louth	3.3
Clare	3.2
Wicklow	3.0
Waterford	2.7
Westmeath	2.5
Kilkenny	2.4
Cavan	2.1
Monaghan	2.0
Sligo	1.6
Laois	1.6
Roscommon	1.5
Offaly	1.5
Carlow	1.3
Longford	1.0
Leitrim	0.8

In the GeoBusiness database, a NACE code is used to identify the industry type that operates at each address. In total, there are 338 NACE codes associated with the commercial address database. A total of 8.7% of the addresses have not been allocated a NACE code. The detailed NACE codes are aggregated to 20 top-level NACE codes. Figure 8 reflects the distribution of top-level NACE codes across the set of business addresses.

Figure 8: Fraction of addresses per top-level NACE code



2.2 Business address database to building database

The GeoBusiness address database was converted into a building database using the full addresses of all businesses. Based on the GeoBusiness database, there are 141,692 buildings, including 116,886 single occupancy and 24,806 multiple[2] occupancy, for 199,565 businesses. The county-level distribution of buildings is different from the county-level distribution of addresses, resulting largely from the fact that Dublin has a significantly higher proportion of businesses sharing a single address than other counties (see the Appendix for the fraction of addresses and buildings by county).

At a national level, the building purpose profile (commercial only or commercial and residential) is not significantly altered in the transition from the business address database to the building database. However, the proportion of addresses corresponding to multiple occupancy buildings is, of course, different from the proportion of multiple occupancy buildings; this is shown in Figure 9. Examining the multiple occupancy premises, it is interesting to note that most (59%) are occupied by two businesses, while 10% are occupied by six or more businesses (Figure 10).

Figure 9: Fraction of addresses and buildings by building use and building occupier

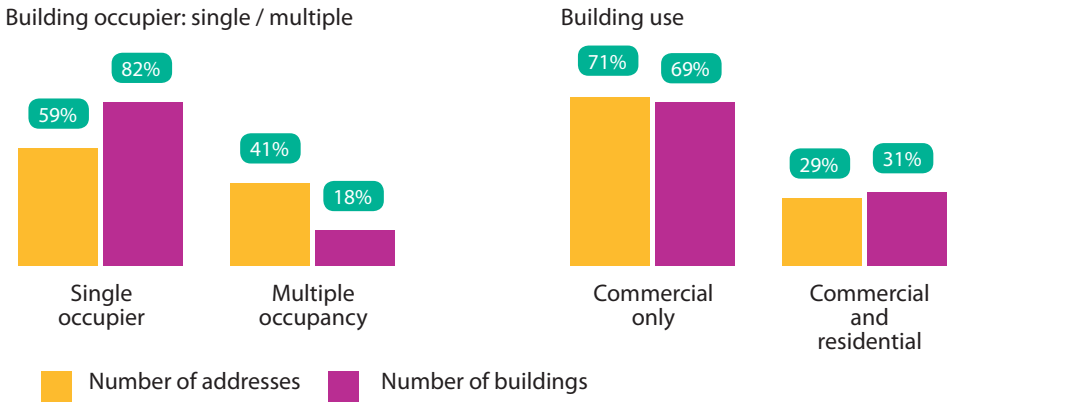
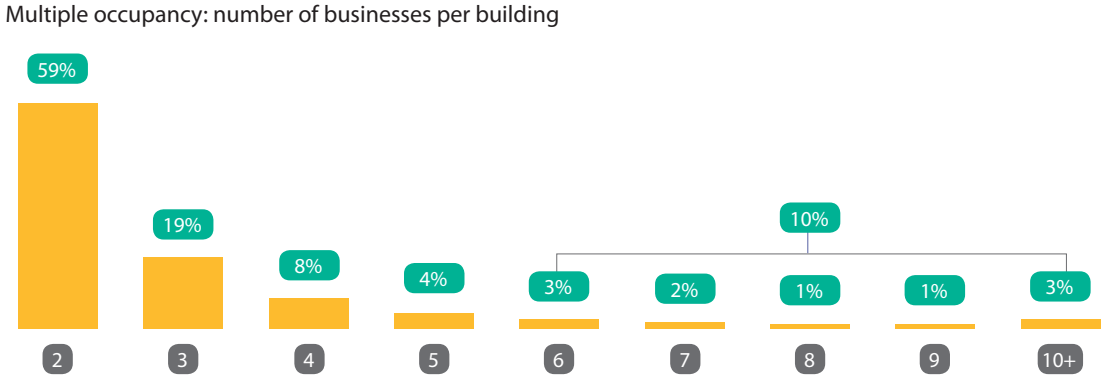


Figure 10: Number of businesses per multiple occupancy building



2 Approximately 180 multiple occupancy buildings with issues such as overlapping addresses or addresses lacking specificity were removed.

2.3 Development of a target database

In the case of single occupancy buildings, the building population was reduced by removing buildings for which there was no NACE code for the associated business (7,350 buildings) or which were marked as vacant, and by excluding any business from the following sectors:

- agriculture, mining, and electricity supply
- activities of religious organisations (exempt from BER due to limited efficiency potential)
- water supply (examined separately in the Public Utilities sector)
- industrial processes (examined separately in the Industry sector)
- public buildings (examined separately in the Public sector).

In total, 31,873 buildings were removed from this population resulting in a reduction of single occupancy buildings from 116,886 to 85,013 buildings.

For the purpose of this study, a limited set of representative building activity types (archetypes) was required in order to ensure a tractable modelling process. Based on a preliminary analysis and a literature review, five building activity types were identified, namely Office, Retail, Hotel, Restaurant / public house, and Warehouse (for further details see Section 3).

As shown in Table 1, the buildings database was therefore classified using six high-level sector definitions, each of which are linked to sets of NACE codes expected to correspond reasonably closely with the desired building activity types. This process was used to maximise the likelihood that buildings of the required activity type would be captured in the sample. A total of 82% of these buildings (69,936) were linked to six high-level commercial sectors as defined in Table 1. Other commercial buildings (~15,000), which are highly diverse and cannot be matched with the main activity types, were not included in the target database so as to ensure the best possible representation of the archetypes to be modelled.

Table 1: High-level commercial sectors identified based on NACE codes

Sectors	NACE codes included	% of eligible single occupancy commercial buildings with NACE codes
Retail	4510–4799 9602	31%
Hotel	5510–5520 5590	7%
Restaurant / public house	5610–5630	11%
Office	5810–7120 7310–8299	17%
Construction	4100–4399	12%
Transportation / storage	4900–5320	4%
Total		82%

In the case of multiple occupancy buildings, the reduction from the population was more complex since buildings were considered valid for surveying if at least one occupant had a valid NACE code and was not excluded based on sector. From a starting point of 24,806 multiple occupancy buildings, a total of 2,861 buildings were excluded by removing buildings for which there was no NACE code (349) and by excluding any business from the excluded sectors (2,512). Out of 21,945 multiple occupancy buildings, 20,287 were linked to the six high-level commercial sectors (~92% coverage). Considering both the single occupancy and multiple occupancy buildings, over 90,000 buildings were included in the target database.

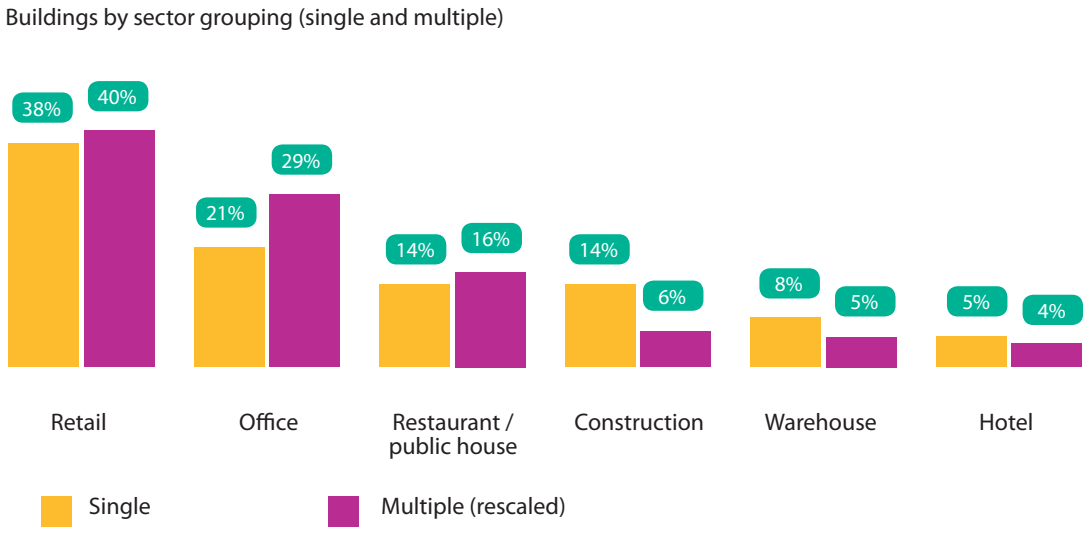
The target sample retained a similar distribution in terms of building use and occupancy as the full buildings database, and also showed a similar distribution in the number of businesses in the multiple occupancy buildings. The proportion of single and multiple occupancy buildings is approximately uniform across most counties. The main exception to this is Dublin, where multiple occupancy buildings are much more common. This effect is less pronounced in other counties with major cities, such as Cork and Galway (see the Appendix for further information).

Sector distribution in the target database

Analysing the sector distribution across single occupancy buildings, it is clear that retail buildings dominate, comprising 37.9% of the buildings, with offices comprising 20.5% and construction buildings comprising 13.9%.

The analysis of the sector distribution of the multiple occupancy buildings requires additional calculation, as one multiple occupancy building may be attributed to multiple sectors. For that reason, the sum of the fractions of multiple occupancy buildings attributed to each sector is greater than 100%. For sampling purposes, the sector distribution among the target database was rescaled to a total of 100%, as shown in Figure 11. The dominance of retail is again clear, with 58.5% of multiple occupancy buildings containing one or more retail business.

Figure 11: Single and multiple occupancy buildings by sector in the target database



Analysing the combinations of sectors within multiple occupancy buildings, 61.9% of buildings contain eligible businesses from only one sector. It should be noted that these buildings could include other businesses from excluded sectors. Among this group of single sector buildings, buildings devoted exclusively to retail are the most common (30.4% of all buildings in the target database) with buildings devoted exclusively to office activity also common (20.2%). Not surprisingly given the overall predominance of these two sectors, the most common combination of sectors is office and retail (11% of all multiple occupancy buildings). The next most common combination is retail and restaurant / public house (see the Appendix for further information).

Across single and multiple occupancy buildings for the largest sectors (retail and office), there is a consistent mix between commercial only and commercial and residential buildings. However, as expected, different patterns emerge for other sectors, reflecting the specific attributes of those sectors. For example, in the case of single occupancy hotels, a high share of commercial and residential buildings (40%) reflects the existence of bed-and-breakfast type businesses within this sector.

