D2.2 – Building requirements

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Executive summary

This report represents Deliverable 2.2 – Building requirements developed in the course of Work Package 2 – Specification of user, building and game requirements of the EnerGAware project.

Deliverable D2.2 – Building requirements is the second of three complimentary reports produced in WP2 that define the requirements for the design of the EnerGAware serious game.

The majority of the data used to define the building requirements outlined in this report were obtained from project partner, DCH's Building Stock Condition and Energy Database. DCH maintains the high quality database which holds information about its housing stock. The dataset provides a comprehensive overview of the key structural elements and services in each home. It also includes what is known as the 'minimum dataset' for the Standard Assessment Procedure RdSAP energy rating methodology which enables an energy efficiency rating to be calculated for every property surveyed.

In addition, data about Internet penetration, Internet connection types and presence of prepayment and standard energy meters in the social housing presented were collected during the EnerGAware Social Housing Survey which was a large-scale, city-wide, housing survey, administered to all 2,772 social houses managed by DCH in the city of Plymouth, UK.

Furthermore, a background review of the energy meter types and their possible locations in UK social housing was undertaken.

The data presented in this report are for the 537 DCH households in Plymouth that completed the EnerGAware Social Housing Survey, thereby addressing the same households as Deliverables D2.1 – User requirements and D2.3 – Game requirements.

The most common building characteristics, building envelope, building services and controls and renewable energy generation were analysed and transformed into the 'typical' social dwelling which can be used to inform the design of the virtual home contained in the EnerGAware serious game. This typical house can also be used to define and limit the boundaries of the option space (i.e. what actions the game players can make in the game) for the simulation engine that underpins the serious game.

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Glossary and abbreviations

CHP	Combined heat and power. System that integrates the production of usable heat and power (electricity), in one single, highly efficient process.
LED	Light-emitting diode. Low energy consumption lighting system.
MCB	Miniature Circuit Breaker. Electric elements installed in a consumer unit designed to protect the cable downstream of the device against overloads and short circuits.
PV	Photovoltaics. Method of converting solar energy into direct current electricity using semiconducting materials that exhibit the photovoltaic effect.
RCD	Residual current device. Life-saving device which is designed to prevent fatal electric shock when touching a live wire.
RdSAP	Reduced data SAP. Domestic energy rating software used to assess the energy efficiency of existing dwellings.
SAP	Standard Assessment Procedure. UK government approved system for assessing the energy rating for a new home.
TRV	Thermostatic radiator valve. Self-regulating valve fitted to hot water heating system radiator, to control the temperature of a room by changing the flow of hot water to the radiator.
UK	United Kingdom.

1.Introduction

This report represents Deliverable 2.2 – Building requirements developed in the course of Work Package 2 – Specification of user, building and game requirements of the EnerGAware project.

The Work Package (WP) 2 tasks (T2.1-2.4) have provided a comprehensive identification and analysis of the specific user, building and game requirements that are necessary to design the EnerGAware serious game. The WP2 tasks focused on understanding, together with the social tenants, what they want and what their priorities and ideas are in relation to a serious game that could help them save energy at home (T2.4 Game requirements). WP2 also aimed to obtain a deeper understanding about social tenants' motivations, behaviour and perceptions regarding their energy use at home (T2.2 User requirements). Furthermore, a detailed analysis of the technical characteristics (building envelope, building services and controls, renewable energy generation and Internet penetration) of the social housing stock was undertaken (T2.3 Building requirements).

Deliverable D2.2 – Building requirements is the second of three complimentary reports produced in WP2 that define the requirements for the design of the EnerGAware serious game. For user and game requirements refer to Deliverables D2.1 – User requirements and D2.3 – Game requirements.

The majority of the data used to define the building requirements outlined in this report were obtained from project partner, DCH's Building Stock Condition and Energy Database. DCH maintains the high quality database which holds information about its housing stock and provides an essential point of reference for managing and maintaining the stock. The dataset provides a comprehensive overview of the key structural elements and services in each home. It also includes what is known as the 'minimum dataset' for the Standard Assessment Procedure RdSAP energy rating methodology which enables an energy efficiency rating to be calculated for every property surveyed. In addition, data about Internet penetration, Internet connection types and presence of prepayment and standard energy meters in the social housing reported were collected during the EnerGAware Social Housing Survey which was a large-scale, city-wide, housing survey, administered to all the 2,772 social houses managed by DCH in the city of Plymouth, UK (T2.1). For more details about the EnerGAware Social Housing Survey, see D2.1 – User requirements. Furthermore, a detailed background review of the energy meter types and their possible locations in the dwellings was undertaken.

The outcomes of WP2 will directly influence the design of the EnerGAware serious game in WP3, and will be used to define the baseline for the monitoring and evaluation of the impact indicators in WP5.

1.1 DCH Building Stock Condition and Energy Databases

The data used to define the building requirements outlined in this report were mainly obtained from project partner, DCH's Building Stock Condition and Energy Database. The databases contain information about the technical characteristics (building envelope, building services and controls and renewable energy generation) of the DCH social housing stock. The data presented in this report are for the 537 DCH households in Plymouth that completed the EnerGAware Social Housing Survey, which was administered to all of the social houses managed by DCH in the city, thereby addressing the same households as Deliverable D2.1 – User requirements and D2.3 – Game requirements.

The Building Stock Condition and Energy Database is maintained and managed by an in-house professional team of building surveyors and data management specialists. A continuous process of carrying out stock condition surveys is maintained to ensure that property data is correct and up to date.

The stock condition survey dataset provides a comprehensive overview of the key structural elements and services in each home. It also includes what is known as the 'minimum dataset' for the RdSAP energy rating methodology which enables a Standard Assessment Procedure (SAP) rating to be calculated for every property surveyed. SAP is the UK government's national calculation methodology for the energy efficiency assessment of existing dwellings. The database also includes a separate system which holds the full dataset for the RdSAP methodology which is used in the UK for producing energy performance certificates (DECC, 2012). This provides comprehensive energy data for the properties. New energy surveys are supplied by and external contractor who employs fully qualified Domestic Energy Assessors to carry out the surveys.

The database also contains some property data which were collected before DCH was formed in 2013. In this case, the data was collected by the housing associations that amalgamated to form DCH. At that time, surveys were carried out either by in-house surveyors or suitably qualified consultants.

The stock condition and energy data is held on a system supplied by Keystone, who are one of the major UK companies operating in this field.

Specific details about the EnerGAware Social Housing Survey can be found in Deliverable D2.1 – User requirements.

2. Results

2.1 Building characteristics

2.1.1 Dwelling type

As can be seen from Figure 1, over half of the social housing tenants live in flats (54.4%). The remaining residents primarily live in houses (35.2%) and just over 10% live in other dwelling types.

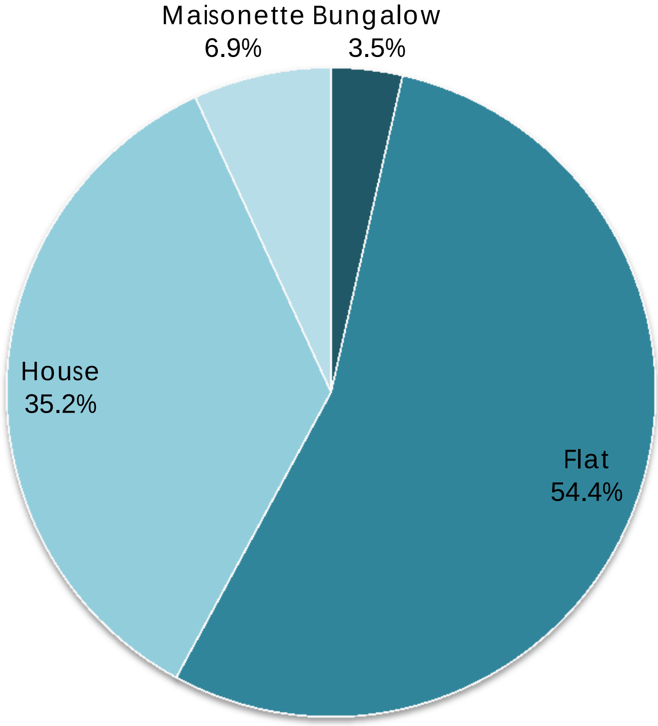

Figure 1. Dwelling type

2.1.2 Year of construction

As can be seen in Figure 2, the dwellings occupied by the social housing residents were constructed over a large period of time, with some dwellings constructed before 1900 (11.2%) and others after 2007 (10.8%). A large proportion of the social housing stock were constructed from the around the mid-1970s to the end of the 1980s (46.4%).

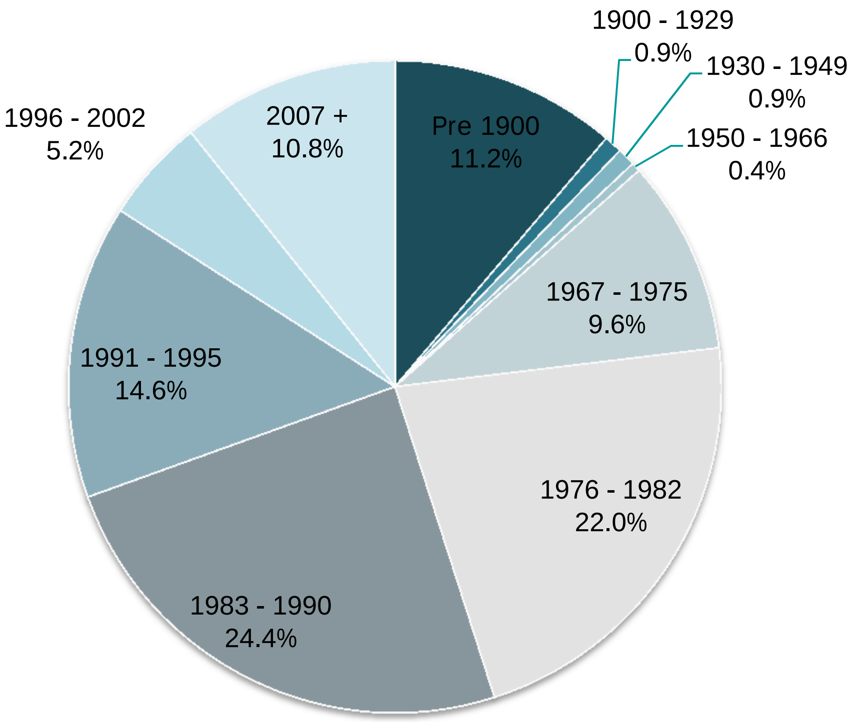

Figure 2. Year of construction

2.1.3 Number of storeys

Figure 3 shows that almost 70% of the dwellings occupied by the social housing tenants have a single storey. The remaining dwellings are mainly comprised of two storeys (28.1%). Only 2.1% of the residents lived in dwellings with more than two storeys.

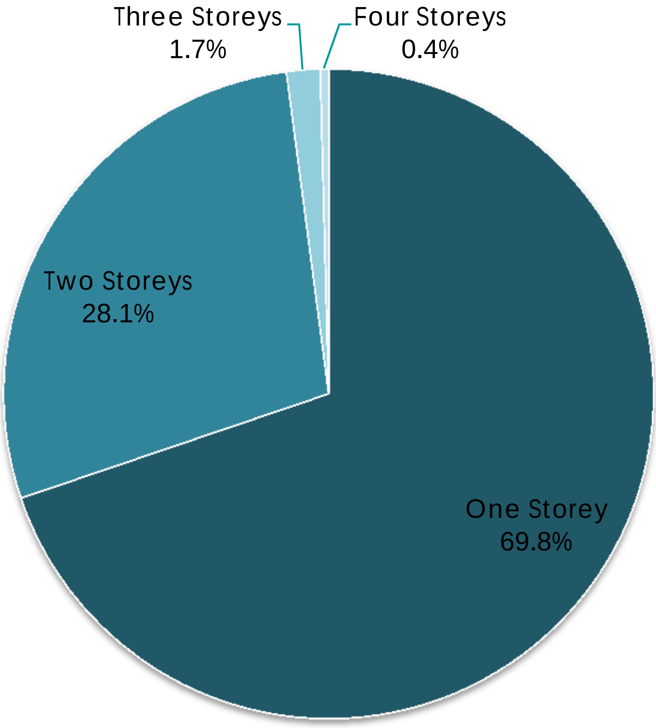

Figure 3. Number of storeys

2.1.4 Number of habitable rooms

The results show that almost 75% of the dwellings occupied by the social housing tenants had either two or three habitable rooms (Figure 4). 17.5% of the dwellings had four habitable rooms and less than 9% of the dwellings had either one or five or more habitable rooms.