Table 2: Fraction of buildings by sector, building use and occupier in the target database

	Single		Multiple	
	Commercial only	Commercial and residential	Commercial only	Commercial and residential
Office	69%	31%	77%	23%
Restaurant / public house	66%	34%	71%	29%
Hotel	60%	40%	66%	34%
Retail	72%	28%	74%	26%
Transportation / storage	65%	35%	76%	24%
Construction	59%	41%	73%	27%

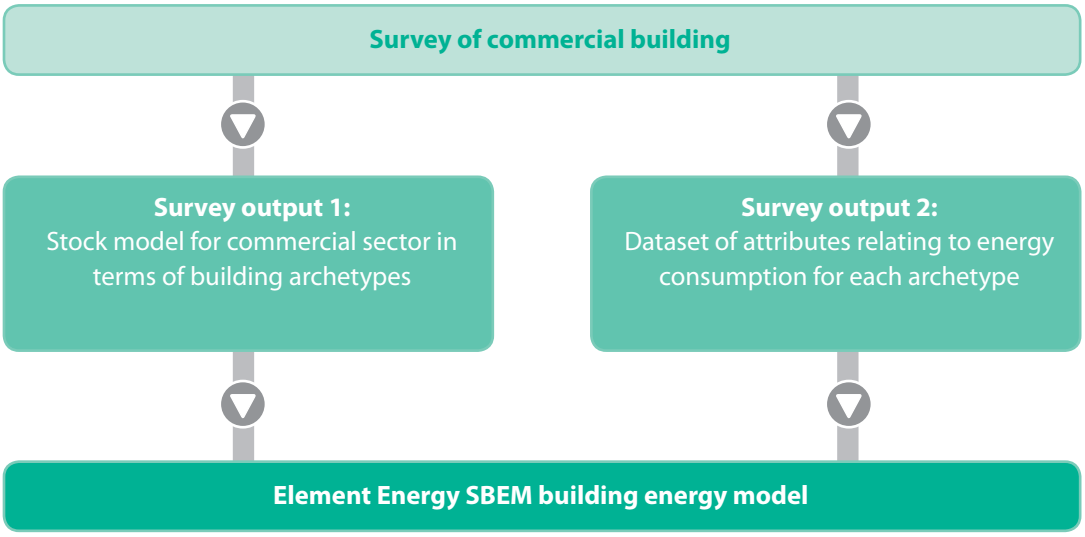
Sampling was carried out using the target database to complete 1,500 responses representative of the relevant sectors. In order to achieve this, commercial buildings from 26 locations distributed across Ireland were selected. The survey sample was structured, in general, to reflect the profile of the target database in terms of sector, building use (commercial, or commercial and residential) and building type (single occupancy or multiple occupancy). In the sampling process, however, it was ensured that sufficient data points were collected for all sectors identified so that the sample was statistically representative for each sector. The number of hotels, Transportation / storage buildings and construction buildings in the survey sample was therefore inflated relative to the proportions in the target database. This is explained in more detail in Section 4.

3 Survey design

The survey was required to provide two key datasets towards an estimate of potential energy savings in the commercial sector (Figure 12). First, the survey was required to provide a representative model of the Irish commercial buildings stock in terms of building activity types. Second, the survey was required to collect a dataset of attributes relating to energy use in those buildings to be used to populate the SBEM building energy model.

This section describes how the design of the survey ensured that both of those requirements were fulfilled with the lowest level of risk and the highest level of consistency possible within the project constraints.

Figure 12: Survey outputs needed for Element Energy SBEM model



3.1 Survey output 1: Profile of the commercial buildings stock

The first required output of the survey was a description of the commercial buildings stock in terms of building activity types. In order to design the survey to collect the building activity type data in the most reliable and efficient manner, it was first necessary to obtain an approximate description of the building stock using the best available data. A review of the available literature and data sources was carried out for this purpose.

Available data on the commercial buildings stock

The commercial sector is highly diverse, and statistical data on the nature of the commercial buildings stock is rarely collected. Reliable data on the profile of the commercial buildings stock in Ireland is thus not available. Indeed, this work was commissioned in part to address that data gap. The same data gap exists to almost the same degree in the UK. Nonetheless, a few previous studies have collected data on the commercial buildings stock in the UK. These studies allow us to identify, to a first approximation, the likely structure of the commercial buildings stock in Ireland in terms of building activity types.

Previous studies of the commercial buildings stock in the UK include datasets constructed by Sheffield Hallam University[3] in the 1990s and, more recently, work undertaken for the CaRB and N-DEEM projects. In addition, as part of energy modelling work in the non-domestic sector in Ireland, KEMA[4] and AECOM[5] have defined their own commercial buildings activity types. The building activity types suggested by these studies were compared with the main data source available on commercial buildings in Ireland, namely the non-domestic building energy rating (ND-BER) database. The ND-BER database, made available to the project team by SEAI, is a source of data on over 10,000 non-domestic buildings in Ireland, collected through the ND-BER assessments. The frequency of building types within the database cannot be considered representative of the national commercial stock due to the selection bias of the ND-BER assessments, but provides a useful first approximation.

For the purpose of this study, a limited set of representative building activity types was required in order to ensure a tractable modelling process and a resulting dataset with meaningful implications for policy design. It was found that the ND-BER database could be well-represented by five main building activity types:

- Office
- Retail
- Hotel
- Restaurant / public house
- Warehouse.

There is a close correspondence between these activity types and those defined in the literature studies listed above, lending strong support to our approach. These five activity types were therefore selected to form the basis of the representation of the commercial stock to be modelled in this study.

3 Mortimer N. D., Elsayed A. M., Grant J. F., 2000. 'Detailed energy surveys of non-domestic buildings'. Environment and Planning B: Planning and Design 2725–32.

4 KEMA, 2008. 'Demand side management in Ireland: evaluating the energy efficiency opportunities'. Report for SEAI.

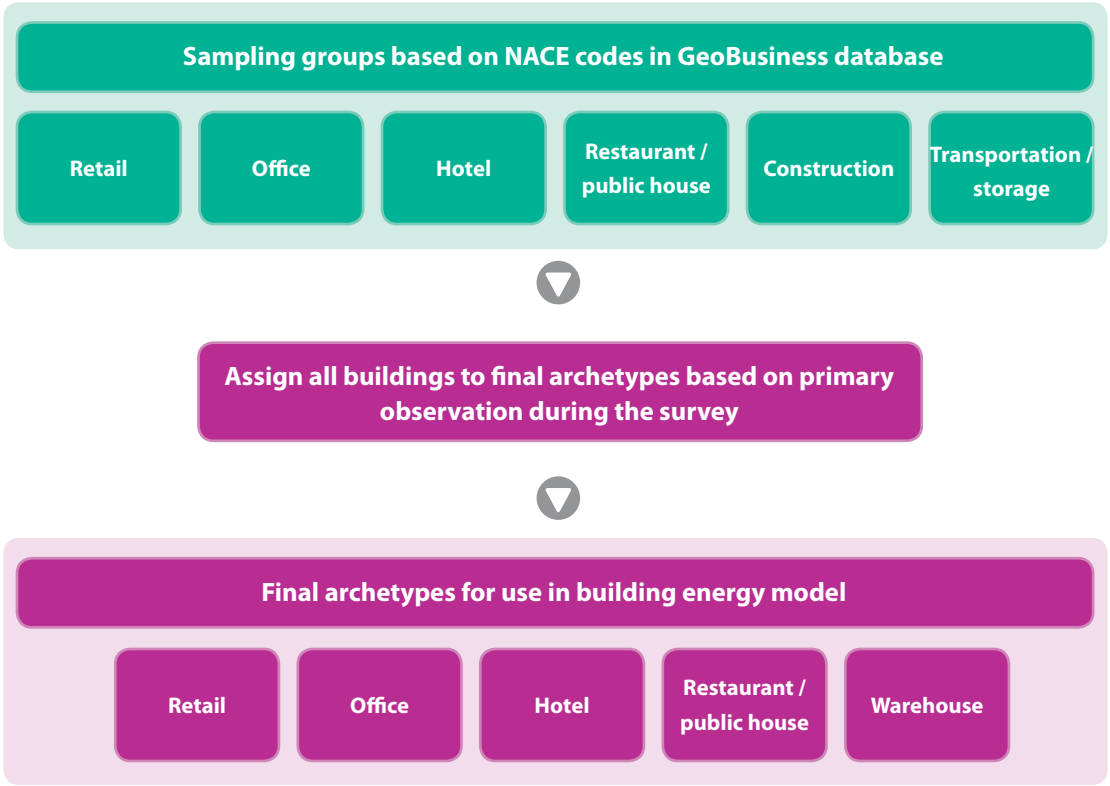
5 AECOM, 2013. 'Report on the development of cost-optimal calculations and gap analysis for buildings in Ireland under Directive 2010/31/EU on the Energy Performance of Buildings (Re-cast): Section 2 – Non-residential'. Report for SEAI.

Implications for survey design

As detailed in Section 2, the GeoBusiness database identifies buildings by NACE code. As described in that section, it was possible to use the NACE codes to form sampling groups expected to correspond reasonably closely with the desired building activity types in the cases of Retail, Office, Hotel and Restaurant / public house. This process maximised the likelihood that buildings of the required activity types would be captured in the survey sample. Warehouses, by contrast, were expected to be distributed across a variety of NACE code groups, and could not be identified in advance of the fieldwork.

In order to determine with accuracy the activity type of the surveyed buildings in terms of the five desired activity types, a question was added to the survey in which the surveyor identified the most appropriate activity type for the building in question. In this way, a 'map' between NACE code sampling groups and building activity types was constructed. This process is illustrated in Figure 13. The results of this mapping will be given in Section 5.

Figure 13: Map between NACE code sectors and building activity types



3.2 Survey output 2: Dataset of attributes relating to energy use to populate the SBEM building energy model

The second requirement of the survey was to gather additional data to populate the Element Energy SBEM-based energy model. SBEM is a model that provides an analysis of a building's energy consumption, and is an officially recognised procedure used to demonstrate compliance with the building regulations in Ireland and other EU member states. It is the procedure used in the non-domestic BER (ND-BER) assessments in Ireland.

Figure 14: Illustration of the SBEM model methodology

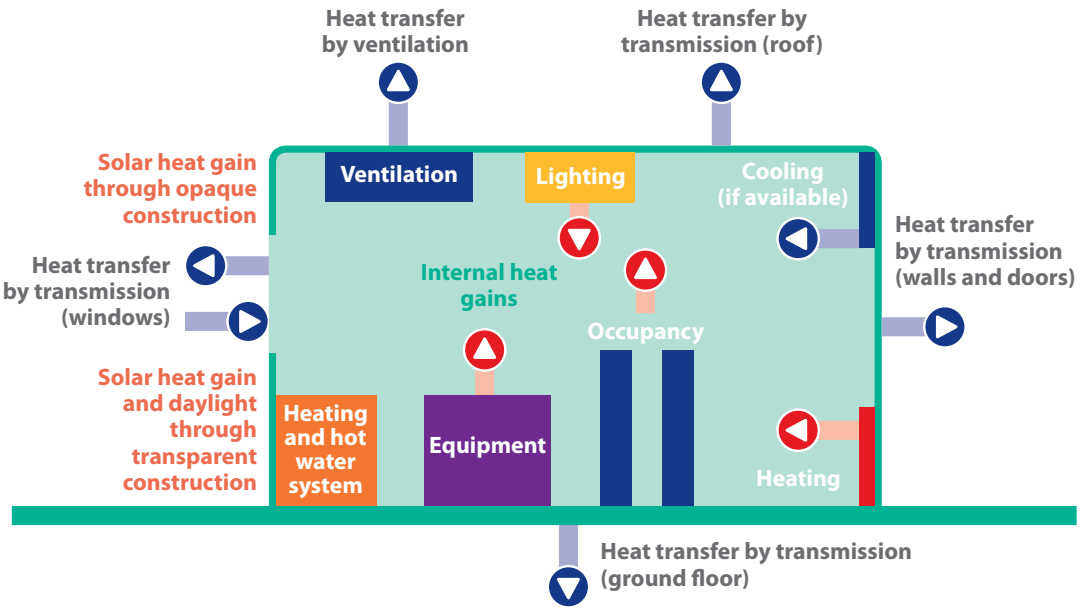
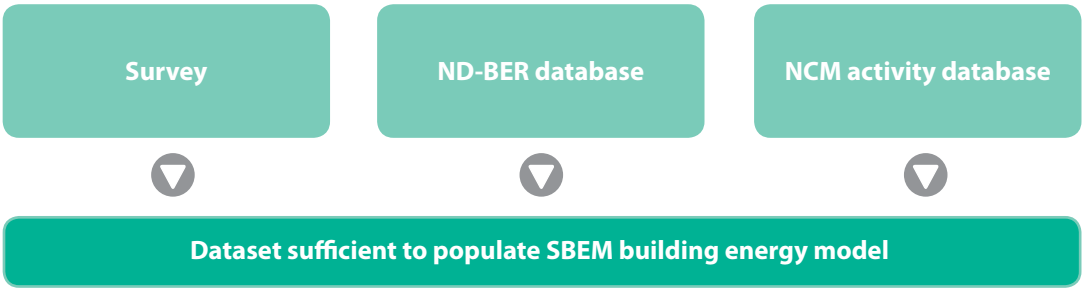


Figure 14 illustrates the calculation process in the SBEM model. The model requires a detailed input dataset, including a description of the building fabric properties, geometry, activity, HVAC system, lighting systems, space heating, cooling, ventilation, lighting, equipment, hot water and auxiliary energy demand, solar irradiance and weather data in Ireland, among other properties.

In order to maximise the likelihood of high response and completion rates, it was necessary to design the survey to an appropriate level of technical detail and an appropriate length. Much of the data required for the SBEM model can be collected quickly by a qualified surveyor, and was thus suitable for collection in the present survey. Such data includes the building geometry, the wall type and details of the building services. However, collecting other items of data, such as the building infiltration rate and the fabric U-values, is not feasible in this case as it involves a significantly lengthier measurement process.

The solution chosen was to combine three datasets: the survey data, the ND-BER database and the National Calculation Methodology (NCM) activity database (Figure 15). The ND-BER and NCM activity datasets were linked to the survey dataset through a number of key variables common to each source, including the building activity type, building size (floor area), heating fuel, HVAC type and variables related to the fabric condition. In this way, the variables that could not be collected through the survey could be 'imputed' for each building archetype in the commercial stock.

Figure 15: Data sources used to populate SBEM building energy model



A detailed version of the ND-BER database was made available to the project team by SEAI. It includes data on the building fabric, energy services and energy consumption of over 10,000 non-domestic buildings in Ireland, and includes U-values of building elements and building infiltration rates. The database cannot be considered representative of buildings across the national commercial stock due to the selection bias of the ND-BER assessments. However, the approach of linking the buildings in the ND-BER database with the commercial building archetypes derived through the survey enabled us to make use of the data available.

The NCM activity database[6] is a set of standard data relating to occupancy and energy service demand in non-domestic buildings, and is the officially recognised database used with SBEM to demonstrate compliance with building regulations. It contains standard schedules of, for example, building occupancy, temperature set points, and lighting demand and ventilation requirements. Data is available for a variety of building activity types and hence can be linked directly to the surveyed buildings.

6 The UK National Calculation Methodology (NCM) has been adapted for use in Ireland to reflect requirements in Ireland, including building regulations, construction practices, weather, BER and advisory report requirements. The activity database for Ireland is available at: http://www.seai.ie/Your_Building/BER/Non_Domestic_buildings/Download_SBEM_Software/Download_SBEM_Software.html

The survey questions were then designed to capture the most important data deemed feasible to collect, including the data required to link the surveyed buildings with the buildings in the ND-BER and NCM databases, and the data not available in either of those sources. The data chosen to be collected through the survey is shown in Table 3.

Table 3: Summary of data gathered in survey

Category	Data gathered in survey
Profile	Building activity type Commercial only or commercial / residential Building type (e.g. terraced, detached) Building age
Geometry	Building size (floor area) Number of storeys Building height Glazed fraction of walls
Fabric	Fraction of double glazing Wall type
Energy services	Primary heating fuel HVAC type Boiler age Heating controls Existence of heat pump Fraction of low-energy lighting Lighting controls
Other	Listed / heritage status Occupancy

4 Survey response profile

The project target was to achieve 1,500 responses representative of the selected sectors (i.e. NACE code groups). In order to achieve this efficiently and within the project timeline, a total of 26 locations distributed across Ireland were selected. Each of these locations had a quota of buildings with identified business respondents (one per building) associated with them, and each of these quotas was structured to reflect the overall profile of the target database in terms of sector, building use (commercial / commercial and residential), and building type (single occupancy / multiple occupancy).

The quotas were specified in order that they would aggregate to the national profile as well as approximately reflect local distributions. Quotas for hotels, transport and storage, and construction were inflated over the proportions in the target database in order to provide a sufficient base of responses for these sectors to ensure statistically representative samples for modelling purposes.

While the quotas could be controlled to a large degree, as the surveyors were instructed on which buildings to visit, variation was introduced in the following scenarios:

- if the occupant of a particular building declined to participate in the survey
- if the business of the selected occupant was no longer operating from the building
- if the building had become vacant subsequent to the most recent update of the data source (the GeoBusiness database).

For each of these cases, a series of rules was established in order to maintain the random selection process and ensure that the sample for each sector remained representative. For example, when any of the above scenarios occurred in the case of retail and office buildings, surveyors were instructed to go instead to the closest building occupied by a business of any one of the eligible sectors. In the case of less common sectors, such as hotels, surveyors were asked to find another hotel in the location, when this was possible.

In total, approximately 22% of the buildings identified from the GeoBusiness database could not be surveyed for one or more of the reasons above. The replacement sampling, as described above, brought the number of buildings surveyed to 1,354. To make up the remainder, a further 146 surveys of 'free-find' buildings within the eligible sectors were carried out, resulting in the completion of 1,500 site visits on schedule.

Fieldwork experience

Fieldworkers for this project were selected on the basis of their construction and engineering expertise and were trained to conduct an interview with the manager of the business. The role of the surveyor was to gather independently, as far as was possible, all the quantitative metrics identified, and to interview the manager of the premises to gather the metrics that were not apparent and visible to the surveyor. The surveyors reported high levels of co-operation from the commercial sector. While there was a total of 22% non-responses across the original sample, a large proportion of these were buildings where the business was no longer in operation,

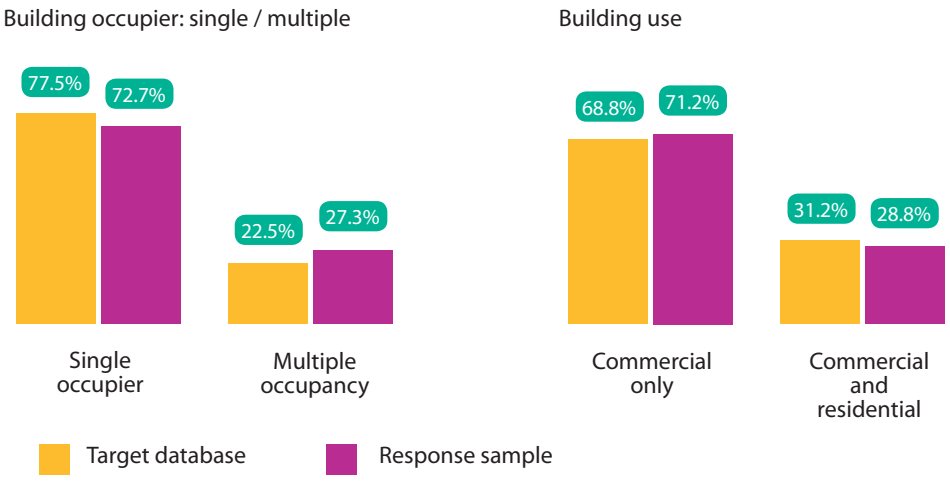
where the resident company had changed and did not qualify in terms of eligibility, or where the manager of the business was not present and the other employees did not feel qualified to provide a response. While the project did not separately identify the actual 'refusal' category, it was estimated to be 5% at point of visit. This represents a very satisfactory response rate, particularly since, because of the complexities of sample selection, the survey was not preceded by a letter or other communication (the letter of introduction was presented at the point of interview).

The surveyors reported a positive reception from the respondents and a willingness to participate and provide the relevant information. Consistent with other research, it is clear that the commercial sector (and particularly the small and medium-sized enterprise sector) is under pressure in terms of time and available resources. Nevertheless, during the interview, the information needed for the survey was willingly imparted and the tone of the responses was co-operative.

Comparison of response sample with target database

The response sample shows similar patterns to the target database with respect to the mix of commercial only or commercial and residential building use, and similar patterns to the target database with respect to the mix of single occupancy and multiple occupancy buildings, with only a slightly reduced proportion of single occupancy buildings in the response sample (Figure 16).

Figure 16: Building use and occupier in the response sample



Among single occupancy buildings, the distribution of sectors is also similar to that in the target database (Figure 17). Among multiple occupancy buildings, the variation is slightly greater (Figure 18). The higher proportion of hotels in the response sample for multiple occupancy buildings reflects the inflated quota, designed to ensure that there was sufficient representation of this sector to support modelling. The other notable attribute of the response sample for multiple occupancy buildings is the higher proportion of retail and the lower proportion of offices. However, the variation from the target database is not statistically significant overall, given that it occurs only in a sub-population (multiple occupancy buildings, corresponding to 27.3% of the response sample overall). Overall, there is a difference of less than 2% between the target and response samples. On this basis, it is reasonable to conclude that the response sample is representative of the target database.

Figure 17: Single occupancy buildings by sector in the response sample

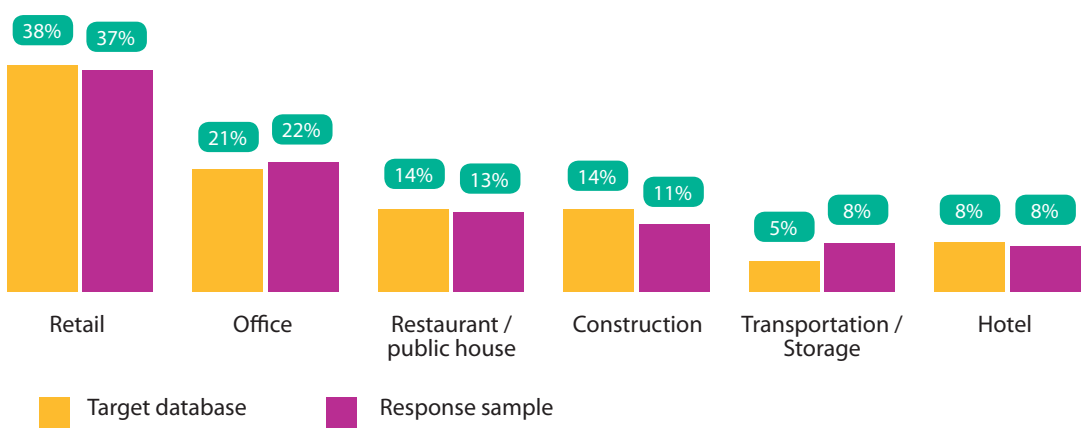
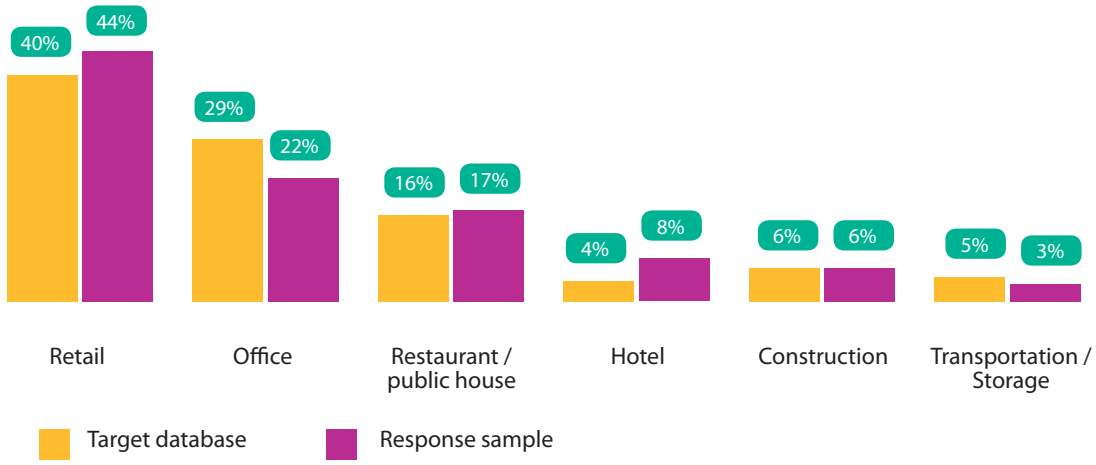


Figure 18: Multiple occupancy buildings by sector in the response sample



5 Derivation of the Irish commercial buildings stock

Building activity in the target database

As explained in Section 2, the target database covers around 90,000 buildings. This includes ~6,600 buildings in the hotel sector. In the GeoBusiness database, the buildings included in the hotel sector include around 5,000 buildings in the 'other accommodation' NACE group. Although commercial buildings such as hostels and bed-and-breakfasts are described as 'other accommodation', these buildings also include boarding houses (residential) and school dormitories (public). Therefore, an independent source was required to determine the share of the 'other accommodation' that should be included in the commercial sector. Fáilte Ireland's 'Accommodation Capacity 2013' report presents recent figures for the total number of commercial accommodation premises in Ireland. Based on this recent report, the total number of commercial buildings in the hotel sector is assumed to be ~3,000 with around 800 large buildings[7].