Habitable rooms include any living room, sitting room, dining room, bedroom, study or similar; and also a conservatory if it has an internal quality door between it and the dwelling. A kitchen/diner having a discrete seating area with a table and four chairs also counts as a habitable room.

Excluded from the room count are any room used solely as a kitchen, utility room, bathroom, cloakroom, en-suite accommodation or similar; any hallway, stairs or landing; and also any room without a window.

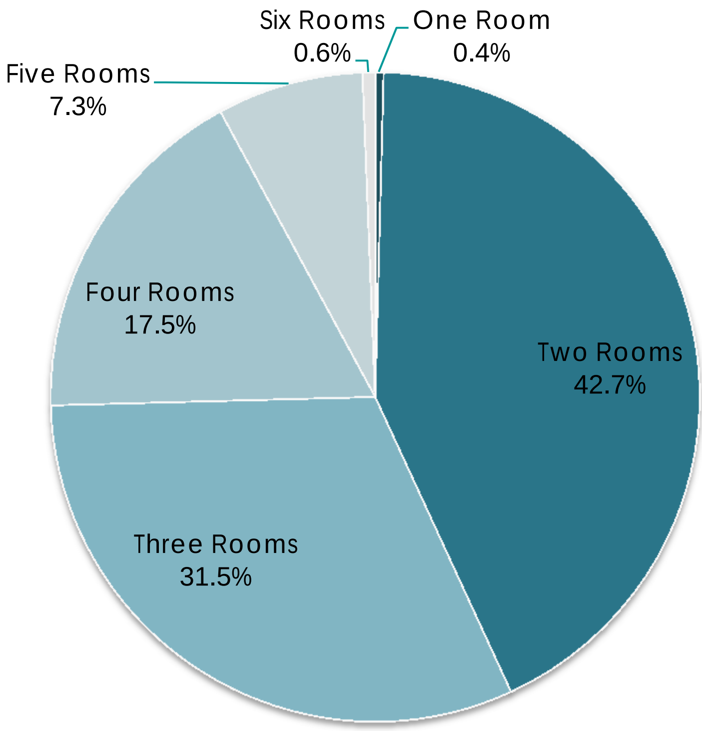

Figure 4. Number of habitable rooms

2.1.5 Energy rating of dwellings

As can be seen in Figure 5, almost 93% of the social housing tenants lived in dwellings with an energy efficiency rating of ‘C’ (69-80 SAP points) or ‘D’ (55-68 SAP points). This energy efficiency rating is from ‘A’ (most efficient: 92-100 SAP points) to ‘G’ (least efficient: 1-20 SAP points). None of the dwellings occupied by the social housing tenants were rated in the highest efficiency ‘A’ band, but 0.3% of residents lived in a home rated in the lowest ‘G’ band.

Table 1 shows a breakdown of the percentage of UK dwellings in each energy efficiency band. The data is from all domestic EPC lodgements for the period from 2008 to 2014. The data consist of 11,765,227 EPCs that were lodged onto the UK Government’s Register.

Table 1. Percentage of UK dwellings in each energy efficiency band

Energy Efficiency Rating	Percentage of Dwellings
A	0.09%
B	8.39%
C	27.68%
D	38.70%
E	18.43%
F	5.20%
G	1.51%

Comparing the energy efficiency results of the dwellings occupied by the social tenants with the UK national picture, it can be seen that whilst the social housing had fewer lower rated dwellings (E, F and G), they also had lower number of higher rated (A and B).

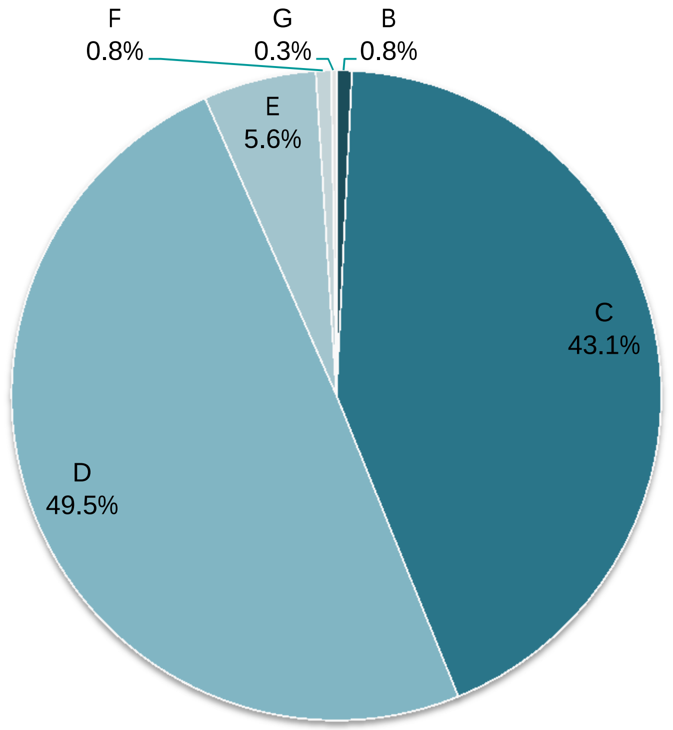

Figure 5. Energy rating of dwellings

2.2 Building envelope

The building envelope is a term for the parts of the building which surround the heated and cooled parts of the building. This includes external walls, floors or ground deck, roofs or constructions towards unheated ceilings, windows and doors. If a basement is heated then the basement walls and the basement floor are part of the building envelope. If it is unheated, the building envelope includes the floor between the ground floor and the basement. The building envelope may also address heat loss through foundations or other thermal bridges (Laustsen, 2008).

2.2.1 Wall construction

The results show that almost 70% of the social housing tenants occupy dwellings with a cavity wall construction (Figure 6). More than a quarter of the dwellings had a solid wall construction. Less than 5% of the dwellings had other types of wall constructions.

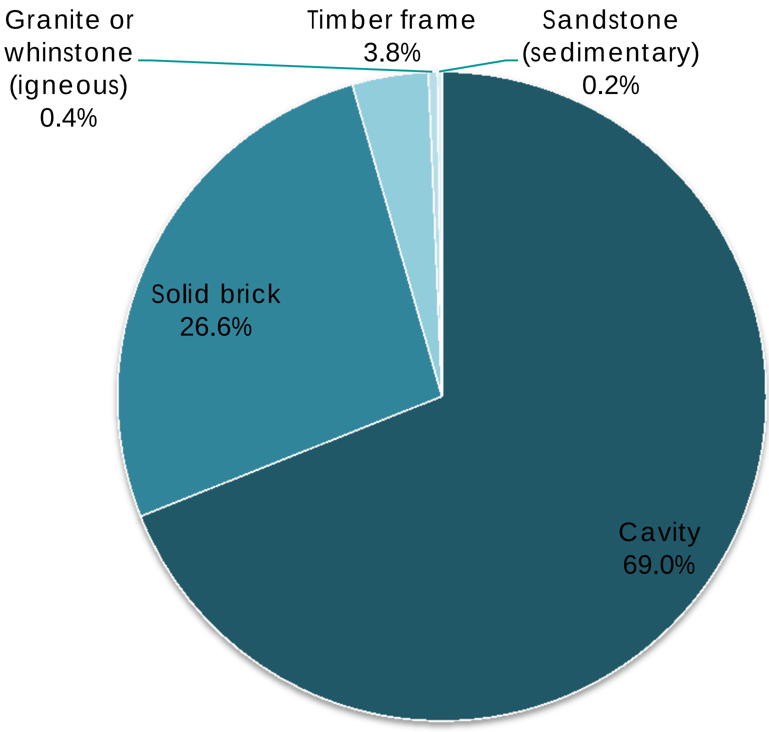

Figure 6. Wall construction

2.2.2 Wall insulation

Figure 7 shows that just under half of the dwellings occupied by the social housing tenants had no wall insulation (i.e. cavity wall or solid wall insulation). From this proportion of uninsulated homes, it is not clear what percentage could actually be insulated if the investment was made. 54.9% of the dwellings had some type of wall insulation.

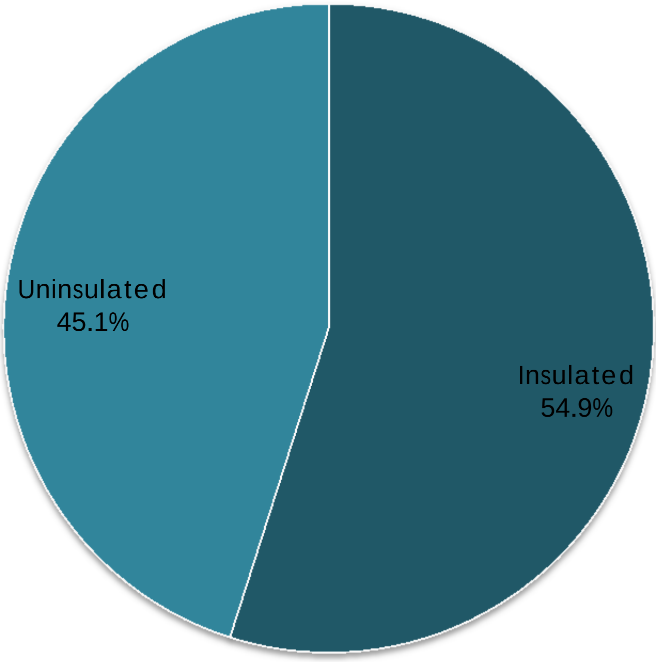

Figure 7. Wall insulation

2.2.3 Roof construction

The dwelling data for roof construction (Figure 8) showed that the majority of social tenants lived in a property with a pitched roof with loft access (60.9%). The remaining dwellings either had another dwelling above (i.e. a flat or a maisonette) or had a flat roof construction. Less than 3% of the dwellings occupied by the social tenants had a converted loft space (same dwelling above) or a pitched roof with no access.

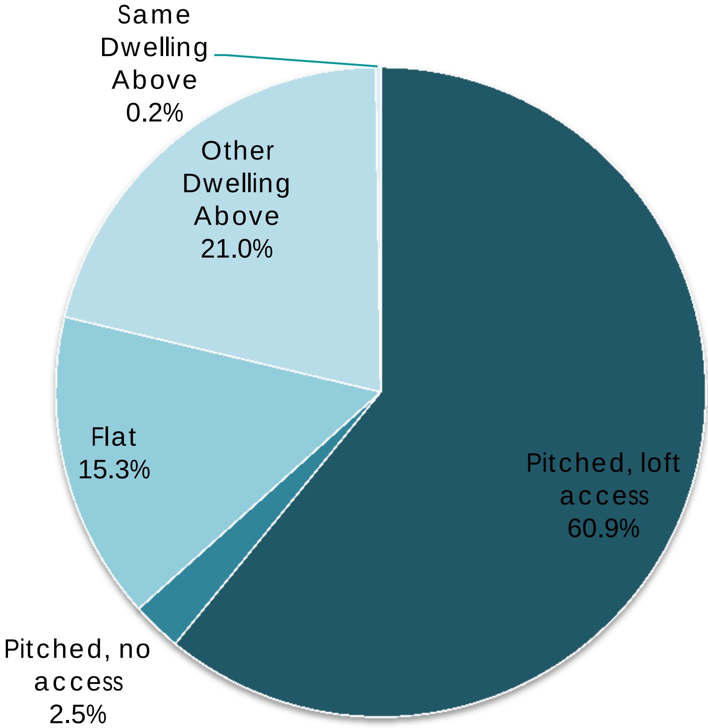

Figure 8. Roof construction

2.2.4 Roof insulation thickness

Figure 9 shows the percentage of dwellings with different thicknesses of roof insulation. The results indicate that around 1% of the social housing tenants lived in dwellings with no roof insulation at all. In addition, only 5% of the dwellings had more than the recommended 270mm of roof insulation installed. The 270mm recommended thickness of roof insulation is based on an assumption that the insulating material is mineral wool (the most common insulating material in the UK). Other insulating materials need different depths and may therefore have an impact on the interpretation of these results.