Table 4: Results of mapping between NACE code sectors and building activity types

Sector in the target database	Number of buildings in the target database (1,000s)	Building activity type based on survey results (%)				
		Hotel	Office	Restaurant / public house	Retail	Warehouse
Construction	11.0	–	85%	–	4%	12%
Hotel	3.01[7]	91%	4%	4%	–	–
Office	20.2	–	89%	–	7%	4%
Restaurant / public house	13.0	1%	2%	94%	4%	–
Retail	34.7	–	8%	2%	83%	7%
Transportation / storage	4.7	–	64%	–	5%	31%

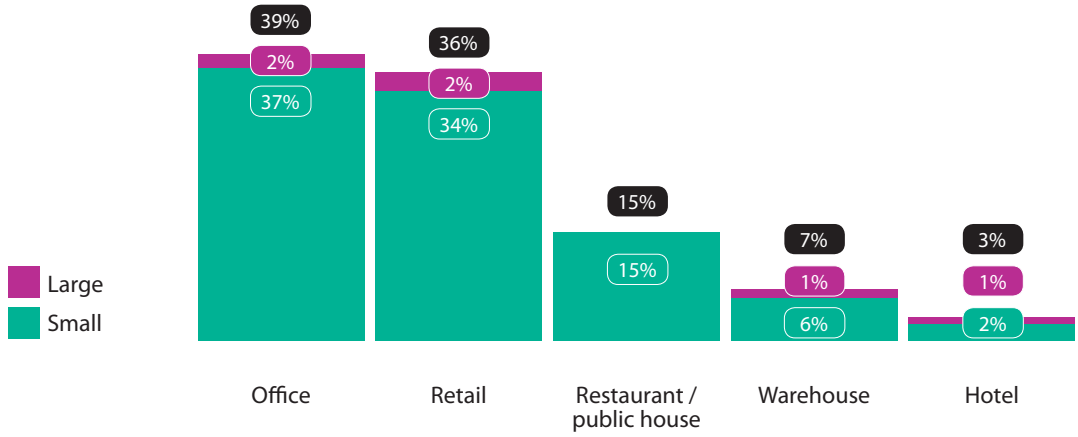
As described in Section 3, all buildings in the NACE code sampling groups were assigned to final building activity types based on an observation of building activity type made during the survey. The 'map' between NACE code groups and building activity types is shown in Table 4. The survey observations suggest that buildings in the construction and Transportation / storage sectors are predominantly office buildings. Although it was not possible to identify warehouses based on NACE code groups before the survey, a number of warehouses were identified within the construction, office, retail and Transportation / storage sectors. Figure 19 presents the overall percentage breakdown of buildings surveyed by activity type and building size[8].

7 Fáilte Ireland, 2013, 'Accommodation Capacity 2013'.

8 All buildings over 1,000 m2 are classified as 'large'.

Figure 19: Percentage of buildings by activity type in the target database

Building activity type in the target database based on survey results



Commercial buildings stock in Ireland

As explained in Section 2, 24,523 single occupancy and 2,512 multiple occupancy buildings were identified as belonging to the excluded sectors in the GeoBusiness database. Removing an additional 3,563 buildings in the hotel sector (those identified as public or residential buildings as described above), the total number of buildings in the excluded sectors adds up to ~30,600. In addition to that, ~7,700 buildings were identified for which there was no NACE code. Therefore, out of 141,692 buildings in the GeoBusiness database, around 103,395 buildings are identified as commercial buildings based on NACE codes.

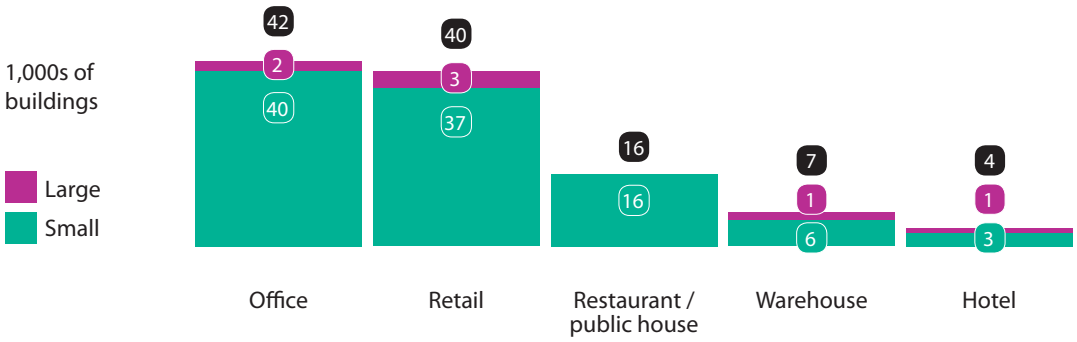
Table 5: Number of buildings in the GeoBusiness database

	Number of buildings in the GeoBusiness database (1,000s)
Commercial buildings identified using NACE codes	103.4
Buildings from the excluded sectors	30.6
Total number of buildings with NACE codes	134.0
Buildings without NACE code	7.7
Total number of buildings in GeoBusiness	141.7

It is not possible, however, to identify how many of the buildings within the 'no NACE code' group are commercial buildings. 77% of the buildings with NACE code are identified as commercial buildings. Applying the same ratio (77%), it is estimated that ~6,000 of the 'no NACE code' buildings are commercial buildings. With the addition of these 'no NACE code' buildings, the total number of commercial buildings in Ireland is therefore estimated to be ~109,300. Multiplying this figure with the percentage of each building activity type shown in Figure 19, the total number of each building activity type within the commercial stock is derived. The resulting model of the Irish commercial buildings stock is presented in Figure 20.

Figure 20: Model of the Irish commercial buildings stock by activity type and size

Number of commercial buildings in Ireland (Total = ~ 109,000)



6 Key survey results

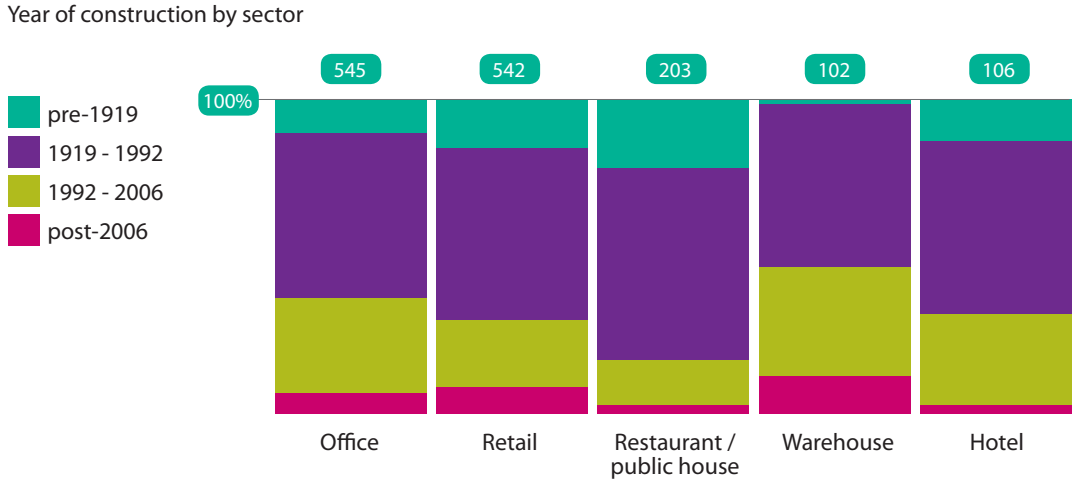
This section presents a selection of more detailed results from the survey, offering an insight into the characteristics of the Republic of Ireland's commercial buildings stock. In Section 5, the derivation of the commercial buildings stock was presented in terms of the five building activity types: Office, Retail, Restaurant / public house, Warehouse and Hotel. In the following, further survey data is presented which highlights the variation of building attributes across the five activity types. It should be noted that in the presentation of the results of each question, only buildings for which a response was received are included.

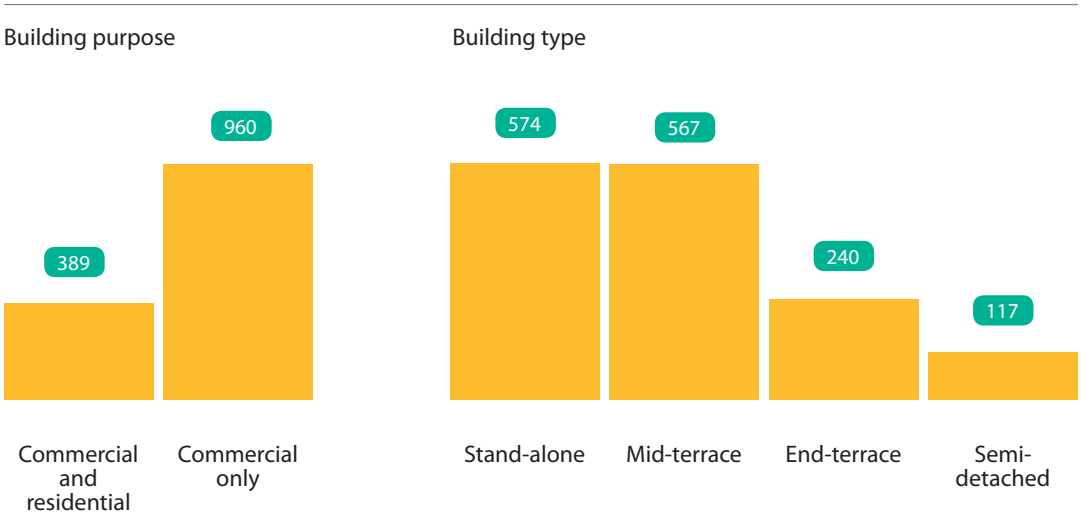
Building profile variables

During the survey, the year of construction of each building was estimated and assigned to one of four date ranges. As shown in Figure 21, more than half of the buildings surveyed were assigned to the range 1919–1992. Buildings constructed before 1919 made up just over 10% of the surveyed buildings. It is notable that the warehouse sector contains the largest share of post-2006 buildings, and the lowest share of pre-1919 buildings. The variation in the age profile of buildings across the other activity types is relatively weak.