The most common insulation thicknesses found in the dwellings was 150mm (35.8%) and 250mm (24.3%). This can be explained because the typical as-built insulation thickness used to be around 150mm, until it was recommended that this level should be topped-up to 250mm. Subsequently, this has been further increased to 270mm.

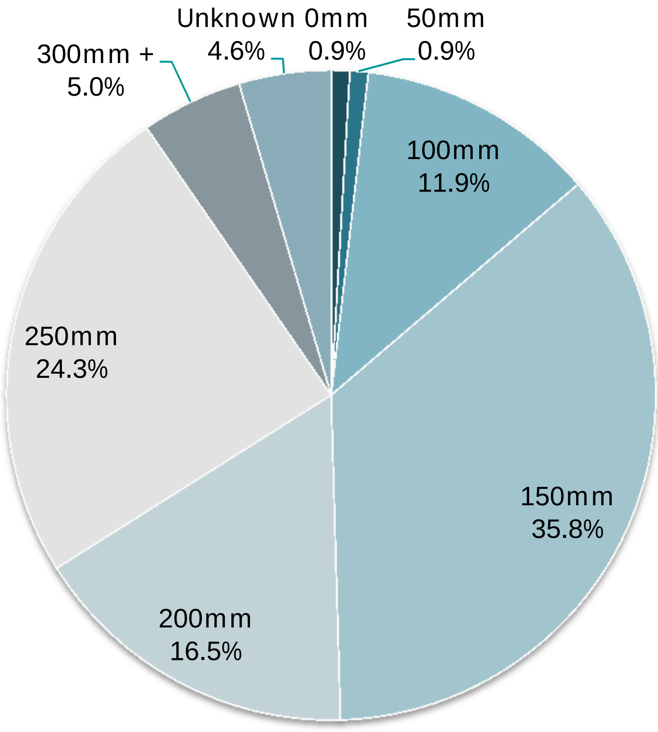

Figure 9. Roof insulation thickness

2.2.5 Glazing

Figure 10 indicates the percentage of dwellings that were single or multiple glazed. It can be seen that just over 50% of the social tenants lived in a single glazed dwelling and just under 50% a multiple glazed dwelling.

Windows, doors and other parts of buildings that include glass areas require special attention. Beyond its role in insulation, glass provides buildings with daylight and heat from sunlight. In cold climates, solar heat gains can reduce a building's need for active heating. The orientation of windows and glass areas should suit the different amounts of light approaching the building and complement a building's needs for heating and cooling.

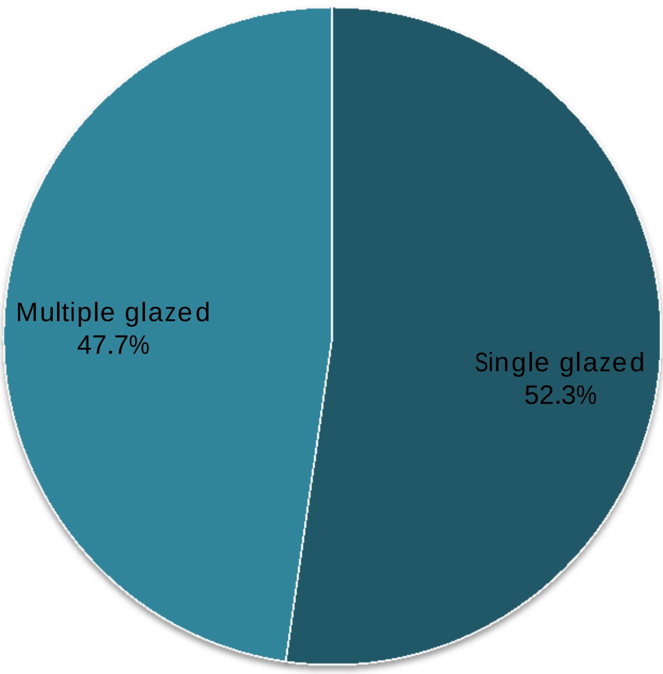

Figure 10. Glazing

2.2.6 Secondary glazing

As can be seen from Figure 11, none of the social housing tenants live in dwellings with secondary glazing.

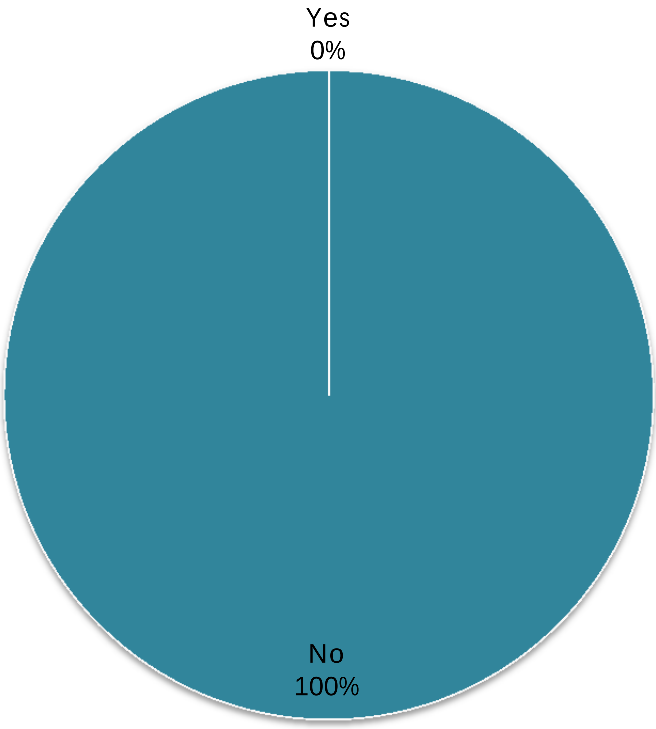

Figure 11. Secondary glazing

2.2.7 Draught-proofing

Air leakage around windows and other glazed areas, such as doors, can create draughts. When considered thermally, the undesired air leakage is a loss of energy as it requires additional heating demands. Draught-proofing is a low cost method of reducing air leakage around glazed areas in a property. However, as can be seen from Figure 12, the vast majority of the social housing (98.8%), had no draught-proofing at all. Only 1% of the dwellings had all the glazed areas draught-proofed and 0.2% had half. It should be noted however, that not all of the dwellings that have no draught-proofing, will require it to be installed.

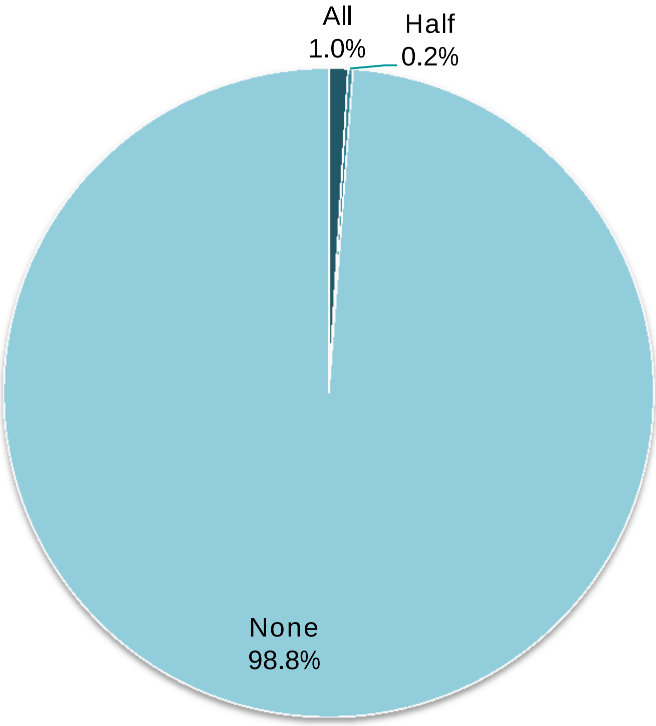

Figure 12. Proportion of draught-proofing installed

2.3 Building services and controls

2.3.1 Electric meter type

The results for electric meter type (Figure 13) show that just under 40% of the dwellings occupied by the social tenants had a dual (economy 7) electricity meter, indicating that the residents have two different tariffs for electricity. One rate is a standard day rate and the other is a cheaper overnight rate. The dual rate was designed so that properties that rely on electric storage heaters can run them overnight when it is cheaper and store the heat energy for release during the day. 43.7% of the dwellings had a standard single tariff electricity meter.

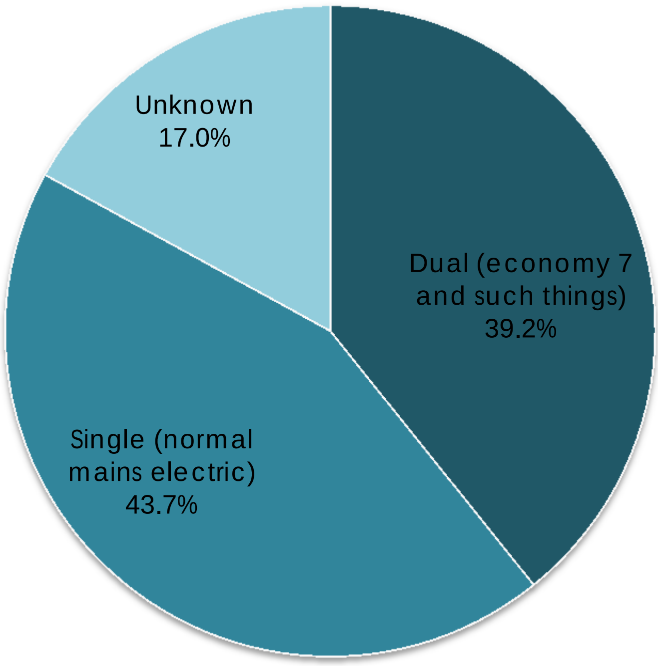

Figure 13. Electric meter type

DCH does not collect data on the specific models of the energy meters fitted in its social housing as they are the property of the national grid and can be changed at any time without notification, therefore such data is hard to keep up-to-date and expensive to continuously collect. The range of models of electricity meter that could be found in DCH's properties could be any of those which are approved for use by utility companies in the UK. Figures 14 to 17 show the four typical electricity meters that could be found in DCH homes.

Figure 14 shows a digital 'key meter' or prepayment electricity meter. The EnerGAware Social Housing Survey found that 40% of the households have this type of electricity meter installed in their houses. This type of meter is installed by direct arrangement between the social housing tenant and their energy company.

Figure 14. Digital key meter / prepayment electricity meter

Figure 15 shows a digital single rate electricity meter for customers with billing accounts with their energy company.

Figure 15. Digital electricity meter

Figure 16 shows two types of analogue single rate electricity meters, dial and numeric, for customers with billing accounts with their energy company.