It was possible to determine, using the GeoBusiness database, whether the building was used for commercial purposes only or for both commercial and residential purposes. This information was required in order to avoid including floor area used for residential premises in the commercial sector energy consumption model. Although not strictly a result of the survey, this data is shown here next to the other building profile data. Of the buildings surveyed, almost one third were mixed purpose, of which the majority were found to be office or retail buildings. As part of the survey, it was also determined whether the building was stand-alone, semi-detached or terraced. This information was used in the building energy model to ensure proper treatment of heat loss through the building fabric. Around one third of the buildings surveyed were found to be stand-alone, another third mid-terrace and the remaining third end-terrace or semi-detached.

Figure 21: Survey results for selected building profile variables



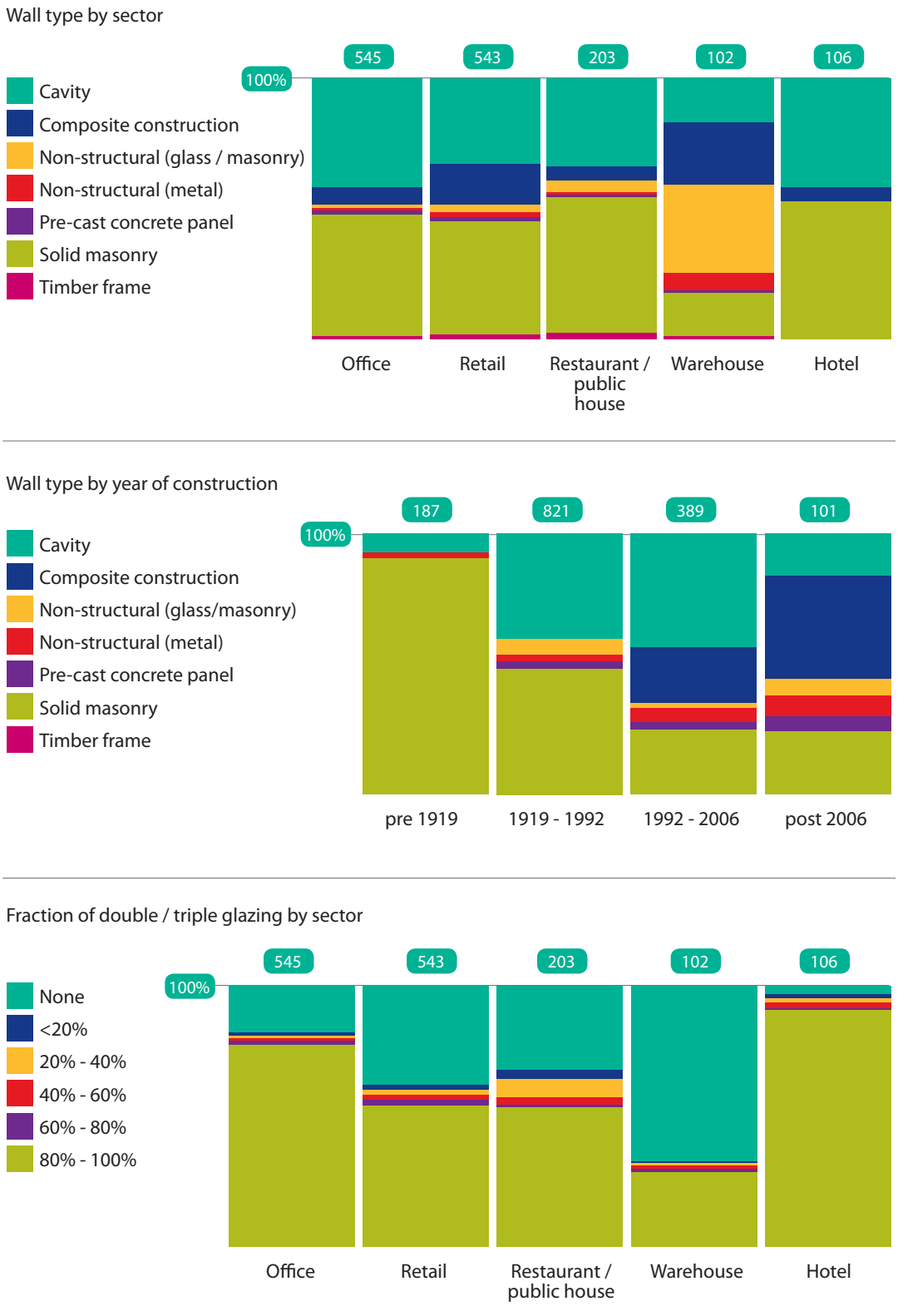


Building fabric

The surveyors were instructed to identify the wall type for each building visited. As shown in Figure 22, the most common wall type was found to be solid masonry wall, making up nearly half of the buildings surveyed. More than one third of the buildings were found to have cavity walls. With the exception of warehouses, in which a high proportion of non-structural walls were observed, the variation in wall type across the building activity types is relatively weak. Rather, the wall types observed reflect the age profile of the buildings included in the survey. As expected, a large majority (91%) of the buildings built before 1919 have solid masonry walls. Solid masonry walls were found to be present in a lower fraction of buildings built between 1919 and 1992, and in a lower fraction still of buildings built after 1992. Cavity walls were found to be significantly more common in both the 1919–1992 and 1992–2006 cohorts, with composite construction the most common construction type in the post-2006 cohort.

The surveyors were also instructed to report the fraction of windows that were double- or triple-glazed. For this attribute, a significant variation was observed across the building activity types. It was found that in almost all hotels surveyed (91%), 80–100% of the windows are double- or triple-glazed. This fraction was 78% for offices, and only 54% for both retail premises and restaurants / public houses. It is noted that more than 90% of buildings had either 80–100% double / triple glazing or none at all. This suggests that, as may be expected, double- or triple-glazing tends to be installed simultaneously across the whole building rather than in a piecemeal fashion.

Figure 22: Survey results for selected building fabric variables

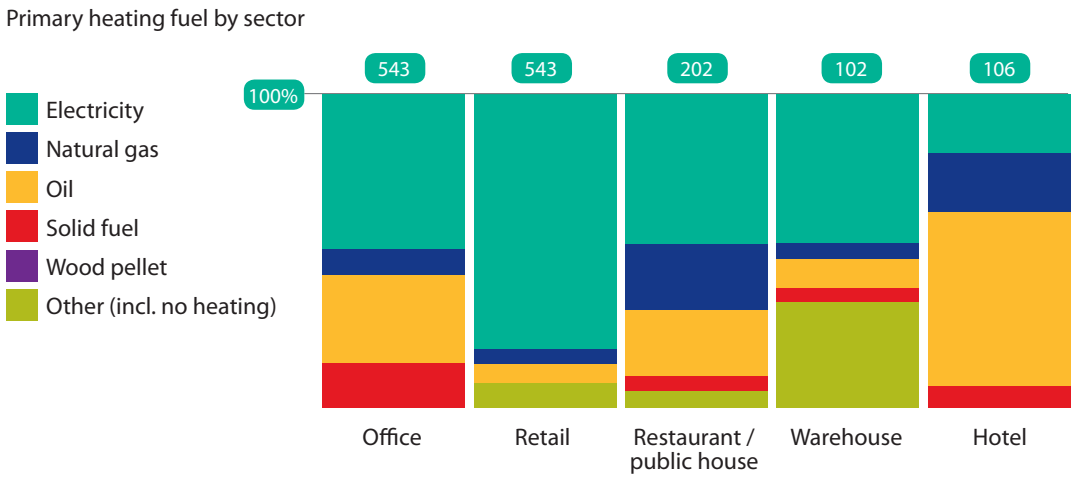


Building energy services

The surveyor was instructed to identify the primary heating fuel in each building visited. It may be expected that, in some buildings, multiple fuels are used in different zones of the building. For the purposes of the current study, the surveyor was instructed to identify the primary heating fuel of the largest accessible zone of the building (typically the main space of the ground floor). As shown in Figure 23, a wide variation in heating fuel was observed across the five building types. More than 80% of retail buildings are heated using electricity. In offices and restaurants / public houses, this fraction drops to approximately one half. The majority of the remaining offices and restaurants / public houses were heated by oil, natural gas or solid fuel. Hotels were heated predominantly by oil, with only a low share of electrical heating. Warehouses were mainly either electrically heated or unheated. It may be expected that the heating fuel would be correlated with the age of the building. A correlation between heating fuel and building age was observed, but it was seen to be fairly weak. Heating by oil is most common in post-1992 buildings and electrical heating is predominant in the newest and the oldest age categories.

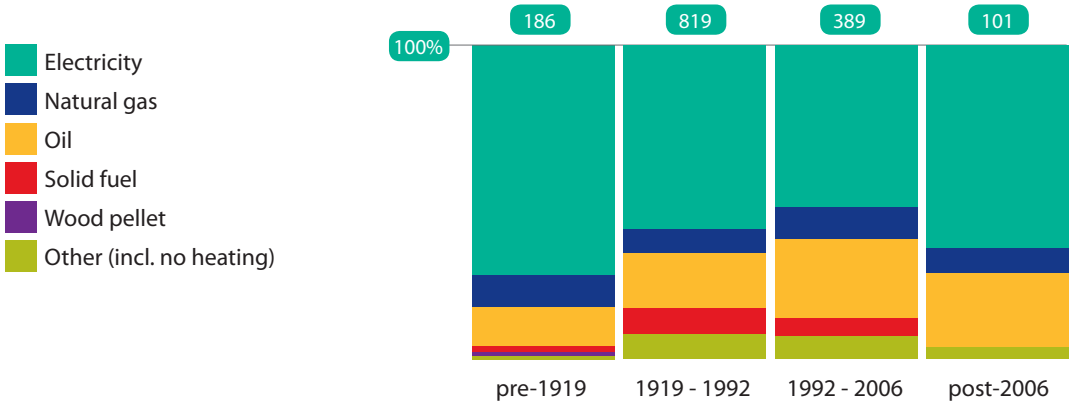
The survey also reported the HVAC type of the building. A low level of sophistication was observed in this metric, with almost half (49%) of buildings having heating only (no cooling) with natural ventilation. The highest share of heating and cooling was observed in restaurants / public houses (32%) and retail buildings (29%), and those building types also showed the highest incidence of mechanical ventilation. It is also notable that 68% of warehouses were identified as unheated[9].

Figure 23: Survey results for primary heating fuel and HVAC type

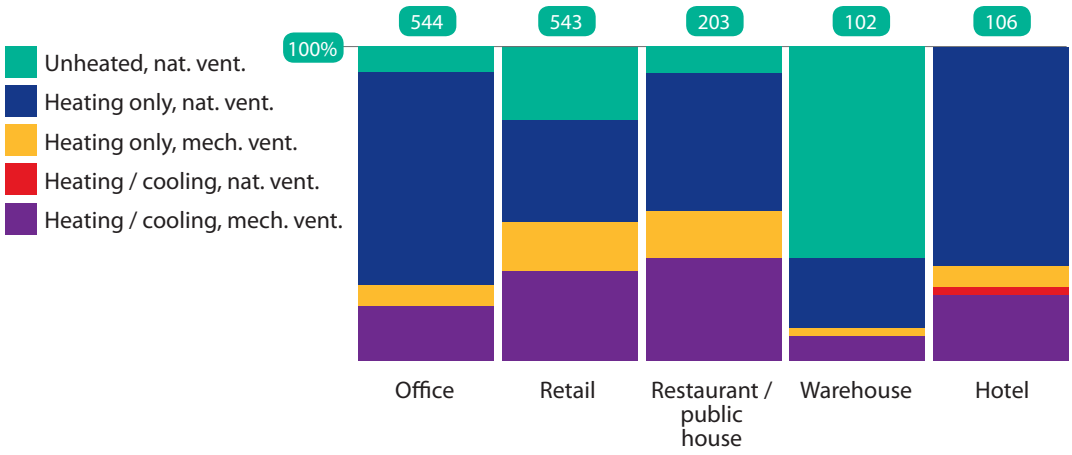


9 This is based on the fact that the largest accessible area was identified as unheated. This indicates that a number of the responses relating to the heating fuel in warehouses referred to secondary spaces within the warehouse building.