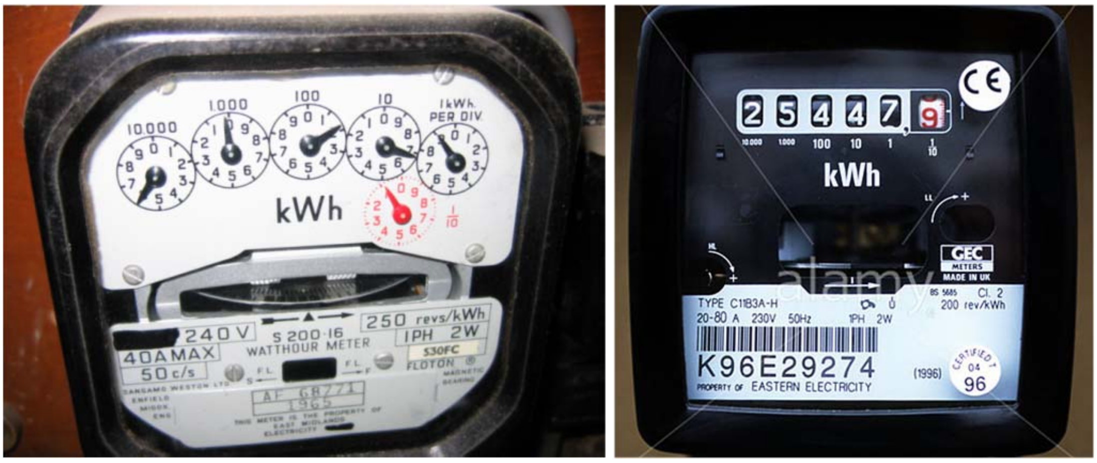

Figure 16. Dial (left) and numeric (right) analogue electricity meters

Figure 17 shows an analogue dual rate electricity meter with two electricity readings for the peak (day) and off-peak (night) tariffs. There are also digital electricity meters, including prepayment meters, which are also dual rate and have two electricity readings for peak and off-peak tariffs, but the consumption values are only displayed one at a time on the LCD interface.

Figure 17. Analogue meter with two electricity readings for peak and off-peak tariffs

The EnerGAware Social Housing Survey indicates that around 54% of the DCH housing stock have either a digital (not prepayment) or analogue (dial or numeric) electricity meter installed.

From the analysis, it can be seen that there could be a range of different electricity meter types in DCH's dwellings. However, regardless of meter type, all domestic installations have the same wiring, a live and neutral cable, between the meter and consumer unit in the homes. This means that an electricity clamp (current transducer) could be attached around the live cable to monitor the electricity consumptions in the dwellings.

The DCH stock condition and energy database does include data on consumer units, so it is possible to report on that information for all properties that have a stock condition survey. There are three possible types of consumer unit installed in DCH's social housing:

1. Consumer unit MCB with RCD
2. Consumer unit MCB
3. Consumer unit rewireable.

Figure 18 shows an example of a typical type 1 and type 2 consumer unit. These can be assumed to be reasonably modern consumer units with demountable MCBs.

Figure 18. Modern consumer unit with demountable MCBs

Figure 19 shows an example of a typical type 3 consumer unit. It cannot be assumed that this type of unit will have space to add extra modules to the existing unit, but this may be possible in some cases. These have not been fitted for many years, but it is possible that some older properties may still have this type.

Figure 19. Older design consumer unit with rewireable fuses

For properties built in the last 30 years (1980s onwards) the electricity meters are usually located outside in a meter box built into the external wall (Figure 20). In older dwellings (before 1980s) the electricity meters are often indoors. The electricity meters and consumer units are often fixed to a wall in the hallway (Figure 21).

Figure 20. External electricity meter

Figure 21. Internal electricity meter

2.3.2 Mains gas available

As can be seen in Figure 22, over half of the dwellings (54.7%) occupied by the social tenants had no mains gas available and therefore the space and water heating in the properties is supplied by electricity or bulk LPG. 43.7% of the dwellings have mains gas available.

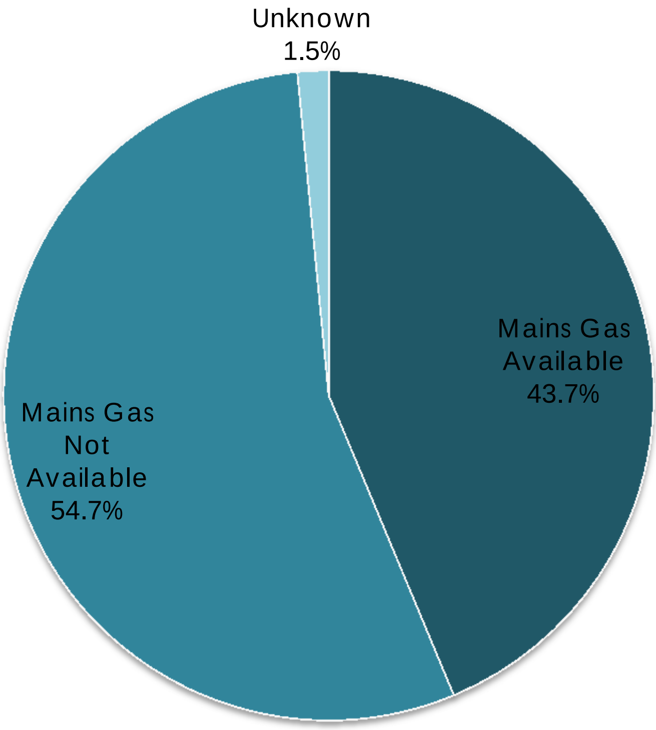

Figure 22. Mains gas available

As stated in section 2.3.1, DCH does not collect data on the specific models of the energy meters fitted in its social housing for the reasons outlined above. In relation to gas meters, there are three different types of gas meter that could be located in the DCH dwellings these are shown in Figures 23 to 25.

Figure 23 shows a digital and hybrid digital-analogue 'key meter' or prepayment gas meter. The EnerGAware Social Housing Survey found that 23% of the households have this type of gas meter installed in their houses. This type of meter is installed by direct arrangement between the social housing tenant and their energy company.

Figure 23. Digital (left) and hybrid digital-analogue (right) key meter / prepayment gas meters

Figure 24 shows a typical modern analogue gas meter for customers with billing accounts with their energy company. The modern gas meters are in m^3 units.

Figure 24. Modern analogue gas meter in m^3 units

Figure 25 shows an old analogue gas meter which might be found in some older properties for residents with billing accounts with their energy company. The older gas meters will display usage in ft^3 ‘imperial’ units. It is possible that the meter reading could be in numeric or dial formats.

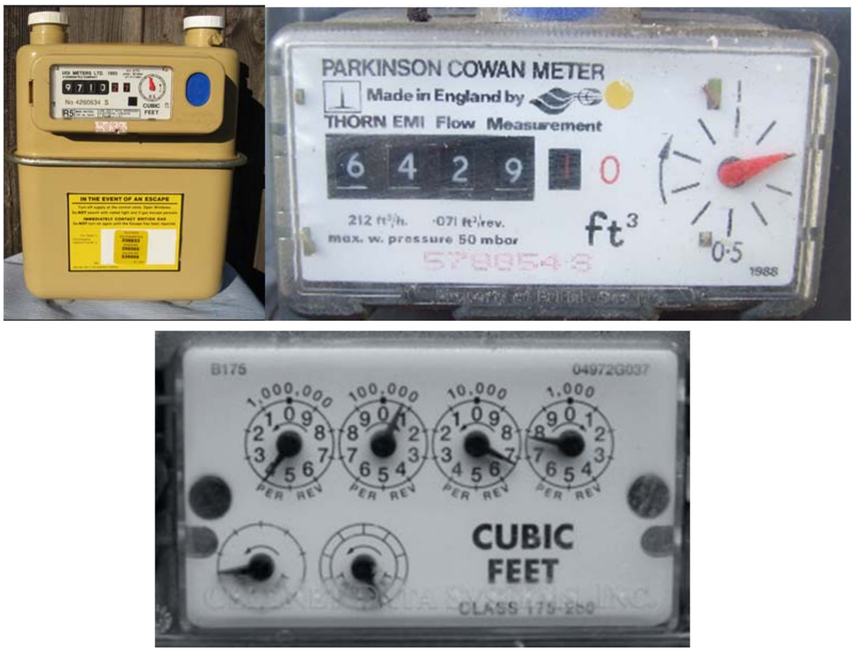

Figure 25. Old analogue gas meter in ft³ units

The EnerGAware Social Housing Survey indicates that around 44% of the DCH housing stock have either a modern analogue (numeric) or old analogue (dial or numeric) gas meter installed. The hybrid digital-analogue prepayment gas meters, as well as the modern and old numeric analogue gas meters should be able to be monitored using an optical meter reading device, however digital prepayment and old analogue dial meters will be more difficult to monitor. Some digital prepayment gas meters have an LED optical pulse output which could be monitored if present.

For properties built in the last 30 years (1980s onwards) the gas meters are usually located outside in a meter box built into the external wall (Figure 26). In older dwellings (before 1980s) the gas meters are often indoors. Internal gas meters are usually located in a cupboard in the kitchen or a utility room (Figure 27).

Figure 26. External gas meter

Figure 27. Internal gas meter

2.3.3 Main space heating system

Many possible systems can be used to heat a building. A broad range of different space heating systems were evident in the social housing (Figure 28). The majority of the dwellings had either a gas-fuelled combi or condensing combi boiler or electric storage heaters. Only 6.5% of the dwellings had another type of space heating system, which includes 2.6% of the dwellings with community/district heating. Community/district heating systems include a distribution system in the building such as pipes, ducts, tanks, pumps, fans, or exchangers.

The efficiency of the overall system will depend on the efficiency of all the components, and an efficient boiler can become an inefficient heating system if parts are poorly connected and badly calibrated. In individual systems, the efficiency often depends on the efficiency in the heating source only.

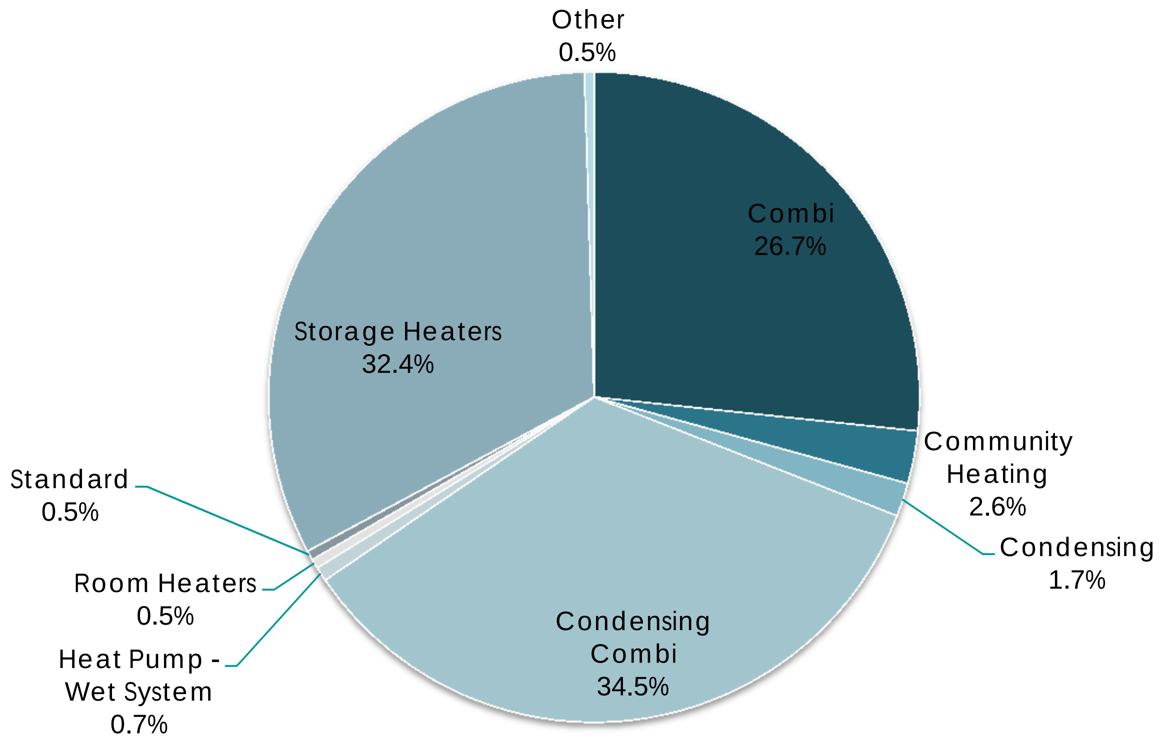

Figure 28. Main space heating system

2.3.4 Main space heating fuel type

The main space heating fuel types of the social housing were gas (66%) and electricity (33.6%). Only 0.5% of the dwelling were heated using bulk LPG (Figure 29).

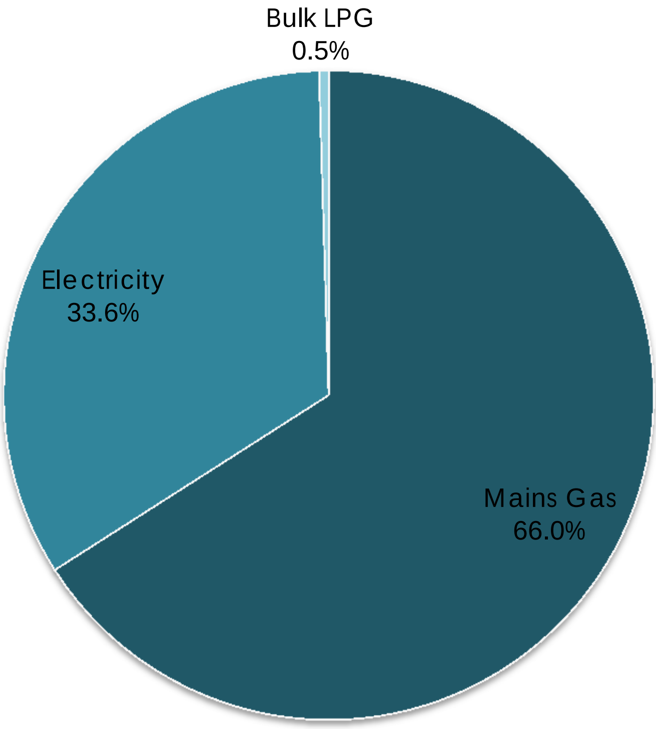

Figure 29. Main space heating fuel type

2.3.5 Main space heating controls

Heating controls can largely determine or influence the efficiency of a heating system. In UK domestic buildings the majority of heating controls are manually operated by the building occupant. Figure 30 shows the main space heating controls present in the homes occupied by the social tenants. It can be seen that around half of the dwellings had a programmer for setting on/off times of space and water heating and a room thermostat for setting a single demand temperature for the dwelling overall. 44.1% of the heating systems had manual charge controls, which are commonly associated with electric heating.

The results show that only 2.4% of the dwellings had a full set of heating controls (defined as a programmer, room thermostat and TRVs). Furthermore, 0.5% of the dwellings were found to have no heating controls at all and an additional 0.5% with only a programmer. In addition, 0.5% of the dwellings were found to have a boiler energy manager installed, which is a type of automated/intelligent heating control system that uses Variable Thermal Response (VTR) and Auto Weather Compensation software to achieve energy savings.

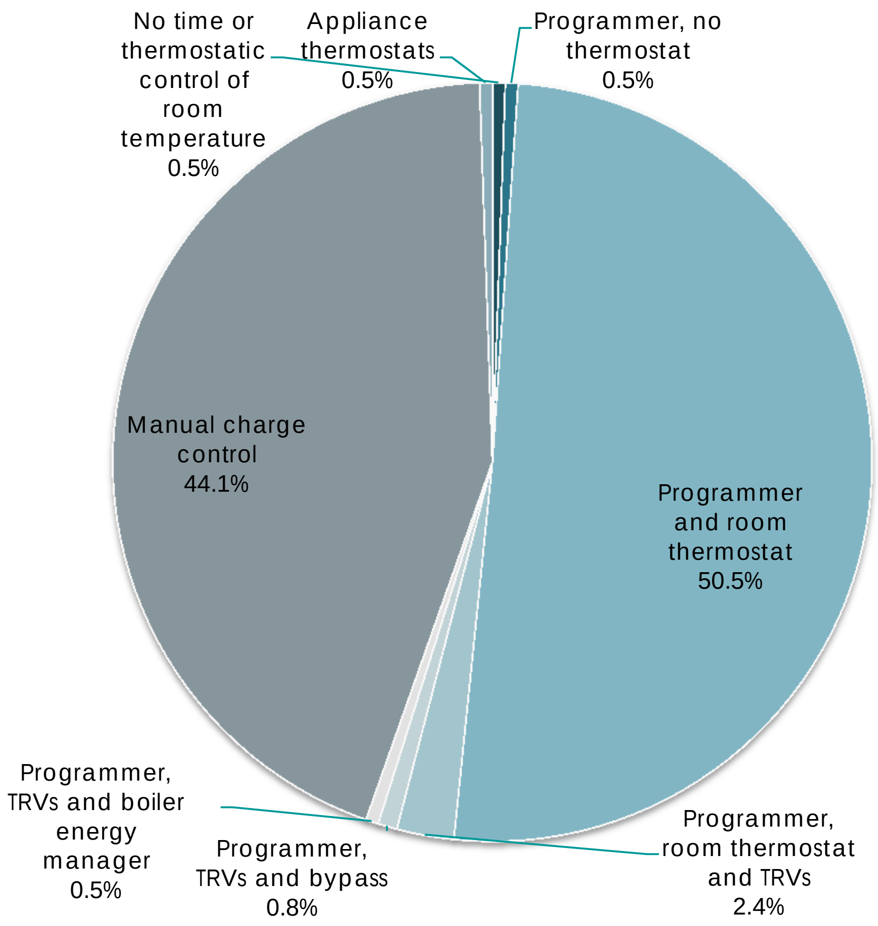

Figure 30. Main space heating controls

2.3.6 Secondary space heating system

As can be seen in Figure 31, the large majority of the dwellings have no secondary space heating system (77.9%). 21.9% of the homes had some form of secondary electrical space heating and 0.2% an open fire using mineral and wood.

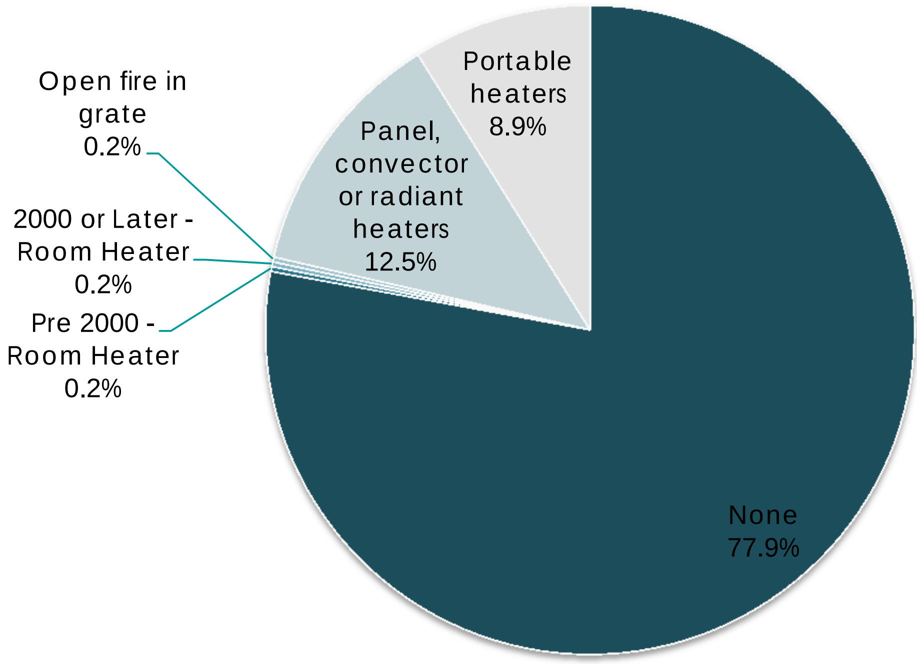

Figure 31. Secondary space heating system

2.3.7 Secondary space heating fuel type

Out of the dwellings with a secondary space heating system present, 21.9% were fuelled by electricity and the other 0.2% by dual fuel (mineral and wood) (Figure 32).

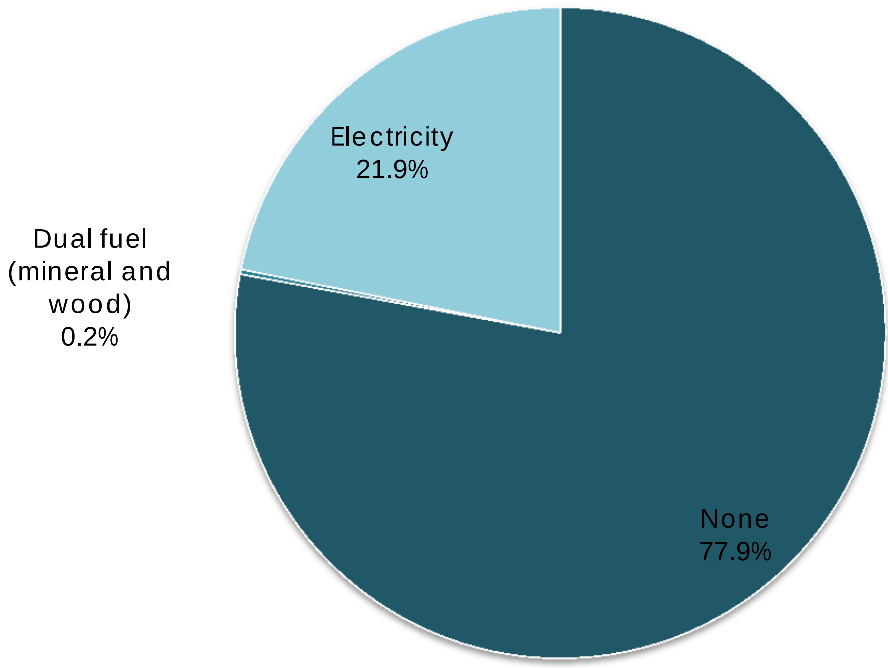

Figure 32. Secondary space heating fuel type

2.3.8 Water heating system

Building occupants require hot water for hygiene, food preparation and cleaning. The central heating system can provide this water, as can a separate system using electricity, oil, gas, solar thermal energy, heat pumps or district heating. A wide range of different water heating systems were located in the dwellings occupied by the social housing tenants (Figure 33). The majority of the dwellings had either a gas-fuelled combi or condensing combi boiler or electric immersion heaters providing hot water. Only 6.5% of the dwellings had another type of water heating system. 3.1% of the dwellings' hot water was supplied by a community/district heating scheme.