Primary heating fuel by year of construction



HVAC type by sector



The fraction of low-energy lighting in each building was reported. It should be noted that here, as with heating fuel and HVAC, the surveyor was instructed to base the report on the largest space accessible during the visit. As shown in Figure 24, it was found that 38% of all buildings are fitted with at least 80% low-energy lighting, but that 27% are fitted with <20% low-energy lighting. This suggests that there remains significant potential for energy savings in this area. A moderate variation was observed between building activity types, with hotels having the largest share of buildings fitted with 80–100% low-energy lighting (47%) and restaurants / public houses having the lowest share along with warehouses (28% and 27% respectively). The survey also reported a low incidence of lighting controls, with only 10% of buildings reported to have automated controls, the remaining having manual on / off switches only.

Centralised time controls for heating were relatively common, being present in nearly half of the buildings surveyed. In contrast, room-by-room time and temperature controls were much less common, being present respectively in only 9% and 15% of surveyed buildings.

Figure 24: Survey results for the fraction of low-energy lighting and the presence of heating and lighting controls

7 Derivation of the energy demand in the commercial buildings sector

In Section 5, the derivation of the Irish commercial stock in terms of the five building activity types – Office, Retail, Restaurant / public house, Warehouse and Hotel – was explained. Section 6 presented further survey data on the building attributes across these five activity types. Here, we build on the findings from these sections and present the derivation of the energy demand in commercial buildings in Ireland.

Selection of archetypes based on coverage of final energy

Buildings visited in the survey were categorised based on building activity, size (floor area), HVAC type, heating fuel, wall type/condition, window condition, building type (detached or mid-terrace) and whether the building was commercial only or both commercial and residential.

In order to select the final archetypes, the energy consumption of each possible archetype was estimated based on the floor area from survey and the kWh/m^2 value from ND-BER. To achieve a set of archetypes representative of the whole sector, but few enough in number to permit meaningful insight and tractable modelling, a limited number of options were included for each category (see Table 6). Overall, 115 commercial building archetypes were selected based on total final energy, covering more than 80% of final energy and floor area for each sub-sector.

Table 6: Options used to categorise the commercial buildings surveyed

Category	Options for category
Building activity	Office, Retail, Hotel, Restaurant / public house, Warehouse
Size	Large (≥1,000 m^2) Small (<1,000 m^2), based on gross floor area
HVAC type	Heating only, natural ventilation Heating only, mechanical ventilation Heating and cooling, mechanical ventilation
Heating fuel	Grid-supplied electricity Natural gas Oil
Wall condition	Poor (≥0.6 W/m^{2}K) Good (<0.6 W/m^{2}K), using ND-BER database
Window condition	Poor (single glazing) Good (double/triple glazing)
Building type	Mid-terrace Detached
Purpose	Commercial only Commercial and residential

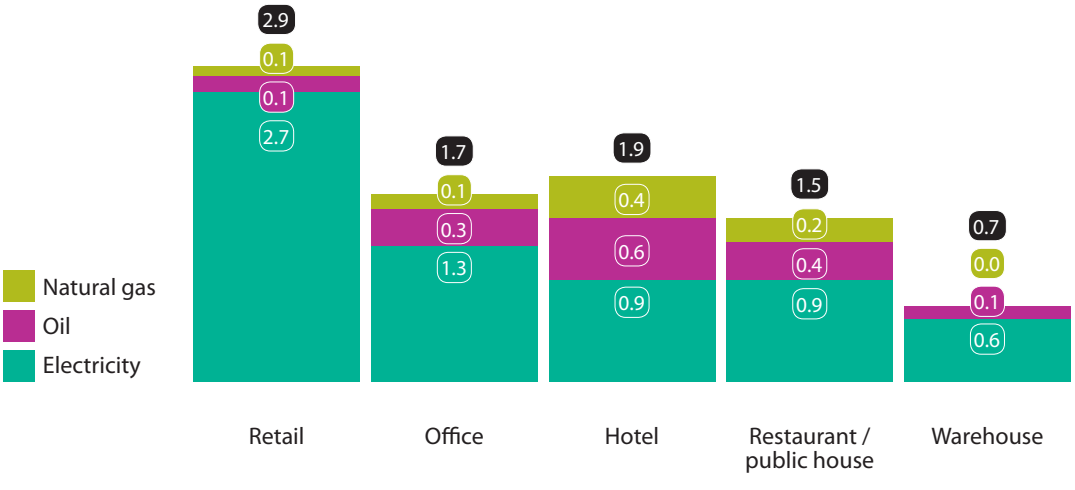
Energy demand in commercial buildings in Ireland

Detailed energy consumption of the final archetypes was calculated using the SBEM model, as explained in Section 3.2. Figure 25 shows the primary and final energy demand of the commercial buildings sector in Ireland by fuel and building activity.

Figure 25: Primary and final energy demand in the Irish commercial buildings sector

Primary energy demand by fuel type in the commercial buildings sector (Total = -18 TWh)

Final energy demand by fuel type in the commercial buildings sector (Total = ~9 TWh)



Modelling suggests that primary energy demand in the commercial buildings sector is around 18 TWh (~9 TWh in final energy). Among all sectors, Retail has the highest energy demand, at around 7 TWh. Retail is followed by Office, Hotel and Restaurant / public house, each having an energy demand varying from 2.9 to 3.6 TWh. Although the number of buildings in Hotel is small compared to other sectors, primary energy demand in this sector is comparable with Office, the sector with the largest number of buildings.

In terms of fuel consumption, electricity dominates the fuel demand of most of the sectors. For instance, electricity corresponds to more than 90% of the total final energy demand for retail buildings. In the other sectors, more than half of the final energy demand is electricity. The electricity fraction in Irish commercial buildings is high due to the high proportion of electrically heated buildings, as well as to high lighting and equipment consumption, and to cooling in some buildings. Hotels, on the other hand, have a relatively lower electricity fraction as the buildings are heated mainly by oil or gas.

8 Conclusion

In conclusion, primary research into the composition and energy consumption profile of the commercial buildings sector in Ireland has been successfully completed. This research represents a new body of information for Ireland. It has been undertaken with the direct aim of enabling a robust estimate of the potential for energy efficiency in the commercial sector. This work forms part of an ongoing study being led by Element Energy for SEAI to assess the potential for energy efficiency across the Irish economy to 2020. The findings of this study will be used to inform Ireland's national strategy to meet its ongoing obligations with respect to the Re-cast Energy Performance in Buildings and Energy Efficiency Directives.

In order to build a detailed profile of energy consumption in the commercial sector, it is important to understand the frequency of the types of building present and to gather data on the fabric of these buildings, their condition, the energy services present and their occupancy. To this end, a survey of commercial buildings was developed to provide two key outputs:

(i) a stock model for the Irish commercial buildings sector in terms of building activity archetypes

(ii) a detailed dataset relating to energy use in the commercial buildings sector for use in the building energy model.

The survey sample was based on GeoDirectory's GeoBusiness product, a database developed by An Post and Ordnance Survey Ireland, which contains all known business addresses in Ireland. The survey questions were designed to ensure that sufficiently detailed data could be collected to populate Element Energy's SBEM building energy model, but without putting at risk the likelihood of high response and completion rates during the survey. Surveyors qualified in construction and engineering were chosen to carry out the fieldwork and were trained by The Research Perspective before embarking on the survey. As a result of the careful design process and extensive training, the survey was highly successful on the doorstep. Surveyors reported a high level of co-operation and engagement, reflected in a very low refusal rate, estimated at 5% at point of contact.

The data obtained through the survey provides detailed insight into the commercial buildings stock and the potential for energy savings in the sector. The data portrays a relatively unsophisticated stock, with a high incidence of buildings in which relatively basic upgrades could lead to significant energy savings. For example, there was found to be significant remaining potential for low-energy lighting, lighting and heating controls and double- or triple-glazing. Another striking conclusion from the data is the high proportion of electrical heating in the commercial sector, making up 59% of the buildings surveyed. Buildings heated by oil make up much of the remainder.

Using the survey outputs, a set of representative commercial building archetypes was constructed and modelled using the Element Energy SBEM energy model in order to develop a detailed profile of energy consumption in the Irish commercial sector. Results suggest that final energy consumption in the commercial buildings sector is approximately 9 TWh, of which more than 6 TWh is electricity.

The survey results have also been used to carry out a detailed assessment of the technical potential for energy savings in the commercial sector. Details of the energy modelling process and the derivation of the energy savings potential are presented in *'Unlocking the Energy Efficiency Opportunity'*, SEAI (2015).

9 Appendix

Fraction of addresses and buildings by county

Table 7: Fraction of addresses and buildings by county

County	% of addresses in county (business address database)	% of addresses in county (buildings database)
Dublin	21.2	15.3
Cork	11.8	12.3
Galway	5.5	5.3
Limerick	4.5	4.7
Tipperary	4.2	4.9
Donegal	4.1	4.5
Meath	4.1	4.3
Kerry	3.9	4.4
Mayo	3.6	4.1
Kildare	3.4	3.3
Wexford	3.3	3.8
Louth	3.3	3.4
Clare	3.2	3.5
Wicklow	3.0	2.9
Waterford	2.7	2.8
Westmeath	2.5	2.6
Kilkenny	2.4	2.6
Cavan	2.1	2.4
Monaghan	2.0	2.4
Sligo	1.6	1.7
Laois	1.6	1.8
Roscommon	1.5	1.8
Offaly	1.5	1.7
Carlow	1.3	1.4
Longford	1.0	1.2
Leitrim	0.8	0.9

Comparison of GeoBusiness buildings database and target database

The target sample retained a similar distribution in terms of building use and occupancy as the full buildings database, and also showed a similar distribution in the number of businesses in the multiple occupancy buildings (as shown in Figures 26 and 27).

Figure 26: Number of buildings by building use and occupier in the target database

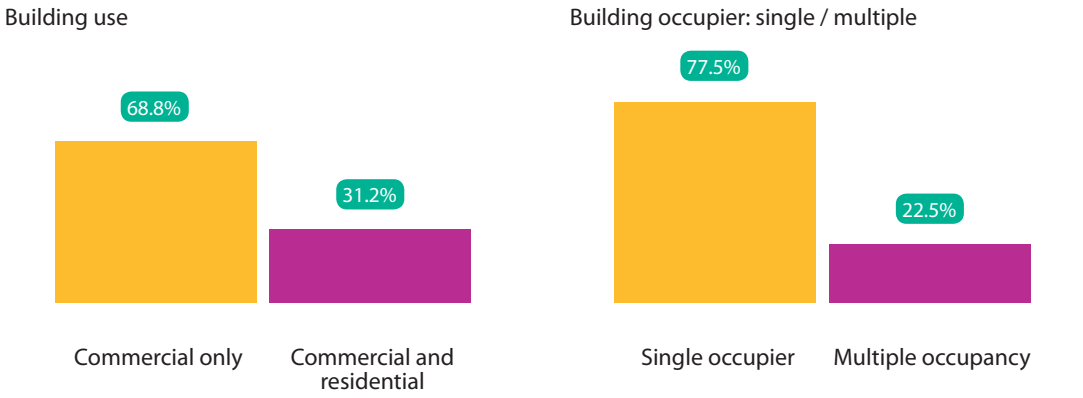
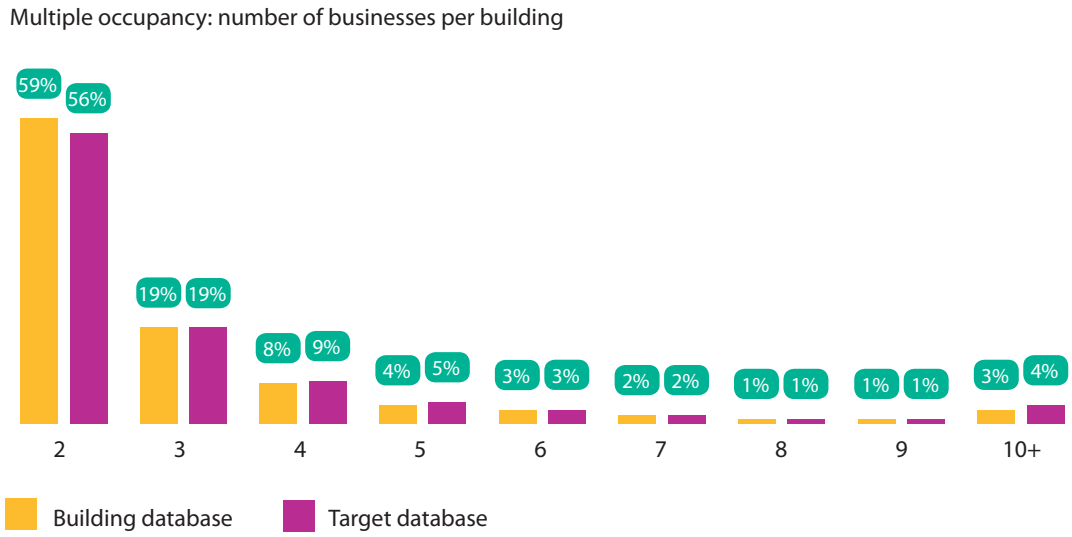


Figure 27: Comparison of multiple occupancy buildings in the GeoBusiness buildings database and in the target database



The proportion of single and multiple occupancy buildings is approximately uniform across most counties (Table 8). The main exception to this is Dublin, where multiple occupancy buildings are much more common. This effect is less pronounced in other counties with major cities, such as Cork and Galway.

Table 8: Comparison of buildings by county in GeoBusiness and target database

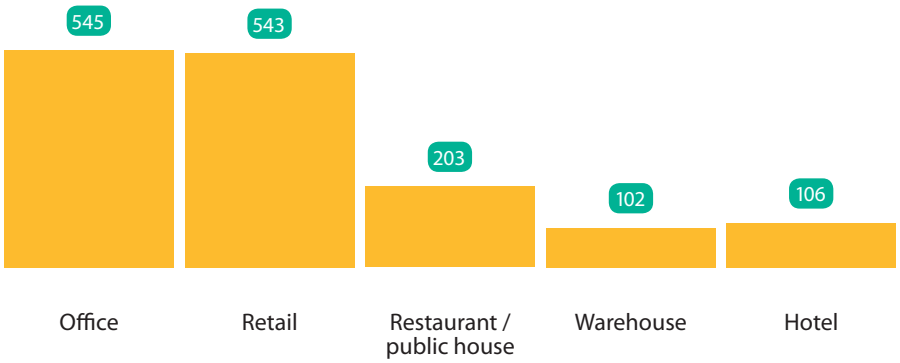
County	% of buildings in county (buildings database)	% of buildings in county (target database)	Target database	
			Single occupancy eligible sample	Multiple occupancy eligible sample
Dublin	15%	15%	12%	27%
Cork	12%	13%	13%	10%
Wicklow	3%	3%	3%	3%
Kildare	3%	3%	3%	4%
Galway	5%	5%	5%	5%
Limerick	5%	5%	5%	4%
Sligo	2%	2%	2%	2%
Westmeath	3%	3%	3%	3%
Meath	4%	4%	4%	4%
Louth	3%	3%	4%	3%
Carlow	1%	1%	1%	1%
Wexford	4%	4%	4%	3%
Monaghan	2%	2%	2%	2%
Mayo	4%	4%	5%	4%
Roscommon	2%	2%	2%	1%
Kilkenny	3%	3%	3%	2%
Cavan	2%	2%	3%	2%
Longford	1%	1%	1%	1%
Donegal	5%	5%	5%	4%
Leitrim	1%	1%	1%	1%
Tipperary	5%	5%	5%	3%
Waterford	3%	3%	3%	2%
Offaly	2%	2%	2%	1%
Clare	4%	4%	4%	3%
Laois	2%	2%	2%	1%
Kerry	4%	5%	5%	3%

Table 9: Fraction of multiple occupancy buildings by sector in the target database

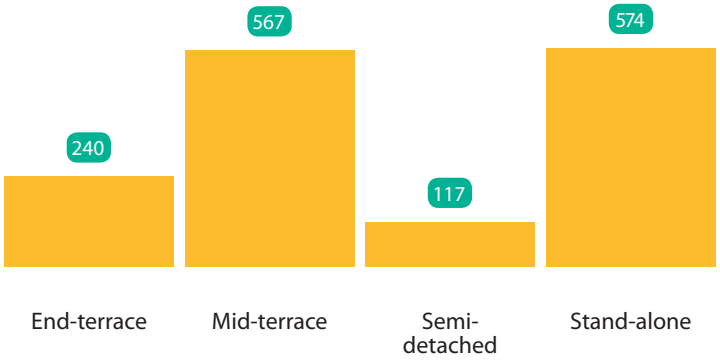
Single purpose and dual purpose	Office	Restaurant / public house	Hotel	Retail	Transportation/ storage	Construction
Single sector	20.3%	5.5%	0.8%	30.4%	2.1%	2.9%
Office	X	2.2%	0.3%	11.0%	1.1%	2.0%
Restaurant / public house	2.2%	X	3.0%	7.8%	0.2%	0.2%
Hotel	0.3%	3.0%	X	0.5%	0.1%	0.2%
Retail	11.0%	7.8%	0.5%	X	2.0%	1.4%
Transportation / storage	1.1%	0.2%	0.1%	2.0%	X	0.2%
Construction	2.0%	0.2%	0.2%	1.4%	0.2%	X

Further results from the survey

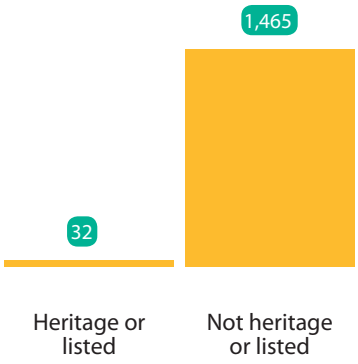
Q1. Number of buildings by sector



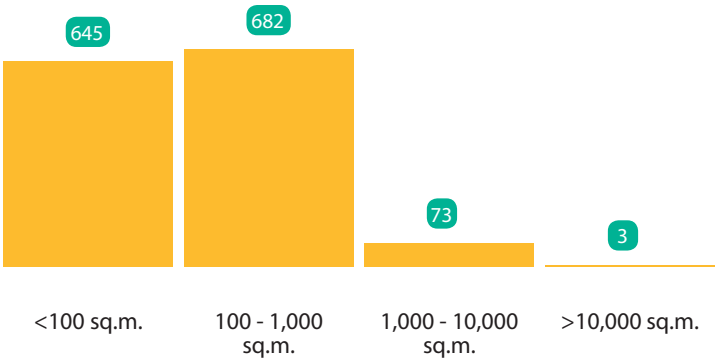
Q2. Number of buildings by type



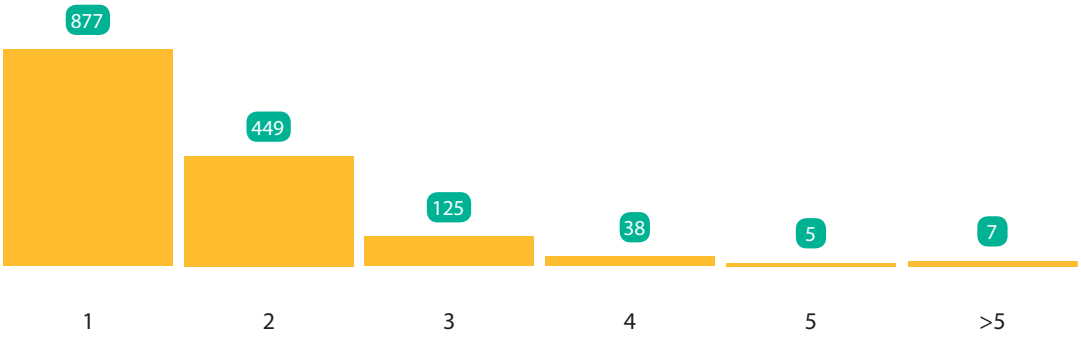
Q3. Number of buildings by type



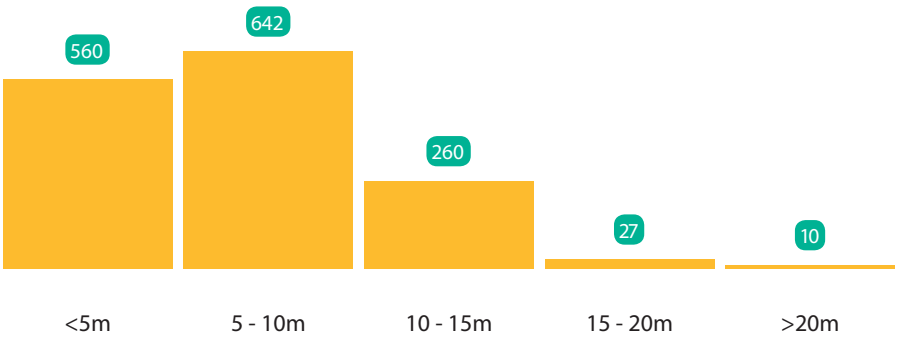
Q4. Number of buildings by ground floor area



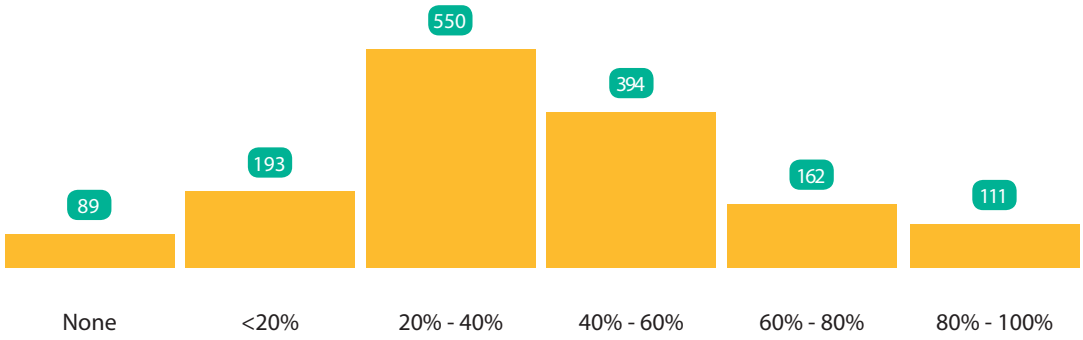
Q5. Number of buildings by number of storeys