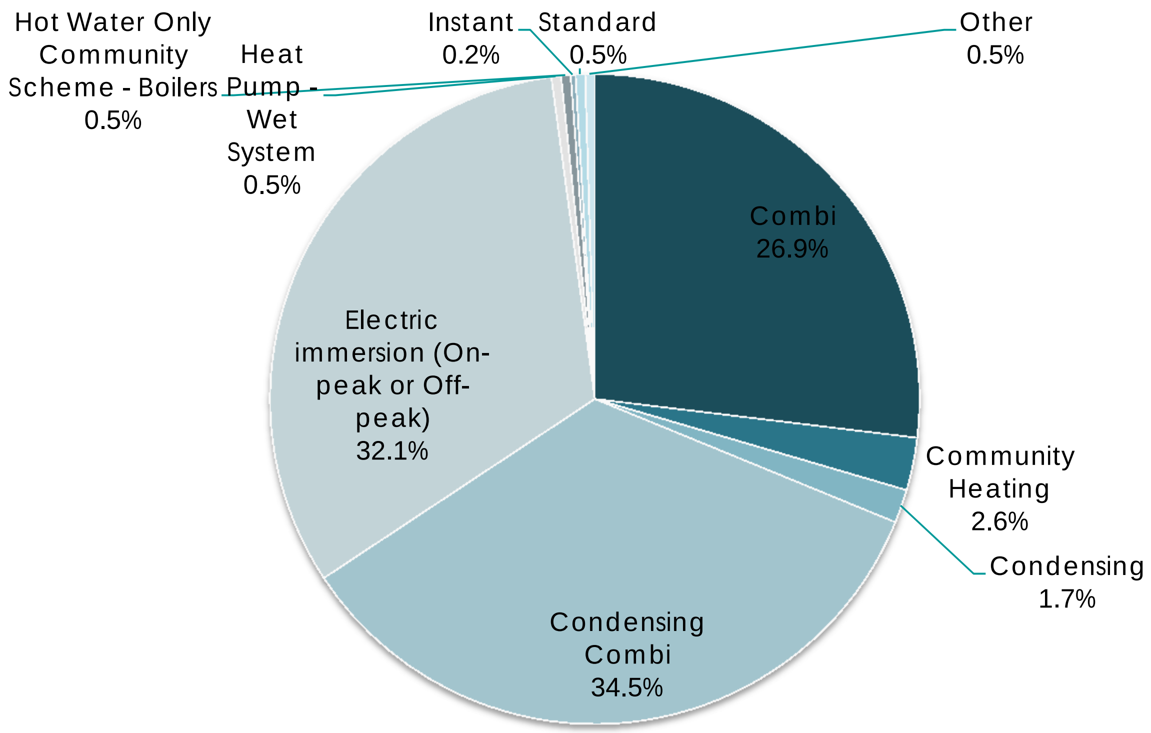

Figure 33. Water heating system

2.3.9 Water heating fuel type

The main water heating fuel types of the social housing were gas (66.9%) and electricity (33.1%) (Figure 34).

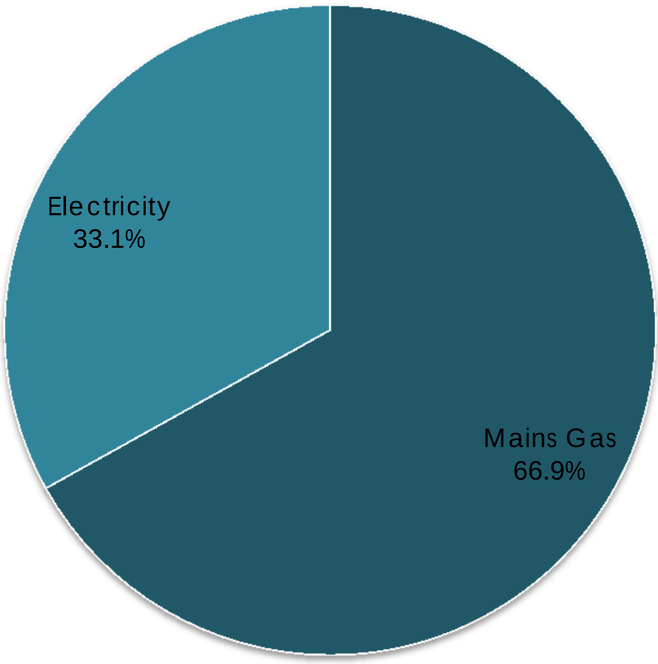

Figure 34. Water heating fuel type

2.3.10 Cylinder size

As shown in Figure 35, around 85% of the dwellings had a hot water cylinder located in their homes. A large number of these could not be accessed by the building surveyor and therefore the cylinder size is unknown. 46.7% of dwellings have a normal (90-130 Litres) cylinder size and 0.4% a medium size (131-170 Litres). These percentages are likely to be higher taking into account the cylinder that could not be accessed.

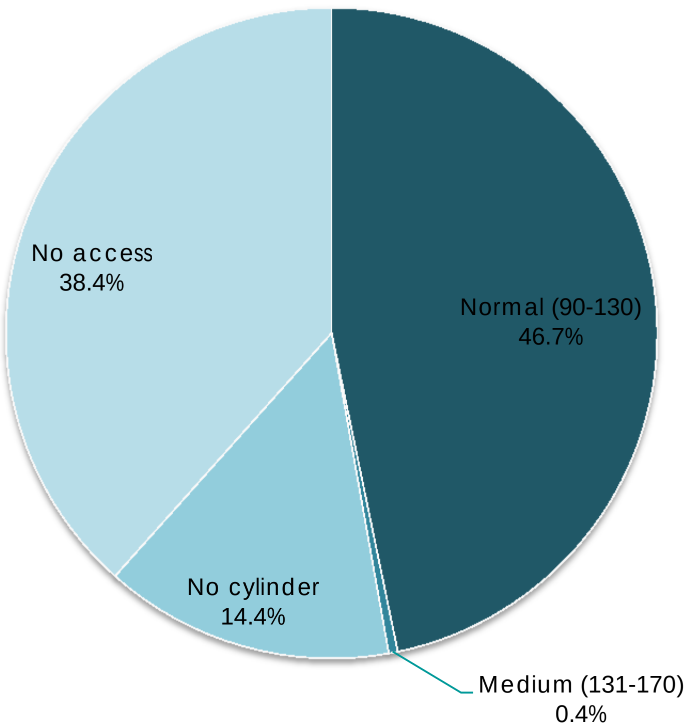

Figure 35. Cylinder size

2.3.11 Cylinder insulation

From those properties with a hot water cylinder, 81.3% had a spray foam insulation layer on the outside and 18.7% a removable insulating jacket (Figure 36).

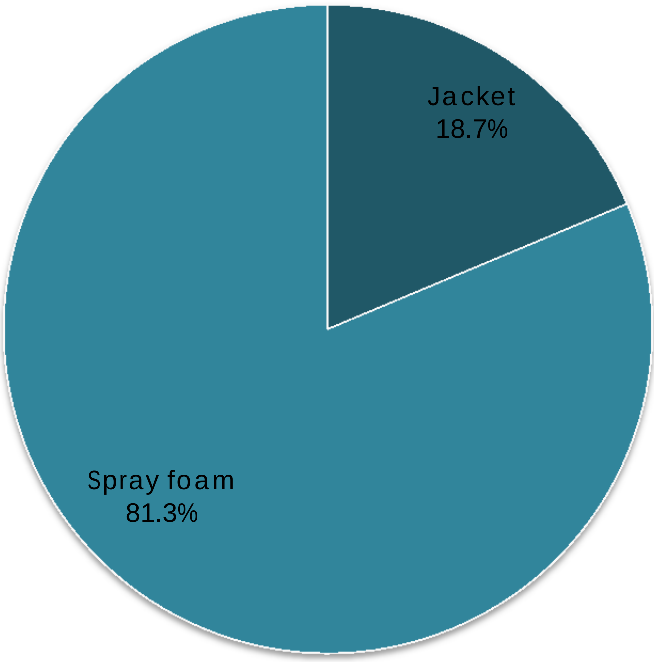

Figure 36. Cylinder insulation

2.3.12 Cylinder thermostat

As can be seen in Figure 37, over half of the dwellings with a hot water cylinder have no thermostat installed. A cylinder thermostat measures the temperature of the hot water cylinder and switches on and off the water heating. A single target temperature may be set by the householder. Without a thermostat, residents have no control over the temperature of their hot water and can lead to inefficient energy use.

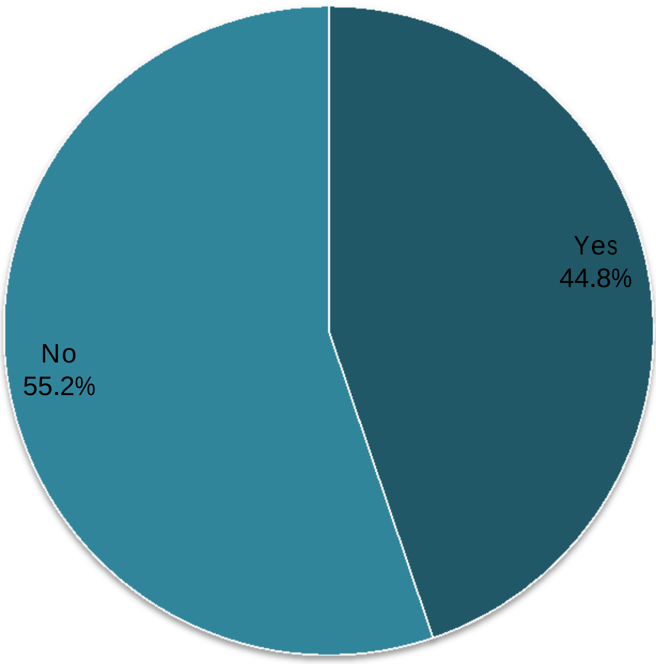

Figure 37. Cylinder thermostat

2.3.13 Air conditioning

To maintain a comfortable and healthy indoor climate, heat must be removed from overheated buildings. Cooling systems can be centralised or decentralised into small units installed in every room. For decentralised units, it is mostly the efficiency of the cooling device and the control system which are of importance for the overall efficiency. Within centralised systems, the dimensions and control of the system itself and the distribution ducts both determine energy efficiency. Air tightness is especially important for building cooling, as air leakage can substantially reduce the efficiency of mechanical cooling. Some buildings work with natural cooling or with night cooling, both of which reduce the need for active cooling.

As can be seen in Figure 38, none of the social housing had air conditioning installed. This is typical for UK domestic buildings due to the cool temperate maritime climate in summer; instead most homes are naturally ventilated.

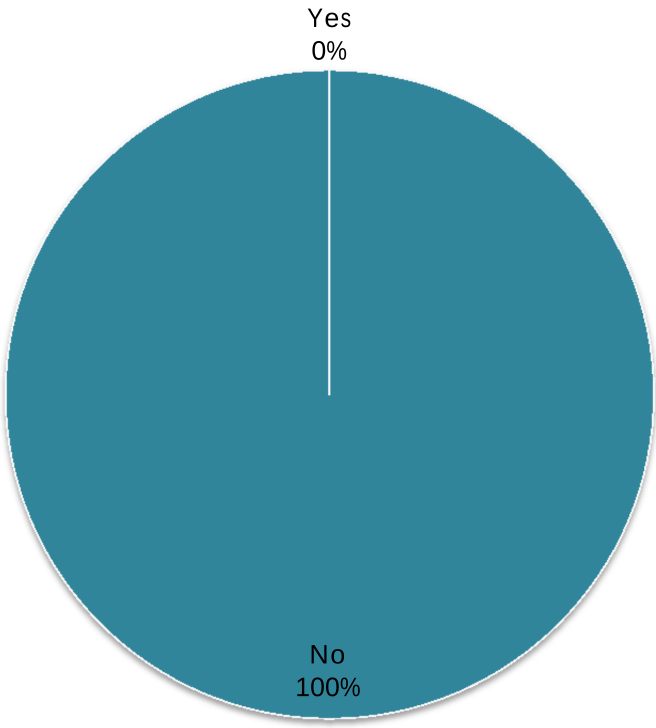

Figure 38. Air conditioning

2.3.14 Low energy lighting

Lighting requirements respond to a building's design. The need for lighting, especially during daytime, will depend on the size and placement of a building's windows and orientation. Inefficient indoor lighting systems, such as incandescent and halogen lamps, produce both light and heat and therefore waste energy. Low energy lighting systems, like Cfl or LED, reduce the amount of energy converted to heat and are consequently a more energy efficient lighting method. However, as can be seen in Figure 39, all of the social dwellings still have inefficient lighting installed.