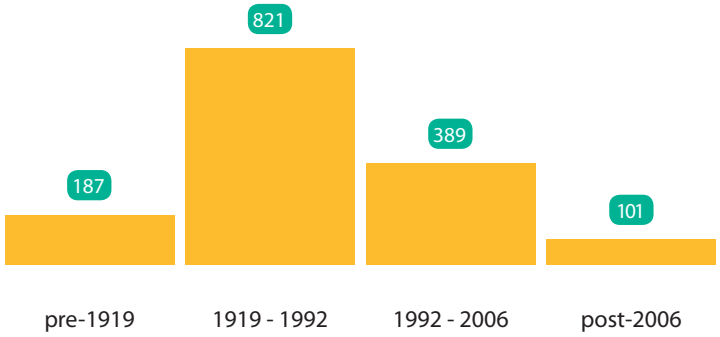
Q6. Number of buildings by building height



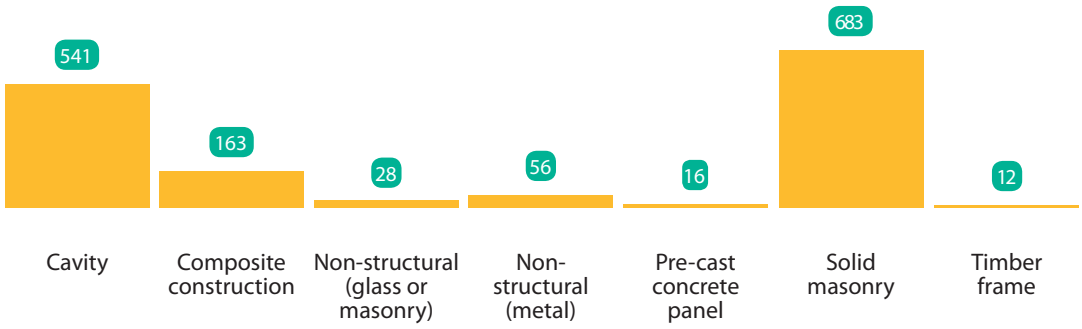
Q7. Number of buildings by glazed fraction of external walls



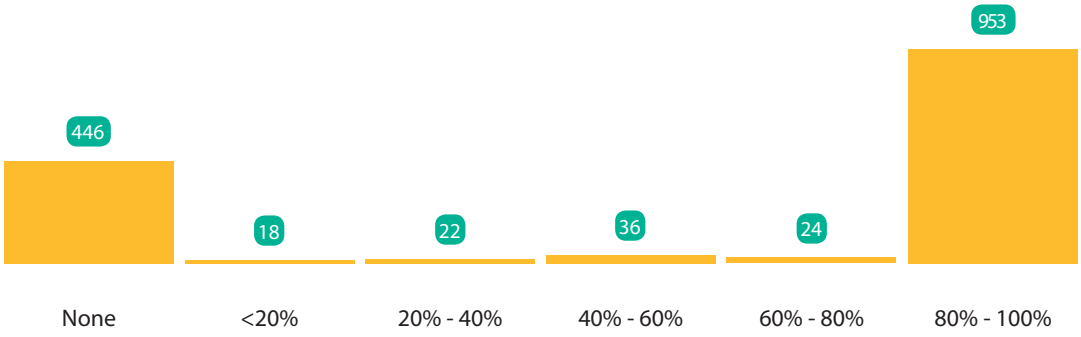
Q8. Number of buildings by year of construction



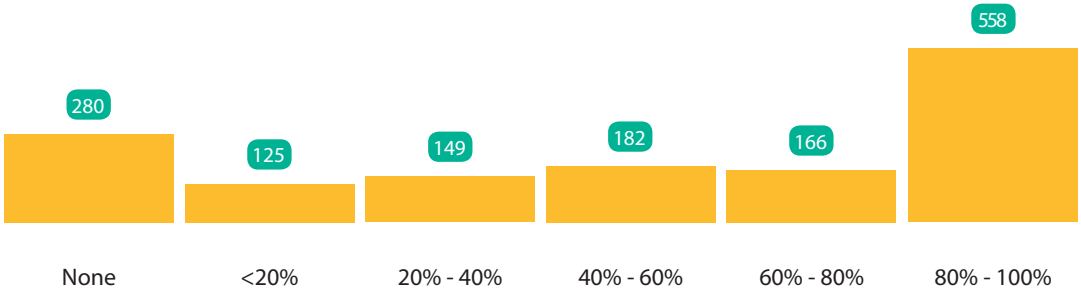
Q9. Number of buildings by wall type



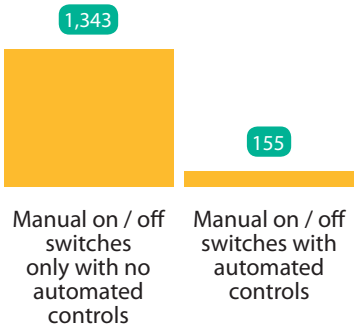
Q10. Number of buildings by fraction of double / triple glazing



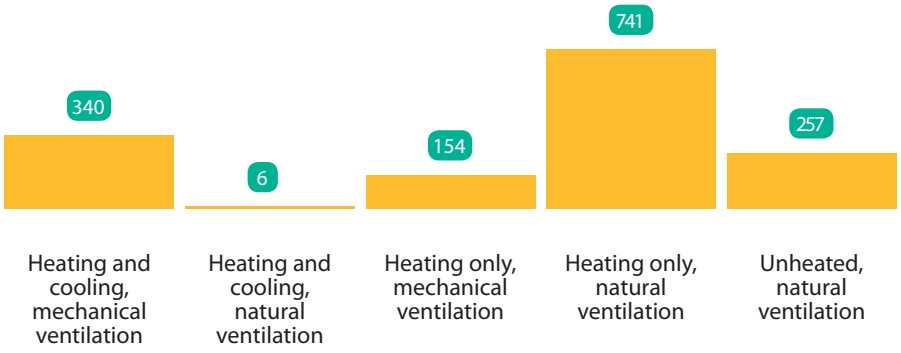
Q11. Number of buildings by fraction of low-energy lighting



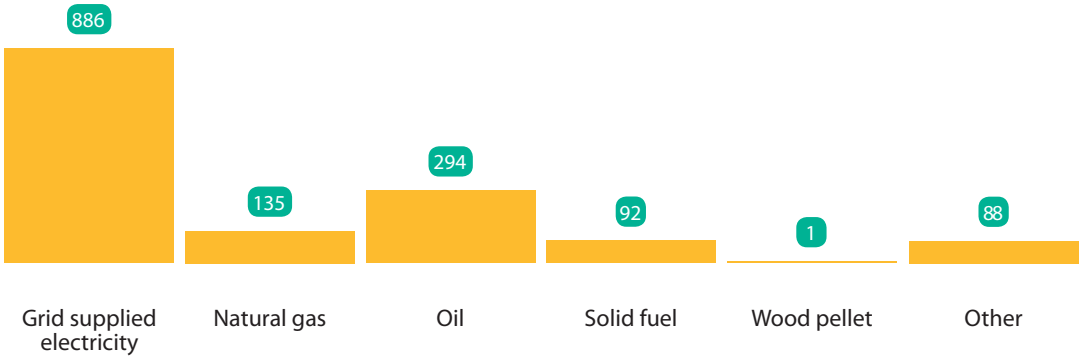
Q12. Number of buildings by main space lighting control type



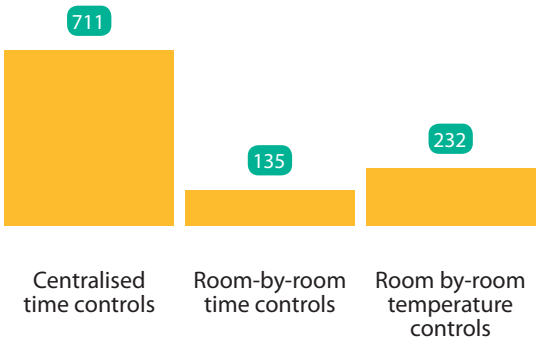
Q13. Number of buildings by HVAC type



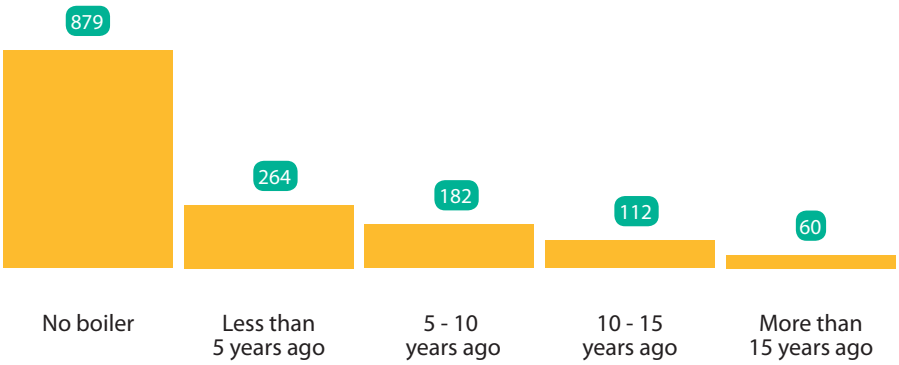
Q14. Number of buildings by primary heating fuel



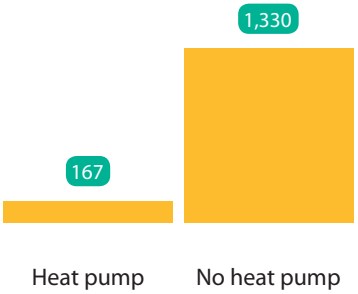
Q15. Number of buildings by heating control type



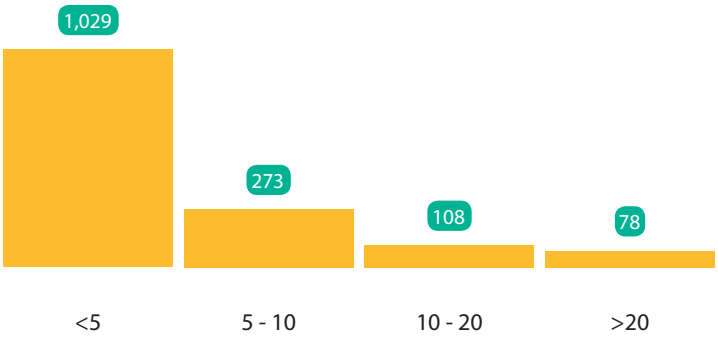
Q16. Number of buildings by time since boiler last replaced



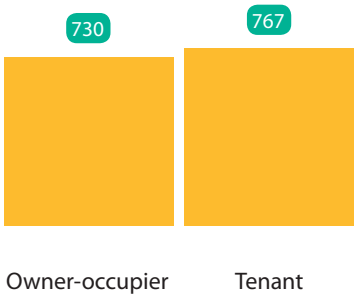
Q17. Number of buildings by existence / non-existence of heat pump



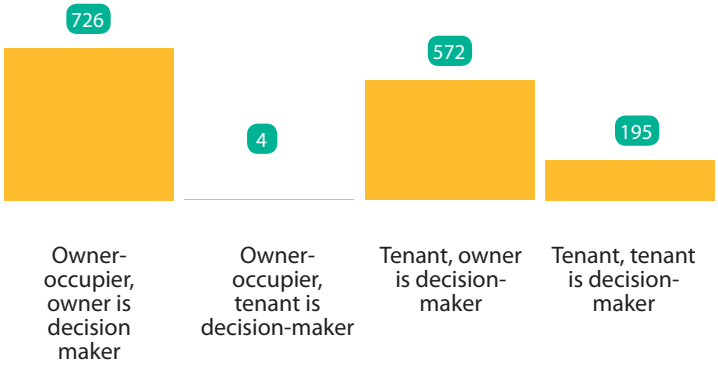
Q18. Number of buildings by average number of employees in building in working hours



Q19. Number of buildings by occupier status



Q20. Number of buildings by occupier status and identity of decision-maker



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