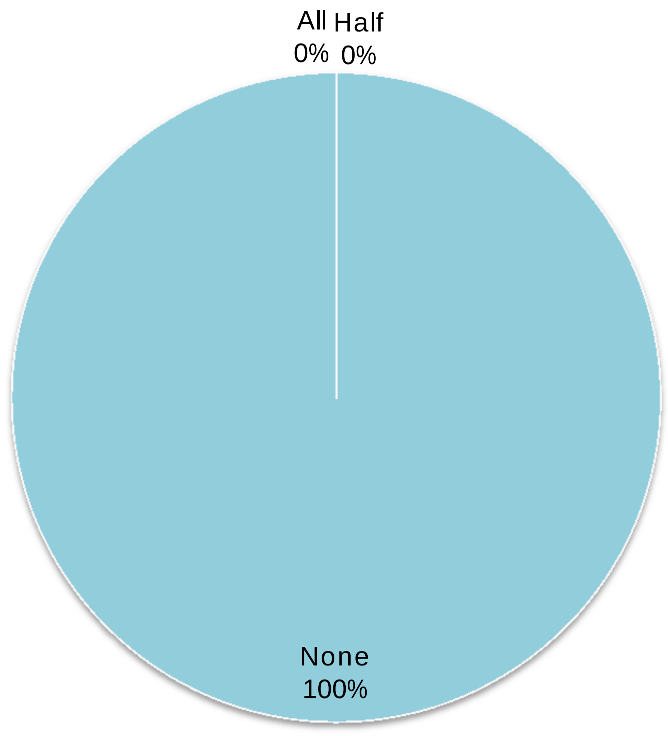

Figure 39. Proportion of low energy lighting installed

2.4 Renewable energy generation

The use of local sources of renewable energy can be either passive or active. In passive systems, the renewable energy is used to avoid the need for heating or cooling, while active systems transform the energy from for instance the sun or the wind into electricity, heat or cooled energy which can then be used by occupants of the building.

2.4.1 Solar water heating

Solar water heating is one of the most commonly used active renewable energy supplies in buildings. In these systems water is heated by the sun and the heat is stored until used. However, Figure 40 shows that only a small percentage (2.1%) of the dwellings occupied by the social housing tenants had a form of renewable hot water heating.

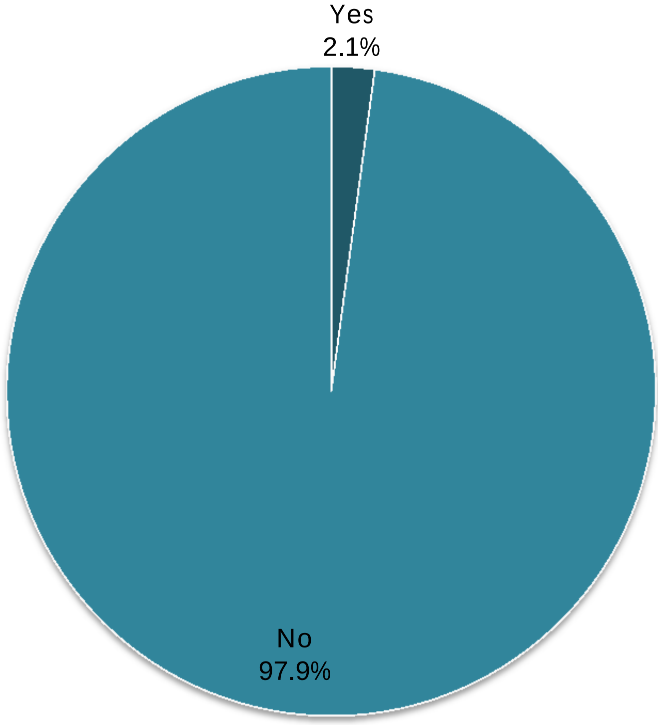

Figure 40. Solar water heating

2.4.2 Photovoltaics (PV)

Photovoltaics (PV) are an example of an active renewable energy source, in which solar energy is transformed into electricity for use in the building. Figure 41 shows that none of the dwellings occupied by the social housing tenants had photovoltaics (PV) for generating renewable electricity.

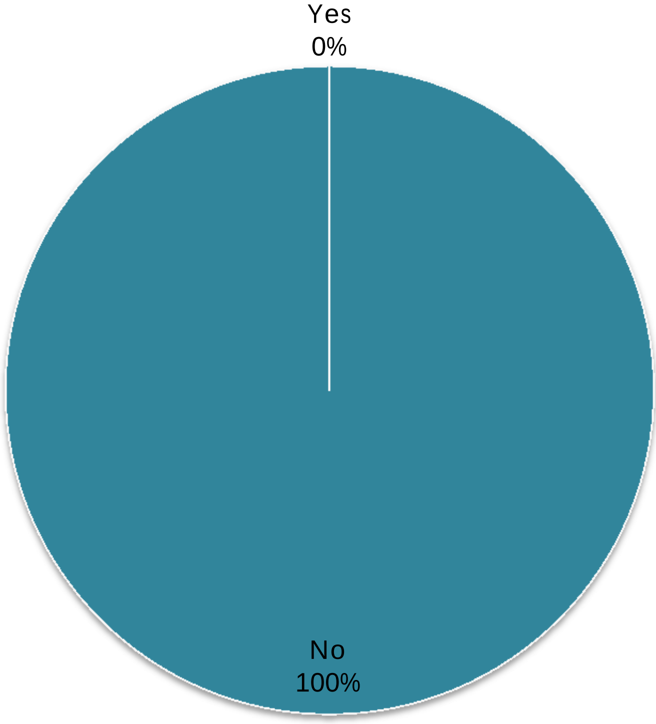

Figure 41. Photovoltaics

2.4.3 Biomass boiler

Figure 42 shows that none of the dwellings occupied by the social housing tenants had biomass boilers installed for renewable heating.

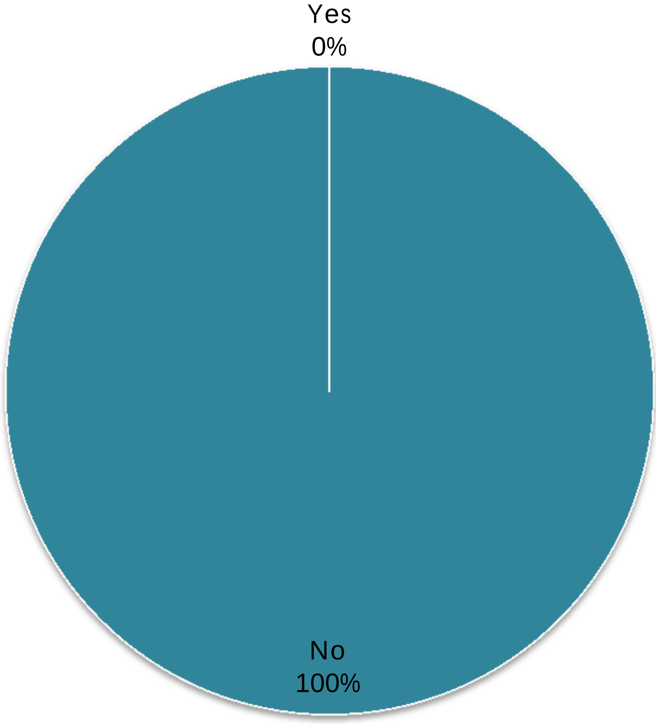

Figure 42. Biomass boiler

2.4.4 Air or ground source heat pump

Figure 43 shows that none of the dwellings occupied by the social housing tenants had air or ground source heat pumps installed for renewable heating.

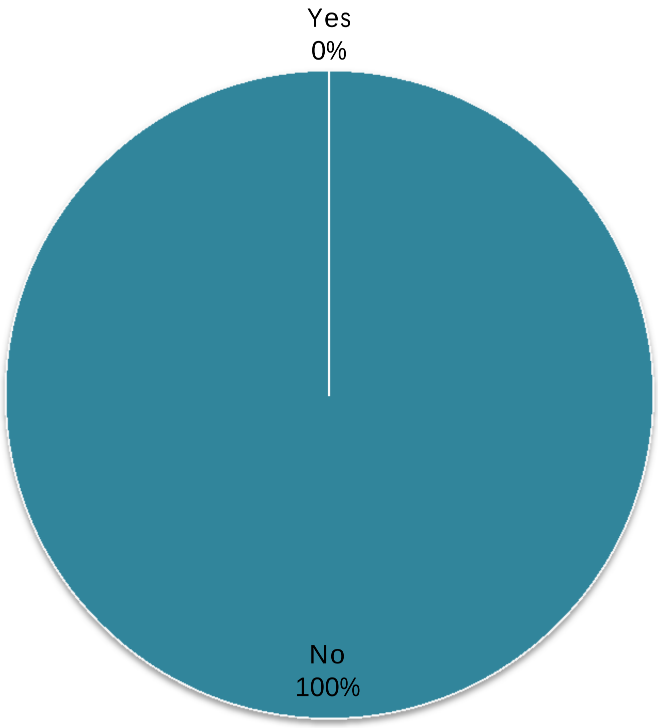

Figure 43. Air or ground source heat pump

2.4.5 Micro Combined Heat and Power (CHP)

Figure 44 shows that none of the dwellings occupied by the social housing tenants had a Micro Combined Heat and Power (CHP) for generating renewable heat and electricity.

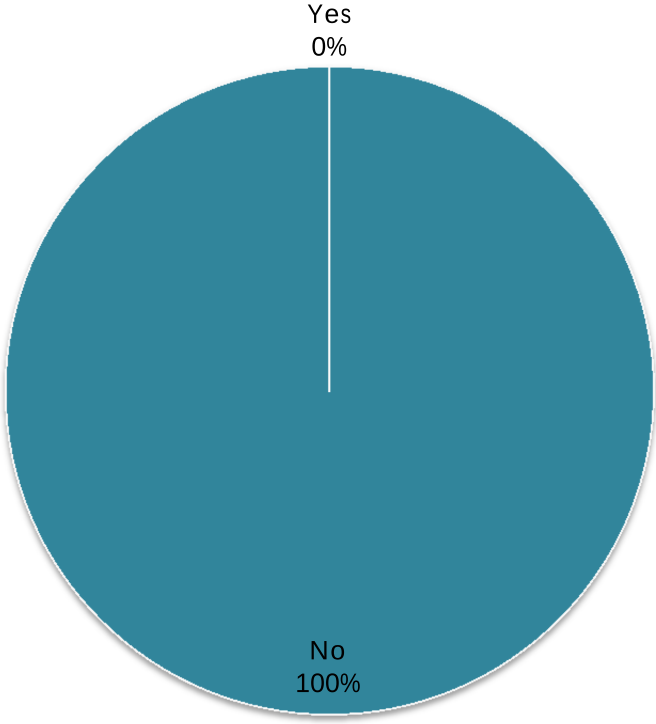

Figure 44. Micro combined heat and power (CHP)

2.5 Internet penetration

2.5.1 Access to Internet in dwelling

Figure 45 shows that around two thirds (66%) of the social housing tenants have access to the Internet at home. Out of the homes with Internet access, 85.7% have wireless broadband, 27.1% Mobile 3G and 19.5% Mobile 4G (Figure 46). The total percentage of Internet connection types is greater than 100% because some of the households have multiple types of Internet connection in the same home.

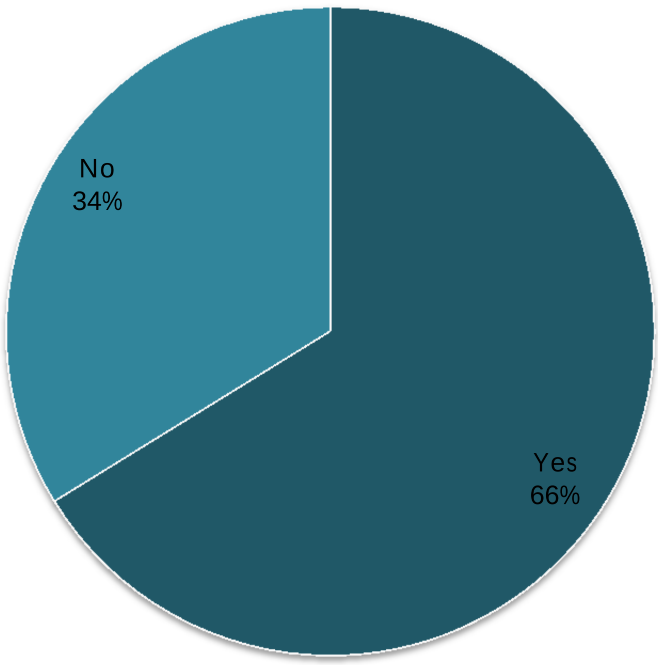

Figure 45. Access to the Internet at home

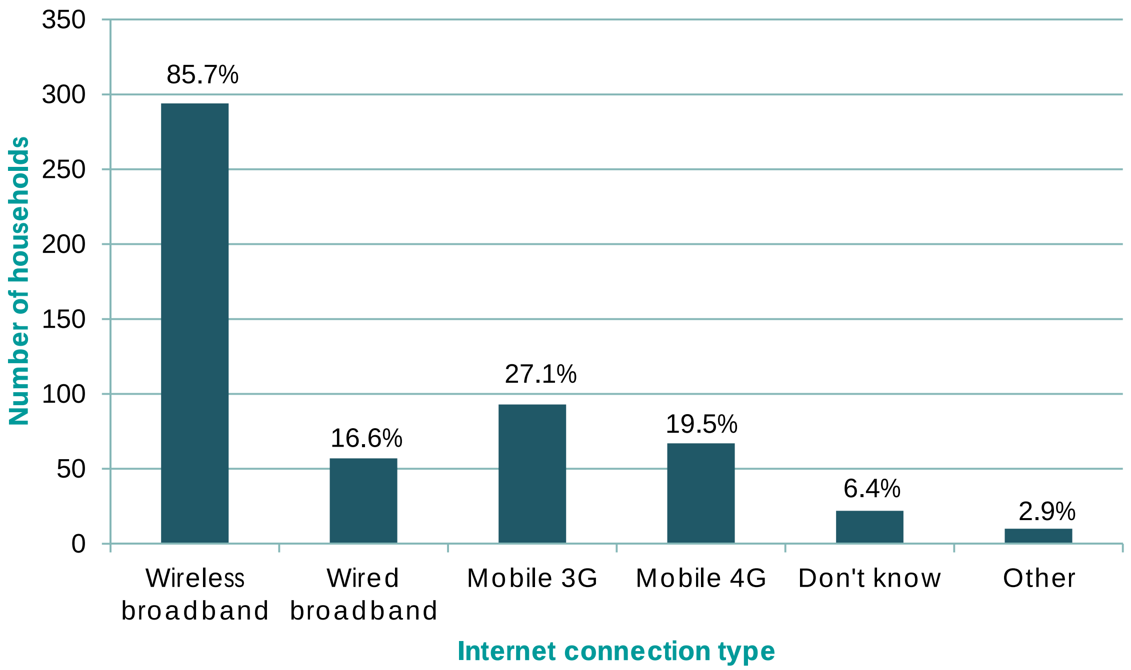

Figure 46. Internet connection type for households with Internet access at home

3. The typical DCH social dwelling

The most common building characteristics, building envelope, building services and controls and renewable energy generation were analysed and transformed into the 'typical' DCH social dwelling which can be used to inform the design of the virtual home contained in the EnerGAware serious game. This typical house can also be used to define and limit the boundaries of the option space (i.e. what actions the game players can make in the game) for the simulation engine that underpins the serious game.

It has been shown that tailoring (Abrahamse et al., 2007; Darby, 2001; Fisher, 2008; Goodhew et al. 2014a; Goodhew et al. 2014b) can help make a visualisation more meaningful and increase the chance of behavioural change; therefore, by having a typical social dwelling within the EnerGAware serious game, the game players (the social housing residents) will be able to more closely relate the virtual home with their real home.

Table 2 presents the features of the typical social dwelling identified from the analysis of the DCH Building Stock Condition and Energy Databases, as well as the EnerGAware Social Housing Survey. The typical dwelling has been defined using the most common building characteristics, building envelope, building services and controls and renewable energy generation evident in the 537 homes surveyed. In some instances, more than one feature is common and therefore it is recommended that perhaps both options could be included in the EnerGAware serious game.

Of particular note, it was identified that almost all of the social housing had no renewable energy generation (only 2.1% had a solar water heating system). In this case, rather than exclude these technologies from the EnerGAware serious game, it might be valuable for the social housing tenants to still learn about these technologies, in preparation for future installation by their housing provider. Also, as a proportion of the social housing tenants have shared ownership of their dwelling with their housing provider, these residents may be encouraged to install renewable energy generation as a result of the serious game.

Furthermore, the results showed that all of the social housing surveyed had no low energy lighting installed and 98.8% had no draught-proofing. Both, low energy lighting and draught-proofing are low cost measures that could be installed by the social housing tenants themselves to save energy at home. It is therefore recommended that these particular energy saving measures should be included in the serious game to increase knowledge about the benefits of installing them, as well as encourage uptake.

As is common in the UK, none of the social housing had air-conditioning installed. As a result, educational content about air conditioning systems and operation could be excluded from the serious game for the UK pilot. Nonetheless, consideration should be given as to whether educational content about air-conditioning still needs to be designed considering future exploitation beyond the UK pilot to other countries where air-conditioning is prevalent.

It can also be seen that around 40% of the social housing have a dual (economy 7) electricity meter, indicating that the residents pay two different tariffs for electricity. One rate is a standard day rate and the other is a cheaper overnight rate. It might therefore be valuable to include information in the EnerGAware serious game about how residents can schedule appliances to operate overnight during the cheaper electricity tariff. In addition, whilst there are currently no time-of-use tariffs in the UK, with the smart meter roll-out, this type of tariff is likely to become more prevalent in domestic buildings. Therefore, the EnerGAware game could educate people about these future tariffs and how residents can shift their electricity use to off-peak periods, when the electricity price will be cheaper.

The results for Internet penetration showed that around two thirds of the social housing had access to the Internet. Out of the dwellings with Internet at home, nearly 86% had wireless broadband. These findings have two key implications for the design of the EnerGAware serious game, first, as the serious game will require access to the Internet, in order to integrate the real-time energy data (to provide feedback and rewards), access the social media functions, as well as to provide game updates, for around one third of social housing tenants this would not be possible. It could therefore be considered whether an offline version of the game could be made available that has enough serious content already developed that could still encourage behavioural change amongst this group. It should be noted that those homes without Internet are likely to be occupied by elderly residents, who are probably the least likely to want to play a serious game and therefore developing an offline version may not be appropriate. Second, the EnerGAware serious game should be developed for a wireless enabled device, in order to connect with the most common Internet connection type present in the homes.

Table 2. The typical DCH social dwelling

Dwelling type	Flat (54.4%) House (35.2%)
Year of construction	Mid-1970s to end 1980s (46.4%)
Storeys	One (69.8%) Two (28.1%)
Habitable rooms	Two (42.7%) Three (31.5%)
Energy rating	D (49.5%) C (43.1%)
Wall construction	Cavity (69%) Solid brick (26.6%)
Wall insulation	Insulated (54.9%) Uninsulated (45.1%)
Roof construction	Pitched, loft access (60.9%) Other dwelling above (21%)
Roof insulation thickness	150mm (35.8%) 250mm (24.3%)
Glazing	Single glazed (52.3%) Multiple glazed (47.7%)
Secondary glazing	None (100%)
Draught-proofing	None (98.8%)
Electric meter type	Single tariff (43.7%) Dual tariff (39.2%)
Mains gas available	No (54.7%) Yes (43.7%)
Main space heating system	Condensing Combi (34.5%) Storage Heaters (32.4%) Combi (26.7%)
Main space heating fuel type	Gas (66%) Electricity (33.6%)
Main space heating controls	Programmer and room thermostat (50.5%) Manual charge control (44.1%)
Secondary space heating system	None (77.9%)
Water heating system	Condensing Combi (34.5%) Electric Immersion (32.1%) Combi (26.9%)
Water heating fuel type	Gas (66.9%) Electricity (33.1%)
Hot water cylinder	Yes (85%)
Cylinder insulation	Spray foam (81.3%) Jacket (18.7%)
Cylinder thermostat	No (55.2%) Yes (44.8%)
Air conditioning	No (100%)
Low energy lighting	None (100%)
Solar water heating	No (97.9%)
Photovoltaics	No (100%)
Biomass boiler	No (100%)
Air or ground source heat pump	No (100%)
Micro combined heat and power	No (100%)
Internet access in dwelling	Yes (66%)
Internet connection type	Wireless broadband (85.7%)

4. Conclusions

This report represents Deliverable 2.2 – Building requirements developed in the course of Work Package 2 – Specification of user, building and game requirements of the EnerGAware project.

The data used to define the building requirements outlined in this report were primarily obtained from project partner, DCH's Building Stock Condition and Energy Database. The dataset contains details about the key structural elements and services in each of the 537 DCH households in Plymouth that completed the EnerGAware Social Housing Survey. It also includes what is known as the 'minimum dataset' for the Standard Assessment Procedure RdSAP energy rating methodology which enables an energy efficiency rating to be calculated for every property surveyed.

The data presented about Internet penetration, Internet connection types, as well as presence of prepayment and standard energy meters in the social housing were collected during the EnerGAware Social Housing Survey which was a large-scale, city-wide, housing survey, administered to all the social houses managed by DCH in the city of Plymouth, UK.

Furthermore, a background review of the energy meter types and their possible locations in UK social housing was undertaken.

The most common building characteristics, building envelope, building services and controls and renewable energy generation were analysed and transformed into the 'typical' social dwelling which can now be used to inform the design of the virtual home contained in the EnerGAware serious game. This typical house can also be used to define and limit the boundaries of the option space (i.e. what actions the game players can make in the game) for the simulation engine that underpins the serious game.

References

[1] Abrahamse, W., Steg, L., Vlek, C., Rothengatter, T., 2007. The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. Journal of Environmental Psychology, 27(4), 265-276.

[2] Darby, S., 2001. Making it obvious: designing feedback into energy consumption. In Energy efficiency in household appliances and lighting. Berlin, Heidelberg: Springer, 685-696.

[3] Department of Energy and Climate Change (DECC). 2012. The Government's Standard Assessment Procedure for Energy Rating of Dwellings. SAP 2012 version 9.92. BRE Garston.

[4] Fischer, C., 2008. Feedback on household electricity consumption: a tool for saving energy? Energy efficiency, 1(1), 79-104.

[5] Goodhew, J., Boomsma, C., Pahl, S., 2014. A longitudinal mixed method study of the role of tailoring in the design of visual interventions for domestic energy efficiency. Proceedings from BEHAVE '14, Oxford, UK.

[6] Goodhew, J., Pahl, S., Auburn, T., Goodhew, S., 2014. Making Heat Visible; Promoting energy conservation behaviors through thermal imaging. Environment and Behavior, 9, 1-30.

[7] Laustsen, J., International Energy Agency Energy., 2008. Efficiency requirements in building codes, energy efficiency policies for new buildings.